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Encouraging social diffusion of pro-environmental behavior through online workshop-based interventions

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Abstract

Motivating people to take environmentally friendly action, especially collective actions that promote greater social engagement, is important for addressing environmental issues like biodiversity loss. We conducted an online workshop-based field experiment to target social-psychological perceptions to motivate people to plant native plants and encourage others to do the same. To shift these perceptions, we added 13 microinterventions to half the workshops, including normative messaging, public commitment-making, and providing feedback on the impact of reaching out to others. We used a voucher system to track real-world behavior by partnering with native plant nurseries. Compared to an information-only control workshop, our intervention workshops initially increased certain social-psychological perceptions related to encouraging others to plant native plants. However, they did not change behaviors, or many perceptions, compared to control workshops. Additional exploratory analyses revealed differing patterns of behavioral perceptions 2 months after the workshops. Further research is needed that implements experimental methods and real-world measures of conservation behavior to evaluate the impacts of theory-based outreach tactics on collective actions.

KEYWORDS

efficacy, field experiment, social diffusion, social norm, workshop intervention

1 | INTRODUCTION

Promoting voluntary, pro-environmental behavior (PEB) change is critical for reducing environmental degradation and biodiversity loss (Byerly et al., 2018; Schultz, 2011). Most PEB change studies have focused on understanding and motivating individual, personal-sphere behaviors that can be done without interacting with other people (Farrow et al., 2017; Niemiec, Champine, et al., 2020). However, recent literature highlights the importance of collective actions that facilitate changes in the broader networks, organizations, and societies in which people are embedded (Amel et al., 2017; Milfont et al., 2020). Such actions can strengthen conservation movements by facilitating the coordinated action necessary to address many environmental problems (Niemiec, Champine, et al., 2020).

As discussed in Champine et al. (2022) and Jones and Niemiec (2020), one type of collective action that can facilitate more rapid social change for conservation causes is "diffusion behavior," or behavior that spreads information and applies social pressure through social

networks. Diffusion behaviors may range from more passive forms, such as putting up a yard sign about a cause, to more active forms, such as sharing information and asking others to engage in a behavior (see Berl et al., 2022; Geiger et al., 2017; Jones & Niemiec, 2020; Niemiec et al., 2016, 2021; Sarrouf Willson et al., 2021; Segar et al., 2022 as examples). The term "diffusion behavior" derives from the theory of social diffusion, which suggests that people are more likely to change their behavior if influenced by a friend, family member, or others in their social network (Rogers, 2003).

Studies suggest that motivating individuals to engage in diffusion behavior can be a highly effective strategy for encouraging more widespread behavior change (Abrahamse & Steg, 2013; Burn, 1991; Hopper & Nielsen, 1991). A meta-analysis by Abrahamse and Steg (2013) found that diffusion behavior (i.e., "the block leader approach") was the most effective social influence technique at promoting large-scale behavior change. Motivating diffusion behavior may be particularly effective because it enables information to spread from an individual to others in their social network who might not otherwise seek out this information, reaching a wider audience than those who are already invested in the target PEB (Abrahamse & Steg, 2013; Burn, 1991; Mbaru & Barnes, 2017; Niemiec et al., 2016). Furthermore, diffusion behaviors may help create new norms because as people are actively encouraged by friends to act in a certain way, they may begin to see this behavior as normal (Sparkman & Walton, 2019).

While a large body of research has focused on the impact of social diffusion, few studies have examined how to encourage people to engage in behaviors that facilitate this diffusion (see Berl et al., 2022; Geiger et al., 2017; Niemiec et al., 2021 for counterexamples). Examining barriers and motivations to diffusion behavior is particularly important because studies show that people who are engaging in a PEB in their own life can be reluctant to reach out to others about the behavior (Amel et al., 2017; Roser-Renouf et al., 2014). For example, Niemiec et al. (2019) found that residents who remove invasive species in their own yard often do not encourage their neighbors to do the same due to a fear of social sanctions. Furthermore, even with the importance of diffusion behavior for climate issues and relevant concerns, less than half of Americans (39%) regularly discuss global warming with others (Leiserowitz et al., 2021). This suggests that there may be unique barriers influencing diffusion behavior compared to personal-sphere behaviors.

There is preliminary evidence that diffusion-specific efficacy and normative beliefs are important for motivating diffusion behavior (Amel et al., 2017; Geiger & Swim, 2016; Jones & Niemiec, 2020; Niemiec et al., 2016). Self-efficacy refers to an individual's belief in their ability to achieve a goal or behave in a certain way, while response efficacy is the belief that one's actions will create the intended response for the overall goal (Bandura, 1977, 1997; Hamann & Reese, 2020; Roser-Renouf et al., 2014). Educational interventions that described what to say to others effectively promoted engagement in public discussion about climate change by boosting participants' perceptions of self-efficacy (Geiger et al., 2017). Efficacy, especially response efficacy (also called personal outcome expectancy; Choi & Hart, 2021), has been important for motivating diffusion for urban biodiversity conservation and climate change political participation (Feldman & Hart, 2016; Niemiec et al., 2021). Alternatively, Berl et al. (2022) found an efficacy-based messaging intervention to be ineffective at influencing behaviors to share information about wolf reintroduction. There remains an opportunity to explore the role of perceptions of self-efficacy and response efficacy in encouraging diffusion behavior.

Social norms, the unwritten rules that determine what is considered acceptable in a social group or culture, have been widely studied in the behavior-change literature with studies demonstrating effective social norm interventions for behaviors like recycling, water conservation, and more (Abrahamse & Steg, 2013; Cialdini et al., 1990; Goldstein et al., 2008; Han & Hyun, 2018; Nolan et al., 2008). Injunctive norms are a person's perceptions of how they should behave and descriptive norms are perceptions of how other people are behaving (Cialdini et al., 1990). Recent studies have found that social norms may be particularly important for motivating more collective actions (see Howell et al., 2015; Jones & Niemiec, 2023; Niemiec et al., 2019). However, other studies have not found normative interventions to be highly effective in motivating conservation behavior (see Berl et al., 2022; Byerly et al., 2019; Niemiec, Sekar, et al., 2020 as examples). While the evidence is mixed, descriptive and injunctive norms may still play a role in diffusion behavior.

When designing interventions to change behavior via enhanced perceptions of efficacy and social norms, research suggests that face-to-face communication and hands-on activities are most effective (Abrahamse & Steg, 2013; Bandura, 1977). Face-to-face interventions include strategies like public commitment-making and social modeling where participants interact with others instead of working individually. Hands-on activities, like creating mastery experiences, allow participants to practice an action rather than listening to a description of it. Less is known about the extent to which online interventions can effectively facilitate hands-on activities and peer-to-peer communication to achieve PEB change.

In this study, we conducted a field experiment to compare a traditional information-transfer online workshop

TABLE 1 Definitions and examples of theoretically derived microinterventions in intervention workshops.

Construct	Intervention	Definition	Example
Self-efficacy	Social modeling (Geiger et al., 2017)	Individuals demonstrating or verbalizing how a behavior can be accomplished to other similar individuals.	Describe a case study of a particular Wildscape Ambassador and how they encouraged others in their community to plant native plants, as part of a bigger movement of many Wildscape Ambassadors engaging in this diffusion.
	Mastery experiences (Bandura, 1977, 1997)	Providing an individual the experience of successfully accomplishing a behavior.	Provide participants a chance to practice encouraging others to plant with native plants in a small group of workshop participants.
	Proximal goal setting (Bandura & Schunk, 1981)	Setting near-term goals to make behaviors seem more manageable and less overwhelming.	Prompt participants to set near-term goals surrounding native plant gardening and diffusion behaviors.
	Social persuasion (Bandura, 1988)	Expressing confidence in a person's ability to engage in a behavior successfully to build self-efficacy.	Use efficacy-building language and activities such as, "You already have a lot of the experience to do this," and "This workshop will provide you all the additional training you need to be confident in reaching out to more people about native plant gardening and adding more native plants to your own yard."
	Knowledge-based interventions (Geiger et al., 2017)	Sharing specific information about exactly how to accomplish target behaviors.	Share step-by-step instructions on how to talk to others about native plant gardening and share diffusion vouchers.
Social response efficacy	Providing feedback on social impacts (Witte & Allen, 2000)	Providing feedback about the positive social impact of target behaviors.	Share stories of how others have succeeded in motivating others to garden with native plants, and how that in turn led to additional benefits to wildlife in other yards. Use language such as, "Simply by planting native plant gardens in your front yard, you can get other people excited about native plant gardening."
Environmental response efficacy	Providing feedback on ecological impacts (Geiger et al., 2017)	Providing feedback about the positive environmental impact of target behaviors.	Share stories of the tangible impacts to wildlife from gardening efforts of past Habitat Hero participants. Use language such as, "When you encourage your friends and neighbors, you are multiplying the benefit to birds, pollinators, and wildlife in your neighborhood."
Dynamic norms	Normative statistics and messaging (Kidd et al., 2019; Sparkman & Walton, 2017)	Sharing statistics and statements about the growing number of people participating in the target behaviors.	Share regional-level norms gathered from studies (Champine et al., 2022; Jones & Niemiec, 2020; Niemiec et al., 2021), and local, group-level norms gathered from workshop participants directly in the pre-survey and in live, interactive polls whose results were shared back with the group. Augment these statistics with messages such as, "You will be joining a growing movement in Colorado and more broadly of residents, businesses, and community leaders who are helping others create more native habitat in residential and urban areas."

(Continues)

TABLE 1 (Continued)

Construct	Intervention	Definition	Example
Descriptive norms	Normative statistics and messaging (Kidd et al., 2019; Sparkman & Walton, 2017)	Sharing statistics and statements about the popularity of the target behaviors and how many others are participating.	Share regional-level norms gathered from studies (Champine et al., 2022; Jones & Niemiec, 2020; Niemiec et al., 2021), and local, group-level norms gathered from workshop participants directly in the pre-survey and in live, interactive polls whose results were shared back with the group. Augment these statistics with messages such as, "You are not alone—there is a whole movement of people across Colorado involved in native plant gardening."
	Public commitment-making (Niemiec et al., 2019)	Sharing a pledge to carry out an action in a public setting to create social pressure to follow through on that action.	Prompt participants to share one of their proximal goals in the form of a public commitment in the group chat for the rest of the group to see.
Injunctive norms	Addressing reputational concerns (Jones & Niemiec, 2020)	Assuring individuals that their behavior will be met with approval rather than disapproval.	Directly address reputation concerns in discussions by explaining that people are often more enthusiastic to engage in these discussions about native plant gardening than one might assume, as evidenced by the descriptive and dynamic normative statistics described above.
	Addressing pluralistic ignorance (Geiger & Swim, 2016)	Correcting the belief that one's private attitudes and judgments are different from those of others.	Explain to participants what pluralistic ignorance is and how it can lead people to "self-silence" even in situations when both they and their audience share an interest or belief.
	Facilitating group communication and expectation setting (Niemiec et al., 2019)	Creating a sense of community within a group by establishing shared interests and goals and providing opportunities to socialize.	Facilitate group communication and expectation setting to build participants' sense that there is a supportive community around them who will help them continue to gain necessary skills, and who will approve of the shared goal of expanding native plant gardening.

with one that includes efficacy and norms-based interventions designed to motivate social diffusion for, as well as personal engagement in, conservation behavior. To build participants' efficacy regarding diffusion and personal behavior, intervention workshops applied research-based strategies, including *social modeling* (Bandura, 1971; Geiger et al., 2017), *mastery experiences* (Bandura, 1977, 1997), *social persuasion* (Bandura, 1988), and *proximal goal setting* (Bandura & Schunk, 1981; Bandura & Simon, 1977). We also *provided feedback* on the positive ecological and social impacts of personal and diffusion behavior (Geiger et al., 2017). To build new social norms among a group of workshop participants, and change perceptions of broader regional social norms around native plant gardening and diffusion, intervention workshops *shared information* about regional and workshop-level social norms (Kidd et al., 2019; Sparkman & Walton, 2017), *prompted participants to compare themselves to the group* (Bartke et al., 2017; Festinger, 1954), had participants *make public commitments* (Jaeger & Schultz, 2017), and explicitly *addressed participants' reputational concerns* (Jones & Niemiec, 2020). See Table 1 for definitions and examples of interventions and see Supporting Information for full descriptions.

Our study is designed to address two critical gaps in the diffusion behavior existing literature: first, it integrates face-to-face efficacy and normative building components to evaluate beliefs that have been associated with diffusion behavior in correlational studies but have not been tested experimentally. As such, we address a recent call for more experimental studies testing theory-based interventions for behavior change for biodiversity

conservation (Kidd et al., 2019). This experimental trial also tests a theory-based intervention for behavior change using real-world measures. Self-report measures and behavioral intentions do not always correlate with real-world behavior (Bamberg & Möser, 2007; Milfont, 2009), so this study explores the effects of an intervention on indicators of actual behavior.

Second, while previous studies on diffusion behavior have typically tested interventions designed to influence one or two perceptual variables at a time, our study tests whether a combination of different normative and efficacy-building micro-interventions influence a broad range of diffusion-specific normative and efficacy beliefs, and whether these or other beliefs alter diffusion behavior and behavioral intentions. This enables us to contribute to a more comprehensive understanding of the diverse perceptions that may influence diffusion behavior.

1.1 | Case study

We focus on the case study of diffusion behavior to promote native plant gardening. The growth of cities and urban sprawl has led to the expansion of "novel ecosystems" where actions like wildlife-friendly gardening are becoming available to a larger number of people (Klaus & Kiehl, 2021). Native plant gardening, a component of wildlife-friendly gardening, can support species biodiversity in urbanized spaces (Berthon et al., 2021; Burghardt et al., 2009; Fukase, 2016; Lerman & Warren, 2011). Many native insect species can only survive with plants that they co-evolved with and native plants host more diverse larval populations for native bird diets, so creating a network of habitat in urban areas can support native species survival (Burghardt et al., 2009). Yards that have replaced turfgrass with native plants help to conserve water use and tend to use fewer environmentally-harmful chemicals (Carrico et al., 2013; Milesi et al., 2005; Robbins, 2007; Vickers, 2006). Furthermore, native plant gardening can promote time spent in nature and increase wildlife encounters that are beneficial for physical and mental health (Aerts et al., 2018; Bell et al., 2018; Goddard et al., 2013). By studying diffusion behavior for native plant gardening, we can deepen our understanding of how urban biodiversity conservation actions can spread through social networks and contribute to cities as hotspots for biodiversity stewardship and better human wellbeing (Mumaw & Raymond, 2021).

1.2 | Hypotheses and objectives

For our primary hypothesis, we posited that compared to the control, the treatment workshop that includes efficacy and norm building interventions would increase diffusion behavioral intentions in the days immediately after the workshop and 2 months later, and self-reported diffusion behavior 2 months after the workshop. In our secondary hypothesis, we theorized that the efficacy and norms workshop intervention would enhance perceptions of diffusion-specific self and response efficacy, and injunctive, descriptive, and dynamic norms, compared to the control workshop. As an exploratory hypothesis, we posited that compared to the control, the treatment workshop would increase real-life diffusion behavior indicators, as measured by a voucher-sharing system. This hypothesis was considered exploratory because our indicator of diffusion behavior measured successful diffusion (i.e., having someone else redeem a participant's voucher) rather than diffusion attempt (i.e., sharing the voucher).

In addition, we examined the research question: Compared to the control, to what extent does the efficacy and norms intervention workshop increase personal-sphere behavioral intention and self-reported personal-sphere behavior (i.e., native plant gardening behavior)? This question built on previous studies that have used social influence and efficacy-based interventions to motivate personal-sphere PEB (see Goldstein et al., 2008; Hamann & Reese, 2020; Niemiec et al., 2019; Sparkman & Walton, 2017). Our hypotheses were pre-registered in an analysis plan posted to Open Science Framework (OSF) prior to the experiment (https://osf.io/zgaqf/).

2 | METHODS

2.1 | Participant recruitment

This field experiment was incorporated into a native plant outreach program that Colorado State University researchers launched in collaboration with Audubon Rockies. This study was conducted under Colorado State University IRB #2735. We administered our experiment to 1072 people in Colorado, USA and surrounding states, via 12 online workshops. This took place during March–May 2021, and each workshop had a maximum of up to 200 spots. Based on attendance rates from previous similar Audubon Rockies online workshops, we expected ~50% of registrants would attend. In total, 1918 people registered, and 1072 attended (a 56% attendance rate). Between 60 and 111 people attended each workshop with a total of 506 participants in control workshops and 566 in treatment workshops.

Audubon Rockies helped with workshop facilitation and marketing. To recruit participants, we also distributed information through Colorado-based organizations

promoting native plant gardening and related groups on Facebook (e.g., Colorado Native Plant Gardening, Colorado Organic Gardening, Colorado Field Ornithologists). As such, participants were likely to be a "highly engaged" audience because they had demonstrated a previous interest in gardening, native plant gardening, xeriscaping, urban pollinators, bird conservation, or other related topics. We targeted a highly engaged audience because the aim of our study was to encourage those engaging in personal-sphere behavior to also participate in diffusion behavior. All workshops were advertised using the same language to ensure there was no bias in participants' selection of workshops (see Supporting Information for advertising flyer).

2.2 | Measures

Participants were asked to complete a pre-survey and two post-surveys. Upon workshop registration, participants took the first half of the pre-survey, answering questions about pre-workshop behaviors, attitudes, behavioral intentions, and demographics. Participants filled out the second half of the pre-survey as the first activity in the beginning of the workshop, which included questions about personal-sphere and diffusion-specific efficacy and norms perceptions. The pre-survey was split into two halves to minimize the time spent to register for the workshop, thus removing a barrier to participate in the study. The first post-survey was sent out via email 1 day after the workshop and the second post-survey was sent to participants via email 2 months after the workshop. Post-surveys measured norm and efficacy perceptions specific to personal-sphere and diffusion behavior, attitudes, behavioral intentions in the same way as the pre-survey, and the second post-survey measured self-reported personal-sphere and diffusion behavior (see Supporting Information for a description of measured variables).

2.2.1 | Survey measures

Besides subjective knowledge about native plants, we included distinct personal-sphere and diffusion-specific measures of each social-psychological variable. Personal-sphere-specific variables focused on the individual action of native plant gardening, or using a native plant voucher for oneself, while diffusion-specific measures focused on the diffusion behavior of encouraging others to plant native plants, or sharing a native plant voucher with someone else. Behavior-specific intentions were measured with a five-point scale asking participants their likelihood of engaging in the target behavior in the next year and self-reported behavior was measured by asking participants to share how many native plant vouchers they had used or shared.

We measured three types of social norms: injunctive norms, descriptive norms, and dynamic norms. Injunctive and descriptive norm measures were adapted from Niemiec et al. (2019) and dynamic norms were adapted from Sparkman and Walton (2017). We also measured self-efficacy and two types of response efficacy: social and environmental. Social response efficacy is a person's belief in their ability to make an intended social impact because of their behavior, such as successfully influencing someone to behave a certain way or inspiring others with one's action (similar to indirect goal efficacy; Hamann & Reese, 2020; Jones & Niemiec, 2020). Environmental response efficacy is the belief in one's ability to create the intended environmental impact, such as increasing biodiversity (similar to direct goal efficacy; Hamann & Reese, 2020). Efficacy measures followed Champine et al. (2022) and Jones and Niemiec (2020) who adapted them from Geiger et al. (2017) and Lubell et al. (2007). We adapted attitude measures from Bright and Manfredo (1996) and personal norms measures from Kim et al. (2012). Subjective knowledge about native plants was measured with a five-point scale and previous personal-sphere and diffusion behavior used binary (i.e., yes/no) responses.

2.2.2 | Real-world measures

After completing the post-survey, participants received one personal voucher code they could redeem at a partnering nursery to receive $10 off a native plant purchase, and three diffusion voucher codes to share with others to receive the same discount. Vouchers acted as an incentive to participate in surveys and workshop activities, but also served as indicators of personal-sphere and diffusion native plant gardening behaviors (i.e., secondary, exploratory outcomes in our analysis). Upon completion of the second post-survey, participants who completed the first post-survey received an additional $10 personal-sphere voucher. Those who participated at this stage but had not completed the first post-survey received their original personal-sphere and diffusion voucher codes. Vouchers were collected through our partnering nurseries, High Country Gardens (an online nursery that shipped plants within the contiguous United States) and High Plains Environmental Center (a nursery located in the "Front Range" of Colorado that provided plant pickup at no added cost).

2.3 | Study outcomes

Our initial a priori power analyses accounted for approximately 250 participants across five original workshops in each experimental condition and calculated power to detect a 0.35 scale point difference in continuous primary outcomes between workshops (i.e., diffusion intentions and self-reported behavior), assuming a standard deviation of 1 (which is the standard deviation of these behaviors in prior surveys; Jones & Niemiec, 2020). Once we ran the study, our analyses were based on over 500 participants across six workshops in each experimental condition. While our study design likely enabled sufficient power to detect small differences in continuous outcomes such as behavioral intentions, we were underpowered to detect small differences in binary outcomes such as voucher usage. A priori power analyses for binary secondary outcomes (e.g., any diffusion voucher usage or not, any personal-sphere usage or not), revealed we could detect a 10% difference in usage rate between conditions (e.g., assuming a 10% voucher usage rate in the control, we could detect a 20% voucher usage rate in the intervention). Given this, our real-world indicators of behavior served as secondary, exploratory outcomes in this study.

2.4 | Workshop design

The 12 workshops were randomly assigned to two different conditions: control (information only) and intervention (efficacy and norms treatment). We matched workshops held on weekday lunchtimes and on weekend mornings into pairs; within each match, we randomly assigned the workshop to receive the control or intervention treatment. All workshops lasted 90 min and followed the same general outline: (1) welcome, introductions, study overview and workshop roadmap, (2) information about native plant gardening (3) information about native plant outreach, (4) breakout group discussions with focused prompts, and (5) wrapping up and next steps. The control workshops focused on a greater variety of possible actions people can take and gave greater detail about native plants, birds, and pollinators while the intervention workshops incorporated theoretically derived activities and messages designed to boost participants' efficacy and norms perceptions. For more information about matching and assignment of treatment and workshop design, see Supporting Information. See Table 1 for a definition and examples of each microintervention and Supporting Information for full descriptions of microinterventions in the intervention workshop.

2.5 | Analyses for primary outcomes

A pre-analysis plan for this study was pre-registered on OSF (https://osf.io/zgaqf/). To assess the impact of the intervention on our primary outcomes, we ran adjusted and unadjusted linear regressions with post-workshop diffusion intentions (measured in the days immediately after the workshop and 2 months after the workshop) and self-reported diffusion behavior (measured 2 months after the workshop) as outcome variables. The intervention was entered in as a binary 0/1 variable, with the control condition as the baseline. We removed rows that had missing data for more than 15 survey responses, taking out participants who had not completed the second half of the pre-workshop survey ($n = 478$, i.e., 15 perceptual measures of norms and efficacy or 22% missingness) leaving 594 useable responses (see Figure 1). Of the remaining data, there were only a few cases missing observations, so we used complete-case analysis to remove fewer than 10 observations per regression analysis.

To avoid overfitting the models, we checked to make sure we had at least 20 observations per variable. We also pre-screened potential covariates with the washb package in R (Mertens & Arnold, 2018) using a bivariate likelihood ratio test with the outcome. If the p-value was less than 0.20, the covariate was included in the adjusted model. After pre-screening, adjusted regressions included a combination of pre-workshop perceptual variables, previous behavior, behavioral intention, and demographics, depending on the results of the likelihood ratio tests. Unadjusted analyses used pre-workshop diffusion intention and the binary intervention variable to predict post-workshop diffusion intention and self-reported behavior. See Supporting Information (Table S1) for a list of outcomes measured and covariates. We also conducted multiple-imputed ordinal logistic regressions as a sensitivity analysis, given that our primary outcomes were measured as five-point scales. Multiple imputation is a technique to handle missing data that can preserve statistical power and maintain validity (McCleary, 2002). We used multiple-imputed data for our sensitivity analysis to compare to our complete-case results because we were unable to prescreen multiple-imputed data in the adjusted regressions.

2.6 | Secondary and exploratory analyses

We conducted secondary analyses of the impact of the intervention on perceptions of social norms and efficacy, self-reported personal-sphere behavior, and intentions to engage in personal-sphere behavior using the same

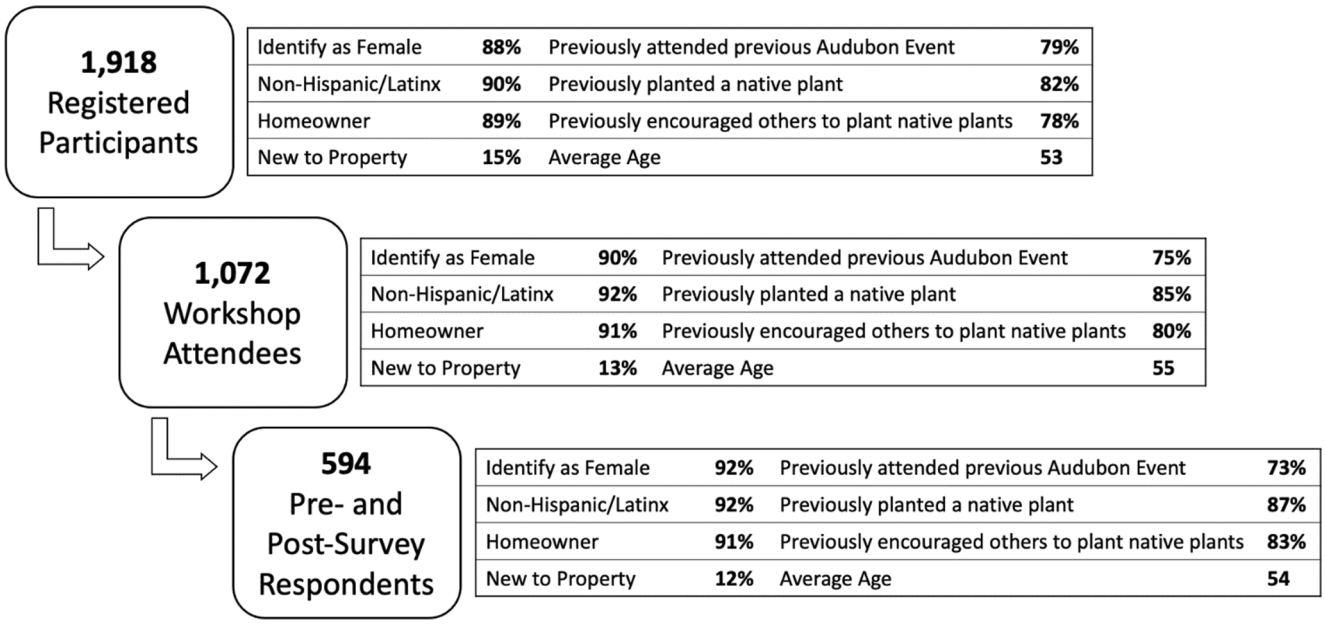

FIGURE 1 Loss to follow up. This figure demonstrates the demographic characteristics of registrants, attendees, and survey respondents at each phase of the study.

procedures described above for the primary outcomes. As an exploratory analysis, we examined the impact of the intervention on voucher usage. To assess the impact of the interventions on participants' personal-sphere and diffusion voucher usage, we conducted two binary logistic regressions with the binary outcome variable of voucher use versus no voucher use. For perceptual measures that were significantly predicted by treatment group directly after the workshop, or increased significantly regardless of workshop, we explored whether any changes remained 2 months after the workshop using mean comparison.

In an additional exploratory analysis, we examined whether there was an interaction between the intervention and pre-workshop participant characteristics, given that previous studies suggest interventions may vary in their effectiveness by sub-groups (see Bolderdijk et al., 2013; Niemiec et al., 2021 as examples). We ran 15 interaction models to test for interaction effects between the treatment and pre-workshop characteristics (i.e., age, gender, subjective knowledge about native plants, education level, income, past behavior, and diffusion-specific attitude, personal norm, self-efficacy, response efficacy, injunctive norm, and dynamic norm) on social diffusion intention.

We had originally planned to run a Poisson regression with the outcome variable of number of diffusion vouchers used but few participants ($n = 30$) had more than one voucher used that they had shared. We also originally intended to explore whether perceptions (i.e., various norms and types of efficacy) mediated the relationship between workshop intervention and behavioral intentions and self-reported behavior or if personal norms moderated workshop effectiveness, but given that relationships between intervention and intentions and behavior were not significant (see below), mediation or moderation was not possible. Data are also available on OSF (https://osf.io/zgaqf/).

3 | RESULTS

3.1 | Description of the sample

Of the workshop registrants ($n = 1918$), there were two groups: attendees, who participated in the online workshop, and non-attendees, who signed up but did not participate. We compared these two groups to explore bias in participants who were lost to follow up. Attendees ($n = 1072$) were older, more likely to own a home, identify as non-Hispanic/Latinx and female, and more likely to be highly educated than non-attendees and Colorado residents in general (U.S. Census Bureau, 2020; see Supporting Information for additional findings from loss to follow up analysis). Demographics between attendees and participants who completed both pre- and post-workshop surveys were not significantly different (see Figure 1 for demographics of samples and loss to follow-up numbers). Pre-workshop perceptions between treatment groups also did not vary significantly (see Supporting Information for an overview of pre-workshop perceptions in each treatment group). In addition, we did

not see a difference in attrition rate (52% vs. 53%) or characteristics between control and treatment participants in pre- and post-surveys.

3.2 | Primary outcomes

Overall, there were no significant differences in primary outcomes between the control and treatment groups. Both unadjusted and adjusted regressions demonstrated that treatment group was not a significant predictor of diffusion behavioral intention directly after the workshop ($B = 0.03$, SE $= 0.07$, $p = .68$, 95% CI [−0.11, 0.16]) or 2 months later ($B = -0.01$, SE 0.08, $p = .92$, 95% CI [−0.17, 0.15]; see Figure 2). Treatment group was also not a significant predictor of self-reported voucher sharing 2 months after the workshop ($B = -0.07$, SE $= 0.23$, $p = .74$, 95% CI [−0.52, 0.37], see Supporting Information for full adjusted regression tables).

3.3 | Secondary outcomes

Treatment group did not significantly predict personal-sphere behavioral intention ($B = -0.04$, SE $= 0.04$, $p = .29$, 95% CI [−0.11, 0.04], see Supporting Information for full adjusted regression table). Among the perceptual secondary outcomes, treatment group significantly affected initial diffusion-specific post-workshop descriptive norm ($B = 0.21$, $SE = 0.10$, $p = .04$, 95% CI [0.01, 0.42]) and social response efficacy ($B = 0.13$, $SE = 0.07$, $p = .04$, 95% CI [0.01, 0.26]) when controlling for respective pre-workshop perceptions. Specifically, participants who received the treatment group microinterventions were more likely than the control group to believe that most people in their community encouraged others to plant native plants (i.e., descriptive norm), and that their native plant diffusion actions would inspire others (i.e., social response efficacy).

Our sensitivity analyses (multiple-imputed regressions that controlled for pre-workshop perceptions), also revealed significant effects of treatment group for diffusion-specific sanctioning injunctive norm ($B = 0.23$, $p = .01$), environmental response efficacy ($B = 0.13$, $p = .06$), and supportive injunctive norm ($B = 0.14$, $p = .09$), but these findings were not replicated in the final models. Indicators of personal-sphere and diffusion real-world behavior (i.e., voucher usage) were not predicted by treatment group (personal-sphere: $B = -0.04$, $SE = 0.18$, $p = .83$, diffusion: $B = 0.28$, $SE = 0.25$, $p = .26$). Overall, 126 participants in the control group (25%) and 129 participants in the treatment group (23%) used an individual voucher. Additionally, 41 participants in the control group (8%) and 54 participants in the treatment group (10%) had at least one voucher used by someone they had shared it with. Of the participants who used an individual voucher, 29 people in the control group (23%) and 43 people in the treatment group (33%) had a shared coupon used by someone else. In addition, 34% of purchases at High Plains Environmental Center (i.e., the nursery that provided plant pickup at no added cost) were at or below the value of the voucher ($10), while only 10% of the purchases at High Country Gardens (i.e., the online nursery that shipped plants) were for orders $10 or less. No other hypothesized secondary outcomes were significantly predicted by treatment group in adjusted analyses.

To examine our secondary hypotheses further, we explored the pattern of mean differences in post-workshop perceptions about native plant gardening (personal-sphere behavior) and native plant diffusion between the two workshop groups (Figure 3). While the regressions did not indicate a statistically significant impact of the intervention on all the different normative perceptions, there was a general trend of static normative perceptions among those in the intervention being higher than those in the control post workshop (Figure 3).

Our exploratory interaction models revealed one significant interaction between pre-workshop diffusion-

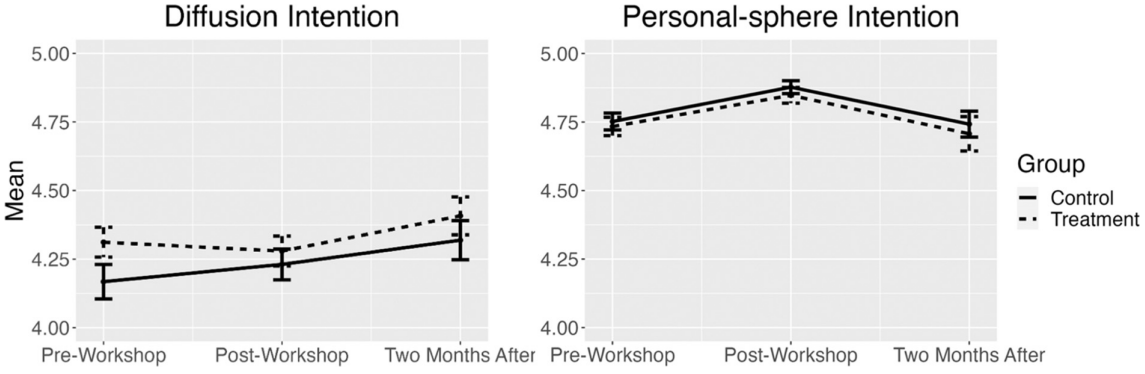

FIGURE 2 Means of participants' diffusion and personal-sphere behavioral intentions over three phases of the study.

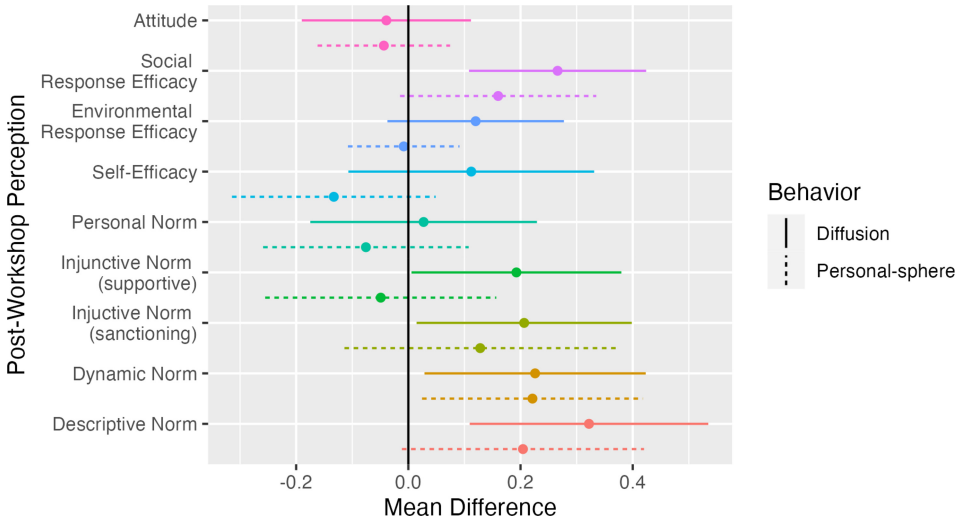

FIGURE 3 Mean differences between treatment ($n = 308$) and control ($n = 286$) workshops immediately after the experiment. A positive mean difference represents stronger perceptions in the intervention and a negative mean difference represents stronger perceptions in the control. Mean differences were calculated from seven-point scales.

specific attitude and the intervention on diffusion behavioral intervention ($B = 0.17$, SE $= 0.08$, $p = .04$, 95% CI [0.01, 0.33]). In other words, the effect of the intervention was higher for participants with a stronger positive attitude towards encouraging others to plant native plants prior to the workshop. That said, diffusion intentions for participants with positive diffusion-specific attitudes were not significantly different between the treatment groups. In addition, this interaction effect would likely not be statistically significant if we were correcting for multiple comparisons (i.e., running 15 different interaction models). See Supporting Information for results of interaction models.

4 | DISCUSSION

Understanding strategies to motivate diffusion behavior can help increase the effectiveness of environmental movements (Amel et al., 2017). We developed outreach interventions to target social-psychological perceptions to motivate diffusion behavior and tested these interventions through a field experiment. We found that when compared to an information-only control, the added microinterventions did not influence participants' intentions to engage in diffusion behavior, self-reported diffusion behavior, or real-world indicators of diffusion behavior. However, in line with our secondary hypothesis, we did find that microinterventions temporarily enhanced two social-psychological perceptions that have been associated with diffusion behavior in prior studies: diffusion-specific descriptive norm and diffusion-specific social response efficacy.

The treatment workshop increased perceptions of diffusion-specific descriptive norms immediately afterwards compared to the control. However, this effect did not persist at 2 months, we found that diffusion-specific descriptive norm perceptions were no longer significantly higher. In fact, perceptions of descriptive norms for both experimental groups decreased significantly after 2 months (see Supporting Information). This may be due to cognitive biases in which our brains focus on new information and pay more attention to relevant examples in our daily lives (i.e., recency and confirmation biases). Participants may have been initially persuaded that many others were talking about native plant gardening, but as they paid more attention to the topic after the workshop, these new norms were not reinforced. Participants may have also had increased interactions with others about native plant gardening after the workshop and these could have influenced perceptions of descriptive norms (Kashima et al., 2013).

Perceptions of diffusion-specific social response efficacy increased immediately after the intervention workshop compared to the control. In other words, treatment group participants were more likely to believe that if they were to encourage someone, they would receive a positive response from that person. At 2 months, treatment group social response efficacy perceptions did not continue to increase but remained higher than control group perceptions. Control group perceptions of diffusion-specific social response efficacy decreased after 2 months, while the treatment group remained relatively stable. It could be that participants in the control group did not have the same tools or information that the treatment group was given to maintain their belief that their actions would have a positive social impact over time.

Normative messaging and public commitment-making were the two microinterventions used to target descriptive norms, so our findings provide further evidence for the short-term effectiveness of these social influence interventions. Abrahamse and Steg (2013)

found that public commitment-making was the second most effective intervention at encouraging behavior change and found smaller effect sizes for normative messaging (i.e., social norm information and feedback). More recently, a review on normative messaging interventions found that those highlighting descriptive norms had consistent positive effects on behavior change (Farrow et al., 2017). Our results suggest that these strategies may effectively influence short-term perceptions of descriptive norms, which are correlated with behavior change.

Our microintervention to provide feedback on the social impact of diffusion behavior also appeared to initially increase social response efficacy compared to the control. We provided this feedback by telling participants that "people are twice as likely to retain scientific information when it comes from friends, family, and others they know, and ten times more likely to change their behavior" (Bollinger et al., 2023; Medley et al., 2009). This supports prior work on the impact of efficacy-based messages about the positive consequences of behavior change on individual and diffusion-related perceptions and behavior (Meijers et al., 2019, 2022). For example, Geiger et al. (2017) found that interventions that focus on the effectiveness of community-level action increased perceptions of both self-efficacy and response efficacy. To our knowledge, only one other study (Berl et al., 2022) has provided feedback on the social impacts of behavior to specifically target social response efficacy though they did not find it effective. Our findings suggest that providing this information may be an effective short-term intervention strategy at increasing positive perceptions around diffusion behavior.

Our nonsignificant findings for treatment group on diffusion and personal-sphere behavioral intentions could be due to a variety of factors. First, a ceiling effect may have contributed to our null results of our primary outcomes. Norms and efficacy may be key barriers to diffusion but it could be that participants already had high perceptions of norms and efficacy before workshops so our interventions could not increase them further. Participants had relatively high positive pre-workshop perceptions of injunctive norms, dynamic norms, self-efficacy, and response efficacy (means ranging from 4.5 to 6.0 on a seven-point scale). If attendees' perceptions of injunctive norms were stronger than an already highly engaged subset of Colorado residents, it is possible that our microinterventions could not increase perceptions of injunctive norms further.

A second explanation for our null findings related to our behavioral metrics is that our control workshop already had a high level of effectiveness. The control workshop was designed to align with previous Audubon Rockies workshops on native plant gardening and native plant diffusion behaviors, and we found that norms and efficacy perceptions increased between pre and post surveys in the control workshop as well as intervention workshop (see Figure S1). The information-transfer model of the control workshop could have served as an effective knowledge-based intervention to encourage diffusion behavioral intentions. Geiger et al. (2017) found a knowledge-based intervention significantly increased efficacy beliefs, which influenced climate change discussion. Preliminary results demonstrate that knowledge of planting native plants predicts intentions to encourage others to plant native plants (Champine et al., 2022). Additionally, workshop characteristics could have created engaging learning environments in both workshops. For example, sharing a favorite plant in the meeting chat may have created a sufficient sense of community in the control workshop without additional treatment activities. Learner-centered, collaborative learning environments have been shown to be effective strategies for adult learning (Conole, 2014).

Alternately, it could be that norms and efficacy alone are not sufficient drivers of diffusion behavior, and that other perceptual factors that were not addressed by workshops (or that were addressed by both conditions) are more important for motivating diffusion behavior. Variables, such as moral exporting (i.e., a person's willingness to influence others to share their own moral values; Maki & Raimi, 2017) or a social identity as an activist in general (Jones et al., 2023; Kurz et al., 2020) may be more influential variables. Future studies to investigate social diffusion behavior may create interventions to specifically highlight additional potential predictors of diffusion behavior.

Additionally, our intervention may not have been a strong enough to influence behavioral intentions or self-reported behavior as it was a one-off event. Our 90-min intervention workshop revealed short-term effects for influencing perceptions of descriptive norms, though it may take a strong stimulus, or consistent interventions over time to motivate behavior change. Interventions that use multiple modalities to communicate with participants and interact with participants for extended periods of time are more effective for health behavior change (Middleton et al., 2013; Webb et al., 2010). Experimental interventions to promote PEB may benefit from more interactive, long-term approaches.

Finally, workshops were facilitated in an online format due to social distancing measures during the COVID-19 pandemic. While this format likely allowed us to reach a larger audience, it is possible that our microinterventions were less effective due to a lack of participant engagement in the online environment. Both students and instructors during COVID-19 reported an

overall decrease in engagement in online versus in-person classes (Walker & Koralesky, 2021), and we noticed many attendees left the workshop when breakout activities began (the face-to-face component). The research team also observed participants running into technical difficulties, dealing with distractions outside of the webinar (e.g., work and childcare responsibilities), and time restrictions (e.g., joining late or leaving early). Any of these factors could have created a less-than-ideal environment for learning and digesting the microinterventions presented in the treatment workshop. Furthermore, the phenomenon of "Zoom Fatigue," or a feeling of exhaustion after videoconferencing, may have effected participants' energy levels during workshops (Fauville et al., 2021).

We do not believe that spill-over effects between the two groups played a large role in our null findings because participants were joining online workshops across the state of Colorado and surrounding states. That said, some of our recruitment strategies, like posting in native plant or wildlife gardening related Facebook groups, could have led to inter-condition influence as people communicate through the platform or people may have interacted at other Audubon Rockies events. Additionally, the native plant gardening community may be considered small in terms of interested individuals, so there may be more social interaction between community members than we expected.

While measuring indicators of real-world behavior is important for behavioral studies, there were limitations to our voucher system. First, the diffusion voucher was not a perfect indicator of diffusion behavior because it only measured successful diffusion (i.e., having someone else redeem a participant's voucher) rather than measuring a participant's action to share of the voucher. Second, the nursery that had shipping costs (i.e., High Country Gardens) attracted fewer participants who made small orders (<$10), so the discount of the voucher might have been less powerful for participants who wanted a free order and who were not within driving distance to the nursery that had free plant pick-up.

Important to the context of our study, topics, tone, word-choice, and speaker characteristics can subconsciously convey appeals to specific norms in online workshop settings. The presenters of the workshops were white-appearing, educated women talking to a majority white educated woman-identifying audience. Even without overt social influence interventions, many participants may have been influenced by subconscious appeals to social norms. Different presenters might have led to differing results, and these kinds of field interventions should be tested across a wide range of audiences to enable better generalizability.

5 | CONCLUSION

Complex social-ecological issues, such as biodiversity loss, require human action, especially diffusion actions which can help spread personal-sphere behaviors more efficiently through a social network (Amel et al., 2017). Our study demonstrates that it is challenging to change biodiversity-related behaviors in real-world settings, and our null findings reinforce the importance of experimental evaluation of conservation communication (Kidd et al., 2019). It also provides further evidence that normative messaging and public commitment-making are effective short-term strategies for increasing perceptions of descriptive norms for diffusion behavior. Additionally, providing feedback on the social impact of diffusion behavior may be an effective short-term strategy to target diffusion-specific social response efficacy in motivated individuals. Importantly, changing longer-term perceptions of norms and efficacy may require additional or repeated interventions beyond a single online workshop. Testing microinterventions to change behavioral perceptions, and behaviors themselves, can inform the way outreach organizations engage audiences and create more effective campaigns to combat issues like climate change and biodiversity loss.

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DATA AVAILABILITY STATEMENT

A pre-analysis preprint and dataset for this study can be found on Open Science Framework (https://osf.io/zgaqf/).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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