



Full length article

Using behavioral interventions to reduce single-use produce bags

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ABSTRACT

Plastic pollution is a major conservation challenge. Current policies have primarily focused on plastic bags but neglected produce bags which are a pervasive source of packaging in grocery stores. To reduce produce bag use, we designed and tested 12 behavioral interventions in a simulated online shopping task. Each intervention reduced produce bag use by 9.2% to 48.7% against the control condition. Among the 12, the most effective interventions included using an indirect incentive or punishment (via donations to an environmental organization), reminding people of the positive consequence of not using produce bags, using normative messaging, drawing attention to the no produce bag option, and reminding or visualizing the negative consequence of using produce bags. These interventions were more effective for liberal participants than conservatives or independents. These findings provide new evidence for effective behavioral interventions and heterogeneous effects in encouraging people to reduce produce bag use to curb plastic pollution.

1. Introduction

Plastic pollution has become a major conservation challenge in recent decades. At a global scale, 29 million metric tons of plastic waste entered aquatic and terrestrial environments in 2016, and the annual rate was estimated to increase 2.8-fold by 2040 in a business-as-usual scenario (Lau et al., 2020). One major source of plastic waste is plastic bags. To address plastic pollution, many countries and municipalities have introduced a levy on plastic bags or banned the use of plastic bags along with non-legislative interventions such as campaigns to raise awareness of plastic pollution (Schnurr et al., 2018). Although plastic bags have been targeted extensively, single-use produce bags which are a common form of packaging in grocery stores around the world, have received little attention. Produce bags are usually free and often used by consumers to pack fruits, vegetables, or bulk foods in grocery stores. Produce bags can be more problematic than plastic bags since some studies have argued that thicker plastic bags can be reused (Muposhi et al., 2022), whereas produce bags cannot.

While a number of factors have been identified to influence plastic consumption (e.g., convenience, social norms, incentives; Heidbreder et al., 2019; Nuojua et al., 2022), it is currently unknown which intervention is the most effective at reducing single-use produce bags. Moreover, an emerging literature suggests that the same intervention

has heterogeneous effects for different groups (Bryan et al., 2021). For example, people with centrist or right-leaning political orientations respond less strongly to interventions promoting climate action (Luo and Zhao, 2019, 2021) and show less concern than people with left-leaning orientation (Davison et al., 2021). Thus, any behavioral intervention targeting plastic pollution needs to consider the heterogeneous effects on different populations.

To curb single-use produce bag use, we designed and tested 12 behavioral interventions targeting six cognitive factors to reduce produce bag use in a simulated grocery shopping task. These behavioral interventions were motivated by a new cognitive framework that categorized behavioral interventions along six cognitive processes: attention, perception, memory, effort, intrinsic motivation, and extrinsic motivation (Luo et al., 2021). For example, an intervention targeting attention is highlighting the rising global temperature which was found to increase pro-climate actions in liberal individuals (Luo and Zhao, 2019). An intervention targeting perception is showing a marine animal (e.g., a turtle) trapped in plastic debris which was found to reduce plastic waste (Luo et al., 2022). An intervention targeting memory is a reminder that highlights the environmental consequences which reduced food waste (Barker et al., 2021). An effort intervention is moving the recycling bins closer to people's doors which increased recycling rates by over 130% (DiGiacomo et al., 2018). An intrinsic motivation

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a) Attention nudge

How many produce bags do you need?



Number of produce bags:

I don't need a produce bag.

b) Perception nudge

How many produce bags do you need?



Number of produce bags:



c) Memory nudge

How many produce bags do you need?



Number of produce bags:

As a reminder, if you do not use produce bags, the impact of plastic pollution on the ocean will be reduced.

d) Effort nudge

How many produce bags do you need?



Number of produce bags:

e) Intrinsic motivation nudge

How many produce bags do you need?



Number of produce bags:

Join your fellow citizens to not use produce bags.

f) Extrinsic motivation nudge

How many produce bags do you need?



Number of produce bags:

If you choose not to use produce bags, we will donate to Ocean Wise, which is a globally focused conservation organization on a mission to protect the ocean.

g) Attention sludge

How many produce bags do you need?



Number of produce bags:

Are you sure that you want to use produce bags?

h) Perception sludge

How many produce bags do you need?



Number of produce bags:



i) Memory sludge

How many produce bags do you need?



Number of produce bags:

As a reminder, if you choose to use produce bags, the impact of plastic pollution on the ocean will be increased.

j) Effort sludge

How many produce bags do you need?



Number of produce bags:

If you would like to use produce bags, please check this box

k) Intrinsic motivation sludge

How many produce bags do you need?



Number of produce bags:

A minority of your fellow citizens choose to use produce bags.

l) Extrinsic motivation sludge

How many produce bags do you need?



Number of produce bags:

If you choose to use produce bags, we will not donate to Ocean Wise, which is a globally focused conservation organization on a mission to protect the ocean.

Fig. 1. a–f) Design of the six nudge interventions; g–l) Designs of the six sludge interventions.

intervention is showing a social norm message which increased towel reuse behavior (Goldstein et al., 2008). Social norm messaging is considered an intrinsic motivation intervention in the current study because normative messaging using a descriptive social norm (e.g., how other people are doing) or calling on citizen identity (e.g., join your fellow citizens to do X) was found to increase people's intrinsic motivation to engage in pro-environmental behaviors (Goldstein et al., 2008; Jaeger and Schultz, 2017). An extrinsic motivation intervention is showing either financial or non-financial incentive or punishment of an action, a common example being applying a small fee to deter plastic bag use (Homonoff, 2018). Moreover, providing a prosocial incentive or punishment, such as whether to donate to an environmental organization, is considered an extrinsic motivation intervention, as it involves an indirect financial incentive or punishment to the individual (Lang et al., 2021). The financial reward or punishment is given to an organization rather than the individual depending on the individual's prior behavior. It is currently unknown which of the six types of interventions is the most effective at reducing plastic waste.

In addition to the six cognitive factors, the cognitive framework distinguished nudge interventions (i.e., those that reduce decision friction) and sludge interventions (i.e., those that increase decision friction), thus forming 12 categories of behavioral interventions (Luo et al., 2021; Mills, 2020; Sunstein, 2019). An example nudge intervention to reduce plastic waste is to provide a small incentive for recycling plastic bottles, and an example sludge intervention to reduce plastic waste is to impose a small fee for using plastic bags. It is also currently unknown whether nudge interventions or sludge interventions are more effective at reducing plastic waste. The current study thus aims to fill the previous knowledge gaps by identifying which behavioral interventions are the most effective at reducing produce bag consumption using a randomized controlled trial. This study is an attempt to tease out which cognitive factor is relevant for plastic consumption and for which population (e.g., liberals, conservatives). It also provides a new methodology to simultaneously test different interventions organized along a cognitive framework to influence one behavioral outcome of produce bag consumption.

2. Methods

2.1. Participants

We conducted a power analysis in G*Power (Faul et al., 2007), using a small effect size of 0.09, 95% power, and an alpha level of 0.05. Based on the power analysis, a minimum sample of 3211 participants would be required to detect an effect in our paradigm. Thus, a total of 3893 participants (2107 female; mean age = 38.3 years, SD = 11.8) from Amazon Mechanical Turk (MTurk) in the U.S. were first recruited to participate in the study for US \$0.25. Participants who failed the attention check or provided a number that was above 2.5 standard deviations of the mean number of produce bags (outliers) were excluded from the study, leaving a final sample of 3591 participants, which was above the minimum number required in the power analysis. We recruited our participants on MTurk for three reasons. First, we wanted our sample to have diverse political orientations. Indeed, our sample consisted of 51% liberals, 19% independents, and 30% conservatives. Second, we wanted to recruit a participant sample more reflective of the general population than undergraduate students who typically serve as research participants in psychology studies. Third, past studies have shown that MTurk participants are more socio-economically and ethnically diverse than other recruitment methods (e.g., Casler et al., 2013), and many experiments tend to replicate with MTurk samples, which was no different from results from national samples (e.g., Coppock, 2019).

2.2. Stimuli and procedure

Participants were randomly assigned to one of the 13 conditions (12

intervention conditions and a control condition). In all conditions, participants were asked to buy groceries at an online store. The screen showed 18 images of fresh fruits and vegetables in a 3 × 6 matrix. After selecting the items, they proceeded to the checkout page where they saw a roll of produce bags and reported the number of produce bags they needed to pack the products they purchased. There was no constraint on how many fruits and vegetable participants could buy or how many produce bags participants could select in the shopping task.

The 12 interventions consisted of six nudge and six sludge interventions. The six nudge interventions were designed to facilitate the choice of not using produce bags by reducing friction (Fig. 1a–f). In the attention nudge, we added a checkbox and highlighted the label “I don't need a produce bag” in red to draw participants' attention. In the perception nudge, we used an image of a turtle in a clean marine environment. In the memory nudge, we reminded participants that if they chose to not use produce bags, the impact of plastic pollution on the ocean would be reduced. In the effort nudge, a zero was shown in the input box for the number of produce bags as the default. In the intrinsic motivation nudge, a social norm message asked participants to join their fellow citizens to not use produce bags. In the extrinsic motivation nudge, participants were informed that if they chose to not use the produce bag, we would donate to an environmental organization.

The six sludge interventions were designed to deter participants from using produce bags by increasing friction (Fig. 1g–l). In the attention sludge, if participants chose to use produce bags, they would see an “Are you sure” pop-out alert asking them to confirm their choice. In the perception sludge, an image of a turtle eating plastic debris was shown to emphasize the harmful consequences associated with plastic pollution. In the memory sludge, we reminded participants that the impacts of plastic pollution on the ocean would increase if they use produce bags. In the effort sludge, participants who would like to use produce bags had to first click on an additional checkbox. In the intrinsic motivation sludge, a social norm messaging stated that a minority of fellow citizens chose to use produce bags. In the extrinsic motivation sludge, participants were informed that if they chose to use produce bags, we would not donate to the environmental organization. The control condition did not use any intervention and just asked participants how many produce bags they needed.

After checkout, participants in all conditions answered a few demographic questions and reported their political orientation on an 11-point scale from -5 (very liberal) to 5 (very conservative). In our analysis, participants were divided into liberals (below 0, $N = 1077$), independents (at 0, $N = 684$), and conservatives (above 0, $N = 1830$). These cutoffs were chosen to separate participants who consider themselves as being completely independent from other liberal-leaning or conservative-leaning participants (Kroh, 2007). Participants also rated their climate concerns, how environmentally friendly the produce bags are, how likely they will use produce bags in general, and how likely other people will use produce bags in general.

3. Results

A multiple linear regression was used to examine produce bag consumption across the 13 conditions while controlling for demographic factors such as age, gender, political orientation, and climate concerns, and purchasing factors such as the total number of items selected in the shopping task and the number of types of items selected (see Table S1). We standardized all continuous variables, dummy coded the 12 conditions with the control condition as the reference group. Compared to the control condition, extrinsic nudge (48.7% reduction, $\beta = -0.38$, $p < 0.001$), extrinsic sludge (45.4% reduction, $\beta = -0.34$, $p < 0.001$), memory nudge (37.8% reduction, $\beta = -0.27$, $p < 0.001$), intrinsic nudge (35.1% reduction, $\beta = -0.28$, $p < 0.001$), attention nudge (34.6% reduction, $\beta = -0.26$, $p < 0.001$), and memory sludge (27% reduction, $\beta = -0.17$, $p = 0.03$), and perception sludge (23% reduction, $\beta = -0.21$, $p = 0.006$) led to significantly fewer produce bag use (Fig. 2a, Table S1).

Although the other interventions were not significantly different from the control (p 's > 0.08), participants still requested between 9.2% to 15.4% fewer produce bags than those in the control condition (Table S2). Thus, the most effective interventions to reduce produce bags were using an indirect incentive or punishment, reminding people of the positive consequence of not using produce bags, using normative messaging, drawing attention to the no produce bag option, reminding people, or visualizing the negative consequence of using produce bags.

We further grouped participants into liberals, conservatives, and independents based on their self-reported political orientation and examined the effectiveness of the interventions in each group. For liberals ($N = 1077$, Fig. 2b), the multiple linear regression analysis showed that liberals in the extrinsic sludge (77.1% reduction, $\beta = -0.65$, $p < 0.001$), extrinsic nudge (70.5% reduction, $\beta = -0.58$, $p < 0.001$), intrinsic nudge (64.5% reduction, $\beta = -0.55$, $p < 0.001$), memory sludge (56.3% reduction, $\beta = -0.45$, $p < 0.001$), attention nudge (56.0% reduction, $\beta = -0.49$, $p < 0.001$), memory nudge (52.9% reduction, $\beta = -0.45$, $p < 0.001$), perception sludge (39.9% reduction, $\beta = -0.40$, $p < 0.001$), perception nudge (39.0% reduction, $\beta = -0.26$, $p = 0.02$), effort sludge (35.1% reduction, $\beta = -0.28$, $p = 0.02$), intrinsic sludge (33.5% reduction, $\beta = -0.31$, $p = 0.005$), and attention sludge (29.8% reduction, $\beta = -0.26$, $p = 0.02$) conditions requested significantly less produce bags than those in the control condition (Table S1). Liberals in the effort nudge condition requested numerically fewer produce bags than those in the control condition (15.4% reduction, $\beta = -0.14$, $p = 0.22$, Table S1, S3). However, for conservatives ($N = 1830$, Fig. 2c) only extrinsic nudge led to less produce bag use than control ($\beta = -0.31$, $p = 0.01$; Table S1, S4). For independents ($N = 684$, Fig. 2d), only extrinsic nudge led to marginally less produce bag use than the control ($\beta = -0.33$, $p = 0.05$; Table S1, S5). Therefore, the interventions showed the strongest effects on liberal participants compared to conservative or independent participants.

Furthermore, we conducted a regression analysis to examine differences between the six cognitive factors (attention, perception, memory, effort, intrinsic motivation, and extrinsic motivation) and a separate regression for the intervention type (nudge and sludge) while controlling for demographic factors and the purchasing factors (Fig. 3a, Tables S6–8).

The regression analysis showed that extrinsic motivation interventions were significantly more effective than effort interventions ($\beta = -0.25$, $p < 0.001$); however, none of the other interventions were different from the effort interventions (p 's > 0.6; Fig. 3a, Table S6). For liberals (Fig. 3b, Table S6, S8), extrinsic motivation ($\beta = -0.40$, $p < 0.001$), intrinsic ($\beta = -0.21$, $p = 0.006$), memory ($\beta = -0.25$, $p = 0.001$), and attention ($\beta = -0.17$, $p = 0.03$) interventions were significantly more effective than effort interventions. For conservatives (Fig. 3c), there was no significant difference among the interventions (p 's > 0.08, Table S6, S8). For independents (Fig. 3d), extrinsic motivation ($\beta = -0.33$, $p = 0.006$) and memory interventions ($\beta = -0.28$, $p = 0.02$) were significantly more effective than effort interventions (Table S6, S8). Lastly, nudge interventions led to numerically but not significantly fewer produce bags than sludge interventions ($\beta = -0.05$, $p = 0.11$; Table S7).

4. General discussion

The current study examined the impact of 12 behavioral interventions on reducing single-use produce bag consumption in a simulated online grocery shopping task. We found that the most effective interventions to reduce single-use produce bags were using an indirect incentive or punishment (via donation to an environmental organization depending on participants' produce bag use), reminding participants of the positive consequence of not using produce bags, using normative messaging, drawing attention to the no produce bag option, and reminding participants or visualizing the negative consequence of using produce bags. Each of the 12 interventions reduced the number of

produce bags by 9.2% – 48.7% compared to the control condition. Moreover, these behavioral interventions were more effective for liberal participants than for conservatives and independents, revealing heterogeneous effects of the interventions for people with different political orientations. These findings suggest that tailored interventions for different sociopolitical groups should be considered to reduce produce bag consumption (Mills, 2022; Zhao and Luo, 2021).

Across the six cognitive factors, interventions targeting extrinsic motivation (using indirect incentives or punishment) were more effective than interventions targeting attention, perception, intrinsic motivation, and effort. This suggests that an indirect incentive of not using produce bags or punishment of using produce bags may be more important to participants than simply drawing attention to the no bag option, visualizing the marine consequences of produce bags, showing the social norms, or changing the effort involved in this task. The success of this intervention could be due to at least four reasons. First, it highlights the indirect consequences (i.e., no donations to Ocean Wise) of produce bag consumption, even though these indirect consequences do not apply directly to the participants themselves. The explicit consequences give participants a reason to not use produce bags, whereas the other interventions (except for memory interventions) do not mention any explicit consequences of their actions. Second, the indirect consequences may resemble the plastic bag fees with which participants may be familiar. The participants may have generalized from not using plastic bags to avoid the fee to not using produce bags to ensure the donation. Third, these interventions are the only ones that involved a third party (i.e., Ocean Wise), which may elicit a sense of guilt in the participants if their use of produce bags results in no donations to the organization. Finally, these interventions imply that the donations (or the lack thereof) to Ocean Wise may consequently impact the protection of marine life which is the organization's mission. This may have encouraged participants who are concerned about harm to the marine environment or have strong biospheric values to reduce produce bags (Mintz et al., 2019).

Imposing an indirect punishment by not donating to Ocean Wise for using produce bags was consistent with previous studies showing that imposing a small fee on plastic bags significantly decreased the number of plastic bags used at grocery stores (Convery et al., 2007; T. Homonoff et al., 2018). Interestingly, providing an indirect incentive by donating to Ocean Wise for not using produce bags seemed to be more effective than imposing an indirect punishment in the current study. This was consistent with a recent study that showed that donating to a charity for customers who did not purchase single-use carrier bags significantly reduced plastic bag consumption (Romano and Sotis, 2021).

Memory interventions that reminded people of the environmental consequences of produce bags were also effective at reducing produce bag use. This is because memory interventions highlighted the environmental benefits of not using produce bags or the environmental costs of using produce bags. Visualizing the negative consequences of produce bags in the perception intervention was also effective at reducing produce bag use (Luo et al., 2022), which was consistent with reminding people of the environmental costs. Both the extrinsic motivation interventions (i.e., donating or not donating to an environmental organization), memory interventions (i.e., being reminded of the positive or negative consequences of plastic pollution), and perception intervention (i.e., visualizing the marine consequences of plastic waste) explicitly described the consequences of participants' choices, whereas the other interventions provided guidance toward reducing produce bag use without providing a justification. Moreover, reminding participants of the positive effect of not using produce bags seemed to be more effective than reminding people of the negative consequence of produce bag consumption, which was again consistent with past studies where reminding people of the benefits of not eating meat significantly reduced meat consumption (Wolstenholme et al., 2020).

The intrinsic motivation nudge intervention (using normative messaging to call on people's identity) was also effective at reducing

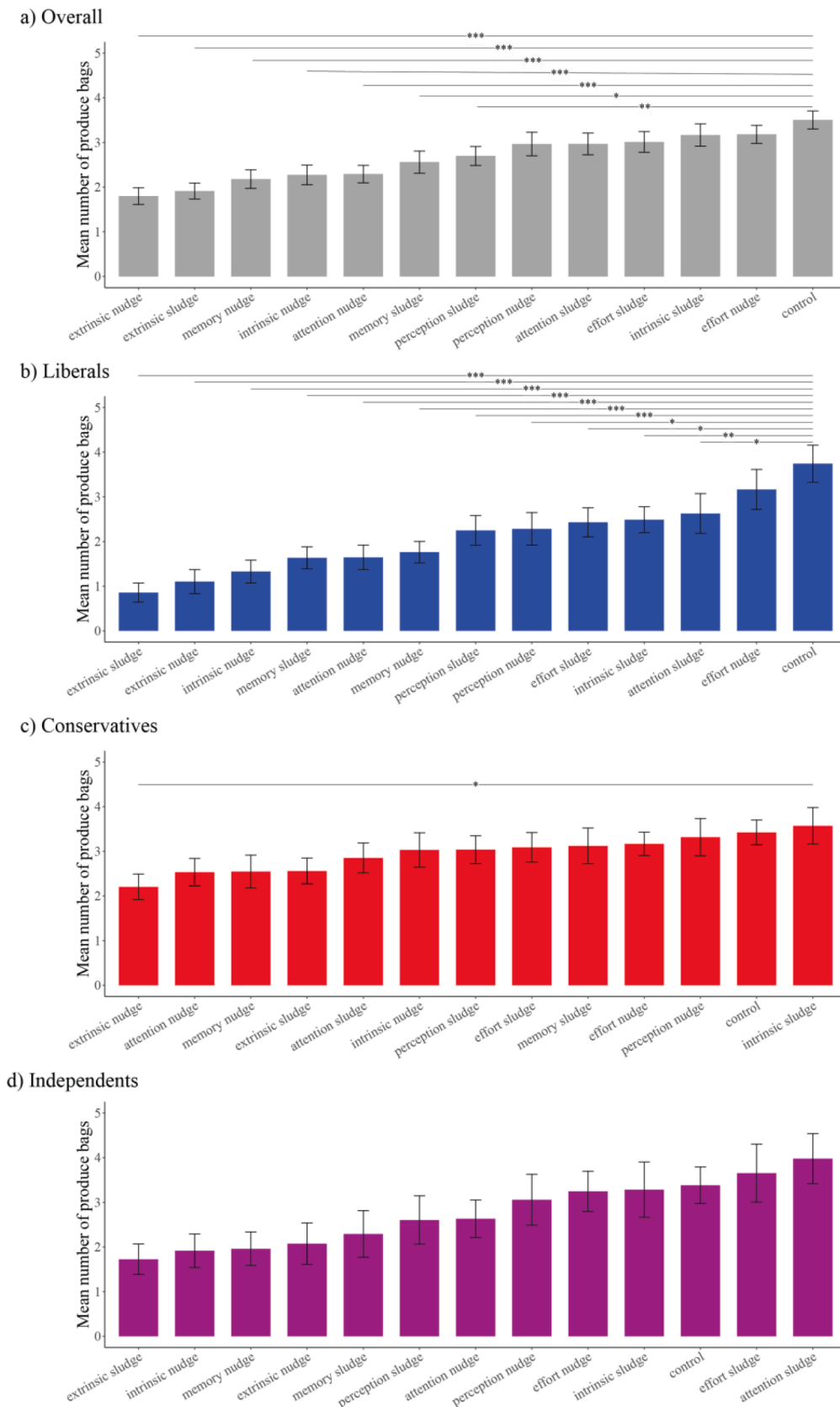


Fig. 2. Mean number of produce bags in the intervention conditions and the control condition for (a) all participants ($N = 3591$), (b) liberals ($N = 1077$), (c) conservatives ($N = 1830$), and (d) independents ($N = 684$). Statistical significant comparisons to the control condition in the multiple linear regression were flagged. (Error bars reflect ± 1 SEM; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$).

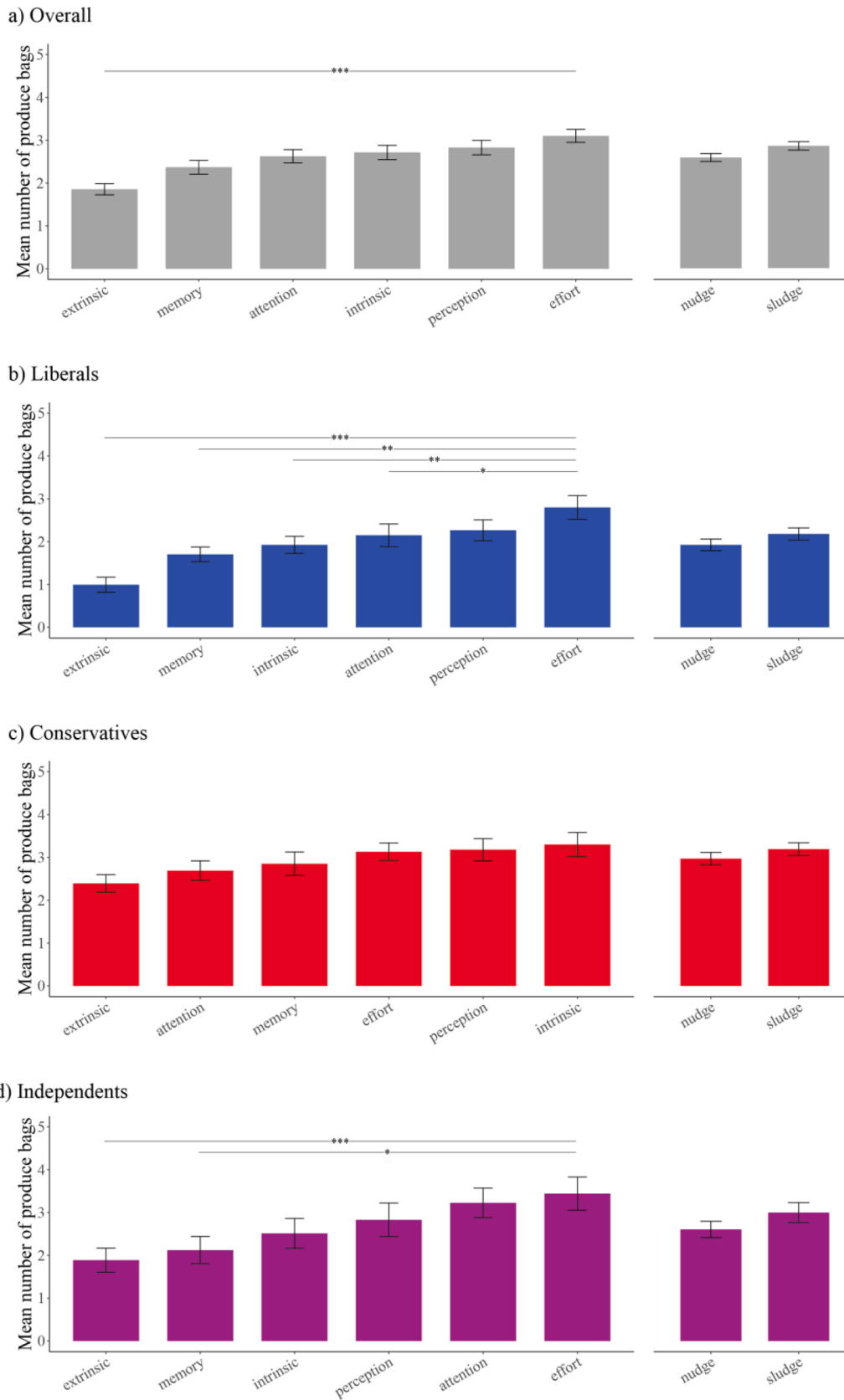


Fig. 3. Comparisons of the mean number of produce bags used across the six cognitive processes and between the two types of intervention (nudge vs. sludge) for (a) all participants ($N = 3591$), (b) liberals ($N = 1077$), (c) conservatives ($N = 1830$), and (d) independents ($N = 684$). Statistical significant comparisons to effort interventions in the multiple linear regression analysis were flagged (Error bars reflect ± 1 SEM; $*p < 0.05$, $**p < 0.01$, $***p < 0.001$).

produce bag consumption compared to the control condition, consistent with a theoretical model showing that social norm was the strongest predictor of plastic avoidance (Borg et al., 2020). The attention nudge intervention enhanced the attentional salience of the option of not using any produce bags, consistent with past studies where drawing attention to vehicle inspection increased inspection rates (Namazu et al., 2018), or highlighting the message of renewing license plate stickers significantly increased the likelihood of license renewal among drivers (Castelo et al., 2015). Lastly, the negative visualization of a turtle in the ocean was effective, consistent with past studies that showed that the impact of plastics on marine animals elicited the motivation to reduce plastic waste (Boomsma et al., 2016; Luo et al., 2022).

Nudge interventions were numerically more effective than sludge interventions in reducing produce bag use. This finding was consistent with the previous meta-analyses showing that interventions that eased decision making were the most effective in the environmental domain (Luo et al., 2021; Mertens et al., 2022) and aligned with past work suggesting that reducing costs of a specific behavior is critical for people to take action (Kaiser et al., 2010). This suggests that behavioral strategies to reduce plastic waste should make the decision to not use produce bags easier rather than making the decision to use produce bags harder. This said, we found effort interventions were the least effective in our study. One explanation is that we asked a simple question where participants indicated how many produce bags they needed, an action that required minimum effort compared to other actions involving physically recycling waste or sorting items into bins. Thus, decreasing the amount of effort by making 0 produce bags the default or increasing effort by requiring participants to check a checkbox if they wanted to use produce bags may not have a meaningful impact on the action compared to reducing the physical or cognitive effort of reducing plastic waste in past experiments (e.g., walking a longer distance to recycle, DiGiacomo et al., 2018; sorting items into bins, Wu et al., 2018).

The current study is significant for several reasons. First, it offers novel theoretical insights on which cognitive factors (e.g., extrinsic motivation, memory, attention) are important in shaping produce bag consumption. It provides the first experimental evidence for which behavioral interventions guided by which cognitive factors are effective at reducing produce bag consumption compared to the control condition without any intervention. Given that our study only examined cognitive factors, future studies can investigate other psychological factors in decision making, such as affective and motivational factors. Second, it offers empirical evidence on the efficacy of nudge vs. sludge interventions in reducing produce bag use. This suggests that behavioral interventions should try to reduce decision friction rather than increase it. Third, the findings demonstrate the heterogeneity of the intervention effects where liberal participants showed the strongest effects of the behavioral interventions, compared to conservative or independent participants. This suggests that behavioral interventions can be used with liberal participants who tend to be more environmentally conscious, but perhaps not with conservative or independent participants, with whom other approaches should be considered. Fourth, the study offers an experimental paradigm to simultaneously examine the impacts of different interventions on a single behavioral outcome.

Finally, the findings provide practical guidance for practitioners (e.g., grocery stores) to develop behaviorally informed strategies to curb produce bag consumption. For example, grocery stores can either impose an indirect cost (e.g., warning customers that the store will not donate to an environmental organization if customers use produce bags) or provide an indirect reward (e.g., informing customers that the store will to an environmental organization on behalf of customers if customers do not use produce bags). Possible barriers to implementing this intervention are that the store may need to increase its donation budget, or customers may feel pressured during their shopping. Signage can be posted beside the produce bags to remind consumers that using fewer produce bags can help reduce plastic pollution in the ocean, encourage them to join fellow citizens to not use produce bags, ask them to bring

reusable produce bags, or visualize the impacts of produce bags on marine animals. Potential difficulties of implementing signage in stores are to figure out the optimal location to display the signage and the best design of the signage to customize the contents locally, as the efficacy of the intervention may differ between customer groups, locations, and store types.

In conclusion, the current study showed that a number of behavioral interventions can effectively reduce produce bag consumption. Although the current study was conducted on a simulated grocery store platform, it demonstrates a promise in the potential impact of nudge and sludge interventions. Future studies should assess the impact of these behavioral interventions on produce bags in actual grocery stores. These findings provide new insights on which cognitive insights can impact produce bag consumption.

CRediT authorship contribution statement

Yu Luo: Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Project administration, Funding acquisition, Software, Formal analysis, Investigation, Resources, Data curation, Visualization. **Jiaying Zhao:** Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Project administration, Funding acquisition, Supervision.

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

[Replication Data for: Using behavioral interventions to reduce single-use produce bags \(Reference data\)](#) (Dataverse)

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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.2023.106942](https://doi.org/10.1016/j.resconrec.2023.106942).

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