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Reducing single-use plastic on college campuses: Theory of planned behavior-based brief interventions

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ABSTRACT

Single-use plastic has devastating impacts on the natural environment and scalable theory-based interventions are urgently needed to curb plastic consumption. The purpose of this study is to test the impact of two brief plastic reduction interventions on consumption on college campuses and whether these effects will be mediated by changes in the extended Theory of Planned Behavior (TPB) model consisting of attitudes, subjective norms, perceived behavioral control, moral norms, descriptive norms, and self-identity. 375 undergraduate students (77% female) from two colleges in the southeastern US completed baseline measures of plastic consumption beliefs and behavior in line with the extended TPB model. Participants were then randomized into one of three groups - control group (n = 152), app intervention group (who tracked plastic behavior on a mobile phone app for a week and received TPB-based daily messages via push notifications; n = 89), or pledge intervention group (who made a pledge to reduce plastic for a week and received TPB-based daily messages via email; n = 134). All participants completed the survey again after the intervention week. Results showed that the extended TPB model along with the intervention condition significantly predicted changes in plastic behavior over the week, (R^2 = 0.24, p < .001). Additionally, mediation analysis revealed that the pledge group (compared to the control group) reported a significant decrease in plastic consumption over the week-long intervention, with indirect effects via changes in attitudes, perceived behavioral control, and descriptive norms. The app group (compared to the control group) decreased plastic consumption less and showed no change to the extended TPB constructs. Results suggest that plastic reduction interventions that influence the extended TPB constructs can be expected to have corresponding changes in plastic consumption behavior.

1. Introduction

1.1. The problem of plastic pollution

Plastic consumption has skyrocketed over the past 70 years and is continuing to increase (Geyer et al., 2017). Although there are many benefits of plastic, disposal remains a significant problem (Thompson et al., 2009). Only a small amount of plastic waste is diverted for recycling (Geyer et al., 2017) and of that, much plastic ends up in landfills due to recycling contamination or economic infeasibility. Thus, the vast majority of plastic waste is in landfills or littered in the natural environment (Geyer et al., 2017), particularly impacting the marine environment (Jambeck et al., 2015; Lavers and Bond, 2017), with negative consequences for human health and the natural environment (Barnes et al., 2009).

Interventions to reduce single-use plastic consumption are urgently needed. As is the case with many environmental issues, the problem of plastic pollution is inherently a result of human behavior. Humans use single-use plastic in their everyday activities, so reducing the demand for plastic requires changing human behavior. Interventions to reduce use of single-use plastic that incorporate an understanding of the motivators of behavior are likely to be most successful (Heidbreder et al., 2019; Jia et al., 2019). Additionally, interventions that have the potential to be scaled up to large swaths of the public are particularly attractive. Although the implementation of plastic consumption bans has begun, these take a long time to develop and can sometimes lead to

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public backlash (Heidbreder et al., 2019). Voluntary behavior change interventions, such as those that involve brief interventions or nudges, show promise in reducing plastic consumption, as larger and more comprehensive policies are developed (Truelove et al., 2022). This paper describes the results of a theory-based behavior change brief intervention to reduce consumption of single-use plastic on college campuses.

1.2. The theory of planned behavior

The Theory of Planned Behavior (TPB) (Ajzen, 1991; Ajzen and Fishbein, 2005; Fishbein, 2000) is one of the most widely used theories to predict individual pro-environmental behavior (see Truelove et al. (2019) for an overview of social psychological theories commonly applied to pro-environmental behavior). The major tenants of the TPB are that attitudes toward the behavior (positive or negative evaluations of the behavior), subjective norms (beliefs that important others believe the person should perform the behavior), and perceived behavioral control (PBC; beliefs about the ease of carrying out the behavior) directly relate to intention to perform the behavior (Ajzen, 2002; Ajzen and Fishbein, 2005). Intention and PBC, to the extent that it reflects actual control, directly predict behavior (Ajzen and Fishbein, 2005). Behavioral beliefs, normative beliefs, and control beliefs underlie attitudes, subjective norms, and PBC, respectively (Ajzen and Fishbein, 2005). The TPB has been used to predict a wide range of pro-environmental behaviors, including recycling intentions and behavior (Botetzagias et al., 2015; Carrus et al., 2009; Chan and Bishop, 2013; Largo-Wight et al., 2012; Passafaro et al., 2019; Terry et al., 1999), eco-friendly travel intentions and behavior (de Groot and Steg, 2007; Harland et al., 1999; Heath and Gifford, 2002), green electricity purchases (Litvine and Wüstenhagen, 2011), eco-friendly food intentions and behaviors (Graham-Rowe et al., 2015; Harland et al., 1999; Sparks and Shepherd, 1992), and environmental activism intentions (Fielding et al., 2008), as well as general pro-environmental intentions and behavior (Carfora et al., 2017; de Leeuw et al., 2015; Kaiser et al., 2005).

1.3. Expanded TPB

Although the TPB has been successful in predicting a wide array of pro-environmental behaviors, several constructs have been added based on their theorized relationship to pro-environmental behavior and empirical results from TPB studies. For example, in tests of the TPB, subjective norm has often been found to be the weakest predictor of pro-environmental behavior, including in studies predicting general measures of pro-environmental behavior (de Leeuw et al., 2015; Harland et al., 1999), recycling intentions (Botetzagias et al., 2015; Chan and Bishop, 2013), and organic vegetable consumption intentions (Sparks and Shepherd, 1992). Furthermore, a recent meta-analysis shows that subjective norms are weaker predictors of pro-environmental behaviors compared to personal norms and descriptive norms (Niemiec et al., 2020).

In light of these findings, several authors have argued for expanding the social norm component of the TPB (Armitage and Conner, 2001; Rivis and Sheeran, 2003) and measuring multiple types of norms when predicting pro-environmental behavior (Niemiec et al., 2020). Injunctive norms refer to what others believe ought to be done in a particular situation, while descriptive norms refer to what others actually do (Cialdini et al., 1990). Much research has shown that both injunctive and descriptive norms influence pro-environmental behavior (Niemiec et al., 2020; Schultz et al., 2007). The subjective norm component of the TPB covers the injunctive norm in that both are concerned with perceptions of what other people think should be done (Rivis and Sheeran, 2003). However, the TPB does not include descriptive norms. The addition of descriptive norms has been shown to add predictive value to TPB in pro-environmental behaviors, such as predicting bus ridership and intentions (Heath and Gifford, 2002), recycling behavior and intentions (Carrus et al., 2009; Largo-Wight et al., 2012; Passafaro et al., 2019), and green electricity purchasing (Litvine and Wüstenhagen, 2011). Furthermore, descriptive norms were found to more strongly relate to intentions among younger participants (Rivis and Sheeran, 2003), suggesting that research on adolescents and young adults should incorporate descriptive norm measures. Additionally, the closer the referent group is spatially, the more perceived descriptive norms related to behavioral intentions to recycle (Carrus et al., 2009; Passafaro et al., 2019) and towel reuse when staying in a hotel (Goldstein et al., 2008). This suggests that university students may be especially receptive to perceived descriptive norms of fellow students on campus.

There have also been calls to add personal norms, or moral norms, in models predicting pro-environmental behavior (Niemiec et al., 2020). Personal norms are feelings of moral obligations to perform a particular behavior (Schwartz, 1977) and are the centerpiece of the Value Belief Norm Theory (Stern et al., 1999), which has been shown to successfully explain pro-environmental behavior (Kaiser et al., 2005). Some work has added personal norms to the TPB and it has been a predictor of pro-environmental behavior, including recycling intentions (Botetzagias et al., 2015; Largo-Wight et al., 2012) and intentions and behavior related to reducing meat consumption, avoiding driving, and using efficient light bulbs (Harland et al., 1999). However, personal norms did not predict bus ridership or intentions (Heath and Gifford, 2002) or add much predictive power to the TPB model in predicting a composite of pro-environmental behavior intentions (de Leeuw et al., 2015). Additionally, several studies have had difficulty separating the two constructs of attitude and personal norm due to multicollinearity (Chan and Bishop, 2013; Graham-Rowe et al., 2015; Kaiser, 2006; Lam and Chen, 2006). However, a meta-analysis of pro-environmental behavior predictors found that personal norms relate to pro-environmental behavior intention as strongly as two of the main TPB components, attitude and PBC (Bamberg and Möser, 2007). An additional meta-analysis showed that personal norms related more strongly than subjective norms, but not as strongly as attitude or PBC (Klöckner, 2013).

Further, other work has argued for the inclusion of self-identity to the TPB (Fekadu and Kraft, 2001). Social identity and self-perception theories argue that people derive their personal identities based on their group memberships and act in line with their identities (Bem, 1972; Tajfel and Turner, 2004). Environmental self-identity is the extent to which one sees themselves as the type of person who acts pro-environmentally (Whitmarsh and O'Neill, 2010). When added to the TPB, environmental self-identity predicted intention to buy organic produce (Sparks and Shepherd, 1992), to participate in environmental activism (Fielding et al., 2008), and to recycle (Largo-Wight et al., 2012; Terry et al., 1999).

1.4. Expanded TPB and plastic consumption

Although much research has used the TPB or TPB-related models to predict pro-environmental behavior, only a handful of studies has tested the theory in predicting plastic consumption. In one study testing the full TPB, attitude, subjective norm, and PBC predicted intention to use plastic bags (Sun et al., 2017). In another study on bag use in hypermarkets, PBC predicted intention and behavior related to bringing reusable bags, while a combined attitude-personal norm variable predicted intention to refuse plastic bags (Lam and Chen, 2006). In another study testing parts of the TPB, intentions to reduce water bottle consumption were related to behavioral and control beliefs, the precursors of attitude and subjective norm (van der Linden, 2015). A study on plastic consumption outside the TPB framework found that environmental self-identity related to straw use behaviors and recycle and reuse behaviors, which included reducing consumption of single-use plastic items like bags, cups, and take-away containers (Truelove and Nugent, 2020). Thus, the literature so far provides some evidence that TPB constructs may predict behavior related to single-use plastic consumption. However, no research

could be located that included personal norms, descriptive norms, and self-identity as additional variables in TPB models predicting single-use plastic consumption, which is one of the strategies of the present study.

1.5. TPB and experimental interventions

In addition to applying the TPB to predict behavior, the TPB can be used as a framework for intervention design where interventions are crafted to target various structures of the TPB (Ajzen, 2014; Steinmetz et al., 2016). TPB-based interventions have been shown to be effective in changing a wide range of beliefs, behavior, and intentions (Anderson et al., 2013; Norman et al., 2018; Parker et al., 1996; Parrott et al., 2008; Sniehotta, 2009; Steinmetz et al., 2016), and are among the most effective theory-based interventions (Webb et al., 2010).

Some work has involved brief interventions focused specifically on persuasive messages to reduce plastic consumption designed in line with the TPB constructs of subjective norm, attitude, and PBC. In one study, a persuasive message encouraging reducing plastic bag use at the grocery was most effective when it included injunctive normative elements (de Groot et al., 2013). In another study, providing participants with information about the environmental effects and social norms of plastic water bottles related to the reduction of intentions to purchase bottled water compared to a control condition (van der Linden, 2015). In another study testing the TPB, attitudes and PBC, but not subjective norm, predicted plastic consumption intentions after viewing plastic reduction messages (Muralidharan and Sheehan, 2016). In a more robust test of a TPB-designed intervention on energy consumption, Litvine and Wüstenhagen (2011) created messages that targeted each of the three main TPB constructs (attitude, PBC, and subjective norm) related to green electricity. The participants who were most likely to switch to green electricity after the experiment were those who received messages specifically targeting attitudes or those that targeted attitudes, subjective norm, and PBC during the intervention (Litvine and Wüstenhagen, 2011). To have the best chance of success, TPB-based interventions should include persuasive messages that target multiple TPB constructs.

In addition to persuasive messages specific to each TPB construct, past findings also suggest that brief interventions that target multiple behavior change strategies may be maximally effective (Webb et al., 2010). A relatively low-cost and practical intervention often used by pro-environmental campaigns involves participants making commitments or pledges to engage in more environmentally friendly behaviors. Meta-analysis has shown that pledge interventions are effective in increasing pro-environmental behavior compared to control groups, and that interventions that involve a pledge in combination with other targeted persuasive strategies may lead to even more behavior change during the intervention (Jacobs et al., 2021; Lokhorst et al., 2013). Additionally, app interventions, where participants track their pro-environmental behavior via a mobile application has grown in recent years (D'Arco and Marino, 2022). Those who report using sustainability apps in their daily life, score higher on pro-environmental beliefs than those who do not (D'Arco and Marino, 2022). Additionally, app users show stronger correlations between environmental beliefs and behavior than non-app users (D'Arco and Marino, 2022). Several recent experimental studies have tested the effectiveness of app interventions combined with supplementary communication methods for participants such as text messages or SMS (Webb et al., 2010). These methods have demonstrated successful behavior change. For example, participants who tracked their water intake behavior using an online app and who received daily persuasive text messages focusing on anticipated negative regret as part of the intervention, increased short term behavior compared to controls (Carfora et al., 2018). In another study on meat consumption, participants exposed to a similar intervention showed changes in attitudes, intentions, and behavior, but not PBC or subjective norms (Carfora et al., 2017b). In both studies, only the construct targeted in the daily messages (i.e., anticipated negative regret), and not the non-targeted TPB constructs, served as a mediator of the relationship between the experimental manipulation and behavior (Carfora et al., 2018; Carfora et al., 2017b). However, research in the health domain has found some evidence that interventions indirectly influence intention and behavior via increasing TPB constructs (Norman et al., 2018; Sniehotta, 2009). Thus, more work is needed to test the effectiveness of interventions targeting TPB constructs in changing plastic consumption directly and indirectly via changing the expanded TPB constructs, which is one of the goals of this present study.

1.6. Present study

In the present study, participants from a mid-sized public university and a small private college in the southeastern US completed baseline surveys assessing expanded TPB constructs related to the consumption of single-use plastic items. Participants were then randomly assigned to one of two treatment groups asked to reduce consumption of single-use plastic for a week or to a control group that was not asked to reduce their consumption. One intervention group was asked to track their daily plastic consumption via a mobile phone application (app group) and one group made an online pledge to reduce their plastic consumption (pledge group). Persuasive messages designed to increase beliefs in line with the TPB were shared with both intervention groups daily via push notification (app group) or email (pledge group). At the end of the intervention week, all participants completed the same measures as Time 1.

The present study aims to fill several gaps in the literature. First, we focus exclusively on consumption of single-use plastic and investigate multiple plastic items, adding to the literature that has included plastic consumption as a part of broader measures of pro-environmental behaviors or studies that have focused on only one or two plastic consumption behaviors (Kaiser and Wilson, 2000; Lam and Chen, 2006; Sun et al., 2017; Truelove and Gillis, 2018; Truelove and Nugent, 2020; van der Linden, 2015). Second, we add to the literature by examining extensions to the TPB (i.e., moral norms, descriptive norms, and self-identity) in predicting change in plastic consumption, and building upon studies that have focused on the main TPB constructs of attitude, subjective norm, and PBC (Muralidharan and Sheehan 2016; c.f., Sun et al. 2017). Third, we investigate two experimental interventions compared to a true control group, heeding the call of Lokhurst et al. (2013) to compare commitment interventions to other interventions. Fourth, we examine the ability of the interventions to indirectly influence behavior change through changing the targeted TPB constructs in line with suggestions to explore the role of the TPB components as mediators of the intervention-behavior change relationship (Hardeman et al., 2002).

Based on the research reviewed above, we forward our hypothesized theoretical model (Fig. 1) and the following hypotheses. First, we hypothesize that changes in the extended TPB constructs will explain significant variance in changes in single-use plastic consumption (H1). Second, we expect that the intervention conditions (compared to the control conditions) will directly decrease plastic consumption over the week (H2). Finally, in line with previous research in the health domain (Norman et al., 2018; Sniehotta, 2009), we hypothesize that the intervention conditions, compared to the control conditions, will indirectly decrease plastic consumption via changing the expanded TPB constructs (H3).

2. Method

2.1. Participants and procedures

The following procedures were approved by the Institutional Review Board (IRB) at the authors' universities and participants were treated in accordance with ethical standards for research on human subjects. Undergraduate students from one mid-sized public university and one private college in the southeastern US served as participants for this study.

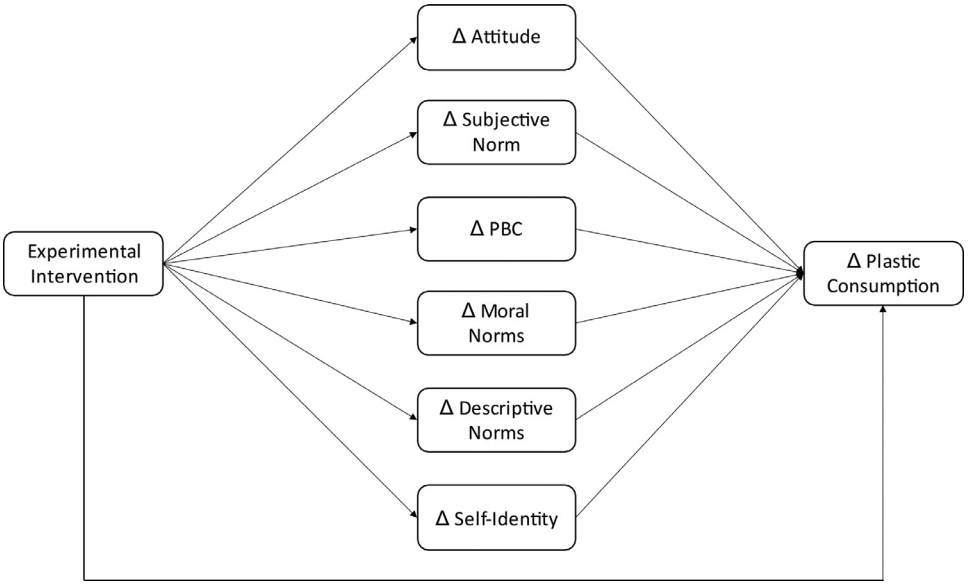

Fig. 1. Hypothesized theoretical model of change in single-use plastic consumption. PBC = Perceived Behavioral Control.

Our recruitment consisted of emailing a census of sophomores, juniors, and seniors (at the private college) and a random sample of sophomores, juniors, and seniors (at the public university) with an invitation to participate in a one-week long project on single-use plastic consumption.

Potential participants were emailed a link to an informed consent statement. Those who consented to participate were routed to begin Survey 1. Five hundred and ninety participants completed Survey 1 and were then randomized to the control condition (n = 198) or one of two intervention conditions — app condition (n = 192) or pledge condition (n = 200). Participants in the intervention conditions then completed their one-week intervention. Following the intervention, all participants were emailed a link to Survey 2, of which 423 completed the second survey. Participants were incentivized with a $10 electronic gift card for completing Survey 1 and a $10 gift card for completing Survey 2. At the conclusion of each survey, participants were thanked for their participation and provided instructions on how to obtain their incentive.

We excluded 48 participants from the intervention groups who were not engaged in their conditions (i.e., participants assigned to the pledge group who did not make the pledge (n = 12) and participants assigned to the app group who did not download and open the app (n = 36)). Therefore, the final sample consisted of 375 participants (control condition: n = 152, app condition: n = 89, and pledge condition: n = 134), with a 64% overall retention rate. Retention rates for each condition was as follows: 77% for the control group, 46% for the app group, and 67% for the pledge group.

The average age of our sample was 21.3 years old (SD = 3.44). Most of our sample identified as female (76.8%), with 21.3% male and 1.9% other gender. The majority of our sample identified as White (80.3%), with the remaining identifying as Asian (8.0%), Black or African American (6.1%), or Other (5.3%). The majority (89.6%) of our sample identified as non-Hispanic.

2.1.1. Survey materials

The Wave 1 and Wave 2 behavioral survey asked TPB-related questions about ten single-use plastic items: snack wrappers, straws, cups, lids, take out containers, bags, utensils, bottles, masks, and hygiene products. Specifically, the questions assessed participants' behavior, intentions, attitudes, subjective norms, PBC, descriptive norms, moral norms, and self-identity relating to each plastic item (Table 1). Thus, the TPB constructs were conceptualized as aggregates (average) of all plastic items, in line with previous research on pro-environmental behavior (Kaiser et al., 2005). In Wave 2 participants in the experimental groups also answered questions about their self-reported adherence to the interventions. Participants also answered questions related to plastic knowledge, policy support, and general environmental beliefs and behavior, which were not analyzed as part of the present study.

2.1.2. Brief interventions description

The app condition consisted of multiple behavior change strategies over the course of a week: tracking single-use plastic consumption and refusal in an iPhone app created for this study that included injunctive normative emoticons, daily reminders to upload data, and TPB-based messages shared via push notifications, as well as a request to reduce plastic consumption delivered within the context of the email that provided instructions for using the app and submitting data. In line with injunctive normative research showing that happy and sad emoticons indicate the expected behavior leading to pro-environmental behavior changes (Schultz et al., 2007), each time participants recorded using a single-use plastic item within the app, they clicked a sad face emoticon and each time they recorded refusing a single-use plastic item, they clicked a happy face emoticon (See Supplemental). The single-use plastic items listed on the app were the same as those listed in the survey. The TPB-based messages were sent as push notifications within the app each morning during the intervention and encouraged plastic refusal by targeting the main constructs of the TPB (See Supplemental). Notably, the app group was not asked to make a pledge to reduce their plastic consumption over the coming week.

The pledge intervention involved participants making a pledge to reduce their plastic consumption over the coming week by agreeing to the following statement in an online survey: "I commit to reducing my single-use plastic consumption over the next week." Additionally, the pledge group was sent the same daily TPB-based messages as the app group via email each morning. Notably, the pledge group was not asked to track their plastic consumption behavior over the week.

3. Results

3.1. Attrition analyzes

We assessed attrition bias by comparing those who completed both Time 1 and Time 2 with those who dropped out of the study on their scores on Time 1 extended TPB constructs and demographics. Completers did not differ from non-completers on any of the Time 1 TPB constructs. Women were more likely to complete than men (67% vs. 53%; X^2 (1) = 9.428, p = .002) and students from the private college were more likely to complete than those from the public university (89%

Table 1
TPB Constructs and Expanded TPB Constructs Measures.

Measure	Question Stem	Response Scale (1–7)
Behavior (α_{T1} = 0.735, α_{T2} = 0.779)	In the past week, how many times have you used each of the following plastic items?	0–6+
Attitude (α_{T1} = 0.865, α_{T2} =0.882)	I think reducing my use of plastic ___ over the next week is:	Very Bad- Very Good
Subjective Norm (α_{T1} = 0.966, α_{T2} =0.966)	Most people who are important to me think I should reduce my use of plastic ___ over the next week.	Strongly Disagree- Strongly Agree
Perceived Behavioral Control (α_{T1} = 0.779, α_{T2} =0.796)	My reduction of plastic ___ over the next week is:	Very Difficult- Very Easy
Descriptive Norm (α_{T1} = 0.871, α_{T2} =0.896)	In the past week, most people on campus have used plastic ___ which number of times?	0–6+
Moral Norm (α_{T1} = 0.951, α_{T2} =0.958)	I have a strong moral obligation to reduce my use of plastic ___ over the next week.	Strongly Disagree- Strongly Agree
Self-identity (α_{T1} = 0.969, α_{T2} =0.966)	Reducing my use of plastic ___ over the next week is an important part of who I am.	Very Unlikely- Very Likely
Intention (α_{T1} = 0.919, α_{T2} =0.919)	I intend to reduce my use of plastic ___ over the next week.	Very Unlikely- Very Likely

Note. The blank was filled with the plastic items including: snack wrappers, straws, cups, lids, take out containers, bags, utensils, bottles, masks, and hygiene products. Time 1 questions referred to the timeframe of the next week and Time 2 questions referred to the next three months.

vs. 59%; X^2 (1) = 57.613, $p < .001$). There were no differences for race or age. Those in the control group were more likely to remain in the study than those in the pledge group and the app group (X^2 (2) = 40.475, $p < .001$).

3.2. Randomization check

We compared the app, pledge, and control groups to confirm that they were not different on key variables at baseline, including the TPB constructs and demographics. One-way ANOVAs revealed that Time 1 scores on the TPB and extended TPB constructs did not differ between the conditions (Table 2, Top Panel). Tukey multiple comparison tests confirmed that all of the bias-corrected and accelerated 95% confidence intervals based on 1000 bootstrap samples for all comparisons contained 0, providing further evidence that the Time 1 TPB scores were not different between the three groups. Additionally, the groups did not differ in terms of demographics [gender: X^2 (2) = 0.082, p = .960; race: X^2 (6) = 0.884, p = .990; university: X^2 (2) = 3.756, p = .153; age: Welch[1] F(2, 228.009) = 2.677, p = .071]. Thus, the randomization was considered successful.

3.3. Descriptive statistics

The means for each group on the TPB-related constructs measured at Time 2 are presented in Table 2 (Middle Panel). As can be seen, mean scores on the TPB-related constructs were above the midpoint, with 1-2 pieces of plastic consumption reported on average across the categories. We tested whether the experimental conditions differed from the control condition on the Time 2 TPB-related outcomes using one-way ANOVAs with bootstrapping 1000 samples and bias-corrected and accelerated 95% confidence intervals around the mean differences between conditions for the pairwise comparisons. The assumption of homogeneity of variance was violated for Time 2 behavior, attitude, moral norms, and intention, therefore the Welch F-ratio is reported for those outcomes and the pairwise comparisons are reported for the Games-Howell post hoc tests. For Time 2 subjective norms, PBC, descriptive norms, and self-identity, homogeneity could be assumed and Tukey tests are reported for the pairwise comparisons. Results showed that there were significant differences between the groups for Time 2 behavior, attitude, moral norms, self-identity, and intentions, but not subjective norms, PBC, or descriptive norms (Table 2). Posthoc tests showed that the pledge group scored higher than the control group on Time 2 attitudes, subjective norms, moral norms, self-identity, and intentions to reduce plastic consumption and lower than the control group on plastic consumption behavior, demonstrating that the pledge group was effective at influencing most of the Time 2 TPB-related constructs. The pledge group also scored lower than the app group on Time 2 behavior and higher than the app group on Time 2 moral norms, self-identity, and intentions. None of the pairwise comparisons between the app group and the control group were significant, suggesting that the app intervention was not more effective than the control group in influencing the Time 2 TPB-related constructs.

Next, we tested whether the experimental conditions differed from the control condition in changes in the TPB-related outcomes over time. We used one-way ANOVAs with experimental group as the independent variable and the difference scores between Time 1 and Time 2 as the dependent variables, with bootstrapping 1000 samples and bias-corrected and accelerated 95% confidence intervals around the mean differences between conditions for the Tukey pairwise comparisons. Results showed that there were significant differences between the groups for changes in behavior, attitude, descriptive norm, moral norm, self-identity, and intentions, but not PBC or subjective norms (Table 2, Bottom Panel). Pairwise comparisons showed that the pledge group increased more than the control group in attitudes, subjective norms, PBC, moral norms, self-identity, and intentions to reduce plastic consumption and decreased more than the control group in plastic consumption behavior and perceived descriptive norms for using plastic, demonstrating that the pledge was effective at changing the TPB-related constructs. The pledge group also reduced plastic consumption more than the app group (which showed no change over the week) and increased self-identity and intention more than the app group. The app group did not differ from the control group on any of the TPB constructs except for plastic consumption behavior, where the control group decreased consumption more than the app group.

3.4. Correlations

We ran correlations between changes in single-use plastic consumption and changes in the expanded TPB constructs (Table 3). Decreases in plastic consumption were related to increased changes in attitudes, PBC,

[1] Note that the robust Welch test was run for age because the homogeneity of variances assumption was violated per the Levene's test, p = .006. Although the Welch test for the effect of condition on age was nonsignificant, the Brown-Forsythe robust test was significant, F(2, 345.541) = 3.373, p = .035. Due to the conflicting results for the two robust tests, we ran the main regression analyses testing our hypotheses with and without controlling for age and the results were unchanged. We presented the results without controlling for age to simplify presentation.

Table 2
Means (SD) for TPB-related constructs by group for Time 1, Time 2, and Change Scores.

T1 Measure	Control Group M	SD	App Group M	SD	Pledge Group M	SD	ANOVA Results F	sig
T1 Behavior	3.10_a	1.09	3.09_a	0.96	3.24_a	1.23	0.71	.493
T1 ATT	5.69_a	1.12	5.72_a	1.20	5.64_a	1.17	0.14	.872
T1 SN	3.79_a	1.96	3.79_a	1.78	3.92_a	1.78	0.19	.824
T1 PBC	5.27_a	1.17	5.17_a	1.09	5.14_a	1.14	0.53	.589
T1 DN	5.37_a	1.27	5.33_a	1.14	5.49_a	1.20	0.55	.577
T1 MN	5.31_a	1.61	5.26_a	1.44	5.47_a	1.46	0.61	.543
T1 SI	4.58_a	1.96	4.69_a	1.70	4.63_a	1.89	0.11	.898
T1 Intention	5.44_a	1.48	5.56_a	1.32	5.46_a	1.41	0.19	.824
T2 Measure	**Control Group M**	**SD**	**App Group M**	**SD**	**Pledge Group M**	**SD**	**ANOVA Results F**	**sig**
T2 Behavior	2.82_a	1.06	3.09_a	1.03	2.27_b	0.83	23.69*	<0.001
T2 ATT	5.71_a	1.16	$5.85_{a,b}$	0.97	6.04_b	0.89	3.88*	0.022
T2 SN	4.18_a	1.80	$4.36_{a,b}$	1.74	4.67_b	1.67	2.87	0.058
T2 PBC	5.13_a	1.13	5.07_a	0.97	5.29_a	1.07	1.27	0.283
T2 DN	5.31_a	1.26	4.98_a	1.25	5.01_a	1.36	2.67	0.070
T2 MN	5.35_a	1.59	5.50_a	1.41	5.98_b	1.16	8.43*	<0.001
T2 SI	4.84_a	1.70	4.91_a	1.70	5.44_b	1.45	5.61	0.004
T2 Intention	5.58_a	1.31	5.50_a	1.34	6.05_b	0.97	9.01*	<0.001
Change Score	**Control Group M**	**SD**	**App Group M**	**SD**	**Pledge Group M**	**SD**	**ANOVA Results F**	**sig**
Δ Behavior	$-.27_b$	1.05	$.00_a$	0.98	$-.97_c$	.99	28.49	<0.001
Δ ATT	$.02_a$	1.21	$.13_{a,b}$	1.13	$.40_b$	1.21	3.83	0.023
Δ SN	$.39_a$	1.76	$.57_{a,b}$	1.55	$.76_b$	1.51	1.84	0.161
Δ PBC	$-.14_a$	1.12	$-.09_{a,b}$	1.05	$.15_b$	1.08	2.84	0.060
Δ DN	$-.06_a$	1.28	$-.35_{a,b}$	1.10	$-.48_b$	1.01	5.00	0.007
Δ MN	$.04_a$	1.57	$.24_{a,b}$	1.26	$.51_b$	1.34	3.96	0.020
Δ SI	$.26_a$	1.39	$.22_a$	1.48	$.81_b$	1.45	6.75	0.001
Δ Intention	$.13_a$	1.26	$-.06_a$	1.32	$.59_b$	1.33	7.75	0.001

*Welch's F-test with pairwise comparisons made using Games-Howell multiple comparison because Levene's test was significant at $p < .05$.

Note. Row means that do not share subscript differ in multiple comparison (Tukey) test using bias-corrected and accelerated bootstrapped 95% confidence intervals.

$n = 152$ (Control group), $n = 89$ (app group), $n = 134$ (pledge group).

ATT = Attitude. SN = Subjective Norms. PBC = Perceived Behavioral Control. DN = Descriptive Norms. MN = Moral Norms. SI = Self-Identity.

Table 3
Correlations among predictors.

Measures	Δ Consumption Behavior	Δ Attitudes	Δ Subjective Norms	Δ PBC	Δ Moral Norms	Δ Descriptive Norms	Δ Self-Identity
Δ Attitudes	-0.273***						
Δ Subjective Norms	-0.086	0.181***					
Δ PBC	-0.304***	0.375***	.052				
Δ Moral Norms	-0.118*	0.156**	0.258***	.209***			
Δ Descriptive Norms	.171**	-0.044	-0.037	-0.052	.022		
Δ Self-Identity	-0.175**	.151**	.123*	.268***	0.340***	-0.041	
Δ Intentions	-0.143**	.302***	0.202***	.336***	0.502***	0.058	.340***

$N = 375$.

***$p < .001$. **$p < .01$. *$p < .05$.

Note. Descriptive Norms refer to perceptions of others' plastic consumption, while all other TPB-related constructs refer to beliefs about plastic reduction.

PBC = Perceived Behavioral Control.

moral norms, self-identity, and intentions related to reducing plastic. Decreases in plastic consumption were also related to decreased perceptions of descriptive norms about plastic consumption. Subjective norms changes were not significantly correlated with plastic consumption decreases. Changes in the TPB constructs were generally weakly to moderately positively intercorrelated, except for changes in descriptive norms which did not relate to any of the other constructs. Additionally, changes in subjective norms were not significantly correlated with changes in PBC.

3.5. Regression predicting changes in plastic consumption

We tested our main hypotheses about whether the interventions changed plastic consumption and whether those changes were mediated by changes in the extended TPB constructs. We ran a regression with the experimental conditions as predictors of changes in plastic consumption behavior (with the control group as the comparison group), with changes in the expanded TPB constructs as parallel mediators, using PROCESS v. 3.5 Model 4 in IBM SPSS v. 27 with bias-corrected (Huber-

Table 4
Regression Predicting Change in Plastic Consumption Behavior.

Predictor	coeff	se(HC0)	*t*	*p*	Boot LLCI	Boot ULCI
Constant	-0.281	0.081	-3.460	0.001	-0.450	-0.124
Pledge Condition*	-0.509	0.119	-4.262	<0.001	-0.741	-0.272
App Condition*	0.335	0.126	2.661	.008	0.096	0.591
Δ Attitudes	-0.135	0.051	-2.652	.008	-0.237	-0.035
Δ Subjective Norms	-0.012	0.031	-0.379	.705	-0.076	0.050
Δ PBC	-0.195	0.079	-2.479	.014	-0.350	-0.039
Δ Moral Norms	-0.007	0.034	-0.194	.846	-0.071	0.064
Δ Descriptive Norms	0.119	0.041	2.878	.004	0.034	0.200
Δ Self-Identity	-0.027	0.033	-0.813	.417	-0.097	0.035

* Control group is comparison for condition. PBC = Perceived Behavioral Control.

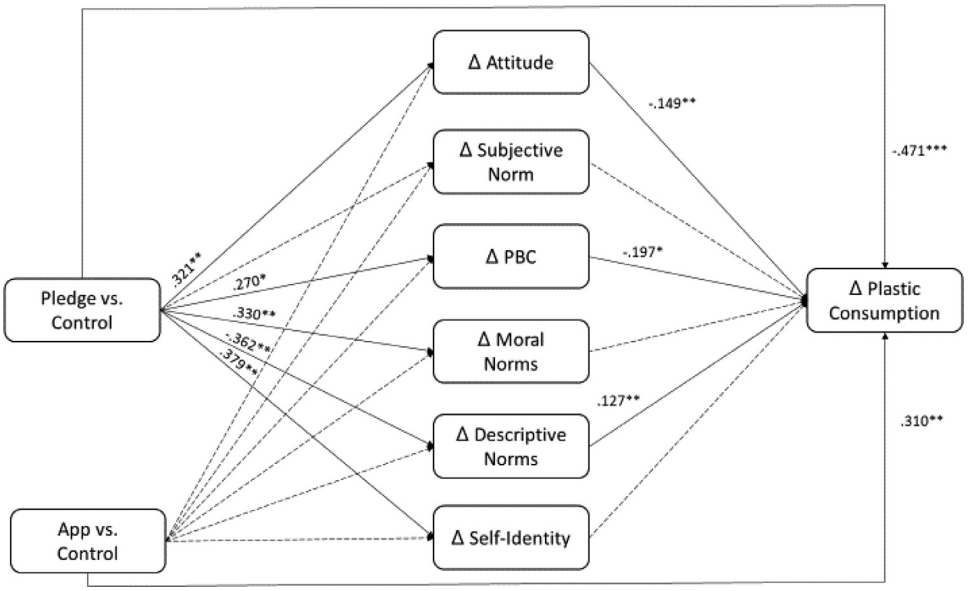

Fig. 2. Standardized direct effects in hypothesized model. Dashed lines are not significant at $p < .05$. PBC = Perceived Behavioral Control.

White) standard errors and 95% confidence intervals based on 5000 bootstrap samples. The model predicting changes in plastic consumption behavior was significant, F(HC0) (8, 366) = 14.948, $p < 0.001$, explaining 24.2% of the variance in plastic consumption changes. Both experimental conditions were significant predictors of changes in behavior (Table 4; Fig. 2). The pledge group (compared to the control group) showed greater reductions in plastic consumption behavior, while the app group (compared to the control group) showed increased plastic consumption behavior. The TPB variables of attitude change and PBC change were both significant predictors of changes in behavior, with increases in positive attitudes toward reducing plastic consumption and perceptions of ease of reducing plastic consumption corresponding with more reductions in plastic consumption. The only TPB extension construct that was significant was the change in descriptive norms, with increases in perceptions that others are using plastic corresponding with increases in own consumption of plastic. Changes in subjective norms, moral norms, or self-identity were not predictive of changes in behavior after controlling for the other variables in the model.

In addition to the direct effects of the experimental intervention on changes in plastic consumption, the experimental groups also had indirect effects through changes in some of the TPB constructs and the expanded TPB constructs (Table 5; See Supplemental). Specifically, the pledge (compared to the control group) indirectly influenced plastic consumption behavior changes via changing attitudes, PBC, and descriptive norms. In other words, participating in the pledge group (compared to the control condition) led to reductions in plastic consumption over the course of the week via increasing beliefs that reducing plastic consumption was good and easy and decreasing perceptions that others are consuming plastic. None of the relative indirect effects for the app condition (compared to the control condition) were significant.

Finally, we examined the total effect, the sum of the indirect effect and the direct effect, of the experimental interventions on plastic consumption. Overall, the total effect of the pledge condition compared to the control condition on changes in plastic consumption was significant, with the pledge leading to a greater reduction in plastic consumption over time compared to the control group (Effect = -0.691 [-0.927, -0.454], $p < .001$). The total effect of the app condition compared to the control condition was also significant, but in the opposite direction, meaning that being in the app group reduced consumption less than being in the control group (Effect = 0.274 [.011, 0.536], $p = .041$).

4. Discussion

4.1. TPB predicting plastic consumption

The present study examined the effectiveness of two interventions on reducing plastic consumption on college campuses. We found support for our hypothesis (H1) that changes in the expanded TPB constructs would significantly predict changes in single-use plastic consumption. The model overall explained almost a quarter of the variance in plastic consumption changes. Attitudes, PBC, and descriptive norms changes were significant predictors. In terms of the main TPB constructs,

Table 5
Indirect effects of Experimental Conditions on Change in Plastic Consumption Behavior via TPB Constructs.

Mediator	Condition*	Effect	Boot SE	Boot LLCI	Boot ULCI
Δ Attitudes					
	Pledge	-0.052	0.027	-0.111	-0.006
	App	-0.015	0.023	-0.067	0.026
Δ Subjective Norms					
	Pledge	-0.004	0.014	-0.036	0.020
	App	-0.002	0.010	-0.028	0.014
Δ PBC					
	Pledge	-0.058	0.039	-0.151	-0.002
	App	-0.010	0.031	-0.081	0.047
Δ Moral Norms					
	Pledge	-0.003	0.017	-0.042	0.029
	App	-0.001	0.010	-0.028	0.013
Δ Descriptive Norms					
	Pledge	-0.050	0.024	-0.101	-0.009
	App	-0.034	0.023	-0.086	0.002
Δ Self-Identity					
	Pledge	-0.015	0.020	-0.063	0.017
	App	0.001	0.008	-0.018	0.018

* Control group is the comparison for condition. PBC = Perceived Behavioral Control.

attitude and PBC were significant predictors, though subjective norms was not. Our finding that subjective norms was not a significant predictor of behavior, fits in line with previous research, finding subjective norms to be one of the weakest TPB predictors of pro-environmental behavior (Botetzagias et al., 2015; de Leeuw et al., 2015).

Previous work has suggested that descriptive norms, moral norms, and self-identity can add predictive utility to the TPB in predicting pro-environmental behavior (Fekadu and Kraft, 2001; Niemiec et al., 2020). Our results confirm previous research on descriptive norms and pro-environmental behavior (Largo-Wight et al., 2012; Passafaro et al., 2019; Rivis and Sheeran, 2003), showing that changes in perceptions of others' plastic consumption predicts one's own plastic consumption changes.

Our results relating to self-identity did not fit with previous research, which has found that increases in environmental self-identity predict increases in pro-environmental behavior (Fielding et al., 2008; Sparks and Shepherd, 1992; Terry et al., 1999). One potential reason for this could be related to measurement conceptualization as other studies often measure self-identity at the general environmental level and this study measured self-identity specifically related to single-use plastic reduction. Additionally, the response scale used in this study of "likely" to "unlikely" may not have been clear to participants. However, Heidbreder et al. (2020) found that although general environmental self-identity related to plastic consumption at baseline, identity did not relate to plastic consumption following a plastic reduction intervention. Future work should continue to include self-identity in studies on plastic consumption to further examine the effect of identity changes on plastic consumption changes.

Moral norm changes also did not predict changes in plastic consumption behavior, contrary to expectations based on previous research in the pro-environmental behavior domain (Botetzagias et al., 2015; Harland et al., 1999). Some previous research that has found a lack of relationship between moral norms and pro-environmental behavior has identified very high correlations between moral norms and attitudes (Chan and Bishop, 2013; Graham-Rowe et al., 2015), which could explain the lack of independent contribution. This multicollinearity was not the case in our study. However, it could be that college aged participants do not view single-use plastic consumption as a moral issue in the same way as other pro-environmental behaviors such as meat consumption. Future research should explore the role of moral norms in predicting specific types of pro-environmental behavior.

4.2. Direct effect of intervention on plastic consumption behavior

We found only partial support for H2 that both intervention conditions would reduce plastic consumption behavior compared to the control condition, in that only the pledge was effective. As expected, the pledge condition showed greater reductions in single-use plastic consumption over the week compared to the control condition. This finding aligns with previous research showing the effectiveness of pledges and commitments to improve environmentally-friendly behavior (Lokhorst et al., 2013).

In contrast, the app condition participants reduced single-use plastic consumption behavior less than the control condition over the course of week. This is contrary to expectations and previous literature (Carfora et al., 2017b). One potential explanation for this effect could be that participants in the app condition were more aware of their plastic consumption behavior as they were recording it within the app, leading to more accurate reports of their behavior at Time 2 compared their own reports for Time 1 or to the other groups at Time 2. In support of this idea, testers during app development often reported surprise that their tracked single-use plastic consumption was greater than their assumed consumption. The self-monitoring of behavior through the app could have also highlighted the difficulty of reducing plastic consumption and also made participants more attuned to the social environment related to plastic consumption. However, this interpretation is unlikely considering the findings that the app and control group did not differ on any of the TPB-related constructs at Time 2, indicating that app participants were not more likely to report higher descriptive norms for consuming plastic nor lower PBC beliefs than control participants at Time 2. Another potential explanation could be that the process of downloading and using the app was perceived as controlling to the participants, leading to reactance and boomerang effects (Miron and Brehm, 2006).

4.3. Indirect effects of intervention on plastic consumption behavior

We found partial support for H3. The pledge intervention was effective in decreasing perceived descriptive norms of plastic consumption, while increasing the expanded TPB constructs of attitudes, PBC, moral norms, and self-identity related to plastic reduction. This set of results provide support for the use of the expanded TPB in guiding the development and evaluation of behavior change interventions. The pledge intervention increased several of the expanded TPB constructs, which theoretically underlie behavior change. Our results further showed that

the pledge intervention had indirect effects on plastic reduction by increasing positive attitudes about plastic reduction, increasing beliefs that plastic reduction is easy, and reducing perceptions that others are consuming plastic. Thus, this study is one of the first to demonstrate that an intervention can change pro-environmental behavior directly and also indirectly by changing the underlying TPB beliefs.

On the other hand, the app intervention did not change the TPB-related constructs, indicating that participating in the app intervention did not change beliefs about plastic reduction over the course of a one-week period. Impacts of app use on change in TPB-related constructs may be more dependent on the functionality of the actual app, which will be context specific (Largo-Wight et al., 2013). In this study, the process to download and use the app was complex, which is reflected in the retention rate for the app group being much lower than the control condition. Because the conditions were randomized and not different on tested variables at Time 1 and because the incentive structure was the same for all conditions, the higher percentage in drop off in the app group suggests the app intervention was harder to complete. Future researchers should refine plastic consumption tracking apps and further explore the impact of behavior monitoring guided by expanded TPB messaging.

4.4. Limitations and future research

One major contribution of the present study is that it is one of the first to examine the effect of an intervention in changing TPB-related variables and changing self-reported behavior over time. Some work has examined the effect of interventions on pro-environmental behavior via TPB constructs measured at Time 2, controlling for past behavior at Time 1 (Carfora et al., 2017a). However, our present analysis that controls for all variables at Time 1 extends this work to show that interventions change TPB constructs over time and that those changes can effect changes in behavior. Our intervention only lasted one week, and research is needed evaluating the lasting effectiveness of interventions beyond one week. Future research should explore the longer-term effects of both interventions. In addition, future research focused on adherence to the interventions and functionality of the behavioral monitoring app should be pursued.

We designed our study as a test of the TPB, which captures many of the known predictors of pro-environmental behavior (Klöckner, 2013). At the same time, our study does not address other variables from other pro-environmental behavior theories such as values (Stern et al., 1999), habit (Verplanken and Whitmarsh, 2021), structural components/physical environment (Varotto and Spagnolli, 2017), and perceived threat (Rogers and Prentice-Dunn, 1997). Future work should continue to design and test interventions in line with theory, with expanded theoretical approaches that bridge multiple social science disciplines.

This study conceptualized plastic consumption as a class of behaviors related to use of multiple plastic items (Heidbreder et al., 2020), whereas previous TPB research on pro-environmental behavior has often operationalized the behavior of interest more broadly, such as recycling household waste (Passafaro et al., 2019; Tonglet et al., 2004), reducing food waste (Graham-Rowe et al., 2015), saving energy (Gao et al., 2017), and pro-environmental behavior (de Leeuw et al., 2015; Gkargkavouzi et al., 2019). Thus, unlike previous research that has often used multiple items to assess each TPB construct, our study utilized single-item measures, aggregated at the behavior level (Heidbreder et al., 2020; Kaiser et al., 2005), due to concerns about survey length and participant fatigue. Although single-item measures of constructs have been used in the past in the TPB literature (Çoker and van der Linden, 2020; Harland et al., 1999), multiple-item measures are preferred to reduce the potential for measurement error. Future research should aim to include multiple item-measures for multiple sub-behaviors within the plastic consumption behavioral domain (Carfora et al., 2017), perhaps focusing on the TPB constructs shown in this work to be most influential on predicting plastic consumption.

Our results show that a commitment intervention in combination with TPB-based messaging is a promising avenue for reducing plastic consumption on college campuses. We found that this intervention was successful in two colleges in the southeastern United States. Future research should test this intervention across colleges more widely, including schools in different regions of the world and those with more diverse student bodies. Additionally, research should test the effect across different types of organizations, cultures, age groups, and countries to test the boundary conditions around the pledge effect. Furthermore, work is needed to further tease out the parts of the intervention that were most effective. Both intervention groups were provided with TPB-based messages daily, with the pledge group receiving them via email and the app group receiving them via push notifications. Further research could explore whether mode of delivery of TPB-based messages impact their effectiveness. Future research should also explore the effectiveness of this brief intervention when incentives are not provided and when data are collected anonymously. Finally, future research should measure observed behavior in addition to self-reported behavior.

4.5. Implications

Our results suggest that an online pledge coupled with emailed messages encouraging plastic reduction in line with the expanded TPB can reduce plastic consumption, at least over the short term, among a population that is typically away from home for the first time and responsible for their own purchasing decisions. Considering that behavioral changes made during such a shift in lifestyle are more likely to persist (Verplanken and Roy, 2016), encouraging these new consumers to reduce single-use plastic consumption has the potential to lead to a lifetime of behavior change. The results are especially promising because this is a relatively easy and low-cost intervention that could be implemented on a wide scale across college campuses to promote meaningful change.

Ethics and informed consent statement

The project was conducted in line with ethical standards for research with human subjects and was approved by the Eckerd College Institutional Review Board (Proposal # 02-03,030,211). All participants provided informed consent electronically.

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

Data will be made available on request.

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Supplementary materials

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