Determinants of Responsible Hiking Behavior: Results from a Stated Choice Experiment

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Abstract This research examined the determinants of responsible hiking behavior through a lab-based experiment in which two managerial factors believed to influence individuals' behavior (the presentation of an educational message and the method of displaying degraded trail conditions) were varied across four experimental treatments in a 2×2 between subjects factorial design. The effect of trail degradation type (muddiness and erosion) and severity (moderate or severe) of trail degradation were also examined within each of the 4 treatment groups. Analyses revealed neither the educational message nor the method of displaying the image had a consistent and expected impact on individuals' behavioral intentions. In fact, participants who viewed the educational message were more likely to indicate they would hike off the trail. The effects of both trail degradation type and severity were consistent and significant with muddiness and more severe levels of degradation having a greater influence on individuals' intent to hike on the edge of or off the trail. The analyses also revealed both gender and hiking frequency had significant effects on behavioral intentions. Female participants were more likely to indicate they would turn around than males when they encountered degraded trail sections. Women were also less likely to indicate they would hike off the trail than men. Collectively, these findings highlight a variety of ways recreation resource

managers can more efficiently inform recreationists about the impacts of off-trail hiking and prioritize trail management needs.

Keywords Contingent behavior · Informational signage · Mixed logit

Introduction

Despite the psychological, social, and economic benefits derived from individuals' engagement in hiking (Driver et al. 1991), numerous studies have documented the environmental impacts of the activity, which include soil compaction, vegetation trampling, wildlife disturbance, and water quality degradation (Cole 2004; Hammitt and Cole 1998; Liddle 1997; Newsome et al. 2012). Many of these impacts are associated with irresponsible hiking behaviors, including hiking off-trail (Coppes and Braunisch 2013; Kolasinska et al. 2015). Promoting responsible hiking behaviors is critical to alleviating many of the environmental impacts caused by the activity. A scientifically rigorous understanding of the determinants of responsible hiking behavior is needed to provide resource managers with clear guidance on how to best promote responsible behaviors (e.g., hiking down the center of an eroded or muddy trail), maintain or enhance the environmental integrity of trails, and consequently ensure the long-term enjoyment of recreational resources.

Managerial approaches to promote responsible hiking behaviors and minimize resource degradation commonly include: (1) the use of educational messages and interpretive programs; (2) setting rules and regulations that reprimand or fine individuals caught engaging in irresponsible hiking behaviors; and (3) using temporal and spatial

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strategies such as closure and limited access (Manning 2011). Educational messaging, such as the use of on-site signage (on the trail or at the trailhead), is a widely used indirect management strategy that attempts to inform recreationists about proper trail etiquette while not deterring from their ability to have desirable recreation experiences. Another common approach to minimizing resource degradation is to alter the biophysical characteristics of the trail environment itself. Trail maintenance, such as resurfacing, is extensively used to maintain a trail's biotic (e.g., vegetation) and abiotic (e.g., soil quality) conditions, and can enhance the quality of recreation experiences offered. Altering the biophysical characteristics of a trail has the potential to promote responsible hiking behaviors and maintain or improve environmental quality. However, extensive trail maintenance is labor intensive and more costly compared to alternative visitor management approaches such as the use of educational messaging. The selection of a 'best' approach among alternative managerial approaches (e.g., educational messaging, biophysical interventions) should be informed by empirical data on how each approach could affect responsible hiking behaviors. In response to this need, this study uses a stated choice experiment to examine the effects of selected managerial factors (i.e., the use of an educational message and the method of displaying trail conditions to resource users), biophysical attributes (i.e., trail condition), and individuals' sociodemographic and behavioral characteristics on responsible hiking behaviors.

The Use of Educational Messaging to Promote Responsible Hiking Behavior

Among varied managerial methods to promote responsible hiking behaviors, educational messages are commonly used. Usually, signage with a message about responsible hiking behaviors is set up on-trail or at a trailhead to remind visitors of acceptable behaviors. This management approach is favorable due to its relatively low financial costs. Educational messaging is also believed to have marginal negative impacts on visitors' experiences, compared to other methods such as regulation and enforcement (Alder 1996). However, signage is limited in the amount of information it can deliver. Given that most on-site signage is read rapidly, informative or educational messages must be condensed to one or two key sentences (Caputo et al. 2008). Abbreviated messaging may not be able to fully explain what behaviors are appropriate under certain conditions (e.g., uphill/downhill trail etiquette or the temporary closure of specific areas when standing water is present) or provide detailed rationale for the recommended behaviors (e.g., deterioration of biophysical conditions). The effectiveness of educational messaging is also limited

because it is an indirect management approach. Visitors may not notice signage, have limited interests in reading the signage, or interpret the sign incorrectly (Aucote et al. 2012; McNamara and Prideaux 2010). Moreover, on-site educational messaging alone does not provide a long-term solution to recreationists' detrimental behaviors, such as walking off-trail (Alder 1996). Detrimental habitual behavior may persist despite individuals being aware of either the environmental impacts or the availability of more sustainable alternative behaviors (Bolderkijk et al. 2013). Therefore, other methods complementing on-site educational messages are worth exploring.

One complementary managerial approach is to offer off-site educational and interpretive programs designed to educate recreationists about responsible hiking behaviors. Display techniques, such as traditional 2-dimensional (2D) pictures, are commonly used in interpretive programs. Recently however, many resource managers and interpretive specialists are exploring the ability to use 3-dimensional (3D) images to more accurately display and visualize on-site resource conditions. For example, the United States Geological Survey is currently compiling a 3D tour of national parks (<http://3dparks.wr.usgs.gov/>). Novel display techniques offer the advantage of being able to more readily attract and engage visitors who otherwise might not be willing to spend time learning about the substantive content of an educational or interpretive program. Additionally, novel display technologies such as 3D imagery allow off-site environmental education and interpretive programs to more realistically simulate actual hiking environments and illustrate proper behavioral responses under specific conditions.

Past research utilizing both neural fMRI scanning (Bülthoff et al. 1998) and task-based visualization experiments (Kirschenbauer 2005) suggests 3D imagery can both mimic natural cognitive depth processing and enhance spatial cognition relative to the use of 2D imagery. It would be logical for natural resource interpretive specialists at visitor and environmental centers to want to capitalize on these benefits and use 3D display techniques to educate and inform resource users. However, despite its great potential, the efficacy of 3D display techniques on priming and changing individuals' behaviors is still under investigation (Bishop and Rohrmann 2003; Doxtater 2008). The question of whether 3D imagery offers unique values in environmental education compared to 2D images needs rigorous empirical investigation.

The Effect of a Trail's Biophysical Characteristics on Responsible Hiking Behavior

Aside from educational messaging, another management approach to promoting responsible hiking behavior is to

alter the biophysical characteristics of recreation settings. This approach is grounded in the belief that human behaviors are determined not only by psychological and social factors, but environmental factors as well (Terborg 1981). Compared to educational messaging, which focuses on using information to change the internal psychological precursors of pro-environmental behaviors and encourage appropriate behaviors, biophysical strategies focus on changing the setting surrounding the individuals' behaviors. These biophysical strategies are believed to be more effective for inconvenient or counter-intuitive behaviors (Gifford 2014). For example, staying on a highly degraded trail, such as one that is muddy or severely eroded, requires conscious efforts from hikers. Even well-informed and environmentally responsible recreationists are more inclined to go off-trail under these degraded conditions. Consequently, management actions that promote and maintain clear and well-drained trails may limit recreationists' desire to engage in environmentally harmful behavior.

Previous research has examined recreationists' perceptions of degraded trail conditions, revealing perceptions of resource impacts vary widely across visitors (Dorwart et al. 2010). This research has also demonstrated that recreationists are more perceptive of resource impacts caused by undesirable recreation behavior, such as hiking off-trail, relative to resource impacts caused by geophysical processes such as erosion (D'Antonio et al. 2012a). While resource users can easily perceive degraded trail conditions, it is unclear whether those perceptions either directly or indirectly influence individuals' behaviors. Only a small body of research has explicitly examined how a trail's biophysical characteristics directly influence hiking behaviors. Pearce-Higgins and Yalden (1997) found resurfacing a stretch of Pennine Way, a popular long-distance footpath in the UK, increased the concentration of recreationists using the resurfaced area, thereby decreasing environmental disturbances adjacent to the trail. In Snowdonia National Park (UK), Keirle and Stephens (2004) found a trail surfaced with stone to prevent erosion encouraged users to stay on-trail, suggesting trail conditions could influence responsible hiking behavior. Kolasinska et al. (2015) examined the factors and motives that influenced off-trail walking behavior in Pieniny National Park (Poland). Their observations of over 12,000 visitors suggest that hikers on uncomfortable trail surfaces (undefined by the authors) and on narrower trail treads were more likely to walk off-trail. Collectively, these studies suggest that trail conditions influence individuals' willingness to engage in responsible hiking behaviors.

There are many attributes and indicators that can be used to describe the quality of a trail's conditions (Leung and Marion 1996). Muddiness and erosion are specific

attributes that have a logical connection to individuals' willingness to engage in responsible on-trail hiking behavior. Both muddiness and erosion are common forms of trail degradation associated with recreational use (Leung and Marion 1996; Wimpey and Marion 2010). A recent field-based study of trail conditions and individuals' on-trail behaviors found a strong correlation between muddiness and off-trail hiking (Conlon 2014). Erosion is also likely to be associated with individuals' hiking behaviors. Specifically, using an innovative on-trail camera trap methodology, Conlon found roughly one-third of hikers in a national forest hiked off or at the edge of trails that had some level of muddiness or erosion (38 % and 31 %, respectively). Similarly, Dragovich and Bajpai (2012) found almost one-half of visitors to a national park (43 %) reported they sometimes trampled vegetation in their attempt to avoid uneven walking surfaces. These findings suggest trails showing some signs of degradation, whether it be muddiness or erosion, may generate more environmental degradation by triggering off-trail hiking behaviors. This study begins exploring this positive behavioral feedback loop by empirically discerning if, and to what extent, muddy and eroded trails influence hikers' on-trail behaviors.

Confounding Sociodemographic and Behavioral Characteristics

Individuals' hiking behaviors are not solely determined by their exposure to educational messages and trails' biophysical attributes. Individuals' sociodemographic and behavioral characteristics are also generally believed to influence on-site behaviors (Haas 2001). Specific to responsible hiking behaviors, past research suggests recreationists' gender and recreation experience level may influence their willingness to stay on-trail when faced with degraded trail conditions.

Walden-Schreiner and Leung (2013) used behavioral mapping to spatially characterize visitor use in the meadows of Yosemite Valley (Yosemite National Park, USA). The method involved field staff geolocating visitor movements across the meadows and subsequently analyzing those data for differences between male and female visitors. The analyses determined when hiking off-trail, men were more likely to deviate further from the designated trail by just over 1 m. In a similar study, Park et al. (2008) used participant observation methods to examine determinants of off-trail hiking behavior at Cadillac Mountain in Acadia National Park (USA). Their analysis however, revealed no differences between the frequency with which men and women deviated from designated trails. Several other studies (Hall et al. 2010; Johnson and Swearingen 1992) have suggested a recreationist's gender may be a

significant factor influencing his/her willingness to adhere to responsible hiking behavior guidelines. However, none of these studies empirically and explicitly examined the relationship between gender and on-/off-trail behaviors. Mixed results from the limited set of previous empirically grounded studies prevented the development of an informed hypothesis around the gender-responsible hiking behavior relationship. Nevertheless, given observed gender differences may influence how recreation resource managers deliver information about environmentally responsible hiking behaviors, this study included gender as a potentially confounding sociodemographic characteristic that may influence individuals' behavioral intentions.

Individuals' hiking experience might also influence their willingness and intent to adhere to responsible hiking behavior guidelines. It is logical to assume that as individuals participate more frequently in the activity, they have a greater chance of being exposed to information about the environmental impacts of off-trail hiking and would be more willing to stay on-trail and preserve the quality of the recreation settings they enjoy. However, all past studies on the relationship between hiking experience and trail impacts or responsible hiking behavior have been attitudinal and not behavioral. A set of empirical studies (Arnberger and Brandenburg 2007; D'Antonio et al. 2012; Eder and Arnberger 2012) have consistently found that individuals who hike more frequently are more sensitive to degraded trail conditions. Given the consistent results observed in previous research, we expect individuals who indicate they hike more frequently to be more likely to stay on-trail when presented with degraded (eroded or muddy) trail conditions. This study includes individuals' self-identified past hiking experience as an additional confounding factor that might influence the intent to hike responsibly.

In summary, previous research suggests the presence of educational messaging and the biophysical characteristics of a trail itself may influence individuals' willingness to engage in responsible hiking behavior. Additionally, the use of alternative display techniques such as 2D and 3D images to educate recreationists about the environmental impacts of hiking off-trail could influence their willingness to engage in responsible hiking behavior. Yet, sociodemographic and behavioral characteristics of hikers may confound the effects of these factors. Therefore, our goal was to empirically examine the influence of educational messaging, the biophysical attributes of a trail, gender, and hiking experience on individuals' hiking behaviors using 2D and 3D imagery. Specifically, this study aimed to answer three research questions:

1. Does the presence of an *educational message* influence hiking behaviors?

2. Does a trail's *biophysical attributes* (muddiness and erosion) influence hiking behaviors?
3. Does the *sociodemographic and behavioral characteristics* of hikers influence their hiking behaviors?

Methods

Experimental Design

We examined the determinants of responsible hiking behavior through a lab-based experiment in which two managerial factors believed to influence individuals' hiking behavior were varied across experimental treatments. The two managerial factors were the presentation of an educational message and the method of displaying degraded trail conditions. The methods of display were either 2D or 3D. The experimental design utilized a 2×2 between subjects factorial design in which participants were systematically assigned to one of four treatment groups:

1. 2D presentation of trail conditions; No educational message displayed
2. 2D presentation of trail conditions; Educational message displayed
3. 3D presentation of trail conditions; No educational message displayed
4. 3D presentation of trail conditions; Educational message displayed

Within each treatment we varied the two biophysical attributes of a trail (type and severity of trail degradation) believed to influence individuals' behavior.

Educational Messaging

One-half of all research participants were systematically assigned to one of the two treatment groups involving the use of an educational message (Fig. 1). The message was presented to individuals on the same 60-inch LCD display they would subsequently view trail photographs. The educational message was displayed while a research assistant set up the display, had participants complete the required informed consent form and read a script describing the purpose of the research and how the data collection process would proceed. Participants were not cued to review the message display.

One-half of all research participants were also assigned to a treatment group involving the use of 3D photographs. We collected photographs of degraded trail conditions in the field in both 2D (.jpg) and 3D-capable (.mpo) file formats. Participants assigned to the 3D treatment groups

Fig. 1 Injunctive-prescriptive educational message

were required to wear active 3D glasses while viewing the trail photographs on the LCD display.

Biophysical Attributes

Individuals within each treatment group were presented with 20 digital photographs of degraded trail conditions (Fig. 2). The type and severity of trail degradation varied across the image set. The set contained 10 photos of eroded trails and 10 photos of muddy trails; half (5) of the photos within each of these degradation types were of ‘severely’ degraded trail conditions (i.e., either severely eroded or severely muddy) while the other half of the photos were of ‘moderately’ degraded trail conditions. Multiple members of the research team collaboratively classified each of the photos.

Sociodemographic and Behavioral Factors

Research participants were asked to indicate their gender as well as the frequency with which they hike, walk, or run on

unpaved trails. Responses to the latter question were collected on a categorical scale in which the response categories were *never*, *1–5 times a year*, *6–10 times a year*, and *more than 10 times a year*.

Data Collection

Research participants were recruited from six undergraduate classes within NC State University’s College of Natural Resources. Data were collected between October and November of 2013 within the College’s Geovisualization Laboratory. Trained research assistants collected data from participants individually. Each participant scheduled a 15-min block of time to come to the Laboratory. Upon arriving, participants were systematically assigned to one of the four treatment groups. A total of 118 participants completed the study.

Contingent Hiking Behavior

For each image, respondents were asked two questions. First, they were asked, “to what extent do you feel forest managers should be concerned with the conditions of this trail?” Responses were provided via a 10-point Likert scale ranging from 1 (*not at all concerned*) to 10 (*extremely concerned*). After providing their response, participants were asked, “if you were hiking along this trail and came to this point, how would you proceed?” Respondents were given four discrete choices, they could either “turn around”, “hike down the center of the trail”, “hike on the edge of the trail”, or “hike off-trail.” If respondents were unsure which category their intended behavior would fall within, they were allowed to point at the location on the screen. The research assistant subsequently classified their response.

Data Analysis

We formally examined the managerial, biophysical, and sociodemographic/behavioral determinants of hiking behavior through a mixed-effects multinomial logistic regression model that accounts for the clustered nature of the data (Hartzel et al. 2001). The multinomial logit model was developed as an elegant modeling solution for data in which respondents can choose only one option from a set of discrete alternatives (McFadden 1974). Multinomial logit models are common in behavioral economics, being most commonly used to fit data collected via stated choice experiments (Smith 2013). Recently, they are becoming more commonly utilized to examine individuals’

Fig. 2 Classification of trail photographs used in experiment

contingent responsible environmental behavior under hypothetical situations (Perry-Hill et al. 2014).

To fit the mixed-effects multinomial logistic regression model, the data are organized such that there are $c = 1, \dots, n$ clusters (panels), each of which has $i = 1, \dots, n$ correlated observations. For these data, we have 4 behavior-specific clusters, each modeled to fit the correlated responses across the 20 images. Consequently, the dependent variable is specific to image i , behavior c , and respondent j . Estimation requires the creation of a dummy variable for each cluster as well as interactions between each cluster (behavior) and each independent variable (Skron dal and Rabe-Hesketh 2004). The full model can be specified as:

$$\begin{aligned} \text{behavior}_{icj} = & \mu + \beta_1 \text{type}_{icj} + \beta_2 \text{severity}_{icj} + \beta_3 \text{message}_{icj} \\ & + \beta_4 \text{display}_{icj} + \beta_5 \text{gender}_{cj} + \beta_6 \text{hikingfreq}_{cj} \\ & + \lambda_j + \varepsilon_{icj} \end{aligned}$$

The intra-cluster correlation is handled through the inclusion of a cluster (panel) estimator while the intra-individual correlations (i.e., the correlation across an individual's 20 responses) are accounted for through the inclusion of the individual-specific random effect λ_j . Specifying the individual-specific random effect allows intercepts to vary across individuals. Consequently, regression slopes are constant within clusters (behaviors). The model was fit with the *xtmelogit* command in Stata 12.1.

Results

Descriptive Statistics

Sociodemographic and Behavioral Factors

Descriptive statistics for the pool of respondents are shown in Table 1. The majority of participants (53 %) were women. Participants' past experience with hiking, walking, and running on unpaved trails varied greatly. Nearly 34 % indicated they hike, walk, or run on unpaved trails less than 5 times a year. Conversely, just over a third (36 %) indicated they hike, walk, or run on unpaved trails more than 10 times a year.

Perceptions of Management Concern for Degraded Trail Conditions

Descriptive statistics for the question "to what extent do you feel forest managers should be concerned with the conditions of this trail?" are reported in Table 2 by type and severity of trail degradation. As would be expected, individuals believe forest managers should be more concerned over either extremely eroded or muddy trails than moderately eroded or muddy trails. Previous ANOVA analysis (Leung et al. 2015) revealed this difference was highly significant, $F(8, 2351) = 1886.71, P < .001$. Participants, by and large, also believed that management should be more concerned over muddy trail conditions ($M = 5.57, SD = 2.77$) than eroded trail conditions ($M = 4.57, SD = 2.70$); this difference was also highly significant, $F(8, 2351) = 144.68, P < .001$.

The data also suggest that managerial factors have less of an impact on the belief that management should be concerned about trail conditions. The average level of suggested management concern for images preceded by the educational message was 5.06 ($SD = 2.84$) while the average level among participants who were not in the educational treatment groups was 5.08 ($SD = 2.72$); this difference was not significant at the .05 level. Comparing across 2D and 3D image display methods, the data suggest only a marginal increase in suggested management concern when the degraded trails are viewed in 3D ($M = 5.09,$

Table 2 Extent to which study participants believe forest managers should be concerned over trail conditions

Image classification	Mean	SD
Eroded trails		
Extreme erosion	6.34	2.24
Moderate erosion	2.79	1.81
Muddy trails		
Extremely muddy trails	7.40	1.98
Moderately muddy trails	3.74	2.18

Responses were elicited on a 10-point Likert scale ranging from 1 (*not at all concerned*) to 10 (*extremely concerned*)

$SD = 2.71$) as opposed to 2D ($M = 5.05, SD = 2.85$); again this difference was not significant at the .05 level.

Regarding sociodemographic and behavioral factors, women ($M = 5.36, SD = 2.76$) tended to believe that management should be more concerned about degraded trail conditions than men ($M = 4.73, SD = 2.77$). This difference between genders was highly significant, $F(8, 2351) = 74.14, P < .001$. The ANOVA also revealed the frequency with which an individual hikes, runs, or walks on unpaved trails was significantly related to suggested management concern, $F(8, 2351) = 15.18, P < .001$. Individuals who used unpaved trails more often believed that management should be less concerned about the degraded trail conditions. Across all 20 images, the suggested level of management concern among participants who never hike, walk, or run on unpaved trails was 5.91 ($SD = 2.85$). Comparatively, the suggested level of management concern among participants who hike, walk, or run on unpaved trails more than 10 times a year was 4.91 ($SD = 2.79$).

Modeling Results

The fixed- and random-effects parameters yielded by our full model are displayed in Table 3. The fixed-effects parameters are unstandardized and are on a logit scale.

Managerial Factors

The model revealed that, by and large, neither the educational message nor the method of displaying the image had a consistent, significant, and expected impact on individuals' behavioral intentions. Counterintuitively, study participants who viewed the educational message were significantly more likely to indicate they would hike off-trail ($Coef. = 0.32, z = 2.01, P < 0.05$). Exponentiating the unstandardized logit coefficient, we can say the odds of a participant indicating they would hike off-trail were 1.38 greater if they received the educational message treatment.

The method of displaying trail degradation was also weakly related to behavioral intentions. The only

Table 1 Descriptive characteristics of study participants ($n = 118$)

Respondent characteristic	
Gender (female)	53.4 %
Frequency of hiking, walking, or running on unpaved trails	
Never	5.9 %
1–5 times a year	28.0 %
6–10 times a year	29.7 %
More than 10 times a year	36.4 %

Table 3 Results from multilevel mixed-effects model of contingent hiking behavior

Behavior and independent variables	Coef.	SE	z	P > z	95 % CI	
					LB	UB
Intention of turning around						
Educational message	−0.16	0.15	−1.10	0.270	−0.46	0.13
Image display method	0.46	0.15	3.10	0.002	0.17	0.74
Type of degradation	1.85	0.17	11.02	0.000	1.52	2.17
Severity of degradation	3.38	0.27	12.28	0.000	2.84	3.91
Gender	0.48	0.15	3.20	0.001	0.19	0.77
Frequency of hiking, walking, or running on unpaved trails	−0.53	0.08	−6.71	0.000	−0.69	−0.38
Intention of hiking down the center of the trail						
Educational message	−0.16	0.11	−1.48	0.138	−0.36	0.05
Image display method	−0.14	0.10	−1.32	0.188	−0.34	0.07
Type of degradation	−2.30	0.12	−19.25	0.000	−2.54	−2.07
Severity of degradation	−2.47	0.12	−20.57	0.000	−2.70	−2.23
Gender	0.03	0.10	0.29	0.774	−0.17	0.23
Frequency of hiking, walking, or running on unpaved trails	0.27	0.06	4.73	0.000	0.16	0.38
Intention of hiking on the edge of the trail						
Educational message	0.08	0.10	0.83	0.406	−0.11	0.28
Image display method	0.01	0.10	0.08	0.936	−0.18	0.20
Type of degradation	0.74	0.10	7.49	0.000	0.55	0.94
Severity of degradation	0.72	0.10	7.21	0.000	0.52	0.91
Gender	−0.05	0.10	−0.54	0.587	−0.25	0.14
Frequency of hiking, walking, or running on unpaved trails	−0.09	0.05	−1.61	0.108	−0.19	0.02
Intention of hiking off-trail						
Educational message	0.32	0.16	2.01	0.044	0.01	0.63
Image display method	−0.21	0.16	−1.37	0.172	−0.52	−0.09
Type of degradation	1.74	0.19	9.01	0.000	1.36	2.12
Severity of degradation	1.27	0.17	7.36	0.000	0.93	1.61
Gender	−0.48	0.16	−3.04	0.002	−0.79	−0.17
Frequency of hiking, walking, or running on unpaved trails	0.24	0.09	2.74	0.006	0.07	0.42
Panel variables						
Intention of turning around (panel 1)	−0.71	0.59	−1.19	0.232	−1.87	0.45
Intention of hiking down the center of the trail (panel 2)	6.37	0.48	13.23	0.000	5.43	7.32
Intention of hiking on the edge of the trail (panel 3)	2.79	0.47	5.90	0.000	1.87	3.72
Intention of hiking off-trail (panel 4)	0.00	(Omitted)				
Constant	−4.40	0.41	−10.70	0.000	−5.21	−3.60
Random-effects parameters		Estimate		S.E.		
Individual		3.48e ^{−09}		2.95e ^{−02}		

Type of degradation: 0 = erosion, 1 = muddiness; Severity of degradation: 0 = moderate, 1 = severe; educational message: 0 = without educational message, 1 = with education message; Image display method: 0 = 2D picture, 1 = 3D picture; Gender: 1 = male, 2 = female; Frequency of hiking: 1 = never, 2 = 1–5 times a year, 3 = 6–10 times a year, 4 = more than 10 times a year

Bold values are significant at the 0.05 level

significant result implies participants were more likely to indicate they would turn around if they viewed the image set in 3D (*Coef.* = 0.46, $z = 3.10$, $P < 0.01$). The odds of an individual indicating they would turn around were 1.58 times greater for images viewed in 3D as opposed to 2D.

Biophysical Attributes

To juxtapose the results from the managerial factors, both of the biophysical attributes (type and severity of trail degradation) yielded consistent and significant findings.

Participants were significantly more likely to indicate they would turn around ($Coef. = 1.85, z = 11.02, P < 0.001$), hike on the edge of the trail ($Coef. = 0.74, z = 7.49, P < 0.001$), and hike off-trail ($Coef. = 1.74, z = 9.01, P < 0.001$) when faced with muddy as opposed to eroded trail conditions. Similarly, participants were also significantly less likely to hike down the center of the trail when faced with muddy as opposed to eroded trail conditions ($Coef. = -2.30, z = -19.25, P < 0.001$). These differences were substantial. The odds of an individual indicating they would turn around were 6.33 times greater when faced with muddy as opposed to eroded trail conditions. Similarly, the odds of an individual indicating they would hike off-trail were 5.71 times greater for muddy trails conditions, relative to eroded trail conditions.

Consistent with our expectations, the model also revealed participants were much more likely to turn around ($Coef. = 3.38, z = 12.28, P < 0.001$), hike on the edge of the trail ($Coef. = 0.72, z = 7.21, P < 0.001$), and hike off-trail ($Coef. = 1.27, z = 7.36, P < 0.001$) when faced with severe as opposed to moderate levels of degradation. Similarly, individuals were much less likely to hike down the center of the trail when faced with more extreme levels of trail degradation ($Coef. = -2.47, z = -20.57, P < 0.001$).

Sociodemographic and Behavioral Factors

The data also revealed both gender and frequency of hiking, walking, or running on unpaved trails had an effect on behavioral intentions. Female participants were significantly more likely to indicate they would turn around ($Coef. = 0.48, z = 3.20, P < 0.001$) than males. The odds of women indicating they would turn around were 1.61 times greater than their male counterparts. However, women were significantly less likely to indicate they would hike off-trail ($Coef. = -0.48, z = -3.04, P < 0.01$) than men.

Regarding individuals' frequency of hiking, walking, or running on unpaved trails, the model revealed more experienced trail users were less likely to indicate they would turn around when confronted with degraded trail conditions ($Coef. = -0.53, z = -6.71, P < 0.01$). Counterintuitively, the model also revealed more experienced trail users were both more likely to indicate they would hike down the center of the trail ($Coef. = 0.27, z = 4.73, P < 0.01$) and more likely to indicate an intent to hike off-trail ($Coef. = 0.24, z = 2.74, P < 0.01$). However, more experienced hikers were no more willing to hike along the edge of the trail relative to their inexperienced counterparts ($Coef. = -0.09, z = -1.61, P = 0.108$).

Discussion and Conclusions

Studying the influence of managerial, biophysical, and sociodemographic/behavioral determinants on recreationists' hiking behavior is methodologically challenging. Field-based studies (e.g., Kolasinska et al. 2015) enable the observation of behaviors under real environmental conditions, but are often limited by high costs and the lack of control over confounding factors such as the presence of others at the recreation setting. On the other hand, laboratory-based studies using experimental designs enable direct control over the factors of interest. Laboratory-based studies also allow data to be collected relatively efficiently. In this study, we have leveraged the rapid development of digital imagery visualization methods, namely wide-screen and high-definition 2D and 3D displays, to simulate and replicate external trail conditions in a lab setting. The results yielded three key findings with direct implications for how resource managers inform recreationists about the impacts of off-trail hiking and prioritize trail management needs. Specifically, these key findings are:

- (1) Typical injunctive-prescriptive educational messaging does not influence responsible hiking behavioral intentions;
- (2) Degraded trail conditions promote off-trail hiking behavior, exacerbating current levels of degradation; and
- (3) The hiking behaviors of women and less-experienced hikers are more likely to be influenced by degraded trail conditions.

Before discussing these three points in detail, we describe the study's limitations. Specifically, the study used a laboratory-based experiment capitalizing on digital imagery visualization methods to examine individuals' responses to a variety of independent factors. However, a long-standing criticism of laboratory-based studies is their lack of external validity (Lynch 1999). Specifically, this study used college students as the sample. Although college students differ from the general population in several key characteristics (e.g., age, income, etc.), it is reasonable to assume their behavioral responses to educational messaging and the biophysical characteristics of a trail are not affected by their age, income, or any other unique sociodemographic characteristic. Consequently, we believe our findings should be applicable to other population groups as well.

Our justification fits an alternative definition of external validity that is being adopted by many social scientists who conduct theory-driven experiments to study human behaviors. Zelditch (2007) defined external validity as "what is generalized is a theory; what is generalized to is a situation to which the theory is applicable; and an

experimental setting is externally valid if application of the theory predicts or explains the behavior of the process the theory describes in any situation to which the theory is applicable” (p. 96). Moreover, this study followed standard experimental design protocols (i.e., systematically assigning participants to treatment groups and comparing behavioral responses across treatment groups). These practices are used to eliminate confounding effects that might arise from heterogeneity in individuals across the sampling frame (Zelditch 2007). With that said, external validity would be improved through future research, particularly research utilizing field-based designs, quasi-experiment methods, and participant observation of actual recreationists. More mixed methods research is needed to expand our knowledge of the managerially significant and theoretical stimulating issue of responsible hiking behaviors.

Educational Messaging Does Not Influence Responsible Hiking Behavioral Intentions

A typical recommendation and frequently employed management strategy for recreation-caused impacts is visitor education. It is often assumed that recreationists, if provided with education, will perform desired behaviors. Moreover, past research has demonstrated that trailside signs reduce unregulated behavior (Johnson and Swearingen 1992), particularly signs with a polite plea and rationale (Winter 2006). However, this laboratory-based study demonstrates that a typical injunctive-prescriptive trail sign with a behavioral message (*Please stay on the trail*), normative message (*Help protect our resources*), and brief rationale (*Hiking around objects widens trails, impacts vegetation, and causes erosion*) neither influenced responsible hiking behaviors nor elevated perceptions of the extent to which managers should be concerned with the trail conditions. The unexpected finding that exposure to such signs may actually increase off-trail hiking behaviors warrants further investigation, as this study did not ensure exposure to the message treatment (i.e., it was displayed at the beginning of the experiment but respondents were not asked if they recalled the sign’s message). Therefore, two potential avenues for future research would be to further advance sign recall experiments (Cole et al. 1997) and further explore the effects of message type (Winter 2006) on behavioral intentions.

Given the minimal advantage of 3D images to influence responsible hiking behaviors, this study does not provide sufficient evidence to justify the additional expenditure of 3D educational displays as a complement to trail signs. This finding does not imply that 3D

educational displays would not enhance behavioral compliance, as the experiment did not test the ability of 3D educational displays to attract a wider audience (i.e., given the novelty of such displays) than standard 2D educational displays. Rather, this study provides initial evidence that neither trail signs nor 3D displays of trail impacts significantly reduce off-trail hiking behaviors in a laboratory setting.

Degraded Trail Conditions Promote Off-Trail Hiking Behavior, Exacerbating Current Levels of Degradation

The analyses also revealed respondents were much more likely to indicate they would hike off-trail when confronted with extreme, as opposed to moderate, levels of trail degradation. This finding was consistent across both types of trail degradation, erosion and muddiness. This result is logical and was expected given environmental factors (the attributes which describe individuals’ immediate surroundings) are consistent and strong predictors of behavioral responses, even when cognitive and sociodemographic characteristics are controlled for (Gifford 2014). While a substantive amount of previous research has either suggested anecdotally or implied a relationship between degraded trail conditions and depreciative behavior (e.g., Keirle and Stephens 2004; Kolasinska et al. 2015; Leung and Marion 1996; Pearce-Higgins and Yalden 1997; Wimpey and Marion 2010), this is the first study to empirically demonstrate the positive behavioral feedback loop.

For recreation resource managers, this finding highlights the importance of maintaining high-quality trail conditions. As trails become more eroded and muddy, recreationists will be more inclined to hike off-trail, exacerbating current levels of degradation. Resource managers should be aware of the direct linkage between recreationists’ behavior and a trail’s environmental conditions. If the repair and maintenance of degraded trail conditions is deferred, recreationists’ behavior is likely to continue to exacerbate current conditions. Consequently, deferred trail repair and maintenance, a long-standing issue within many recreation resource management agencies, may not only impact the quality of recreation experience provided, it is also likely to have cumulative impacts on environmental quality. Future field-based experiments involving more detailed metrics of trail degradation (Leung and Marion 1999) are needed to more fully explore how degraded conditions affect recreationists’ hiking behavior. More concentrated and detailed explorations of the positive feedback loop between environmental conditions and trail behavior may yield some nuanced findings for the field of recreation ecology.

The Hiking Behaviors of Women and Less-Experienced Hikers are More Likely to be Influenced by Degraded Trail Conditions

The analysis revealed that after controlling for all treatment effects, both individuals' gender and the frequency with which they hike, walk, or run on unpaved trails influence hiking behaviors. Women were significantly more likely to indicate they would turn around when confronted with degraded trail conditions and less likely to indicate they would hike off-trail. These results align with previous field-based studies suggesting men are more likely to deviate further from designated trail routes (Walden-Schreiner & Leung 2013). For managers, this suggests environmental degradation caused by off-trail hiking is likely more attributable to male recreationists relative to their female counterparts. Proactive managers would be wise to implement or expand environmental education campaigns and programs that solely engage males. For example, the Boy Scouts of America offer numerous merit badges and a Leave No Trace Award related to responsible recreation behavior (Boy Scouts of America 2001). The organization also facilitates numerous trail building and maintenance activities for young men that could be leveraged as complementary service-learning opportunities.

Our results also revealed, somewhat counterintuitively, that hiking experience was positively correlated with both a greater intent to hike down the center of the trail and the intent to hike off-trail. Hiking experience was not related to individuals' willingness to hike along the edge of the trail. It appears that more experienced hikers either understand the environmental consequences of hiking off-trail and therefore are more willing to 'trudge through' heavily eroded or severely muddy trails or they enjoy navigating their way around degraded sections (and possibly believe they can do so in such a way that minimizes impacts to vegetation and soil). If the former is the case, then resource managers have nothing to worry about and should commend frequent hikers for their willingness to endure temporary personal discomfort for the sake of the trail's environmental integrity. However if the latter is the case, that more experienced hikers enjoy navigating their way around degraded trail sections, managers would be wise to seek out ways to reinforce the need for recreationists to adhere to responsible hiking behavior guidelines when confronted with degraded sections of trail. One potential solution that would be feasible if managers did not have the operating budgets or labor required to repair severely eroded or muddy trails, would be to selectively place signage at the beginning of highly degraded trail sections. Simple placards denoting the presence of sensitive soils and vegetation are likely to be highly effective behavioral change tools, especially when read by frequent outdoor

recreationists who generally tend to hold pro-conservation worldviews and attitudes (Dunlap and Heffernan 1975; Theodori et al. 1998).

Collectively, these three findings have highlighted a variety of ways recreation resource managers can more efficiently inform recreationists about the impacts of off-trail hiking and prioritize trail management needs. Further research is still needed to validate these findings with field-based observations. Proactive recreation resource managers are advised to experiment with and employ the widest variety of complementary solutions available within the given budgetary limitations, and the managerial recommendations offered here can be viewed as complementary. For example, engaged and committed resource managers could selectively seek out and engage with organizations that offer trail-based service-learning opportunities and place informative placards denoting the presence of sensitive soils and vegetation. The manager might also be able to educate visitors about recreation resource impacts through more active and engaging methods than simple trailhead signage. Altering recreation behavior in a manner that results in higher quality trail environments is not likely to emerge from one single solution. Rather, a full suite of tools and techniques should be deployed in a coordinated effort to successfully maximize recreation settings' environmental integrity and the quality of the experiences that depend upon them.

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