Public Messaging and Behavior Change Systems for Circular Economies

Research Final Report from The University of Memphis | Sabya Mishra, Avani Aravind, Aman Agrawal | March 29, 2026

Sponsored by Tennessee Department of Transportation Strategic Planning, Research & Innovation Division & Federal Highway Administration

THE UNIVERSITY OF MEMPHIS

DISCLAIMER

This research was funded through the State Planning and Research (SPR) Program by the Tennessee Department of Transportation and the Federal Highway Administration under ***RES #2024-01: Public Messaging and Behavior Change Systems for Circular Economies.***

Technical Report Documentation Page

1. Report No. RES: 2024-01	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle *Public Messaging and Behavior Change Systems for Circular Economies*		5. Report Date July 2026 6. Performing Organization Code
7. Author(s) Sabyasachee Mishra, Avani Aravind, Aman Agrawal		8. Performing Organization Report No.
9. Performing Organization Name and Address University of Memphis 3815 Central Avenue Memphis, TN 38152		10. Work Unit No. (TRAIS) 11. Contract or Grant No. RES2024-01
12. Sponsoring Agency Name and Address Tennessee Department of Transportation WRS – TN Tower, 12th Floor 312 Rosa L. Parks Avenue Nashville, TN 37243		13. Type of Report and Period Covered 14. Sponsoring Agency Code
15. Supplementary Notes Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.		

16. Abstract

This study investigates the effectiveness of positive message framing in fostering sustainable behaviors, particularly in the context of litter prevention and circular economies. Focusing on the principles of Reduce, Reuse, and Recycle (3R), as well as anti-littering initiatives, the research evaluates public messaging strategies designed to influence behavior change and address environmental challenges. A Sustainability Awareness Index (SAI) was developed to assess baseline knowledge, followed by a randomized control trial in Tennessee, USA. Three message-framing treatments, Anthropomorphic, Behavioral Impact, and Economic Gain, were tested for their effectiveness in promoting sustainable practices. Emotional appeals such as awe with anthropomorphism, power, and humor were also incorporated into anti-littering messages within hypothetical scenarios involving technological innovations, such as GPS-based applications displaying trash can locations. The findings indicate that Anthropomorphic and Behavioral Impact framings significantly increased engagement in 3R behaviors, while all messaging approaches enhanced anti-littering behaviors. Key psychological factors, such as altruistic values and self-efficacy, emerged as critical predictors of pro-environmental actions. Additionally, higher SAI scores strongly correlated with greater adoption of sustainable practices and improved message effectiveness. The study underscores the importance of tailored interventions that consider demographic, socioeconomic, and psychological factors to bridge the gap between awareness and action. These insights offer valuable guidance for policymakers and stakeholders in designing targeted communication strategies to mitigate the impacts of roadside littering and foster a culture of sustainability.

17. Key Words		18. Distribution Statement	
REDUCE; REUSE; RECYCLE; CIRCULAR ECONOMY; MESSAGE FRAMING		No restriction. This document is available to the public from the sponsoring agency at the website http://www.tn.gov/.	
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 54	22. Price

Acknowledgement

The authors would like to convey their sincere appreciation for the help provided by numerous persons at TDOT throughout this study. Special thanks to Victoria Cooper, who is the Project Manager for defining the study's direction and providing insightful suggestions. Additionally, the authors wish to express their gratitude to Steve Allen, Mike McClanahan, Stacy Carter, Amelia Spina and the entire TDOT team for providing the required help. Also, the authors would extend their appreciation to the University of Memphis for providing the necessary facilities.

Executive Summary

Statement of Purpose

The purpose of this study is to investigate the effectiveness of public messaging and behavior change systems in promoting sustainable practices aligned with circular economy principles, where materials and products are kept in use for as long as possible through reducing consumption, reusing items, recycling materials, and minimizing waste that enters landfills or the roadside environment. Focusing on the 3R framework (Reduce, Reuse, Recycle) and anti-littering behaviors, the study examines how targeted messages can encourage individuals to make choices that support waste prevention and resource conservation. By leveraging randomized control trials (RCTs) and targeted message-framing strategies emphasizing anthropomorphism, behavioral impact, and economic gain, the study aims to assess how public messaging influences individual awareness, attitudes, and long-term adoption of pro-environmental behaviors. Additionally, the research explores the interplay of sustainability awareness, socio-demographics, and behavioral nudges in shaping sustainable habits, providing insights into scalable, cost-effective interventions for advancing circular economies and fostering environmental stewardship.

What was the research need?

The growing environmental challenges associated with resource overconsumption, waste generation, and litter highlight the urgent need for effective strategies to promote sustainable behaviors. While infrastructure investments and policy changes play a significant role in advancing circular economies, they are often costly, time-intensive, and limited in reach. There is a pressing need to explore cost-effective, scalable approaches, such as public messaging and behavioral nudges, that influence individual decision-making and drive immediate behavior change.

Specifically, understanding how targeted message-framing strategies, including emotional appeals, economic incentives, and tangible environmental impacts, can shape awareness, attitudes, and behaviors is critical.

These strategies must address psychological and demographic factors that influence sustainable practices, such as reducing resource use, reusing materials, recycling, and preventing littering. Additionally, integrating behavioral insights with digital tools, such as real-time messaging systems or apps, can amplify the impact of these interventions and foster long-term behavioral shifts. This research is essential to bridge the gap between awareness and action, providing evidence-based insights to design and implement effective behavior change systems that advance the principles of circular economies.

What were the research objectives?

The primary objectives of this study were as follows:

1. **Evaluate the Effectiveness of Positive Message Framing for Behavioral Change:** The study aimed to assess how different positive message-framing strategies (anthropomorphic framing, behavioral impact framing, and economic gain framing) could influence individuals' adoption of sustainable behaviors aligned with the 3R principles (Reduce, Reuse, Recycle) and anti-littering practices. These interventions were designed to resonate with participants' values and motivations to foster sustainable actions.
2. **Develop and Test a Sustainability Awareness Index (SAI):** The research sought to establish a metric to quantify baseline sustainability knowledge and evaluate its role in shaping participants' responses to targeted informational interventions. The SAI was designed to capture familiarity with sustainability symbols, recycling processes, and general environmental practices.
3. **Analyze the Role of Demographics and Values in Behavior Change:** The study explored how socio-demographic factors (e.g., income, age, gender) and psychological constructs (e.g., altruistic, hedonic, and egoistic values) influenced the effectiveness of message-framing strategies and participants' engagement with pro-environmental behaviors.
4. **Examine the Applicability of Behavior Change Systems for Circular Economies:** By integrating experimental findings with behavior change theories, the study aimed to provide insights into how public messaging systems and nudging interventions can support the transition to a circular economy. The research specifically focused on addressing gaps in waste reduction, resource conservation, and pollution mitigation through targeted communication strategies.
5. **Inform Policy and Practice for Circular Economies:** The research aimed to deliver actionable recommendations for policymakers and practitioners on designing effective public messaging and behavior change systems that drive sustainable practices, ensuring alignment with the principles of circular economies.

What was the research approach?

The research employed a mixed-methods experimental approach to evaluate the effectiveness of public messaging and behavior-change systems for circular economies, focusing on the 3R principles and anti-littering behaviors. A RCT was conducted to assess the impact of three positive message-framing strategies compared to a neutral control group. Participants were randomly assigned to these groups to ensure statistical comparability, and their responses were collected through a structured online survey platform that incorporated built-in randomization features. To establish a baseline understanding of sustainability knowledge, the study introduced the SAI, which measured participants' familiarity with sustainability symbols, recycling processes, and general practices. The interventions included educational posters addressing common misconceptions, such as resin identification numbers on plastics, and messages tailored to align with participants' values and motivations.

For anti-littering behaviors, participants imagined scenarios where GPS-based apps delivered real-time persuasive messages, testing the effectiveness of awe, power, and humor as framing strategies. Advanced statistical techniques, including structural equation modeling (SEM) and

ordered logit regression models, were employed to analyze the relationships between the interventions, socio-demographic factors, and behavioral outcomes. These methods provided insights into both direct and indirect effects of interventions, enabling a comprehensive evaluation of their impact on fostering pro-environmental actions. This structured and theory-driven approach integrated behavioral science and communication strategies to advance understanding of how tailored public messaging can promote sustainability and support circular economies

Key Findings

- Positive message framing significantly increases adoption of 3R behaviors, with anthropomorphic framing most effective for reuse and behavioral impact framing most effective for reducing and recycling.
- The SAI is a strong predictor of behavior, with higher awareness consistently associated with greater engagement in 3R practices.
- Humor-based messaging is the most effective strategy for reducing littering, outperforming power and awe-based approaches in influencing behavioral intent.
- Individual characteristics, particularly altruistic and hedonic values, along with self-efficacy, strongly influence pro-environmental behavior, indicating that message effectiveness depends on underlying user traits.
- Socio-demographic factors (age, income, gender) show measurable effects, reinforcing the need for targeted and segmented communication strategies.

Key Recommendations

- Prioritize humor-based messaging for anti-littering campaigns, as it demonstrates the strongest behavioral impact by creating memorable and engaging communication that increases compliance.
- Use anthropomorphic and behavioral impact framing in 3R campaigns, since these approaches significantly improve reuse, reduction, and recycling behaviors by making environmental consequences more relatable and tangible.
- Segment communication strategies based on user characteristics (values, demographics, self-efficacy) to improve effectiveness, as behavior change varies across population groups and uniform messaging reduces impact.
- Incorporate sustainability awareness tracking (e.g., SAI) into program evaluation, enabling agencies to monitor behavioral shifts and refine interventions based on measurable outcomes.
- Integrate nudging strategies through technology (e.g., mobile alerts, location-based prompts) to provide real-time behavioral cues, increasing the likelihood of immediate pro-environmental actions.

Research Conclusions, Benefits and Implementations

The findings of this study indicate that targeted public messaging can serve as a practical and cost-effective approach for improving sustainability awareness and encouraging pro-environmental behaviors. For the 3R framework, anthropomorphic and behavioral impact

messages were especially useful because they helped respondents connect individual actions with broader environmental outcomes. For anti-littering behavior, humor-based messaging showed the strongest response, suggesting that memorable and engaging messages may be particularly effective in encouraging proper disposal behavior.

These results provide useful guidance for TDOT in designing public-facing sustainability and litter-prevention campaigns. The study shows that messaging strategies should not be treated as uniform public information materials. Instead, messages can be tailored based on the intended behavior, the audience being reached, and the setting in which the message is delivered. Humor-based messages may be most appropriate for roadside litter prevention, while anthropomorphic and behavioral impact messages may be more suitable for broader education efforts related to waste reduction, reuse, and recycling.

The findings can be implemented through pilot campaigns using TDOT communication channels, rest-area and roadside education materials, social media outreach, partner agency programs, and location-based prompts where appropriate. The Sustainability Awareness Index can also be used as an evaluation tool to measure baseline awareness and assess whether public messaging improves understanding after campaign exposure.

The study also has limitations that should be considered when applying the findings. The results are based on online survey responses and stated behavioral intentions rather than direct observation of field behavior. In addition, the anti-littering experiment used a hypothetical app-based prompt, so real-world deployment should first be tested through pilot studies. Future research should evaluate these strategies in field settings, measure observed behavior and examine whether the effects of public messaging are sustained over time.

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Glossary of Key Terms and Acronyms

3R: Reduce, Reuse, Recycle

SAI: Sustainability Awareness Index

RCT: Randomized Control Trials

MC: Manipulation Check

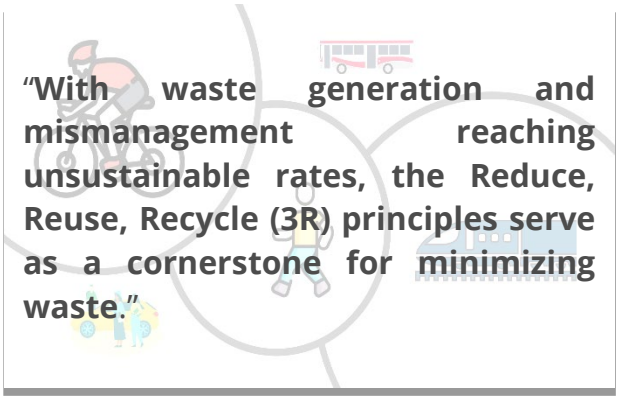
SEM: Structural Equation Modeling

Chapter 1 Introduction

The escalating environmental challenges of today underscore the urgent need for cultivating sustainability awareness as a foundation for promoting responsible behaviors essential for preserving our planet. With waste generation and mismanagement reaching unsustainable rates, the Reduce, Reuse, Recycle (3R) principles serve as a cornerstone for minimizing waste, conserving resources, and mitigating pollution (Barnett et al., 2023; Mohan et al., 2024). While these principles emphasize reducing waste as the most impactful step, many individuals lack clarity on how to implement these practices effectively in their daily lives. This gap between knowledge and action necessitates targeted informational interventions to drive behavioral change (Gerber, 2023).

Effective message framing has emerged as a powerful tool in this context, capable of influencing behavior by strategically presenting information that resonates with individual values and motivations (Luo & Zhao, 2023; Pickering et al., 2020). Positive framing, which emphasizes benefits and emotional engagement, offers an alternative to traditional negative emotional appeals that often dominate environmental communication (Skurka et al., 2022). This study explores the potential of positive message framing in promoting sustainable behaviors across two complementary domains: the adoption of 3R principles and anti-littering behaviors.

The first part of the study focuses on the 3R principles and introduces a Sustainability Awareness Index (SAI) to assess participants' basic sustainability knowledge. These metrics capture familiarity with sustainability symbols, understanding of recycling processes, and general awareness of sustainable practices. As highlighted by Barnett et al. (2023), misconceptions-such as an overemphasis on recycling at the expense of reducing and reusing- undermine the effectiveness of sustainability initiatives. By addressing these gaps, this study evaluates the impact of three distinct positive message-framing strategies:



1. **Anthropomorphic framing**, which humanizes environmental elements to foster emotional connections.
2. **Behavioral Impact framing**, emphasizing tangible consequences of individual actions.
3. **Economic Gain framing**, highlighting the financial benefits of sustainable practices.

A randomized control trial (RCT) was employed to test these interventions. Participants were exposed to framed messages presented in the hierarchical order of the 3R principles (1. Reduce, 2. Reuse, 3. Recycle). The interventions also addressed prevalent misconceptions, such as the misinterpretation of resin identification numbers on plastics. The outcomes were

analyzed using Structural Equation Modeling to assess the direct and indirect effects of the framing strategies and SAI on participants' sustainable behaviors.

The second part of the study shifts focus to the pressing issue of roadside litter, which poses not only aesthetic but also significant social, economic, and environmental challenges (Karimi & Faghri, 2021). In the United States, addressing roadside litter costs approximately $11.5 billion annually, with substantial contributions from governments and volunteer organizations (Delgado, 2022). Advances in technology, such as AI-powered image detection systems (O'Neill, 2023) and GPS-based applications that provide real-time trash bin locations (Sensoneo, 2024), offer promising solutions for mitigating littering. However, these technological interventions must be complemented by effective information campaigns that encourage individual behavior change.

This study examines how positive emotional appeals such as **awe**, **power**, and **humor** can be leveraged to design anti-littering messages. These messages were tested through RCTs, where participants were asked to imagine a hypothetical scenario involving GPS-based apps delivering real-time persuasive messages. Four groups were included in the intervention: a control group with no framing and three treatment groups receiving messages framed around awe with anthropomorphism, power, and humor. The study also explores the role of human values (altruistic, egoistic, biospheric, and hedonic) and self-efficacy in shaping pro-environmental actions, recognizing that these psychological factors significantly influence behavior (Schwartz, 1992; De Groot & Steg, 2008).

By combining these two domains, **3R adoption** and **anti-littering behavior**, this study provides a comprehensive framework for understanding how tailored communication strategies, rooted in positive message framing, can drive pro-environmental actions. The findings contribute to the broader discourse on sustainability by offering actionable insights for policymakers and practitioners seeking to design effective campaigns that bridge the gap between awareness and action. By integrating insights from values-based psychology, technological advancements, and message framing, this study advances the field of environmental communication and offers practical implications for fostering a culture of sustainability.

This study is framed as an experimental evaluation of public messaging strategies and their influence on stated pro-environmental intentions. The analysis assumes that stated behavioral intentions after exposure to message treatments provide useful insight into how individuals may respond to sustainability and anti-littering campaigns. However, the findings should be interpreted within the scope of the study design. The survey was conducted through an online platform, and the responses may not fully represent all Tennessee road users or all populations reached by TDOT communication efforts. In addition, the anti-littering component used a hypothetical location-based prompt rather than an observed field intervention. Therefore, the results provide controlled experimental evidence on message effectiveness, while future pilot studies are needed to evaluate how these strategies perform in real-world settings using observed behavioral outcomes.

Study Objectives and Scope

The purpose of this study was to evaluate whether positive message framing and behavior change systems can improve sustainability awareness and stated pro-environmental behavior. The study focused on two related behavioral domains. The first was adoption of the 3R principles, which include reducing, reusing, and recycling. The second was anti-littering behavior, with emphasis on roadside litter prevention.

The specific objectives were to:

1. Evaluate whether anthropomorphic, behavioral impact, and economic gain framings improve stated 3R behavior.
2. Develop and test a Sustainability Awareness Index to measure baseline sustainability knowledge.
3. Examine whether sustainability awareness, demographic factors, values, and self-efficacy influence message effectiveness.
4. Test whether awe, power, and humor-based message framings improve stated anti-littering behavior.
5. Translate the findings into practical recommendations for public agencies designing sustainability and litter-prevention campaigns.

In this study, behavior change systems refer to coordinated communication tools, prompts, feedback mechanisms, and evaluation measures designed to influence decisions at the point where sustainable action is possible. These systems include framed posters, informational prompts, hypothetical app-based messages, and survey-based evaluation measures.

Chapter 2 Literature Review

The effectiveness of different emotional appeals and communication strategies in fostering sustainable behavior, such as reducing roadside litter, is a key focus in contemporary research. This literature review explores several prominent positive messaging approaches with varying levels of self-transcendence, such as awe-inspiring anthropomorphic cues, power-based messaging, humor, and the impact of self-efficacy and human values, each of which has been shown to influence pro-environmental actions in unique ways (Figure 2-1).

Environmental education involves mass media and education campaigns to promote public awareness about the problem. The prompt is to provide specific instructions on what to do or not to do. Prompts are often written signs or occasionally verbal reminders (e.g., anti-litter signs). The environmental design focuses on planning and designing the environment that facilitates anti-litter behavior (e.g., providing attractive and well-placed trash receptacles). The approach of consequence control is to give positive or negative feedback, such as rewards for good behavior and penalties for poor behavior. Some studies have shown that distinctly decorated trash receptacles placed along the roadside can reduce roadside litter by up to 25% (De Kort et al., 2008). Literature has shown that using signs with positive language and placing trash receptacles along interstates have reduced the amount of roadside litter (Forbes, 2009; Karimi & Faghri, 2021, 2022). The literature recommends combining the above approaches for cost-effectiveness (4)

Figure 2-1 Approaches for litter prevention

2.1 A Systematic Approach to Behavioral Interventions

Behavioral studies in the literature sought to assess the impact of anti-littering measures, such as wording and placement of warning signs, design and placement of litter bins, providing small litter bags, and rewards for collecting litter by observing individuals' behavior in public spaces. Some of these studies used questionnaires and interviews to identify if there is any difference in people's behavior from their stated littering behavior, and also asked how they felt about specific anti-litter interventions (Curnow, 1995; Curnow et al., 1997). The following are some findings from the literature based on behavioral studies. People are inclined to litter in already littered areas. The convenience of reaching bins will incline people not to litter. The *obtrusiveness* of bins (attractive bins) tends to capture people's attention and reduce littering. People respond to new signs and more polite signs; however, the impact diminishes over time. Social engagement and community involvement have proven to be effective. Providing rewards

for not littering is more effective than penalties for littering. The awareness about recycling programs would encourage individuals to litter less or to pick up and dispose of litter properly; however, recycling programs had little effect on non-recyclable litter (Reeve et al., 2013).

2.1.1. Case Studies

We performed a preliminary literature search to identify the best litter prevention campaigns around the world and presented some of them here. The summary of these studies is presented in Table 2-1 and their details are elaborated further.

Table 2-1. Summary of selected global case studies on litter prevention programs

S. No.	Case Study	Strategy	Details/Outcomes
1	London and Edinburgh, United Kingdom	Environmental Design	• Ballot bins – Customisable ashtrays with simple questions • Reduced cigarette litter by 46%
2	Scotland	Anti-litter Prompts	• Campaigns restraining throwing trash out of vehicles • Media: Posters, social media, press events
3	New South Wales, Australia	Anti-litter Prompts	• Campaigns promoting self-realization by making people think about their own actions • TV, radio, outdoor billboards, and online ads • Reduced litter in NSW by 43% from 2014 to 2020

(i) Ballot bins in London and Edinburgh, United Kingdom (UK): The ballot bin is a prototype of the *environmental design* strategy, which is a customizable ashtray that tackles cigarette butt litter. In 2016, the Hubbub Foundation installed ballot bins in London and Edinburgh for general waste and cigarette butts (Hubbub, n.d.). The bins gave people a chance to vote with their trash. Simple and light-hearted questions, such as "*Messi or Ronaldo? Flying or Invisibility? Star Trek or Star Wars?*" kept them engaged. The ballot bins have proven to reduce cigarette butt litter by 46% (Common Works, n.d.; Hubbub & Common Works, n.d.) and have collected 29% of a street's correctly disposed-of-waste (Hubbub & Common Works, n.d.). Figure 2-2 shows a roadside-installed ballot bin in the UK.

Figure 2-2 Ballot bin

Figure 2-3. Example poster of Scotland's litter prevention campaign

(ii) Flingin's Mingin', Scotland: Zero Waste Scotland and the Transport Litter Group conducted a campaign in Scotland in 2013 focused on restraining people from throwing trash out of their vehicle windows. They used posters, social media, press events, and much more to spread the '*Flingin's Mingin*' message, which had a wide reach (Figure 2-3).

(iii) *Don't be a Tosser!*, New South Wales (NSW), Australia: "*Don't be a Tosser!*" campaign promotes self-realization by placing the responsibility for littering on the individual and making people think about their own actions. The strategy uses a variety of "excuses" that litterers use to justify tossing. The strategy was found effective as the excuses provided the best balance in making people feel guilty for tossing and forcing them to realize how silly their excuses are to justify littering. The *Tosser!* anti-littering campaigns have been running in NSW since 2014 as part of the Litter Prevention Strategy on TV, radio, outdoor billboards, and online (Figure 2-4). The message has massively reduced litter in NSW by 43% from 2014 to 2020 (NSW Government, n.d.).

Figure 2-4. Example poster of Don't be a Tosser!

Spacek (Spacek, n.d.) conducts a comprehensive examination of littering in the United States, leading to an American State Litter Scorecard, which ranks the states with respect to environmental quality indicators and litter abatement programs. The rankings are based on various objective and subjective factors. The objective factors are states with litter taxation, states with comprehensive recycling rules/legislation, authorities with state-specific litter prevention slogans, per person overall state environmental expenditures, per person daily waste disposal by state, states with the highest chance for debris-related fatal vehicle collision, and percentage profiled litterers age 16-25 by state. The subjective factors are environmental stewardship of state thoroughfares, state-licensed drivers' knowledge of littering and other road laws, and overall corruption risk in public service activities by state governments. Washington state has been performing best over the past decade (Spacek, 2008, 2014), and California, Connecticut, Florida, Maine, Oregon, Vermont, Iowa, Maryland, and Missouri are among the top-performing states. The common practices seen among the top-performing states are comprehensive recycling for all counties, cities, and towns in the state, recognized statewide litter slogan campaigns, low per capita per day solid waste disposals, and fewer deaths from vehicle-debris-related crashes. The best-performing states according to the litter scorecard are taken and are studied here to understand what made them best. The summary of these case studies is provided in Table 2-2 and their details are elaborated further.

Table 2-2. Summary of selected US case studies on litter prevention programs

S. No.	Case Study	Strategy	Details/Outcomes
1	Washington	Environmental Education, Anti-litter Prompts, Consequence Control	• "*Litter Just Ain't Natural*" - Cascade Jack campaign: TV ads and schools • "*Litter and It Will Hurt*" - reduced roadside litter by 25% (4 million pounds) in the first two years of the campaign
2	Oregon	Anti-litter and recycling Prompts	• Recycling is the major focus • Recycled 1.4 million tons in 2016, reducing 2.9 million metric tons of CO2-equivalent emissions • Public awareness campaigns about recycling ○ "*Make Every Thread Count*"

			○ "*Wasted Food Wasted Money*"
3	California	Anti-litter and recycling Prompts	• Awareness campaigns "Let's Change This to That" and "*Don't Trash California*" ○ Billboards, Radio, Digital Marketing, Social media, Live events, Community Outreach • Signs to provide visual information on the acceptable recyclables and prohibited items for recyling
4	Florida	Environmental Education, Anti-litter Prompts	• "Think Before You Throw" Campaign ○ TV ads, billboards, buses, and radio

Washington (WA)

Since 1971, Washington state has led a partnership of state, county, and local agencies to keep Washington's roads and highways clean, pickup illegal dumps, and prevent people from littering. Initially, the department of ecology, WA, passed the Model Litter Control Act, which levies a 0.015% tax on frequently littered items. Primarily, the law aimed to change citizens' habits and behaviors through education programs. It also set enforcement policies for littering, created a youth jobs program in litter pickup, placed trash cans in certain public places, encouraged the setting up small recycling plants, and more. The state has implemented several litter control efforts, including anti-litter campaigns. The "*Litter and It Will Hurt*" campaign was run from 2002-2009 and gained national attention. The campaign had a strong enforcement theme and highlighted littering fines and litter reporting. There was a 24/7 litter-reporting hotline, and reported violators were sent an educational warning letter on State Patrol letterhead. The campaign has reduced roadside litter by 25% (4 million pounds) in the first two years of the campaign.

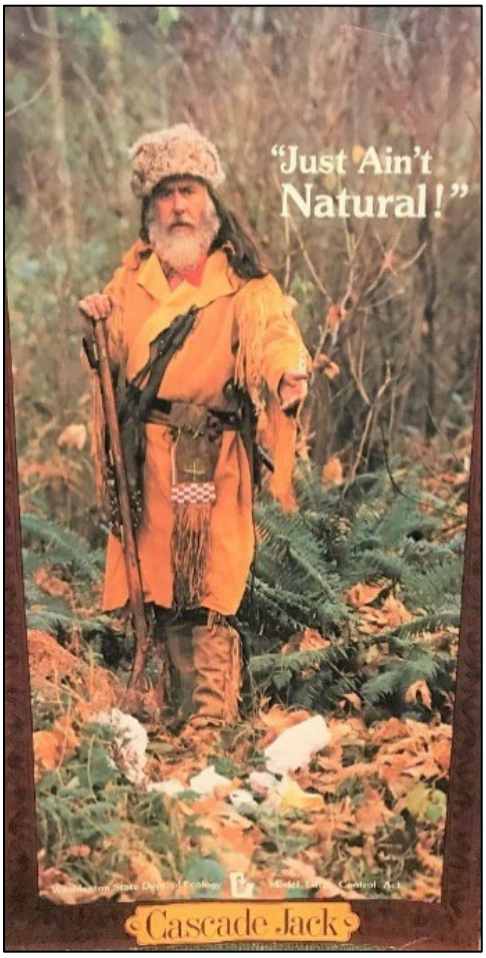


Figure 2-5 Cascade Jack visited schools across the state to encourage kids to help reduce litter for nine years, beginning in 1974.

Educating and engaging the youth was a big focus of the state in the early years. A unique litter prevention curriculum was provided to schools. As a part of the anti-litter campaign, the "*Litter just ain't natural*" message was passed across televisions and to every school in the state. In 1974, the regionally famous Cascade Jack, a litter-fighting, story-telling, rugged mountain man with buckskin clothes and a black powder rifle, carried the message (see Figure 2-5). The city and county governments facilitated full-time police officers dedicated to litter enforcement and education. These officers patrolled with the emblem "*Litter*

Patrol" on the side of their cars. They would go to schools and talk to kids about the enforcement of litter and recycling laws. Following this, the annual litter studies in the state confirmed that the litter decreased by 66% across the state between 1971-1976. The Ecology Youth Corps (EYC) program is the most extensive litter pickup program in the state, which hires teens and adults to pick up litter on the state's roads and highways.

The state funds local governments for litter and illegal dump cleanup and litter prevention education through *Community Litter Cleanup Program*. The state has launched the "*We Keep WA Litter Free*" campaign, where Litter Prevention Partner Toolkit is designed for sub-campaigns by local jurisdictions, non-profits, community groups, and others to promote litter prevention and amplify campaign messages focused on changing specific littering behaviors. WA's behavioral change campaigns use a social marketing framework built on audience research that helped WA understand the barriers to changing littering behavior. They tested the messages and creative concepts with a priority audience, which shaped the campaigns, messaging, and distribution of behavior change tools. The various programs conducted by Washington State are given in Table 2-3.

Table 2-3. Various Litter Prevention Programs in Washington

S. No.	Public message/Program	Details	
1	Litter just ain't natural	Televisions and every school curriculum in the state	
2	Ecology Youth Corps (EYC)	Jobs for teens	
3	Shoot for Zero litter	A program for hunters	
4	Pick up a Mountain	For backpackers	
5	Ski Litterless	For skiers	
6	Shore Patrol	Full-time police officers dedicated to enforcement and education	
7	Don't Waste Washington	Posters	
8	Don't Splash Your Trash	Posters	
9	Litter and It Will Hurt	Various television and radio commercials	
10	We Keep Washington Litter Free	Various types of public service announcements (PSA)	
		• Window clings • Video ads • Radio ads • Social media ads	• Social media content • Highways signs • Posters • Gas station pump toppers

Access Washington's website: https://ecology.wa.gov/Waste-Toxics/Solid-waste-litter/Litter

Oregon (OR)

A circular economy is based on the maximum use of resources by reducing, reusing, and recycling materials. Oregon has a strong recycling history and was able to reduce the amount of energy required to make new products, reduce pollution, and create jobs. Oregon recycled 1.4 million tons in 2016, reducing 2.9 million metric tons of CO_2-equivalent emissions. Oregon's Bottle Bill was

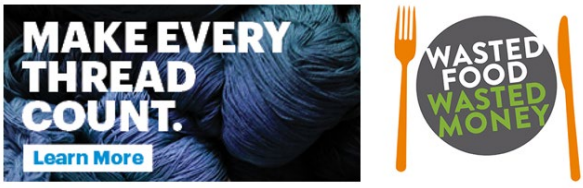


Figure 2-6 Oregon's Waste Prevention Campaigns

introduced in 1971 as the first bottle bill in the USA. The bill was aimed at addressing the growing litter problem along beaches, highways, and other public areas. Oregon has developed waste prevention campaigns (see Figure 2-6) to help local governments encourage a waste reduction in communities. "*Make Every Thread Count*" is a public awareness campaign that encourages people to think differently before buying clothes, make smarter choices, and extend the life of their clothing.

"*Wasted Food Wasted Money*" is a public awareness campaign designed to help commercial food generators save money by reducing wasted food. This includes grocers, restaurants, and commercial kitchens, and campaign materials are designed to address each audience.

Access Oregon's website: https://www.oregon.gov/deq/recycling/Pages/default.aspx

California (CA)

The California Department of Transportation (Caltrans) developed the *Clean California* Local Grant Program, which provides funds to local communities for beautifying local streets, roads, parks, public places, and transit centers. *Clean California* makes significant investments in litter collection, community engagement, and education to transform unsightly littered roadsides into spaces of pride for all Californians. "*Let's Change This to That*" is a three-year statewide public awareness campaign to help reduce the amount of litter and other pollutants on highways that end up in California's water system (shown in Figure 2-7). The state collaborates with all counties for advertising on billboards, radio, digital marketing, social media, and live events, community outreach in partnership with public, private, and non-profit groups, multilingual information and public outreach, comprehensive information on pollution, resources, partnerships, and how to get involved in cleanup events along California waterways. Caltrans conducts the "*Don't Trash California*" campaign to target primary offenders of highway littering, as well as the general public, to create a social mindset in California that the state does not tolerate polluting freeways and highways. The campaign implements strategies, including media advocacy, special events, partnerships, paid media, and community outreach, to raise the level of awareness of the effects of littering and encourage the public to avoid littering.

Figure 2-8 Example of billboards in Caltrans' public awareness campaign to keep roadside trash out of waterways.

Figure 2-7. Sign to provide the visual information of the acceptable recyclables and prohibited items for a green waste only bin

A generation ago, California adopted recycling, aiming to reduce litter, conserve natural resources, and reduce dependence on landfills. California's Department of Resources, Recycling and Recovery (CalRecycle) brings together the state's recycling and waste management

programs through initiatives, such as the Integrated Waste Management Act and Beverage Container Recycling and Litter Reduction Act. CalRecycle administers California's state-managed non-hazardous waste handling and recycling programs. Figure 2-8 shows the "*Green Waste Only*" sign to provide visual information on the acceptable recyclables and prohibited items for a *green waste only* bin. The state's "bottle bill" incentivizes the collection and recycling of aluminum, plastic, and glass beverage containers through California Redemption Value (CRV). The CRV is a fee levied at the point of purchase, which is refundable when empty containers are returned to any of the CalRecycle-certified redemption centers across the state. Another important CalRecycle mission is environmental education. The California Education and the Environment Initiative is to foster environmental literacy among all California students as part of a high-quality K-12 education. CalRecycle conducts public meetings, media events, CalRecycle projects, training, public service announcements, and broadcasts to create awareness about recycling.

Access California's websites: https://cleancalifornia.dot.ca.gov/, https://calrecycle.ca.gov/, https://www.donttrashcalifornia.info/

Florida (FL)

Florida's litter program involves a focused effort to reduce litter, marine debris, and illegal dumping. In 2001, the program's focus included grassroots public education programs and public-private partnerships coordinated by Florida's local Keep America Beautiful (KAB) affiliates, state agencies, business associations, civic organizations, and local government. These programs are working to build individual responsibility within local communities that work to reduce habitual and thoughtless littering and illegal dumping. The Solid Waste Management Act provides that the state department of transportation (DOT) must place signs discouraging litter at all off-ramps on the Interstate highway system. The Florida DOT has determined that litter law signs may be installed on the Interstate where excessive littering occurs. A 2010 Florida Litter Survey conducted by the University of Florida found that nearly 75% of those surveyed felt that anti-littering messages were somewhat effective. Thus, the Florida DOT, in coordination with the Center for Urban Transportation Research (CUTR) at the University of South Florida, launched a paid media campaign to inform residents not to litter. The campaign featured the primary message "*Think Before You Throw*". The campaign consisted of paid production of three TV ads, billboards, buses, and radio advertising, as shown in Figure 2-9.

Figure 2-9 Billboard and bus advertisements in Florida

In 2014, the Florida DOT introduced the state's official Roadside Litter Prevention Education (RLPE) Media Campaign, which aims to reduce littering on Florida highways, promote pride in

the beauty of Florida's landscapes, and educate Florida motorists about the dangers and hazards of roadside litter. Built around the theme, "*Drive It Home, Keep Our Paradise Litter-Free,*" the campaign enlists professional and amateur athletes from various sports who will appear in television and radio public service announcements, print ads, outdoor billboards, and public appearances. The three-year campaign seeks to educate Floridians and visitors on litter issues and change their behavior by leveraging the influence of athletes portrayed in a high-visibility multi-media campaign with television, radio, and outdoor advertising components, as well as community events. The primary audience focus for the campaign will include driving motorists between the ages of 15 – 35.A list of different messages is illustrated in Figure 2-10.

Figure 2-10. Some examples of Litter Prevention Campaign signs by FDOT

Access Florida's website: https://www.fdot.gov/, https://floridadep.gov/Waste

2.2. Message Framing

> "Framing is the process of rearranging words and concepts inside a communication **to support a specific change in decisions** or attitudes without affecting the message's overall meaning **"**

Framing is the process of rearranging words and concepts inside a communication to support a specific change in decisions or attitudes without affecting the message's overall meaning. The purpose of framing is also to induce conduct without restricting the recipients' freedom of choice. For instance, a message may be designed to encourage employees to sign up for a cheap train pass by default, while allowing them to opt out of the program if they want. Message-framing is most

effective when decision-makers base at least a portion of their decisions on the messages they read.

2.2.1. Positive Message Framing

In the prospect theory, Tversky & Kahneman (1981) established the concept of the framing effect, which elucidates how humans make decisions when faced with risky alternatives. This impact is based on the framing of outcomes as either perceived advantages (gain-framing) or perceived disadvantages (loss-framing). A compelling appeal might focus on either the benefits of taking action or the drawbacks of not taking action (Piñon & Gambara, 2005). Historically, environmental campaigns have typically employed negative framing as their primary technique, focusing on highlighting the detrimental outcomes that result from not taking action to address climate change (Hulme, 2008). Nevertheless, recent research has brought up doubts over the efficacy of negative framing. For example, Feinberg & Willer (2011) discovered that a message that presented global warming's severe effects in a negative way led to greater doubt. Similarly, Smith & Leiserowitz (2014) found that fear-inducing negative framing did not accurately predict support for mitigation strategies

The effectiveness of gain- and loss-framing varies significantly based on factors such as the specific activity being encouraged and its personal significance to the individual (Spence & Pidgeon, 2010). The varied outcomes in the framing study may be attributed to the distinctive characteristics of environmental issues and individuals' perceptions of pro-environmental messages. Although negative emotions are commonly used in pro-environmental messages, the significance of positive emotions has not been thoroughly investigated. Positive emotions have the ability to expand our mindset, which in turn helps us develop social and psychological skills that can be beneficial in future situations (Fredrickson, 2001b). Positive emotions could broaden our thoughts and improve cognitive flexibility, unlike negative emotions, which limit our awareness and cognitive abilities to inputs related to emotions (Fredrickson, 2001c).

2.2.2. Anthropic Framing

Anthropomorphic cues are frequently used in advertising to effectively convince and encourage desired behaviors. These are visual and/or verbal rhetorical devices that anthropomorphize inanimate objects, portraying them as human-like entities. For example, products are depicted with human bodies and engaging in conversations, laughter, or humor. Anthropomorphic signals are employed to elicit anthropomorphism, which is a cognitive process of interpreting non-living objects, abstract concepts, or animals as if they were human. Anthropomorphism refers to the process of applying human characteristics or behaviors to nonhuman objects. It is influenced by the need to understand and interact with the world around us, as well as our social tendencies. This concept has been studied and defined by researchers (Epley et al., 2007; Waytz et al., 2010). Anthropomorphism relies heavily on an individual's motivation to function well as a social actor. This motivation might be driven by the desire to control, explain, and interpret one's surroundings or to establish connections and affiliations with others. Humanizing an object has the effect of enhancing its predictability and improving its comprehensibility (Waytz et al., 2010). Individuals have been found to have less willingness to replace a product when they are encouraged to think of it in anthropomorphic terms (Chandler

& Schwarz, 2010). Within the sustainability literature, it has been discovered that thinking of nature in human-like terms leads to a sense of connectivity (Tam et al., 2013), increases feelings of remorse for harming the environment and encourages more involvement in conservation efforts (Tam, 2019).

2.2.3. Behavior Impact Message Framing

Impact, as defined by the United Nations Development Group (2011), is the positive or negative effects on identifiable population groups that a development intervention produces, whether direct or indirect, intended or unintended (UNSDG, 2012). The impact can be conveyed either as a specific objective or intention, along with the methods to accomplish it. According to Sheng et al. (2023), a "behavioral impact message" is a message that explains the effects of a behavior in order to persuade the audience to either adopt a desired behavior or avoid an undesired one (Sheng et al., 2023). The central focus of this communication is the consequences or effects of a particular activity, rather than the specific actions taken to achieve a desired outcome. Environmental behavioral decisions frequently entail evaluating the costs and benefits, which are evident in the problem-and-solution framework, a crucial concept in environmental educational campaigns (Obermiller, 1995). The problem frame facilitates comprehension of the issue and teaches individuals about complete risk management (Moser, 2010). On the other hand, the solution frame effectively communicates practical answers and reinforces the potential influence of both individual and group activities, with strengthened beliefs in efficacy (Miller et al., 2022). In this context, the idea of message framing emphasizes the incorporation of the "target" of the communication, rather than focusing primarily on its structure (Davis, 1995). Hence, behavioral impact messages can highlight the immediate outcomes of behaviors to promote sustainable activities, incorporating lessons from different framing tactics to optimize their persuasive effectiveness.

2.2.4. Economic Gain Message Framing

Another effective approach to encouraging pro-environmental actions is to highlight the financial consequences of climate change and the advantages of implementing relevant policies. This strategy exploits the notion that economic arguments are typically more comprehensible and convincing to the general public compared to intricate climate science (Mildenberger & Leiserowitz, 2017). Pro-environmental communication can emphasize different aspects of policy, with the economic aspect being particularly influential. Gain-framed messages highlight the financial advantages of adopting pro-environmental policies, whereas loss-framed messages underscore the expenses linked to these measures (DeGolia et al., 2019). These economic costs may encompass augmented public expenditure on infrastructure, the implementation of new levies such as carbon taxes, or diminished profitability in specific economic sectors because of regulatory actions. The response of individuals who believe in climate change to economic arguments has received less research attention, with the notion that they may maintain their partisan beliefs without being influenced. Nevertheless, studies

suggest that presenting environmental policies in the context of economic expenses may sway even individuals who are supportive of environmental causes to resist policies perceived as financially onerous. According to studies like the European Social Survey and the World Values Survey, people generally start prioritizing environmental concerns only when they have achieved a certain degree of wealth (*European Social Survey*, 2023; *WVS Database*, 2022). Thus, it is important to emphasize the economic benefits of sustainable practices, and this approach to message framing can effectively support efforts to promote environmental sustainability through informational interventions (Mildenberger & Leiserowitz, 2017).

2.2.5. Awe Inspiring Framing

Awe, similar to compassion and thankfulness, is a self-transcendent emotion that goes beyond oneself and inspires us to consider beyond our concerns, reducing our sense of self-importance (Stellar et al., 2017). According to the broaden-and-build theory (Fredrickson, 2001a), positive emotions typically do not limit our attention to the current situation (unlike negative emotions), but instead encourage receptiveness to new ideas and direct us towards acquiring new experiences (Fredrickson, 2013). As a result, awe captivates us with stimuli that contain a lot of information (Van Elk et al., 2016) and causes us to feel that our beliefs and problems are insignificant in the larger context (Piff et al., 2015). This phenomenon of self-diminishment partially explains why awe inspires prosocial activities.

"Awe, similar to compassion and thankfulness, is a self-transcendent emotion that goes **beyond oneself and inspires us to consider beyond our concerns**, reducing our sense of self-importance."

2.2.6. Power Impact Framing

Over the years, researchers have examined power in all its manifestations- as an innate quality, a way of thinking, and a contextual element influencing one's emotional and mental states to accomplish goals, also with the ability to control other people or situations (Guinote, 2017). On the scale of self-transcendence, power can be both self-transcendent (Chen et al., 2001; De Cremer & Van Dijk, 2005) and non-transcendent (Fiske, 1993; Keltner et al., 2003), depending on its exercise and perception. In the context of environmental messaging, messaging that affects the individual's sense of power and, by extension, their self-efficacy amplifies the effect of goal-oriented information. Studies show that when people are given environmental information along with a power message that makes them feel more powerful and in charge, it has a greater impact on their purchasing intentions. Research has looked at how power influences people's preferences for environmentally friendly products. For instance, Huang et al., 2023, mentioned that messages framing environmental choices in terms of power can significantly influence consumer behavior.

However, a comprehensive comparison with other message framings is needed to fully understand the unique impact of power-based messaging. Moreover, power-messages can leverage individuals' desire for control and effectiveness, aligning with their goals and motivations (Mannem et al., 2023). By emphasizing the power individuals have in making environmentally friendly choices, these messages can enhance self-efficacy and drive sustainable behavior (Mannem et al., 2023). This approach can be particularly effective in marketing and educational campaigns aimed at fostering environmental consciousness and action.

2.2.7. Humor Framing

When it comes to self-transcendence, it is important to determine whether the message is effective due to positive appeals, its overall effectiveness, or if there is a specific aspect of messaging that makes it a powerful motivator for pro-environmental results (Skurka et al., 2018). To achieve this, we need a non-transcendent emotion as a positive emotion to contrast with. Humor serves this purpose well, as it elicits amusement, a pleasant and hedonic experience (Janicke-Bowles et al., 2022; Skurka et al., 2018). Humor messaging strategy is an intriguing approach that has garnered significant attention from communication academics. It is considered an effective method to educate audiences and influence their opinions, as seen by the substantial interest it has received (Walter et al., 2018). This can be largely related to the rise of comedic coverage in the current scenario of entertainment as well as the widespread circulation of amusing memes and social media content related to environmental concerns (Chattoo & Feldman, 2020). Over the years, humor researchers have proposed various theories to account for why audiences enjoy humor. These theories suggest that humor arises from psychological incongruities, the relief of tension, a feeling of superiority over others, or harmless transgressions (Warren et al., 2021). Regarding the impact of humor on audiences, it is considered that humor enhances the likability of the source (Nabi et al., 2007) and promotes attention to the information (Eisend, 2009). This can also be a reason why there is strong evidence that comedy can lead to increased awareness of environmental issues and improved learning (Bonnici et al., 2023).

2.3. Self-Efficacy and Human Values

Self-efficacy is defined as confidence in one's capability to carry out activities and have an impact on outcomes (Maibach & Murphy, 1995) and plays a crucial role in shaping self-regulation, choices, and perseverance (Fishbein & Cappella, 2006). In consumer contexts, self-efficacy is often conceptualized as perceived consumer effectiveness, which

"Self-efficacy is defined as confidence in one's capability to carry out activities and have an impact on outcomes "

is positively associated with pro-environmental behaviors (Berger & Corbin, 1992). For example, individuals with high environmental self-efficacy are more likely to act on climate change information and include environmental wellness in their purchase decisions (H. Huang, 2016). While self-efficacy is typically studied as a characteristic, researchers have demonstrated that it may be intentionally manipulated (Mannem et al., 2023). Message interventions, such as showing power messages, are believed to have the ability to influence state self-efficacy (Mannem et al., 2023). Nevertheless, along with self-efficacy, individuals' motives are also influenced by their values, beliefs, and norms. To gain a deeper comprehension of the function of motives, it is crucial to consider an individual's values, as they determine which objective becomes the central focus in a certain circumstance, therefore affecting intentions and behaviors. Four types of values are particularly relevant in predicting environmental beliefs and behaviors (De Groot & Steg, 2008; Stern et al., 1998): biospheric values (valuing the environment), altruistic values (valuing the well-being of others), egoistic values (valuing personal resources), and hedonic values (valuing pleasure and comfort) (De Groot & Steg, 2008). Understanding these innate human factors can help predict changes in individuals' environmental views and behaviors, as well as find ways to motivate them to participate in more ecologically conscious actions.

2.4. Randomized Control Trials

A common approach in assessing experimental measures is the use of randomized controlled experiments (RCTs). Under this approach, the participants are divided into separate groups at random. The first group is called the control group, while the others are called the experimental groups. Behavioral interventions are implemented in the experimental groups over a period. After completion of the experimental period, the groups are compared with the control group to quantify the effect of interventions. This randomization ensures that the groups are statistically similar in terms of various characteristics such as gender, age, motivation, and other observable or unobservable traits. The only distinction between the groups is that one receives the intervention while the other remains unchanged. By comparing the outcomes of the treatment and control groups, biases that typically complicate evaluation processes are eliminated (Alta Planning, 2018; Haynes et al., 2012). Numerous

Behavioral interventions, which focus on psychological factors rather than physical infrastructure, involve providing information, persuasion, or incentives to individuals. This makes them suitable for RCTs because they can be offered to some people while excluding others, facilitating the randomization process. RCTs necessitate clearly defined treatment and control groups, which can be challenging when the treatment variable is continuous, like the distance to campus. Randomization into treatment groups can also pose difficulties, particularly in cases where it is impractical to exclude a random segment of the population from new or improved transportation services. On the other hand, RCTs offer advantages such as automatically controlling for the effects of unmeasured variables, including attitudes, and addressing the issue of self-selection. Cross-sectional research designs may have an edge over RCTs in terms of external validity since they can more easily incorporate diverse populations and contexts (Merlin et al., 2022). While we acknowledge that experimental designs are generally preferred, there are situations in transportation research where conducting

experiments is not feasible or leads to significant constraints in terms of external validity. As a result, researchers often have to rely on quasi-experimental designs. Consequently, we deemed it important to evaluate how closely the findings from quasi-experimental studies align with those from experimental studies, which are considered the most reliable.

Chapter 3 Experiment Design and Methodology

This study employs a structured experimental methodology to investigate the effectiveness of different message-framing strategies in promoting sustainable behaviors aligned with the 3R principles (Reduce, Reuse, Recycle). To achieve this, three distinct treatments were developed based on the ideologies of anthropomorphism, behavioral impact, and economic gain. These treatments were compared against a control group that did not receive any specific message framing or information intervention. In addition to assessing the influence of these treatments, the study examines how respondents' prior knowledge of sustainability, measured through the SAI, and socio-demographic factors shape their sustainable behaviors and future intentions. The methodology integrates an RCT with an online survey, leveraging targeted interventions to measure participants' awareness, attitudes, and intentions toward sustainability. By combining the RCT approach with SAI and post-intervention evaluations, the study systematically examines the relationship between message framing, prior knowledge, and socio-demographic factors in shaping sustainable practices. The collected data is further analyzed using Structural Equation Modeling (SEM) to explore the direct and indirect effects of the interventions on respondents' stated ratings of sustainable behaviors. The detailed methodology is described in the following sections.

3.1. Survey Data

The survey was designed to evaluate the effectiveness of message-framing treatments and was distributed across four randomized groups, which included three treatment groups and a control group. Each group was exposed to a specific intervention using posters as part of the experimental design. The survey consisted of five distinct sections: (*i*) a sustainability awareness questionnaire, (*ii*) message framing through RCTs, (*iii*) a stated rating experiment, (*iv*) a manipulation check, and (*v*) socio-demographic questions. As illustrated in Figure 3-1, participants were randomly assigned to these groups to ensure statistical comparability and eliminate biases. RCTs are widely recognized for their robustness in evaluating policy and intervention effectiveness, as they enable a controlled analysis of treatment outcomes (Haynes et al., 2012).

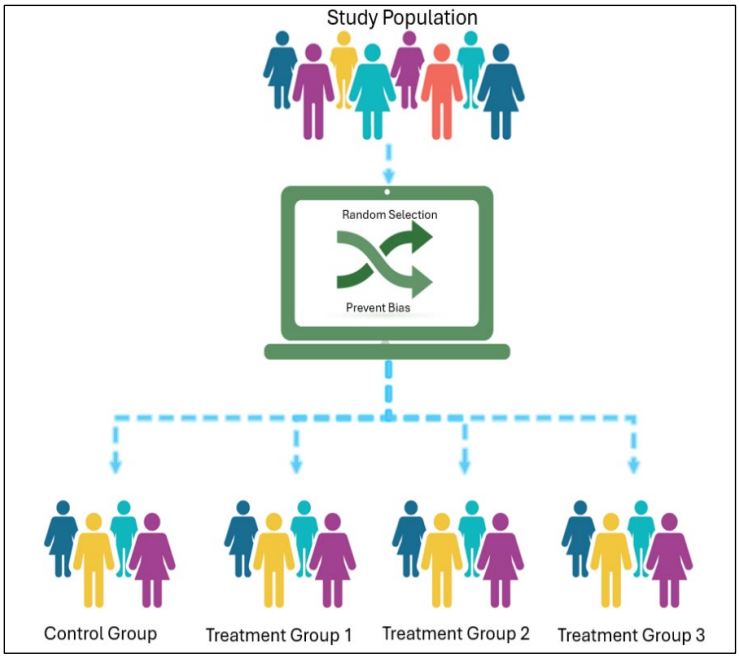


Figure 3-1 Randomized Control Experiment Design

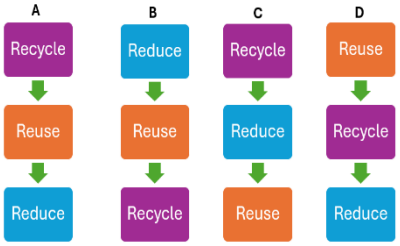
3.2. 3R Awareness Study

3.2.1. Sustainability Awareness Index (SAI)

In this study, the Sustainability Awareness Index (SAI) was developed as a baseline measure of respondents' knowledge of sustainable practices before they were exposed to the message-framing treatments. The SAI is a simple additive knowledge score that reflects how well respondents understood basic concepts related to the 3R framework, Reduce, Reuse, and Recycle, and common recycling information used in everyday disposal decisions. Including this measure allowed the study to examine whether respondents with different levels of prior sustainability awareness responded differently to the treatment messages.

The index was constructed from seven survey questions. Each question was coded as one point for a correct response and zero points for an incorrect, unsure, or "do not know" response. The total score therefore ranged from zero to seven, with higher scores indicating greater baseline sustainability awareness. The seven items included recognition of the 3R symbol, familiarity with the 3R principles, understanding of the correct 3R hierarchy, interpretation of resin identification numbers on plastic products, identification of specific plastic resin categories, knowledge of proper recycling and sorting practices, and awareness of the approximate share of global plastic waste that is successfully recycled. For example, one question displayed the 3R symbol and asked participants whether they were familiar with or had previously encountered it. Other questions assessed whether participants understood recycling labels and how such information should guide disposal decisions. The complete set of questions used to construct the SAI is presented in Table 3-1.

Table 3-1. Questions for SAI

	Questions	Options	Answer/Score
Recognizing 3R Symbol	Have you ever seen this symbol before (3R symbol)? 	a) Yes, b) No, c) Not sure	a) Yes (+1 point)
Familiarity with the 3R Principles	Have you heard about the 3R principles for environmental sustainability?	a) Yes, b) No, c) Not sure	a) Yes (+1 point)
Correct Order of the 3R Principles	Can you identify the correct order of the 3R principles? 	a) A, b) B, c) C, d) D	b) Option B (+1 point)

Understanding Resin Identification Numbers	What does the number on the back of a plastic bottle indicate? 	a) Whether it is recyclable or not, b) The manufacturer of the bottle, c) The type of plastic resin, d) The safety level of the contents	c) The type of plastic resin (+1 point)
Significance of the Numbers on Plastic Bottles	What does the number 6 on the back of a plastic bottle indicate?	a) Highly recyclable, b) Generally not recyclable, c) Not sure, d) Do not know at all	b) Generally, not recyclable (+1 point)
Knowledge of Sorting and Recycling	Do you know how to properly sort and recycle different materials?	a) Yes, completely, b) Mostly, c) Somewhat, d) Not really	a) Yes, completely, b) Mostly (both options "a" and "b" were given +1 points)
Perception of Global Plastic Waste Recycling	What percentage of global plastic waste do you think is successfully recycled?	a) 9%, b) 27%, c) 54%, d) 78%, e) 83%	a) 9% (+1 point)

Following the administration of these initial questions, respondents were exposed to the informational intervention, which included either treatment or control posters. This sequential design ensured that any subsequent changes in participants' knowledge, affinity for the 3R principles, or sustainable behavior could be attributed to the intervention.

3.2.2. Experimental Design with Treatments

This study employed an online platform to facilitate the randomization of participants into four distinct groups: three treatment groups and one control group. Each group was exposed to a specific intervention presented in the form of a poster. These posters emphasized the correct order of the 3R principles (Reduce, Reuse, Recycle) and incorporated positive messages tailored to the underlying ideology of each treatment principle. In addition, all treatment posters included information about resin identification numbers on plastic bottles, clarifying common misconceptions and emphasizing that these numbers do not necessarily indicate recyclability. This design enabled a comparative analysis of the effectiveness of various message-framing strategies on respondents' sustainable behaviors and understanding of the 3R principles. Details of the treatment messages are summarized in Table 3-2 and are explained below, while the corresponding posters are provided in the Appendix (Figure A-1to A-4).

Table 3-2. Treatment Messages

	Treatment-1: Anthropomorphic	**Treatment-1: Behavior Impact**	**Treatment-1: Economic Impact**
Reduce	From reducing single-use plastics, your choices make a difference. Together, we can create a sustainable world.	Join millions who are cutting down waste! **Reducing** is already a habit for many thoughtful consumers like you. If just one person switches to a reusable bag, we can replace **500** plastic bags per year!	**Stop Throwing Away Money and Food!** • **Reduce Food Waste:** Plan meals, shop with a list, and use leftovers! • **Save $1,500 a Year**: That's groceries you can use, not toss!
Reuse	From jars to clothes, give your **items a second life**. Reuse is a powerful step towards sustainability!	"Revive, not replace! Reuse to cut down on waste and conserve natural resources significantly. Reusing and refurbishing a computer can **save up to 80%** of the energy required to make a new one!	**Revive, not replace!** • Reuse to cut down on waste and conserve natural resources significantly. • By reusing items like containers, bags, and clothing, the average American household can save **hundreds of dollars** each year.
Recycle	**Be a Recycling Champion**: Every Item Recycled Makes a Difference!"	**Transform Your Trash into Treasures!** Recycle One Ton of Paper: Save **17 Trees** Conserve **7,000** Gallons of Water Save **463** Gallons of **Oil**	**Recycling isn't just about the environment.** • It's powering a million-strong green machine! Every time you recycle, you contribute to nation. • The recycling industry employs over **1 million people** in the US.

Treatment 1: Anthropomorphic: Anthropomorphic treatment employs human-like characteristics to make messages more engaging and relatable for participants. This approach personalizes the 3R principles by associating them with positive emotional appeal and anthropomorphic elements. For the Reduce principle, the message emphasizes personal responsibility and collective effort by stating, "From reducing single-use plastics, your choices make a difference. Together, we can create a sustainable world." For Reuse, it encourages giving items a second life with the message, "From jars to clothes, give your items a second life. Reuse is a powerful step towards sustainability!" The Recycle message urges participants to be champions of recycling by highlighting the impact of individual actions: "Be a Recycling Champion: Every Item Recycled Makes a Difference!". Anthropomorphic visuals were used to reinforce these

messages, as shown in the poster in Figure 9, to make it more engaging to the respondents. For example, a sad face was depicted on a plastic bag, while a happy, cheerful face was shown on organic sustainable bags. These anthropomorphic elements added can establish an emotional connection and motivate respondents.

Treatment 2: Behavioral Impact: The behavioral impact treatment focuses on the tangible effects of respondents' actions on the environment, aiming to demonstrate the direct consequences of sustainable behaviors. This approach highlights the measurable benefits of reducing, reusing, and recycling, making the impact of individual efforts more relatable and compelling. For Reduce, it stresses community involvement and the habitual nature of reducing waste: "Join millions who are cutting down waste! Reducing is already a habit for many thoughtful consumers like you. If just one person switches to a reusable bag, we can replace 500 plastic bags per year!" The Reuse message highlights significant resource conservation: "Revive, not replace! Reuse to cut down on waste and conserve natural resources significantly. Reusing and refurbishing a computer can save up to 80% of the energy required to make a new one!". For Recycle, the message illustrates the substantial environmental benefits of recycling: "Transform Your Trash into Treasures! Recycle One Ton of Paper: Save 17 Trees, Conserve 7,000 Gallons of Water, Save 463 Gallons of Oil."

Treatment 3: Economic Gain Framing: The economic gain framing treatment emphasizes the financial benefits of adopting 3R practices, appealing to respondents' economic interests. For Reduce, the message underscores the financial savings from reducing food waste like: "Stop Throwing Away Money and Food! Reduce Food Waste: Plan meals, shop with a list, and use leftovers! Save $1,500 a Year: That's groceries you can use, not toss!". The Reuse message focuses on cost savings from reusing items: "Revive, not replace! Reuse to cut down on waste and conserve natural resources significantly. By reusing items like containers, bags, and clothing, the average American household can save hundreds of dollars each year." For Recycle, the message highlights the economic impact of recycling: "Recycling isn't just about the environment. It's powering a million-strong green machine! Every time you recycle, you contribute to the nation. The recycling industry employs over 1 million people in the US." This treatment seeks to motivate sustainable behaviors by showcasing the tangible financial and economic benefits of adopting the 3R principles.

Control Group: The control group received a straightforward message that did not employ any specific treatment or framing. The poster was still informative by simply stating the order of the 3R principles: 1) reduce, 2) reuse, and 3) recycle.

Post-Intervention Evaluation- Stated Rating of 3R: After the intervention, participants were presented with a series of questions designed to assess their intentions to adopt sustainable practices. Responses were collected using a Likert scale, an ordered response format commonly used to measure attitudes, intentions, and self-reported behavior. In this study,

participants used the scale to indicate their likelihood of engaging in behaviors aligned with the 3R principles, with higher values representing stronger stated intent to reduce, reuse, and recycle. These questions were designed to capture participants' behavioral intentions after exposure to the treatment messages. By analyzing these stated ratings, the study assessed the effectiveness of the different message-framing treatments in influencing sustainable practices and encouraging greater commitment to the 3R principles.

3.2.3. Structural Equation Models

We employ Structural Equation Modeling (SEM) to understand the stated rating of the respondents with respect to the treatment, along with SAI and the socio-demographics of the respondents. SEM is a pivotal statistical technique in behavioral science, enabling researchers to test complex relationships between observed and latent variables. SEM combines multiple regression analyses and factor analyses to provide a comprehensive understanding of the structural relationships in a theoretical model (Kline, 2016). This method is particularly important in behavioral science as it allows for the examination of both direct and indirect effects among variables, accommodating the multifaceted nature of human behavior (Byrne, 2016). The study model is depicted in Figure 3-2, illustrating the independent variables and three endogenous variables: "Reduce," "Reuse," and "Recycle." These endogenous variables, captured through the stated rating questionnaire post-intervention, reflect respondents' self-reported likelihood of adopting behaviors aligned with the 3R principles.

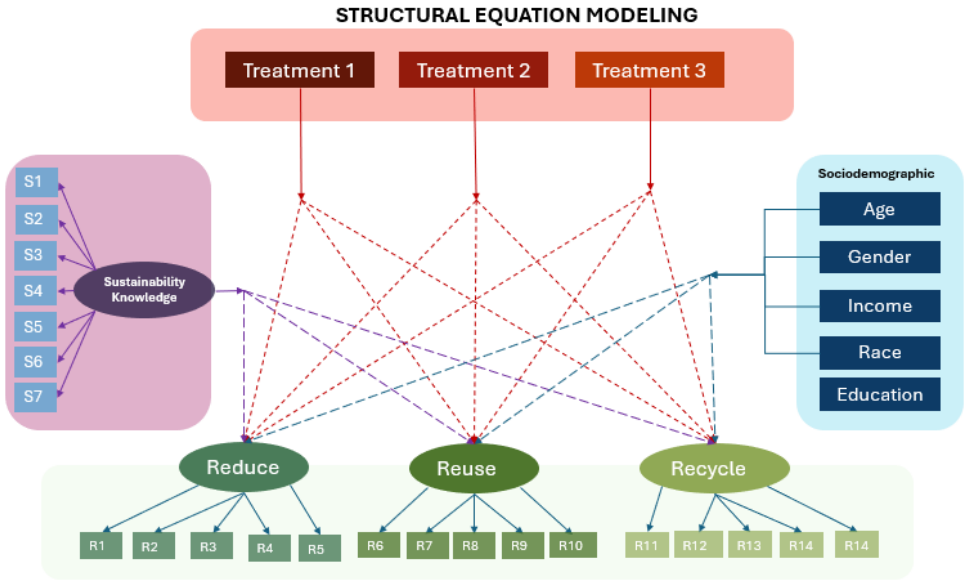


Figure 3-2 SEM Model

3.2.4. Manipulation Checks

Empirical research generally advises the inclusion of Manipulation checks (MCs) in experimental investigations to guarantee that respondents perceive treatments accurately (Kane & Barabas, 2019). This is especially crucial in the case of online surveys and opt-in panels,

as participants may be vulnerable to distractions. MCs serve to confirm that participants are actively engaged with the treatments they receive. An efficient approach to perform manipulation checks is by using multiple-choice questions. These questions evaluate whether participants have comprehended and perceived the experimental manipulations as planned (Morton & Williams, 2010). To address the issue of limited attention and imperfect information among respondents, it is essential that the provided information is clear and engaging, effectively activating the respondents' moral compass. One MC question used was: “Do you think using reusable grocery bags is a more sustainable practice than using plastic bags?” with response options being “True” and “False.” A response of “True” was considered successful. Another focus of the manipulation check was to assess the cognitive abilities of the respondents, ensuring they could comprehend the long-term benefits described. To this end, a mathematical question was posed: “Recycling 1 ton of paper saves about 17 trees. How many trees are saved by recycling 10 tons of paper?” The options were a) 170, b) 1700, c) 100, and d) 1000. The correct response, option “a,” was used to determine the successful completion of this cognitive assessment. This approach ensures that participants' attention and understanding are accurately measured, thereby validating the effectiveness of the experimental treatments.

3.3. Anti-Littering Awareness Index

3.3.1. Experimental design with treatments

In this study, three distinct positive message framings were randomly assigned to respondents, who were then asked to rate their anti-littering behavior on a Likert scale. In light of ongoing governmental and public initiatives aimed at reducing roadside littering, such as the successful implementation of applications that display the location of nearby trash cans (Sensoneo, 2024), participants were instructed to imagine a hypothetical scenario in which the message was delivered through a navigation app. This app would show the location of the nearest available trash cans while driving, accompanied by digital messages encouraging anti-littering behavior.

Participants were divided into four groups, with each treatment group exposed to a framed poster, and the control group receiving a poster without any specific framing. The treatment groups viewed posters containing different positive framings. After being presented with the message, participants were asked to rate their littering habits upon reading the poster on a Likert scale ranging from 1 ("I always litter") to 7 ("I do not litter at all"). This response was termed the "anti-littering index" and served as the primary outcome measure of the experiment. The questionnaire also asked about the

Figure 3-3 Treatment 1-Awe with Anthropomorphism

respondent's general behavior on the littering index prior to the messaging intervention, to not create any confusion. Additionally, respondents assessed various statements related to their values, beliefs, and norms using a Likert scale. These variables were included to further evaluate potential behavioral changes resulting from the message framing treatments, allowing for a comprehensive analysis of how different emotional and cognitive appeals influenced anti-littering behaviors. In this study, the randomization process was made easier by the web-based application; the four groups and their characteristics are explained below.

Treatment 1: Awe with Anthropomorphism

The poster for this treatment is designed to evoke awe and anthropomorphism, inspiring environmental protection (Figure 3-3). The primary message reads: "Help Keep Our Earth Beautiful! Imagine a world where every roadside reflects the majesty of nature. Be the change you wish to see!" After reading this message, respondents should feel inspired to think about the beauty of the natural world and how they can help preserve it. To enhance the anthropomorphic element, an image of a smiling earth was included in the poster so that it becomes more personified and relatable. This anthropomorphism aims to foster a personal connection between the viewer and the environment, encouraging them to take action to protect it. Additionally, the poster includes a visual of someone throwing garbage into a bin, accompanied by the text: "Bin your trash, keep our roads litter-free!"

Treatment 2: Power

The Power Messaging intervention is designed to promote a sense of power and responsibility in individuals to encourage engagement in pro-environmental behavior (Figure 3-4). The textual component of the treatment includes empowering messages such as: "Take Charge: Your Power to Protect the Earth Starts Here! Every piece of litter you throw in the dustbin is a powerful action that protects our planet. Be Earth's Hero. Your choice matters!" This message aims to evoke a feeling of empowerment, encouraging individuals to recognize the significant impact of their actions on the environment. In addition to the text, the intervention contains a graphic component that includes an image of a person disposing of litter properly in a bin accompanied by the text caption "Bin your trash, please do not litter."

Figure 3-4 Treatment 2-Power Messaging

This visual reinforcement is crucial as it not only demonstrates the desired behavior but also aligns with the empowering message by showing positive action in practice.

Treatment 3 Humor Messaging

The humor framing treatment utilizes a light-hearted and engaging message to encourage proper waste disposal. The text reads, "This Trash Ain't Taking Flight: Unless You Aim it at the Bin ;)," aiming to catch the audience's attention with a playful tone. To reinforce this message, the treatment includes a visual component featuring an image of a person correctly disposing of litter in a bin. The image is accompanied by the caption: "Bin your trash, please do not litter" (Figure 3-5). The use of humor is intended to create a positive and memorable association with the act of proper waste disposal, thereby encouraging more consistent and conscientious behavior among the audience.

Figure 3-5 Treatment 3- Humor Messaging

Control group

The control group was presented with a straightforward message that did not utilize any specific psychological treatment or framing techniques. This message included a visual component featuring an image of an individual correctly disposing of litter in a bin. The accompanying caption, "Bin your trash, please do not litter," was designed to convey a clear and direct appeal to proper waste disposal behavior (Figure 3-6). The simplicity of this message aimed to establish a baseline for comparing the effectiveness of other strategically framed interventions.

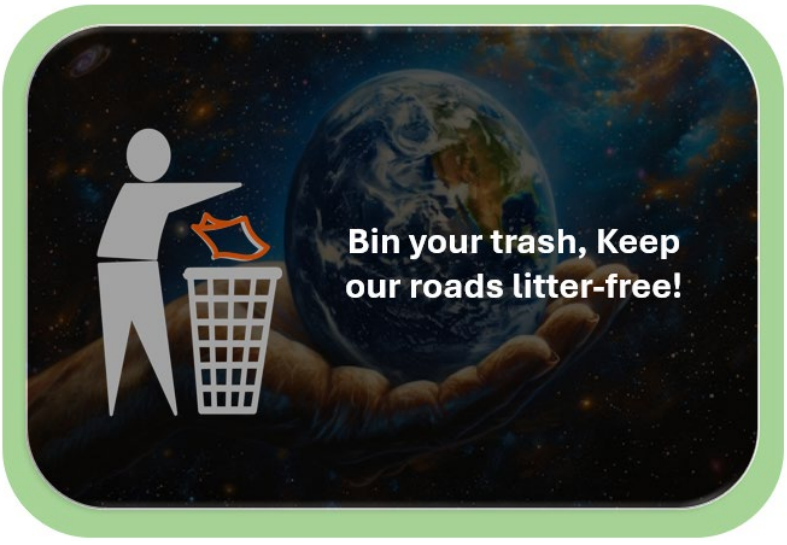


Figure 3-6 Control Group

3.3.2. Model Specifications

By randomly assigning respondents to different information treatments, we may estimate the average impact of these treatments by looking at the mean values of the proportion of respondents that report a higher anti-littering index. Nevertheless, to comprehensively consider potential impacts from socio-economic and other explanatory factors and to examine the effects of different treatments on littering behavior, we utilized an ordered logit regression model. The model design and variables are shown in Figure 3-7. Ordinal dependent variables are those that possess a natural ranking or order, and one statistical method for analyzing them is the ordered logit model (*Analysis of Ordinal Categorical Data, 2nd Edition | Wiley*, n.d.). This model allows us to examine the relationships between multiple independent variables and the ordinal dependent variable, which in this case is the anti-littering index. Mathematically the model is specified as:

$$\log\left(\frac{P(Y \leq k)}{P(Y > k)}\right) = \alpha_k + \beta_{T1}(Awe) + \beta_{T2}(Power) + \beta_{T3}(Humor) + \beta_2(Selfefficacy) + \beta_3(Values) + \beta_4(Sociodemographics) \quad (1)$$

Where, Y is the ordinal Anti-Littering Index and, α_k are the intercepts for the categories. β terms are coefficients for each independent variable, and β_{T1}, β_{T1} and $\beta_{T1}$are the coefficients for the respective treatment groups. Each participant will have a value of 1 for the treatment they received and 0 for the others, if no treatment (control group) all the values are zero, ensuring only one treatment effect is applied per participant. We have made a combined model that includes all three treatment indicators and separately for each of the three treatment groups.

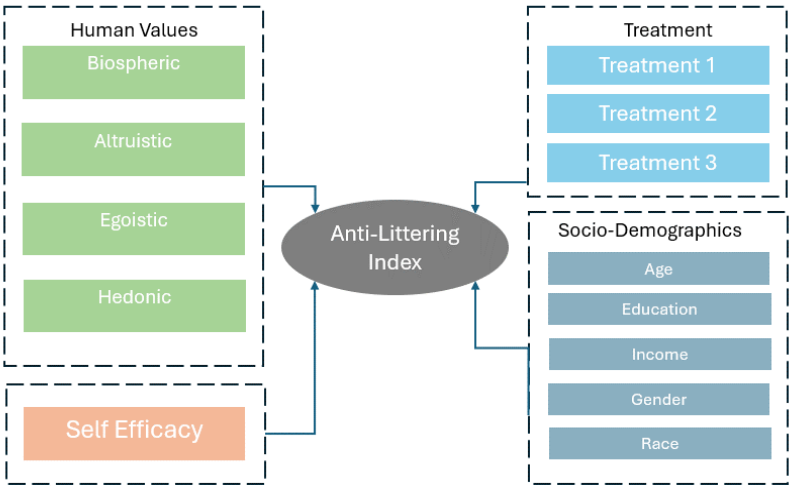


Figure 3-7 Model Design and Variables

Chapter 4 Results and Discussion

4.1. 3R Awareness Study

4.1.1. Data and Descriptive Statistics

The survey participants involved in this study were chosen from several places within the state of Tennessee. After implementing data cleaning processes, the sample size decreased to 1,674 observations. The cleaning method entailed removing surveys that had incomplete responses to the specified choice treatment questions and surveys that were completed in less than 5 minutes. The survey included a detailed questionnaire that was expected to take about 15 minutes to complete. To assure the quality of the data and meaningful participation from the participants, a minimum time requirement for completing the survey was considered important. The sample was partitioned into four groups: 420 participants in the control group, 432 participants in Treatment 1, 427 participants in Treatment 2, and 395 participants in Treatment 3. Table 4-1 provides information on the distribution of important covariates among the four groups in our data set, which allows us to assess the quality of randomization. An individual analysis of the variables was conducted across the treatment groups, revealing that each category of variables had a similar number of occurrences across the groups. Given that respondents were randomly assigned to various information treatments, these findings indicate that the randomization approach successfully ensured that the treatment groups were comparable and appropriate for conducting further analyses.

Table 4-1. Descriptive Statistics (N=1,674)

	N	Control Group	Treatment 1 (Anthropomorphic)	Treatment 2 (Behavioral Impact)	Treatment 3 (Economic Gain)
		420	432	427	395
Gender	Man	176	177	168	185
	Woman	244	255	259	210
Age	18-24	39	48	32	43
	25-34	79	76	84	72
	35-44	74	84	90	75
	45-65	133	147	149	133
	65+	95	77	72	72
Race	Asian	5	3	7	9
	Black or African American	66	95	74	67
	Hispanic / Latino	9	11	2	4
	Other	17	8	13	7
	White	323	315	331	308

Income	Less than $25,000	116	116	110	90
	$75,000 to $99,999	121	138	130	116
	$50,000 to $74,999	79	75	73	75
	$25,000 to $49,999	55	43	47	44
	$100,000 or more	49	60	67	70
Education	Less than a high school degree	29	21	20	21
	High school degree	228	273	249	216
	Bachelor's degree	52	42	40	41
	Associate's degree	78	62	74	73
	Postgraduate	33	34	44	44

Prior to examining the evaluation of treatment results, the MCs utilized in the study were analyzed. Figure 4-1 illustrates the proportion of individuals who completed each of the MCs. The figure shows that more than 63.7% of the individuals in all the treatment groups and the control group successfully passed the MC for cognitive skills limitation. This data suggests that more than 63.7% of the participants could evaluate the advantages or benefits and did not experience any cognitive constraints or limitations in analyzing the messaging. The MC that focused on analyzing the incomplete information resulted in the lowest pass rate compared to the control group, with a rate of 86.9%. It is possible that for the remaining participants, either the information was not effectively communicated, or their replies were a result of intentional decision-making processes. The MC asked whether the respondents believe that using reusable grocery bags is a more sustainable activity compared to using plastic bags. It is likely that, despite being exposed to the messaging, either the communication was not effectively transmitted, or the respondents were not persuaded by its content.

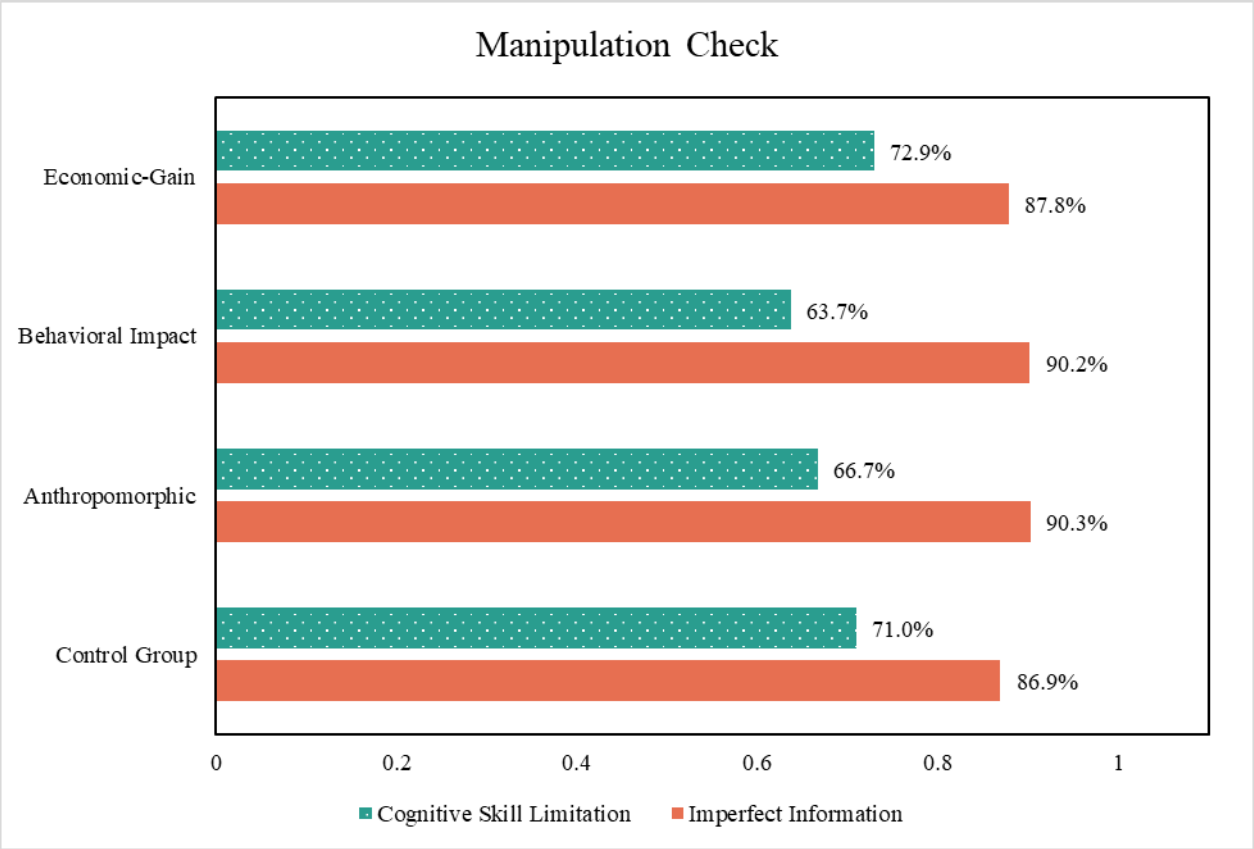


Figure 4-1 Percentage of respondents passing the Manipulation Checks for different Treatment Groups

4.1.2. Treatment Results

The stated ratings of each of the 3R principles, 'Reduce', 'Reuse', and 'Recycle', were assessed using a Likert scale ranging from 1 to 7. A score of 1 represented the least support for the question, while a score of 7 indicated the strongest support. The internal consistency of the survey responses for each principle was assessed using Cronbach's alpha (Tavakol & Dennick, 2011). A higher alpha value indicates greater consistency in responses, thus affirming the reliability of the measure. The study found that the variables, as presented in Table 4-2, demonstrated good internal consistency, as evidenced by their high Cronbach's alpha values.

Figure 4-2 illustrates the average stated ratings for three categories (reduce, reuse, recycle) across four different treatments (Control, Anthropomorphic, Behavioral Impact, and Economic Impact). These average ratings provide an initial comparison of the effectiveness of the treatments in enhancing respondents' affinity toward the principles of the 3R framework. Overall, Treatments-1:Anthropomorphic, Treatment-2:Behavioral impact, and Treatment-3:Economic Gain show consistent improvements in promoting reducing, reusing, and recycling behaviors compared to the control group. Treatment 3 improvements were comparatively less

than those of Treatments 1 and 2. This suggests that while all treatments have some positive impact, Treatments 1 and 2 are particularly effective in encouraging sustainable behaviors.

Table 4-2 Cronbach's alpha of 'Reduce', 'Reuse', and 'Recycle' measured using the Likert Scale

Variable	Items on Likert Scale (1-7, 7 being highest)	Mean	Reliability Cronbach's alpha
Reduce	How often will you consciously buy products with minimal packaging? When shopping, will you prefer to buy items in bulk to reduce packaging waste? Will you try to reduce your use of single-use plastic items (e.g., straws, cutlery, bottles)? How frequently will you use reusable bags when shopping? Will you prioritize buying products that are durable and have a longer lifespan over cheaper, less durable options? Will you take your own coffee cups to your daily coffee shop?	4.431	0.854
Reuse	How often will you use reusable shopping bags instead of single-use plastic bags? Will you repurpose containers (like jars or boxes) for storage or other uses at home? How frequently will you donate or sell items you no longer need instead of throwing them away? How often will you repair items (like clothing, electronics, or furniture) instead of replacing them with new ones? When organizing events or parties, will you opt for reusable plates, cups, and utensils? Will you practice any form of upcycling (creating new items from old or discarded materials)? Will you borrow or rent items that you only need temporarily instead of buying them?	4.694	0.879
Recycle	How often will you separate recyclables (paper, plastic, metal) from your regular trash? Will you check if an item is recyclable before disposing of it? When buying new products, how often will you consider if the product can be recycled after use? Will you check your local recycling guidelines to ensure you're putting the right items in the recycling bin? How often will you recycle paper products (e.g., newspapers, magazines, office paper) and plastic bottles How often will you educate or encourage others in your household or community to recycle?	4.459	0.941

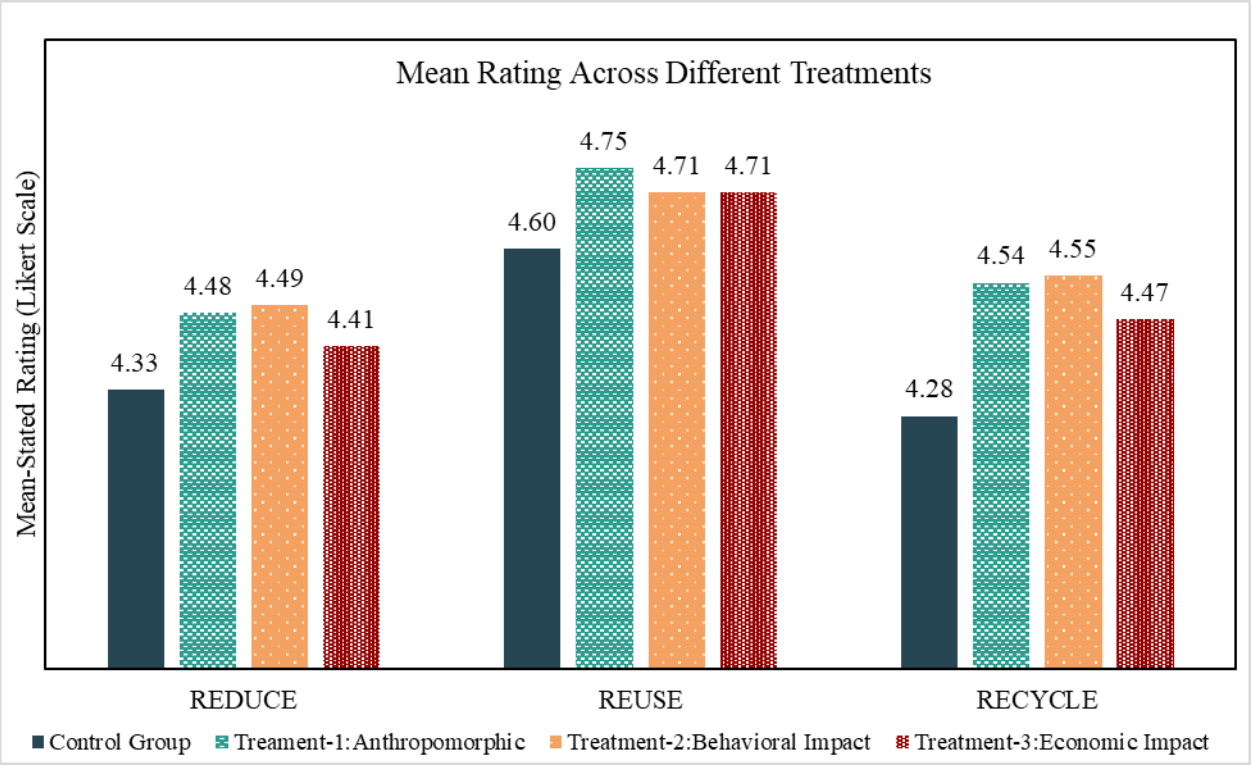


Figure 4-2 Treatment Effect-Mean Rating

When analyzing each of the 3R principles individually, distinct message-framing strategies were found to have varying levels of effectiveness in enhancing respondents' sustainable behaviors. For the Reduce principle, Treatment 2: Behavioral Impact emerged as the most effective strategy, achieving a mean Likert rating of 4.49 on a Likert scale of 1-7. This finding indicates that framing messages emphasizing the tangible environmental benefits of reducing waste successfully resonates with respondents, motivating them to engage in the reduction of consumerism. While, for the Reuse principle, Treatment 1: Anthropomorphic proved to be the most effective, with a mean rating of 4.75. The use of anthropomorphic elements, likely created an emotional connection with participants, making the concept of reuse more engaging and relatable, and appears to effectively encourage respondents to adopt behaviors that do extend the life of materials through reuse. For the Recycle principle, Treatment 2: Behavioral Impact again demonstrated the highest effectiveness, achieving a mean rating of 4.55. Highlighting the measurable environmental outcomes of recycling likely reinforced respondents' perceptions of its importance, increasing their inclination to participate in recycling activities. These findings underscore the nuanced impact of different message framing strategies on sustainable behaviors.

Structural Equation Model: While the mean ratings provide an initial understanding of the effectiveness of different positive message framing strategies, this study also sought to explore the interplay between the SAI and socio-demographic variables in respondents' decision-making processes, and SEM was used for analyzing this. Table A-1 displays the structural

equation model results, which elucidate the relationships between various treatments, the sustainability awareness index, and socio-demographic variables concerning the three key pro-environmental behaviors: reducing, reusing, and recycling.

Effectiveness of Treatments: The SEM results indicate that all three treatments positively influence respondents' stated ratings of behaviors related to the 3R principles: reducing, reusing, and recycling. Among the interventions, Treatment 1: Anthropomorphic emerged as the most effective strategy for enhancing all three pro-environmental behaviors. This treatment demonstrates statistically significant effects across all 3R principles. While, Behavioral impact also demonstrates positive effects, particularly in reducing and recycling behaviors, though its impact on reusing is less pronounced. In comparison, the Treatment-3: Economic-Gain framing also produced positive outcomes; however, these effects were not statistically significant with the current dataset. This result suggests that while economic incentives may encourage some level of engagement with sustainable behaviors, their impact may be less effective than strategies that evoke emotional connections or emphasize tangible behavioral outcomes.

Sustainability index: The sustainability awareness index emerges as a pivotal predictor within the model, demonstrating a strong and positive correlation with pro-environmental behaviors across all three 3R principles. Higher scores on the sustainability index correlate strongly with positive changes in all three behaviors, reducing, reusing, and recycling, and are statistically significant. This finding underscores the importance of sustainability awareness in fostering environmentally friendly practices, as individuals with greater initial awareness are more likely to engage consistently in behaviors that support environmental conservation. Figure 4-3 illustrates the relationship between the SAI and mean stated Likert ratings for the 3R principles, presenting a clear trend: individuals with higher SAI scores consistently report higher Likert ratings for their engagement in reducing, reusing, and recycling behaviors. This positive association reinforces the idea that improving sustainability awareness not only increases the likelihood of individuals engaging in environmentally responsible practices but also amplifies the effectiveness of targeted interventions, such as message-framing strategies.

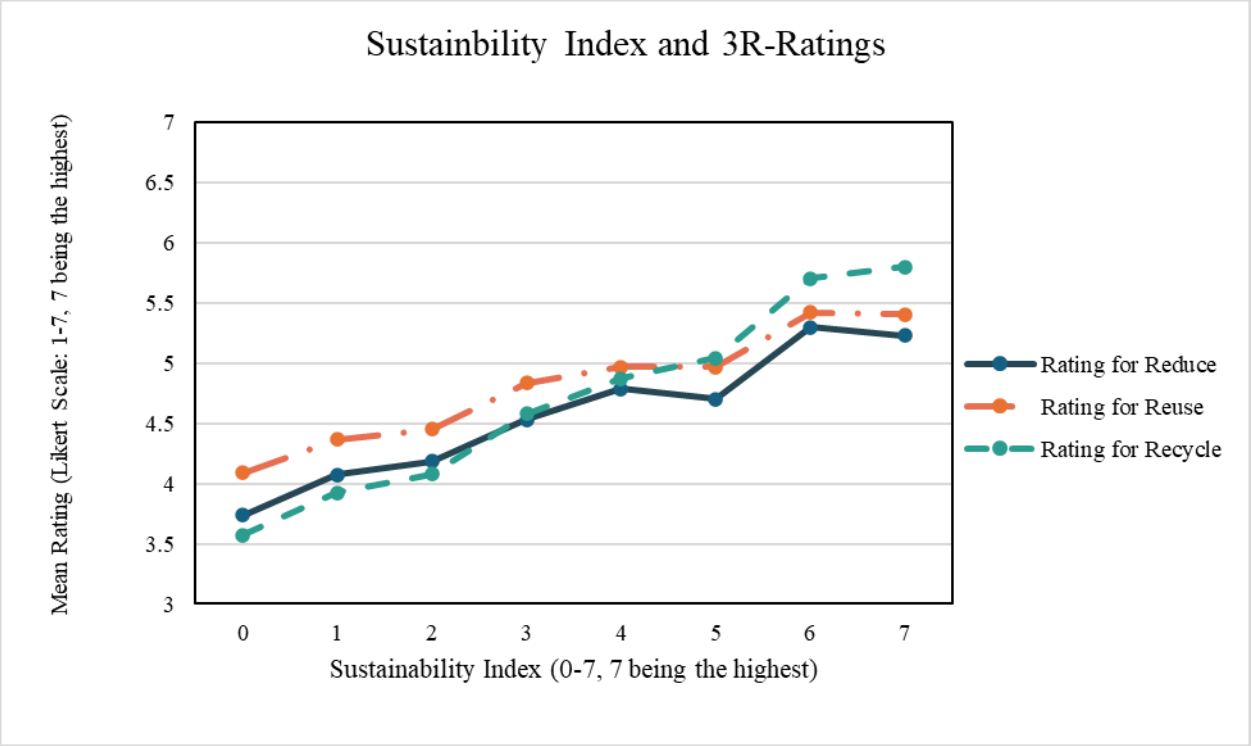


Figure 4-3 Sustainability Index and 3R-Ratings

Sociodemographics: The statistical analysis of the study data indicates that higher income levels play a significant role in predicting pro-environmental behaviors. Participants with higher incomes generally exhibit greater tendencies towards reducing, reusing, and recycling compared to those earning less than $25,000. This trend suggests that financial stability provides the resources and opportunities necessary for individuals to adopt and maintain sustainable practices. Age also emerges as an important factor influencing pro-environmental behaviors. Older age groups show a stronger likelihood of engaging in reducing, reusing, and recycling compared to the younger age group (18–24). This difference may be attributed to older individuals having more established habits and a heightened sense of responsibility toward environmental conservation. The analysis reveals no significant effects of educational attainment on pro-environmental behaviors from the data when comparing various educational categories to the base category (less than a high school degree) while gender differences are evident in the data, with men generally less likely than women to engage in reducing, reusing, and recycling behaviors. This observed sociodemographic disparity underscores the need for targeted interventions aimed at encouraging more sustainable behaviors across specific population groups.

4.2. Anti-Littering Awareness Study

4.2.1. Data and Descriptive Statistics

Survey participants were selected from various locations throughout Tennessee for this research. The sample size was reduced to 1,724 observations after the data-cleaning procedures were implemented. As part of the cleaning process, surveys that were completed in under five minutes or didn't have full answers to the treatment questions were taken out. The questionnaire in the survey would take about 15 minutes to complete and the minimum time limit for finishing the survey was thought to be important to make sure the quality of the data. The sample was split into four groups: the control group had 440 people, Treatment 1 had 434 people, Treatment 2 had 405 people, and Treatment 3 had 445 people. Table 4-3 shows how the four groups in our data set distribute themselves out over important variables. Individual analyses of the variables were done for each treatment group, and it was found that the number of cases of each type of variable was about the same across all groups. These results show that the randomization method worked to make sure that the treatment groups were similar enough to be used for further analyses.

Table 4-3. Descriptive Statistics (N=1,724)

		Treatment 1: Awe	Treatment 1: Power	Treatment 1: Humor	Control Group
	N	434	405	445	440
Gender	Man	178	164	162	180
	Woman	256	241	283	260
Age	18-24	37	44	37	37
	25-34	79	77	86	91
	35-44	91	72	76	96
	45-65	148	144	161	127
	65+	79	68	85	89
Race	Asian	5	6	12	3
	Black or African American	80	69	79	86
	Hispanic / Latino	9	8	3	6
	Other	13	11	9	10
	White	327	311	342	335
Income	Less than $25,000	107	100	122	122
	$75,000 to $99,999	129	127	136	130
	$50,000 to $74,999	86	70	83	74
	$25,000 to $49,999	44	45	48	53
	$100,000 or more	68	63	56	61
Education	Less than high school degree	20	25	21	29

High school degree	251	240	273	259
Bachelors degree	76	66	64	74
Associates Degree	51	34	46	41
Postgraduate	36	40	41	37

Considering the message is imagined to be delivered while driving, as an alert showing the nearest trash can, respondents were asked if they were comfortable with such an alert system. Figure 4-4 presents respondents' views on the necessity of an alert system that displays the nearest litter bin while driving, aimed at reducing littering. Opinions across different treatment groups showed similar trends. In each group, a significant portion perceived such an alert system as beneficial, though at least 12% in every group considered it potentially distracting. Additionally, a minimum of 18% in each group felt the system was unnecessary. Despite some concerns about its distraction potential, a considerable number of respondents were positive about the utility of such an alert system.

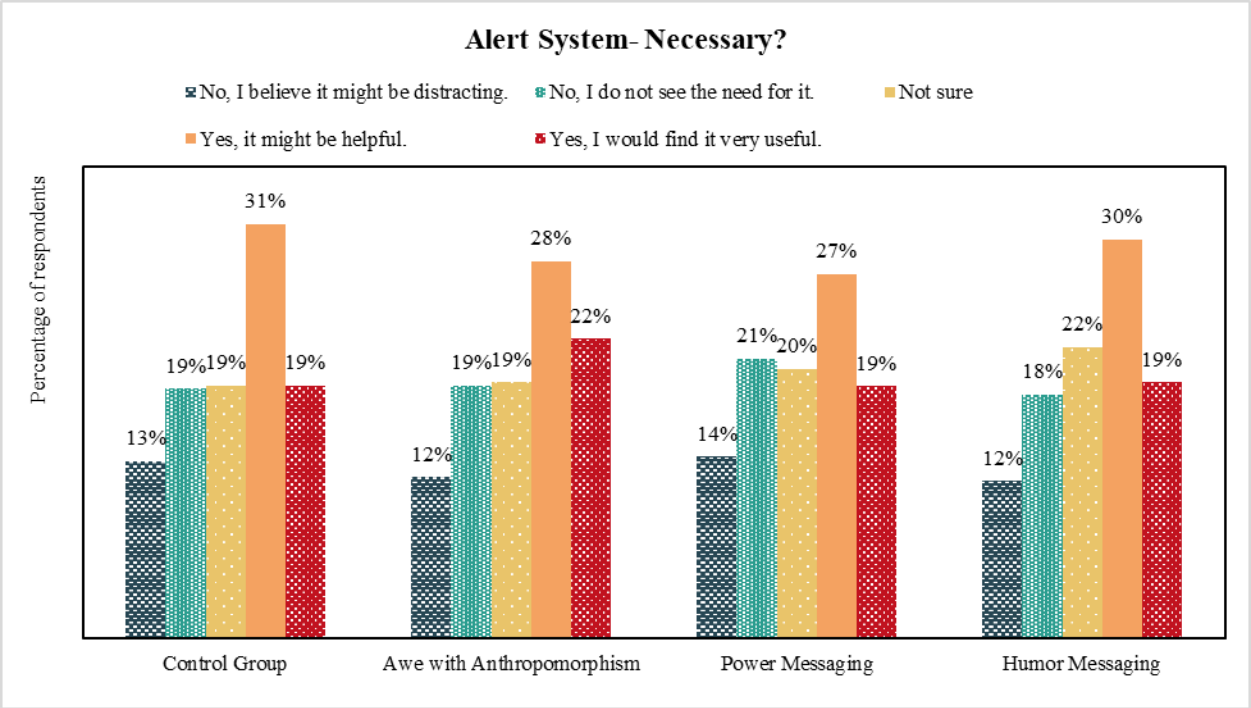


Figure 4-4 Importance of Alert System- Percentage of Responses

Considering other factors, the study used a 7-point Likert scale to measure human values and self-efficacy, with 1 indicating minimal agreement and 7 indicating strong agreement. To evaluate the survey's reliability and internal consistency, Cronbach's alpha coefficient was used. This coefficient ranges from 0 to 1, with higher values indicating greater consistency among participant responses (Tavakol & Dennick, 2011). The study's variables (presented in Table 4-4) showed a high degree of reliability in participants' answers, as reflected in their high Cronbach's alpha scores.

Table 4-4. Cronbach's alpha of Variables, measured using the Likert Scale

Variable	Items on Likert Scale (1-7, 7 being highest)	Mean	Reliability Cronbach's alpha
Biospheric Values	It is important for you to prevent environmental pollution It is important for you to protect environment It is important for you to be in unity with nature	5.221	0.888
Altruistic Values	It is important for you that every person have equal opportunities It is important for you to take care of those who are worse off It is important for you that every person is treated justly It is important for you to that there is no war or conflict It is important for you to be helpful to others	5.719	0.893
Egoistic Values	It is important for you to be influential It is important for you to have money and possessions It is important for you to work hard and be ambitious	4.821	0.654
Hedonic Values	It is important for you have fun It is important for you to enjoy the life's pleasures It is important for you to do things he/she enjoys	5.588	0.878
Self Efficacy	I am confident in my ability to complete tasks successfully overcoming obstacles I am sure I can achieve my goals if I put in the effort in I am able to adapt to unexpected changes in my life I am confident in my ability to learn new skill and techniques	5.568	0.898

4.2.2. Treatment Effects

Figure 4-5 illustrates the average ratings for anti-littering index scores from the experiment. Humor messaging treatment had the most effective impact on reducing littering behaviors, scoring 6.27, which is above the Control Group's score of 6.13. Power Messaging also improved littering behaviors with a score of 6.17, also higher than the Control Group. While Awe with Anthropomorphism also did perform as effectively, with a score of 6.18, which is higher than the Control Group. This suggests that these messages can potentially enhance anti-littering behaviors.

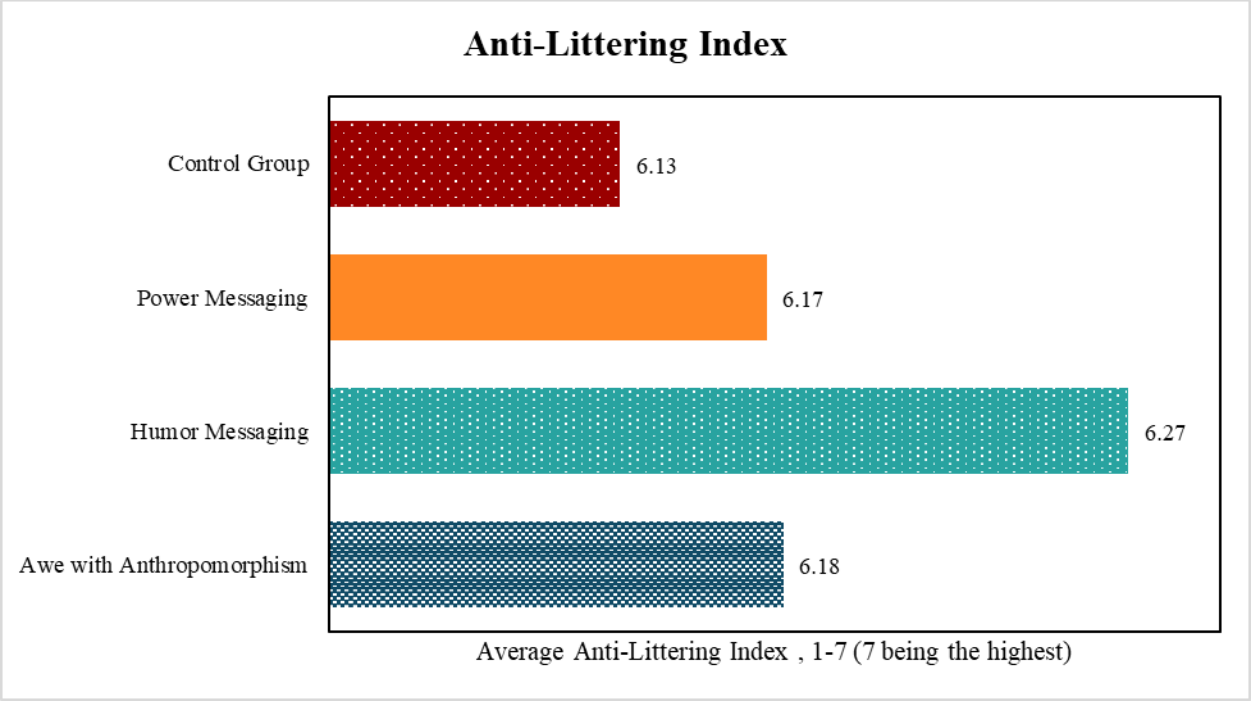


Figure 4-5 Treatment Effect-Mean Rating

The analysis of the ordinal regression model reveals nuanced effects of various treatments and factors on anti-littering behaviors, the parameter estimates are shown in Table A-2. In examining Model 1, which includes all treatment groups, the analysis from our data indicates that although the treatment effects on anti-littering behavior were statistically insignificant, they all exhibited a positive influence compared to the control group. This suggests that while the treatments did not demonstrate a significant impact in statistical terms, they still showed a potential to promote anti-littering behavior, and it hints at the possibility that the treatments resonated with respondents. Therefore, it can be inferred that while the messaging might not have produced a strong differentiation in outcomes, it did not perform worse than the control and may have subtly influenced behavior in a positive direction.

When examining the individual treatment models in comparison to the control group, the results align across treatments but offer valuable insights into the influence of human values and self-efficacy. In the awe treatment, our study data shows that individuals with higher altruistic values exhibited significantly higher odds of achieving a high anti-littering index, while those with lower egoistic values were also more likely to show improved behavior. Similarly, in the power treatment, participants with higher altruistic values and elevated self-efficacy demonstrated greater odds of adopting anti-littering behavior. The humor treatment showed that individuals with both higher altruistic and hedonic values were more likely to report stronger anti-littering behaviors. Consistent with existing research, our study finds that individuals with higher altruistic values are more likely to engage in pro-environmental actions and notably, altruistic values had a strong positive influence on anti-littering behaviors.

Conversely, egoistic values had a significant negative impact, suggesting they may hinder pro-environmental actions. Interestingly, individuals with higher hedonic values, who prioritize self-happiness, also exhibited pro-environmental behavior, possibly due to the satisfaction derived from not littering. Furthermore, self-efficacy had a positive and significant impact, enhancing the propensity towards environmental preservation. This indicates that independence through self-efficacy may drive individuals towards more sustainable behavior when manipulated through targeted messaging.

Demographic factors:

Gender differences were apparent from the analysis of our study data, with men less likely than women to participate in anti-littering behaviors. Age also played a critical role; younger individuals demonstrated significantly lower anti-littering behaviors compared to the oldest cohort, highlighting the importance of targeted educational initiatives for younger demographics. Racial disparities were also evident, considering income, different income levels influenced anti-littering behaviors, with higher-income people having a positive influence on anti-littering behavior. with individuals earning between $50,000 and $74,999 showing a higher likelihood of such behavior. Education, however, from the data did not show a consistent pattern in influencing anti-littering behavior, suggesting that income might be a more significant determinant in this context. These insights emphasize the complex interplay of personal values, demographic factors, and socioeconomic status in shaping anti-littering behaviors and highlight the need for multifaceted approaches in environmental policy and interventions.

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Chapter 5 Conclusion

This study evaluated how positive message framing can support public messaging and behavior change systems for circular economy practices, with a focus on 3R behaviors and anti-littering behavior. The findings show that targeted messages can influence stated pro-environmental intentions and can serve as a practical complement to education, outreach, cleanup, and enforcement programs. The results also show that message effectiveness depends on both the type of behavior being encouraged and the characteristics of the audience receiving the message.

5.1 Key Conclusions

The main conclusions from the study are as follows:

1. Positive message framing influenced stated 3R behavior. Anthropomorphic and behavioral impact messages were particularly useful because they helped respondents connect individual choices with broader environmental outcomes.
2. The Sustainability Awareness Index provided a useful baseline measure of respondents' knowledge of sustainable practices. Respondents with higher awareness scores were generally more likely to report stronger willingness to engage in reduce, reuse, and recycle behaviors.
3. Humor-based messaging produced the strongest response in the anti-littering experiment. This suggests that anti-littering campaigns may benefit from messages that are memorable, approachable, and easy for the public to engage with.
4. Respondent characteristics influenced behavioral intentions. Demographic factors, values, and self-efficacy were associated with differences in stated pro-environmental behavior, indicating that uniform messaging may not be equally effective for all groups.
5. The study demonstrates that public messaging can be designed more strategically. Rather than using general environmental messages, agencies can select framing approaches based on the intended behavior, campaign setting, and target audience.

5.2. Benefits to TDOT and limitations:

The findings provide TDOT with an evidence-based approach for designing and evaluating public-facing sustainability and litter-prevention campaigns. For roadside litter prevention, humor-based messages may be useful because they can attract attention and reduce resistance to behavioral prompts. For 3R-related campaigns, anthropomorphic and behavioral impact messages may be more appropriate because they make sustainability actions more relatable and connect individual behavior to visible environmental outcomes.

TDOT can apply these findings in several ways:

1. Use humor-based messaging in roadside litter prevention campaigns, rest-area materials, digital outreach, and public education content.
2. Use anthropomorphic and behavioral impact framing in broader sustainability campaigns focused on waste reduction, reuse, and recycling.
3. Tailor messaging by audience and setting, since the results show that demographic factors, values, and self-efficacy influence behavioral response.

4. Use SAI-type questions before and after campaigns to measure whether public awareness improves after exposure to targeted messaging.

Begin implementation through small pilot campaigns, followed by pre- and post-campaign evaluation before broader deployment.5.3. Recommendations

The following recommendations are proposed based on the findings:

1. Prioritize humor-based messaging for anti-littering campaigns, especially in settings where messages need to quickly capture public attention.
2. Use anthropomorphic and behavioral impact messages for 3R campaigns because these approaches help make sustainability practices more understandable and relatable.
3. Avoid relying on one uniform message for all audiences. Campaigns should be adapted based on the behavioral goal, audience characteristics, and delivery context.
4. Incorporate awareness measurement into campaign evaluation. The Sustainability Awareness Index can be adapted as a practical tool for measuring baseline knowledge and post-campaign changes in awareness.
5. Test digital and location-based prompts before large-scale use. App-based messages, QR-code prompts, social media content, and location-based alerts should first be evaluated through pilot studies.
6. Link message design with implementation setting. Messages used at rest areas, roadways, campuses, parks, and social media platforms may need different formats and levels of detail.

5.3. Study Limitations and Future Research Directions

This study provides a comprehensive understanding of how message framing and nudging strategies can promote sustainable behaviors; however, certain limitations must be acknowledged. A primary limitation is the reliance on stated preference data, which, while insightful for gauging intentions and attitudes, may not fully reflect real-world behaviors. The hypothetical scenarios used in the surveys might not capture the complexities of actual decision-making, as respondents' choices could be influenced by situational or contextual factors not addressed in the study. Additionally, the controlled experimental design of the interventions, though methodologically robust, does not fully account for the dynamic and multifaceted nature of real-world behavioral contexts. The sample's demographic diversity, while substantial, may not fully represent all population segments in Tennessee or beyond, potentially limiting the generalizability of the findings.

Future research should focus on:

1. Adapt the treatment messages into implementable communication materials, including roadside signs, posters, social media content, QR-code prompts, educational displays, and location-based digital alerts. This would allow the research to evaluate how message format and delivery channel affect public response.
2. Deploy selected messages at practical TDOT and partner-agency locations, such as rest areas, welcome centers, roadway corridors, campuses, parks, and other high-visibility public spaces. Humor-based messages can be tested for anti-littering behavior, while

anthropomorphic and behavioral impact messages can be tested for 3R-related practices.

3. Examine whether behavior change is sustained over time. Longitudinal evaluation would help determine whether repeated exposure to targeted messaging produces lasting improvements in litter prevention, recycling awareness, and broader circular economy practices.
4. Develop a field-based evaluation framework using pre- and post-campaign measurements. Potential measures include litter levels, proper disposal behavior, recycling participation, public awareness, message recall, and stated willingness to engage in sustainable practices after campaign exposure.
5. Evaluate the cost-effectiveness of public messaging compared with or in support of traditional cleanup, enforcement, and education programs. This would help TDOT determine which strategies provide the greatest benefit relative to implementation cost.

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Appendices

Figure A-1 Anthromorphic Poster

Figure A-2 Economic Gain Poster

Figure A-3 Behavioral Impact Poster

Figure A-4 Control Group Poster

Table A-1 SEM Model Estimates

		Reduce			Reuse			Recycle		
		Unstandardized	SE	P_value	Unstandardized	SE	P_value	Unstandardized	SE	P_value
Treatment	Base: Control									
	Treatment-1	0.155	0.07	0.027**	0.151	0.071	0.033**	0.21	0.082	0.011**
	Treatment-2	0.141	0.07	0.046**	0.09	0.071	0.204	0.209	0.083	0.012**
	Treatment-3	0.039	0.072	0.593	0.075	0.073	0.304	0.094	0.085	0.268
Awareness	SAI	0.231	0.02	***	0.215	0.019	***	0.324	0.022	***
Income	Base: Less than $25,000									
	$25,000 to $49,999	0.098	0.067	0.141	0.124	0.067	0.067*	0.053	0.079	0.503
	$50,000 to $74,999	0.193	0.08	0.016**	0.18	0.08	0.026**	0.126	0.094	0.177
	$75,000 to $99,999	0.252	0.097	0.01**	0.285	0.098	0.004**	0.212	0.114	0.063*
	$100,000 or more	0.208	0.087	0.017**	0.193	0.087	0.027**	0.265	0.102	0.009**
Age	Base: 18-24									
	25-34	0.246	0.079	0.002**	0.172	0.08	0.03**	0.133	0.093	0.15
	35-44	0.251	0.078	0.001**	0.184	0.078	0.019**	0.157	0.091	0.086*
	45-65	0.236	0.065	***	0.17	0.066	0.01**	0.281	0.076	***
	65plus	0.254	0.079	0.001**	0.227	0.079	0.004**	0.287	0.092	0.002**
Race	Base: White									
	Asian	0.331	0.258	0.2	0.036	0.26	0.889	0.449	0.303	0.139
	Black or African American	-0.018	0.08	0.825	-0.158	0.08	0.049**	0.143	0.094	0.128
	Hispanic / Latino	-0.215	0.248	0.386	0.017	0.25	0.945	-0.183	0.291	0.531

	Other	0.079	0.189	0.677	0.062	0.191	0.745	0.303	0.223	0.174
Education	Base: Less than high school degree									
	High school degree	-0.022	0.062	0.725	0.097	0.063	0.122	-0.023	0.073	0.753
	Bachelors degree	-0.022	0.1	0.83	-0.026	0.101	0.796	-0.03	0.118	0.802
	Associates Degree	0.038	0.081	0.64	0.029	0.082	0.726	-0.035	0.096	0.711
	Postgraduate	-0.136	0.106	0.198	-0.03	0.107	0.78	-0.033	0.124	0.793
Gender	Base: Woman									
	Man	-0.227	0.063	***	-0.256	0.063	***	-0.171	0.073	0.02

Table A-2 Anti-Littering Model Estimates

		Model-1 All Treatments		**Model-2 Treatment=1: Awe**		**Model-3 Treatment=2: Power**		**Model-4 Treatment=3: Humor**	
		Estimate	**Sig.**	**Estimate**	**Sig.**	**Estimate**	**Sig.**	**Estimate**	**Estimate**
Treatment	Treatment=1: Awe	0.057	0.683	0.097	0.494				
	Treatment=2: Power	0.038	0.790			0.046	0.750		
	Treatment=3:Humor	0.054	0.704					0.058	0.680
	Control								
Human values and Self-Efficacy	Biospheric	0.041	0.409	0.001	0.986	-0.008	0.913	-0.024	0.744
	Altruistic	0.311	0.000	0.335	0.000	0.289	0.001	0.319	0.000
	Egoistic	-0.211	0.000	-0.209	0.007	-0.172	0.026	-0.117	0.115
	hedonic	0.155	0.006	0.032	0.699	0.078	0.328	0.181	0.019
	Self-efficacy	0.222	0.000	0.289	0.000	0.237	0.002	0.095	0.204
Gender	Base: Woman								
	Man	-0.267	0.011	-0.426	0.004	-0.024	0.876	-0.126	0.392
Age	Base: 65+								
	[age=18-24]	-1.037	0.000	-1.057	0.000	-1.031	0.001	-0.976	0.001
	[age=25-34]	-0.905	0.000	-0.713	0.004	-1.082	0.000	-0.796	0.001
	[age=35-44]	-0.770	0.000	-0.628	0.009	-0.757	0.003	-0.642	0.008
	[age=45-65]	-0.497	0.003	-0.311	0.171	-0.377	0.113	-0.441	0.050
Race	Base: White								
	Asian	-0.107	0.791	-1.206	0.063	-0.673	0.293	0.075	0.893
	Black or African American	-0.360	0.006	-0.386	0.035	-0.192	0.309	-0.385	0.035

	Hispanic / Latino	0.444	0.321	0.680	0.270	0.491	0.430	0.796	0.353
	Other	-0.399	0.198	-0.813	0.050	-0.252	0.558	-0.308	0.513
Income	Base: Less than $25,000								
	$25,000 to $49,999	0.109	0.408	-0.077	0.680	0.382	0.043	0.211	0.251
	$50,000 to $74,999	0.525	0.001	0.401	0.081	0.610	0.009	0.623	0.007
	$75,000 to $99,999	0.142	0.452	0.175	0.512	0.378	0.144	0.112	0.660
	$100,000 or more	0.395	0.039	0.079	0.761	0.339	0.201	0.557	0.040
Education	Base: Postgraduate								
	Less than high school degree	-0.223	0.421	0.371	0.339	0.262	0.492	-0.190	0.619
	High school degree	0.110	0.584	0.532	0.054	0.233	0.396	0.317	0.257
	Associate's degree	-0.068	0.778	0.098	0.768	0.072	0.834	0.392	0.254
	Bachelor's degree	0.015	0.945	0.329	0.261	0.208	0.488	-0.099	0.741

Model Fitting Information

Model	**-2 Log Likelihood**	**Sig**	**-2 Log Likelihood**	**Sig**	**-2 Log Likelihood**	**Sig**	**-2 Log Likelihood**	**Sig**
Intercept Only	4143.255		2133.691		2076.903		2106.622	
Final	3866.050	0.000	1993.632	0.000	1953.058	0.000	1987.183	0.000