

The Long-Lasting Impact of Long-Term Feedback on Waste Management

Sebastien Meineri

*Laboratoire Psychologie, Communication Cognition Comportement
Université Bretagne-Sud, France*

Isabelle Dangeard

Université de Bretagne Occidentale, France

Mickaël Dupré

Université de Polynésie Française, France

Abstract

Waste reduction is an important concern for local authorities and could be enhanced by feedback strategies. A field experiment focused on the impact of feedback on household waste reduction is presented. Residents living in single-family houses were sorted by per capita waste generation rate, phoned, and asked their email addresses. The 236 resulting households were then alternatively assigned to one of the two experimental conditions: Feedback and Control. Households in the Feedback condition received weekly emails for two months, followed by monthly emails during the rest of the experimental year. Each email included the household waste generation rate (kg per week), its past generation rates, and, depending on the household size, mean generation rates and objectives of the local authorities; detailed tips about waste reduction were added. The weight data were recorded during collection, using the electronic tags of the wheeled containers, and covered three years: the experimental year, the previous year, and the following year, during which no feedback was provided. Results revealed that the two experimental conditions become significantly different during the feedback year and are still significantly different during the post-feedback year. The results are interpreted through a two-step process combining different theories, suggesting directions to build an encompassing framework.

Keywords: social influence, feedback, waste reduction, cognitive dissonance.

Declaration of interest: none

Introduction

Municipal solid waste is a major concern in many countries, which can be addressed in many different ways. Even garbage can be valued, burnt in so-called energy recovery units. Organic waste can be composted into valuable fertilizer. Materials recycling or downcycling are common processes for paper, cardboard, plastics, metal, and glass. More effective management can save goods from perishing or becoming obsolete, using just-in-time principles. From repairing to reusing and re-purposing, many actions can increase the lifetime of durable goods. Material flows can radically be stopped upstream by buying fewer packaged goods or simply minimizing consumption. All these solutions make material

flows more circular and slower, and there is a move from waste management to resource management (UNEP, 2015).

Until recently, experimental studies have primarily focused on “waste recycling” by households. Currently, however, recycling rates are higher, and we should therefore rather engage in waste prevention (UNEP, 2015). Analyses of reported behaviors and intentions about waste reveal that recycling behavior is quite different from reuse at home and from reduction behaviors (Barr & al, 2001; Tonglet, Philips, & Read, 2004), Although, scientific work has not focused on the issue of reuse and reduction at source as often as it has dealt with recycling (Nickerson, 2003).

We successively review research work focused on waste sorting and on waste reduction by households from the perspective of different influence strategies.

Influence Strategies and Waste Sorting

Household waste sorting has been widely investigated. Personal and socio demographical variables, such as Age (Lansana, 1992); Gender (Zelezny, Chua, & Aldrich, 2000) or Incoming level (Gamba & Oskamp, 1994) (Vining & Ebreo, 1999) reveal weak to moderate correlation with intentions to sort and self reported behaviors (Schultz, Oskamp, & Mainieri, 1995). Typical recyclers would be an aged women with comfortable income. Intervention strategies have been reviewed (Dupré, Dangeard, & Meineri, 2014; Varotto & Spagnoli, 2017) and can be grouped into three main categories: information strategies, incentives, and behavioral strategies.

Information strategies are antecedent strategies. Information about problems and related solutions is provided to the subjects, so that they can manage more effectively the social and environmental consequences, either negative or positive, of their behavior. This information is not contingent on the behavior. Based on Ajzen’s theory of planned behavior (Ajzen, 1991), research work has revealed positive correlations between cognition (attitudes, perceived norms, and perceived behavioral control) and sorting behaviors and sorting intentions (Humphrey, Bord, Hammond, & Mann, 1977; Tonglet, Phillips, & Read, 2004; Nigbur, Lyons, & Uzzell, 2005; Botetzagias, Dima, & Malesios, 2015). This suggests that influencing cognition could influence behavior, which has sometimes proved to be successful (Jacobs & Bailey, 1982; Luyben & Bailey, 1979; Burn & Oskamp, 2013; Hopper & Nielsen, 1991; Jacobs, Bailey & Crews, 1984). Nevertheless, researchers tend to agree that only providing information can somehow make a prior behavior last longer (Geller, 1992) but is not enough to induce important changes (Nickerson, 2003; Gardner & Stern, 1996; Bamberg & Moser, 2007). The indirect and moderate association between cognition and behaviors could explain the limited impact of these strategies (Webb & Sheeran, 2006; Davies, Foxall, and Pallister, 2002).

Incentive strategies are consequence strategies, providing reward or punishment contingent upon the behavior. According to behaviorist theories (Thorndike, 1998; Skinner, 1953), positive reinforcement results in an increased probability of the behavior occurring in the future, and negative reinforcement in a decreased probability. Researchers have successfully used different rewards (gift or discount vouchers, lottery tickets) to influence sorting behaviors (Timlett & Williams, 2008; Geller, Chaffee, & Ingram, 1975; Hamad, Bettinger, Cooper, & Semb, 1980; Witmer & Geller, 1976). The impact could increase if information is added (Geller, 1992) or if the participation rate is initially very low (Woodard, Firoozmand, and Harder, 2006). However, there are limits to these strategies: first, the impact vanishes after the reward is obtained (Iyer & Kashyap, 2007; Oskamp, 1995; Pardini & Katzev, 1983; Katzev & Pardini, 1988; De Young, 1990), and second, the impact is limited to the rewarded behavior. For instance, Needleman and Geller (1992) observe that a financial reward for metal can sorting does not induce any increase of paper or glass sorting. Similarly, Hong (1999) notes that the efficiency of rewards for waste sorting is not aligned with waste reduction. Rewards constitute an extrinsic motivation, which would inhibit the search for intrinsic motivations (Deci & Ryan, 1988) that could make change last and spread toward similar behaviors.

Finally, behavioral strategies rely upon commitment theories (Kiesler, 1971; Joule & Beauvois, 1998). In this framework, a preparatory act is obtained in specific conditions: the behavior should be costly, repeated, irrevocable, explicit, and voluntary. This preparatory act would bind individuals to their acts and make them engage in action, fostering the expected behavior. This technique has successfully been used to improve sorting behaviors (Burn & Oskamp, 2013; Porter, Leeming, & Dwyer, 1995; Katzev & Pardini, 1988; Wang & Katzev, 1990; Werner & al., 1995; Zbinden, Souchet, Girandola, & Bourg, 2011; Dupré, Meineri, & Guéguen, 2014; Guéguen, Meineri, Martin, & Grandjean, 2010). Two types of preparatory acts have been implemented: the first is an individual or group commitment to engage into a sorting campaign during a given time period; the second is the completion of a short questionnaire administered during a prior survey. Results differ from those of incentive strategies in the medium term, as the impact remains in evidence after the commitment period (Katzev & Pardini, 1988; Wang & Katzev, 1990). Initially triggered by the preparatory act, the behavior later results from the internal motivations emerging through the behavioral process (Pallak & Cummings, 1976).

Researchers have also investigated the feedback technique, which is viewed as an interface between the three previous strategies. Like information strategies, feedback is an information flow. The difference is that the information is specific to the recipients' behavior, therefore shifting from the antecedent to the consequence category. Like incentive strategies, feedback transmits information about the evaluation of a performance, but neither rewards nor punishments are provided, leaving the evaluation of the behavior an open question. This last property makes feedback share features of behavioral strategies. The theoretically committing situation (freely chosen, costly, and repeated behavior) is expected to turn the first performances into better ones, through increased perceived control and an internalization of motivations. Initially tested on energy consumption (Winett, Neale, & Grier, 1979; Katzev, Cooper, & Fisher, 1981; Darby, 2006), feedback techniques have also been applied to sorting behaviors. The quantitative results are mainly positive, whether the feedback is collective (Katzev & Mishima, 1992; Hamad & al., 1980; Goldenhar & Connel, 1991-1992) or individual (Fuqua & Deleon, 1995), and whether it lasts over a few weeks (Schultz, 1999; Fuqua & Deleon, 1995) or is just provided once (Perrin & Barton, 2001). The quality of waste sorting also increased during feedback experiments, except for initially non-sorters (Timlett & Williams, 2008). As regards the longer term impact of quantitative feedback, Schultz (1999) measured an increased weight of sorted waste during a 12-week experiment, lasting over the next 4 weeks, apart from a rebound effect for initially high performers.

Influence Strategies and Waste Reduction

Recycling has successfully diverted 28% of municipal solid waste from landfills in the United States, but 72% of waste is still either burned or buried (Lehman and Geller, 2005). In France, only 26% of waste was diverted towards materials recycling in 2013 (ADEME, 2015). More than waste sorting, waste reduction by households requires a high level of environmental concern (Barr & al., 2001), and intrinsic motivations make a decisive impact after the necessary information is provided (Robertson & Walkington, 2009).

Throughout the world, many local governments have added incentive strategies to traditional information and persuasive strategies. Pay As You Throw (PAYT) systems have been implemented and charge households depending on the volume or the weight of the waste they generate. Waste reduction reaches 20% to 30% (Callan & Thomas, 2006; Dahlén, Åberg, Lagerkvist, & Berg, 2009; Allers & Hoeben, 2010), and sorted waste increases. Regrettably, illegal dumping and disposal in neighboring communities may occur (Fullerton & Kinnaman, 1996; Linderhof, Kooreman, Allers, & Wiersma, 2001). In France, incentive strategies have recently been developed, with legal provisions and community funding to start incentive schemes (Gatier, 2016). In 2014, 4.2 million inhabitants in

159 communities were charged according to their waste production, usually calculated from the number of curbside presentations of their waste containers. The impact has been mainly positive (ADEME inquiry, in Gatier, 2016), in line with the research results mentioned above. The analysis reveals that the impact appears when the local authorities start communicating about the future incentive tool, increases as the tool is implemented, and eventually stabilizes. The decrease of residual waste is accompanied by an increase of sorted waste. However, findings also show a decrease of the sorting quality, especially during the first two years, and the proportion of voluntary or involuntary errors is unknown. For the local authorities, implementing PAYT systems can be lengthy, costly, and sometimes complex, and some of them finally decided to give up the incentive scheme (Gatier, 2016).

The Research Study

The present research study led in partnership with the French metropolis Rennes Métropole. Local authorities have been implementing waste reduction strategies for several years, resulting in 2013 in a residual waste production rate of 206 kg per inhabitant, which is lower than the national rate of 268 kg per inhabitant, but the decrease has diminished in the past 3 years (-1.7 % per year) (Rennes Métropole, 2017). The present experiment was launched, targeting high waste producers and aiming at reducing their residual waste production through long-term emailed augmented feedback. Following Howard's (1995) proposition that "*if one technique is effective, then perhaps the use of two or three of them together might be even more effective*" (cited in Howard, Shu, & Kerin, 2007, p. 18), the procedure included personal feedback, personal historical data, mean results and reduction objectives of similar households, and advice on waste reduction solutions. The short-term and the long-term impact of feedback were to be observed.

Method

Participants

We were provided with a database of households living in detached houses, equipped with individual residual waste containers placed curbside at least 20 times during the previous year. This minimum was viewed by the representatives of the partnering metropolis as a necessary condition to exclude abnormal cases. Participant households were sorted by the decreasing amount of per capita waste (i.e. the weight collected during the year before the experiment was due to start). Then, they were phoned, following this ranking order, so that their email addresses could be added to the database, as part of a project of the local authorities to use new media to communicate with the citizens. Therefore the subjects' attitudes towards waste reduction did not interfere with the recruitment process. This process stopped when 236 households viewed as high waste producers had given their email addresses, a little above the initial objective of obtaining 200 valid subjects.

The subjects were then sorted according to their waste collection day and their waste production, before being assigned to one of the two experimental conditions: Feedback and Control.

At the end of the intervention, a door to door check of households was completed and some of them were excluded from the analysis. From the initial sample of 236 subjects, 47 were excluded because they had move away, were professionals or used shared containers, 45 were excluded because they did not receive the whole feedback (the emails contains errors, came back as spammed or households unsubscribed from the mailing list), 32 were excluded because their weight data had anomalies (the threshold was set at 15 consecutive weeks without any weight data during the 3 years). Finally, by drawing a boxplot and performing a Cook distance analysis, we identified three outliers wich were excluded to. The final sample had 109 subjects: 43 subjects in the feedback group and 66 subjects in the control group.

Intervention

In May 2015, the households in the feedback condition were sent an email by the local authorities. It informed them that during one year, they would receive information about their waste production (kg per week); it provided a table displaying, for each household size (from 1 to 6 members), mean weekly waste production rates of the previous year and objectives corresponding to a -10% reduction.

The feedback process started in June 2015. The subjects received weekly emails during 8 weeks, followed by monthly emails during 10 months. In June 2016, they received an email from the local authorities, informing them of the end of the emailing campaign.

Each of the feedback emails included:

- the waste production rate (kg of residual waste per week) of the household for the previous time period (weeks during the first two months, and months later),
- a table displaying a short-term history of the waste production of the household for the previous six time periods (kg of residual waste per week),
- the previously mentioned table, included in the first email by the local authorities,
- a detailed tip about one way to reduce waste, specific to each email, derived from an official French source (the French Environment and Energy Management Agency - ADEME). The tips are listed in Appendix 1. An example of a feedback email is provided in Appendix 2.

The curbside collection vehicles were equipped with a weighing system, and the data for each tagged container were stored in the database of the waste collection company. The database of the local authorities allowed the identification of the subjects from their container identification number. When combined with the waste collection data, it provided the weight data of the waste of the residents. These data were observed over 3 years: the pre-experimental year (June 2014-May 2015), the experimental year (June 2015-May 2016), and the post-experimental year (June 2016-May 2017). Weekly weight data were averaged over each of the three years (52 weeks for each period: pre-experimental, experimental, and post-experimental) for each household and determined the main dependent variable of the experiment.

In June 2017, the subjects were canvassed in order to check the household identification. The door-to-door campaign was previously announced by a flyer from the local authorities placed in the letterboxes, so that the doors opened easily. In this process, data were also gathered about the memorization of the feedback emails. The detailed questions are listed in Appendix 3.

In line with previous research work, we expected the feedback to reduce residual waste during the feedback year (Hypothesis H1) and during the following year (Hypothesis H2).

Results

Intervention Results

A repeated measures ANOVA (3 periods*2 groups) was conducted on the data. Results reveal a main effect of the period ($F(2, 214)=72.10$; $p<.001$; $\eta^2=.399$) and a main effect of the group ($F(1, 107)=3.792$; $p=.05$; $\eta^2=.034$).

As regards the period effect, the breakdown presents an effect in the feedback group ($F(2, 84)=45.64$; $p<.001$; $\eta^2=.521$) and in the control group ($F(2, 130)=33.46$; $p<.001$; $\eta^2=.340$). Post-hoc T-tests reveal significant decreases of household mean weekly waste production rates: for the control group, 1.4 kg between the pre-feedback and the feedback years, and 1.8 kg between the

feedback and the post-feedback years (from 2014-2015 to 2015-2016, $t(65) = 3.408$; p (Bonferroni) $<.01$; and from 2015-2016 to 2016-2017, $t(65) = 4.947$; p (Bonferroni) $<.001$); for the feedback group, 2.3 kg between the pre-feedback and the feedback years, and 1.4 kg between the feedback and the post-feedback years (resp. $t(42)=5.249$; p (Bonferroni) $<.001$ – $t(42) = 5.559$; p (Bonferroni) $<.001$).

Concerning the group effect, the breakdown reveals, as expected, no significant difference between the two groups in the pre-feedback period ($F(1,107)$, 1.428 ; $p=.235$ NS) but a significant difference between the groups during the feedback period (resp. $F(1,107) = 4.753$; $p=.031$; $\eta p^2=.043$) and the post-feedback year ($F(1.107) = 4.032$; $p=.047$; $\eta p^2=.036$)

Table 1: Mean waste production rates by year and experimental condition (kg per week)

Group (n)	Pre-feedback (S.D.)	Feedback (S.D.)	Post-feedback (S.D.)
Control (66)	12.40 (4.08)	11.03 (4.99)	9.23 (4.46)
Feedback (43)	11.37 (4.86)	9.03 (4.16)	7.58 (3.75)
Total (109)	11.99 (4.41)	10.24 (4.76)	8.58 (4.26)

Memorization of the email campaign

Among the 43 feedback subjects, 41 answered the household enquiry form (two were not at home during the canvassing, and their identity was controlled only from the letterbox) and answered questions about email memorization. Findings are as follows:

- 68% remembered the emails, with a variable unaided / aided recall score: the weight information was best remembered (96% / 100%), references were less often remembered (20% / 76%), and waste reduction tips even less (8% / 52%).
- 32% of the subjects did not remember the emails; among them, 85% declared that the email address was that of another member of the family.

Discussion

The present study aimed to test the effect on household waste production of regular feedback about the weekly weight of people’s residual waste. The literature about feedback effects on sorting behaviors led to a first hypothesis of a feedback impact during the feedback implementation stage (Hypothesis H1) and a second hypothesis of a lasting impact after the implementation stage (Hypothesis H2). Two experimental conditions and three time periods were defined. The first period was a pre-experimental phase of one year (52 weeks), during which the households in the two conditions received no information; the second period was an experimental phase of one year (52 weeks) during which only the households in the experimental condition were regularly emailed the weight of their residual waste, among other information; and the third period was a post-experimental year (52 weeks), with no feedback provided. The results show a main effect of the period, revealing a reduction over time in the weight of the residual waste, regardless of the condition, and, in line with our hypothesis, a main effect of the condition, revealing a significantly lower residual waste production in the experimental condition than in the control condition, during both the experimental stage (H1) and the post-experimental stage (H2).

Regarding the main effect of the period, the data reveal reductions in the weight of residual waste, respectively 20.6% and 11% for households in the Feedback and Control conditions between the pre-experimental period and the experimental period (14.6% overall), and reductions of 16% and 16.3% respectively for the Feedback and Control conditions between the experimental period and the post-experimental period (16.2% overall). These reductions are much greater than those recorded in the metropolis both before and during the project. As mentioned earlier, previous records showed a

reduction of 1.7% per capita and per year of the waste production during the 3 years preceding the project, and the most recent activity report (2017) indicates a reduction of 1.3% per year and per capita. The difference between the global data observed in the metropolis and our data can be explained by the high and well-known turnover of households; this turnover was excluded by the sampling criteria of our experiment that excluded moving households, but it was not excluded in the global data of the metropolis that included moving households. This gap suggests that the impacts of the continuous prevention efforts carried out in the metropolis are lost with intra-urban moves, due to the loss of benchmarks and habits intrinsically resulting from change, but also with inter-urban moves, with the export of better practices than imported ones. Awareness-raising efforts and waste flow patterns can vary considerably from one community to another, penalizing leading metropolises. This gap means that the evaluation of awareness-raising campaigns should be calculated on stable households, excluding those that have moved recently into an area. However, the overall reduction revealed by our data seems encouraging, indicating regular and valuable changes towards waste reduction behaviors under both general and tailored waste reduction policies.

As regards the main effect of the condition, similar results have already been obtained. Schultz (1999), observing the 4-week effect of individual feedback and 8-week effect of group feedback (providing information about the average behavior of similar households), interprets results in terms of social, personal, or descriptive norms, according to the experiment condition. Under individual feedback, participants, knowing they are observed, are said to activate a personal norm leading them to act in a socially desirable way during the time of the observation. Under group feedback, a descriptive social norm progressively emerges, and participants then conform to this norm. The effect would, therefore, be slower to appear but more durable than that of individual feedback. Meineri et al. (2016), observing the 14-week effect of mere feedback, interpret the effect as triggered by the project presentation and the community target of waste reduction and perpetuated by a commitment mechanism (Kiesler, 1971; Joule and Beauvois, 1998) by which the first unrewarded efforts would further incite households to follow the expected path.

These interpretations could also apply to our results. However, in order to optimize the effect of the procedure in an applied perspective (Howard, 1995), the present experiment email feedback included, in addition to the waste production rate of the previous time period of the household, historical data about the previous time periods, comparative group data and community reduction objectives of 10 %, for each household size, and one of the 18 waste reduction tips mentioned above.

Independently, each of these elements could make an impact. Following Schultz's (1999) interpretation, knowing they are observed could make households act in a socially desirable way. Personal information coupled with a reduction goal was consistent with feedback effectiveness conditions (Katzev & Johnson, 1987; Schultz, 2014). Information on the average weights of comparable households could have induced comparison and compliance with their behaviors (Cialdini, Reno & Kalgreen, 1990; Schultz, 1999). Finally, the 18 reduction tips can be considered as light forms of Prompts, promoting suggested behaviors rather than delivering mandatory instructions. Such information has also proved effective in several studies (Geller 1992, Austin, Hatfield, Grindle & Bailey, 1993).

Viewed as a whole, these elements suggest an interpretation in terms of reduction of cognitive dissonance (Festinger, 1957). Among the different paradigms of this theory, induced hypocrisy (Dickerson, Thibodeau, Aronson, & Miller, 1992) makes individuals defend a socially desirable position or activate an injunctive (Priolo & Liegeois, 2008) or descriptive (Matz & Wood, 2005) social norm, before asking them to recall a series of personal transgressions of this position or norm. This sequence makes individuals feel a psychological discomfort resulting from the inconsistency between the two elements, which they then seek to reduce. The paradigm, going on with the explicit or implicit proposal of a pro-normative behavior, preferentially guides the participants towards a path of positive behavioral rationalization, increasing the prevalence of the suggested behavior.

The prior existence of a pro-environmental injunctive social norm (Felonneau & Becker, 2008) could have been activated by the project presentation and the general reduction objectives, precisely stated as production rates by household size. At the same time, the household feedback figures, highlighting the differences, could have made the transgression salient and created the psychological discomfort. In this psychological state, the presentation of a tip to implement, renewed in each of the mailings, would have directed the households towards a positive behavioral rationalization. Information on the averaged residual waste weight of comparable households could have moderated the perceived cognitive dissonance and psychological discomfort, increasing it if the household waste production rate was over the mean, and decreasing it at least partially, if it was under the mean. As noted above, we observed that 20 households spontaneously unsubscribed from the project. These opt-out demands can be explained by the psychological discomfort created by the feedback information, driving households less involved in environmental issues, or having less control over the weight of their waste, to avoid the problematic information. Among these unsubscribers, a person, widowed and often inviting her family, sent us a particularly derogatory message, describing the goal to achieve as *"violent"*. Other rationalization types such as denial of responsibility (Gosling Denizeau & Oberlé, 2006) or trivialisation (Simon, Greenberg & Brehm, 1995) also seem to appear in the informal post-experimental feedback of some participants. Questioned about their potential interest for such an information service, one of the participants said *"we had to put the waste somewhere"*, while another said *"I'm very busy and I have other things to think about"*.

Another explanation that cannot be excluded derives from an anticipatory effect of a PAYT system. In a context where several neighboring communities have already adopted this system, the procedure to which households were submitted could have been interpreted as a first step of the deployment of an incentive scheme, encouraging them to reconsider their waste management. In this respect, Gatier (2016) observes that the mere communication of the future deployment of such a system was enough to make an impact on the waste production. This would make an anticipated external motivation act as a trigger of behavioral change, at least for some of the subjects. This explanation can also be interpreted as the result of psychological discomfort, created by the contradiction between future penalty payments for imperfect behaviors and the widespread value of money.

Assuming that the cycle of emergence of cognitive dissonance and reduction through some behavior occurred during the experimental phase, after one or more feedback emails, it seems unlikely that, on its own, it can explain all the results. Analyses reveal an impact during the post-feedback year, when the households were no longer receiving emailed information. In addition, the regular information regarding the weight of waste produced by the households was certainly less problematic, as the efforts made resulted in a weight reduction, made salient by the historical data.

Therefore, we are considering a second mechanism to explain the long-term results: behavioral commitment (Kiesler, 1971; Joule & Beauvois, 1998; Guéguen et al., 2010; Dupré et al., 2014; Meineri et al., 2016). Initially attempting to reduce their psychological discomfort, individuals were led to perform behaviors in a theoretically committing situation. First, these behaviors were free (some subjects even unsubscribed from the project). Second, they were potentially costly and repeated (e.g. installing and using a composter, modifying purchasing habits, bringing waste more regularly to waste collection facilities) and public, if we recognize that the households were aware of being observed. These behaviors, with no external reinforcement, could generate their own rationales (Pallack & Cummings, 1976), facilitating intrinsic motivation (Deci & Ryan, 2000) and therefore long-term impacts, which tend to vanish under extrinsic motivations. In addition to these theoretical commitment conditions, regular feedback can facilitate internalization. Feedback on the households' own waste production, by creating functional links between the subjects and their behaviors, probably reinforced the binding properties of the second stage.

In short, multiple feedback information generates greater or lesser cognitive dissonance, depending on the subjects. It drives some of them towards behavioral change, while others reduce

dissonance in other ways. This triggering stage is followed by a second stage, characterized by committing conditions. It fosters a progressive internalization of motivations for the triggered behaviors, which tends to make changes last after the feedback stops.

Despite encouraging results, the present study is not without limitations. The size of the final sample was much smaller than expected. The longer an experiment, the higher is the probability that a family moves away, a rather frequent event in our sample due to the high turnover in the partnering metropolis, and the longer is the probability that abnormal events occur, such as tag breakdowns. Experiments on households that are intended to span over a few years should thus start from much larger samples than finally needed for statistical treatment. Constant yearly loss rates require the initial sample size to grow exponentially with time.

Also, in relation with the duration of the experiment. The availability and ease of use of general or specific waste reduction solutions changed over the 3 years of the project (e.g. when drop-off containers were added). These facilitating conditions have an effect on waste reduction, but it was impossible to ensure that they remained the same during the 3 years, or at least changed simultaneously for the two experimental conditions.

Finally, personal variables in the two experimental groups, and inside of them (e.g. family structure or income) could not be controlled and also may have changed during the experiment. If theoretically, these have changed consistently in the two groups, we cannot exclude a sampling effect on results.

Conclusion

While PAYT systems are spreading worldwide, feedback strategies could be serious challengers as waste minimization solutions. Reducing waste without risks of illegal dumping or burning and without the risk of unpopularity associated with coercive payment solutions, they could be favored by local authorities. Further research is needed to explore the range of channels through which the feedback information can be delivered; the present experiment used a centralized database and emailing, but other long feedback loops and shorter ones could also be explored.

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Appendix 1.

List of the waste reduction tips (translated from French by the authors)

1. I avoid disposable bags
2. I compost organic waste
3. I have a “No Ad Mail” sticker
4. I am becoming a recycling champion
5. I bring damaged items to the recycling center
6. My glass sorting has become flawless
7. I buy in bulk and at the counter
8. I save on batteries
9. I have started mulching
10. I offer dematerialized presents
11. I drink tap water
12. I fight against food waste
13. I do not use disposable wipes
14. I give or sell unwanted items
15. I make my own laundry detergent
16. I fight retail overpackaging
17. I repair rather than throw away
18. I use homemade household products

Appendix 2

Example of feedback email (translated from French by the authors)

You produced **kg** of residual waste (grey container) between March 31 and April 27, which is a weekly mean of **kg**.

Your mean production rates during the previous months was the following :

October, 29 - November, 2	November, 3 - December, 2	December, 3 - December, 30	Decembre, 31 January, 27	January, 28 - March, 2	March, 3 - March, 30
kg	kg	kg	kg	kg	kg

Mean weekly waste production rates, for households living in detached houses in Rennes Metropole

Number of people in the household	« Grey container » (kg per week)	Your objective - 10% !
1	2,85	2.57
2	4.16	3.74
3	5.37	4.83
4	6.52	5.87
5	7.60	6.84
6	8.94	8.05

We recall the objective we suggest for you : 10 % less than similar households !

To help you reach your -10 % objective, here is a new tip !

The monthly tip: ...

Appendix 3

The canvassing questions (translated from French by the authors)

1. Identity control

Greetings and question: “Are you Mr. /Mrs. ... ?”

2a. Email receipt control

Question: “You were the recipient of an email information campaign regarding your waste production between June 2015 and May 2016. Did you receive the emails?”

2b. Email address control

Question: “The emails were sent to the address ...@..., is this your email address?”

3a. Unaided recall

Question: “Could you tell me what the emails were about?”

3b. Aided recall

Questioning regarding “the weight of household waste”, “means and objectives by household size”, “tips”.

4a. Yearly feedback

Statement: “During the previous year, you produced ... kg of residual waste per week. This is ...% less (or more) than the previous year”.

4b. Interest in feedback

Question: “If you were offered an information service about your waste weight, would you like to get information about the weight of your own waste?”

4c. Ideal frequency

Question: “How many times per year would you like to receive this information?”

5. End