Measuring the Impacts of Bike-to-Work Day Events and Identifying Barriers to Increased Commuter Cycling

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Abstract: Despite much enthusiasm among practitioners to spur rates of bicycle commuting via promotional measures such as community rides or commuter incentive programs, there is little research regarding their impact. Using data from one such event, Bike-to-Work Day (BTWD), this paper aims to understand the following: (1) who attends BTWD; (2) the impacts of these event-based promotional strategies across different groups; and (3) lessons for increasing commuter cycling in general. The authors assess these research questions by examining motives to participate, behavior change, and influences of the event using over 1,000 surveys collected in the Denver region. Using an ordered logit model, the authors then identify significant factors for grouping cyclists' by behavior category. The results suggest that event attendees vary widely, from those who only bicycle on BTWD to those who report year-round bicycling, while reasons for participation and impacts of participation vary across bicycling behavior groups. This research also identifies specific barriers to increased commuter cycling. While the long-term impact of such events remains uncertain, this research illustrates that BTWD has the unique ability to capture a wide range of bicyclists and provide insights into barriers impacting diverse cycling populations. **DOI: 10.1061/(ASCE)UP.1943-5444.0000239.**

Introduction

Increasing bicycling in the United States may be an important strategy for mitigating the harmful effects of automobile reliance on individual health as well as the environment (Gotschi and Mills 2008). Currently, bicycling in the United States accounts for less than 1% of commuter mode share (U.S. Census Bureau 2009). Encouraging more Americans to bike to work involves myriad strategies that include but are not limited to safer routes, more attractive routes, and better education (for auto users and cyclists). These types of strategies tend to be costly for a city and take time to implement. An alternative approach is to rely on promotional measures such as community bike rides or commuter incentive programs. Such events are frequently well attended and publicized; however, their impacts are unclear (Krizek et al. 2009b; Pucher et al. 2010; Hu and Schneider 2014), owing primarily to a lack of data and literature on the topic.

Single-day promotional events are particularly common, and in the United States, Bike-to-Work Day (BTWD) is one of the most prevalent forms of such events. Almost all large U.S. cities promote BTWD at least once per year, which might consist of breakfast stations along popular bicycling routes, coordinated group rides, business challenges in which local businesses are encouraged to compete for highest rates of participation in the event, promotional materials (e.g., t-shirts and water bottles), and media coverage. The central aim is to raise awareness of bicycling in the short term and increase bicycling mode share to work in the long term. As BTWD events become more popular, it is increasingly important for cities to be able to assess and understand the successes and failures of their efforts, both in terms of short-term impacts on bicycling awareness and long-term impacts on behavior change. In turn, what is the significance of such events in supporting both behavior change and infrastructure investments to foster more bicycle-friendly urban environments? BTWD may be one element of a comprehensive, city-scale approach to travel behavior change; however, little is known about its role in this process.

The limited research on BTWD as *event-based behavior change* that is available confirms BTWD's unique ability to draw out a wide variety of individuals: both those experimenting with bicycle commuting as well as existing commuter bicyclists (Rose and Marfurt 2007). Other common bicycle-promoting activities are more permanent in nature (such as share-the-road campaigns and/or safe routes to school initiatives). While longer-term promotion may spur accompanying longer-term impacts, none have demonstrated an acute impact on first-time bicyclists or typically nonbicyclists—impacts that tend to be characteristic of BTWD type events. This paper aims to understand who attends BTWD events and how impacts of these event-based promotional strategies vary across different groups of bicyclists.

The present research employs a survey of over 1,000 participants of the 2012 Denver, Colorado area BTWD; it was administered by the Denver Regional Council of Governments (DRCOG) and included questions drafted by the authors to clarify the impacts of BTWD across a behavioral typology of participants, and understand barriers to increased commute cycling. The authors first identify BTWD participants and group them according to self-reported bicycling behavior categories. Second, the authors employ descriptive statistics and ANOVA to elucidate the impacts of BTWD on bicycling behavior, motivation to participate, and perceived influences of the event across each of these behavior groups. Third, a

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principal components analysis (PCA) is used to specify barriers to increasing commuter cycling. Finally, the results of an ordered logistic regression identify significant barriers impacting additional commute cycling across behavior groups, while controlling for sociodemographic characteristics. Taken together, this work sheds new light on the impact of bicycle promotion events and capitalizes on the opportunity for understanding barriers to cycling among diverse cycling populations, many of whom only cycle on BTWD.

Literature Review

Despite the widespread popularity of BTWD events in the United States, there is a dearth of literature examining its impact. Our review identified limited efforts focused on BTWD events: reports on bicycle counts from multiple U.S. cities associated with BTWD activities (Nordback 2013; Pucher et al. 2010) and a detailed analysis of one BTWD event in the peer-reviewed literature (Rose and Marfurt 2007). The latter study evaluated a 2004 Ride-to-Work Day (RTWD) event in Victoria, Australia, analyzing responses to an e-mail survey of RTWD participants. They found that one-fifth of participants were riding to work for the first time, and approximately one-quarter of those first-time riders continued to commute by bicycle 5 months after the event. Survey responses also indicated positive self-reported impacts of the event among all users but particularly among female riders. Specifically, along a continuum of "no impact" to "it influenced me to ride to work," 50% of females reported some impact, while only 37% of males reported an impact.

Such findings, while suggestive of possible behavior changes due to event participation, are limited as they apply a binary classification to participants (i.e., first-time participants and all others). Cyclists in the United States are most typically white, middle-aged men (Moudon et al. 2005), but that does not necessarily mean that all cyclists are the same, and may in fact differ dramatically within demographic categories, such as by bicycling behavior. Understanding BTWD bicyclists across behavioral categories (or typologies) offers an informative approach to understanding impacts of such events—one that has been limited in previous analysis.

The decision to expand the typology of BTWD participants in our analysis is grounded in preliminary findings suggesting that BTWD may have distinct impacts on different populations of cyclists. These varying impacts may be based on their general cycling behavior and history of participation in the event (Rose and Marfurt 2007). Recent empirical research into more general cycling behavior categories (or typologies) also supports a disaggregate analysis of cyclists by behavioral categories (J. Dill and N. Mcneil, "Four types of transportation cyclists; testing a typology to better understand bicycling behavior and potential," working paper, Oregon Transportation Research and Education Consortium, Portland, Oregon). Previous studies have identified typologies of travelers (broadly) and bicyclists (specifically); that is, bicyclists are a subset of all travelers defined by their primary mode choice. General typologies of travelers have been identified through attitude surveys (Anable 2005) and more broadly associated with residential location decisions (Krizek 2006).

The bicycling literature has recently focused on classifying different types of cyclists to better understand factors associated with each type and their typical bicycling behavior (Gatersleben and Haddad 2010; Heinen et al. 2011; Winters et al. 2011). Dill provides a concise overview and empirical evaluation of cyclist typologies (examining the validity of Roger Geller's four types of cyclists in the general population) (J. Dill and N. Mcneil, "Four types of transportation cyclists; testing a typology to better understand bicycling behavior and potential," working paper, Oregon Transportation Research and Education Consortium). Similar studies provide insights into attitudinal differences between groups (Bergström and Magnusson 2003; Gatersleben and Haddad 2010; Heinen et al. 2011). The analysis conducted herein provides a more nuanced analysis of BTWD participants (i.e., current and possible commute cyclists) along a four-tier spectrum of bicycling behaviors and includes sociodemographic variables and barriers to cycling not previously modeled in BTWD research (see "Data" section for a full description of variables included in the analysis).

One of these demographic variables, gender, has recently gained prominence in the literature (Pucher et al. 2011). Rose and Marfurt (2007) found a stronger impact of BTWD on women, but such an analysis from the United States is lacking. Available literature suggests that men are more likely to bicycle than women (Dill and Voros 2007; Moudon et al. 2005; Pucher et al. 2011), while women prefer offstreet infrastructure (Dill and Voros 2007; Garrard et al. 2008), and women's odds of riding depend significantly on their level of comfort (Emond et al. 2009). Differences in infrastructure preferences are consistent with gender differences in risk aversion (Garrard et al. 2008), and amount of bicycling may also be associated with household responsibilities and social factors (Emond et al. 2009). Consistent with the literature, the authors posit that BTWD may be an important strategy for encouraging cycling among women.

Despite scant literature focusing specifically on BTWD type promotion, these events might have an important role in drawing out diverse types of bicyclists. It is unclear, however, who these populations are, and a more nuanced approach to classifying attendees can offer additional insights into the impact of BTWD. The reasons different behavioral groups attend BTWD events in the United States, and the possible unique impacts the event has on these groups, provides an important contribution to the literature.

Data

The data analyzed in this study are drawn from a survey of participants in the 2012 Bike-to-Work Day event in Denver, Colorado. To specifically address our research aims, the survey instrument measured a series of variables to specify type of participant (by their self-reported *typical* bicycling behavior, history of participation in the event, reason for participation, perceived influence of the event, and self-reported cycling behavior before and after the event). These measures are described in detail in the following sections.

While the event itself occurred in June 2012, individuals who registered online prior to the event were contacted in October via e-mail and asked to take a brief online survey about their experiences with BTWD. From a total of 17,600 BTWD registrants, a randomized sample of 3,200 e-mail addresses was selected [using the random sample generator in SPSS v.21 (IBM Corporation, Armonk, New York)] to receive e-mail invitations. Assuming a response rate of 25%, $n = 3{,}200$ was selected to generate a sample population of at least 800 (800/0.25). Of the 3,200 e-mail addresses, 3,154 were valid. In total, 1,018 surveys were completed, yielding a 32% response rate. Response rates for similar cross-sectional surveys can range widely, from over 40% (Lu et al. 2008) to less than 20% (Heinen et al. 2011), with some researchers raising concerns about the impact of nonresponse bias at 25% response rates (Lovejoy et al. 2010). Given the already highly selective sampling frame (BTWD participants) and relatively high response rate, nonresponse bias is less of a concern with these results.

Table 1. Impact of Bike to Work Day on Behavior (Pre and Post the Event)

Type of bicyclist	Days per month bicycling to work				Monthly nonwork bike trips			
	Pre	Post	t	df	Pre	Post	t	df
Year-round commuter	18.93 (7.62)	19.33 (7.34)	−1.982[a]	201	12.23 (13.52)	12.80 (14.02)	−1.732	199
Frequent commuter	12.01 (7.51)	13.42 (7.702)	−6.016[b]	303	7.83 (14.22)	8.57 (14.87)	−2.760[a]	399
Occasional commuter	3.05 (3.57)	3.54 (3.66)	−2.976[a]	316	5.76 (8.83)	6.42 (10.10)	−2.802[a]	307
Only on BTWD	0.25 (1.04)	0.11 (0.35)	1.724	168	3.93 (9.33)	3.85 (9.57)	0.553	164
Full sample	8.53 (8.97)	9.16 (9.18)	−6.315[b]	1,004	7.44 (12.10)	7.97 (12.80)	−3.965[b]	982

Note: Standard deviation appears in parentheses below means.
[a]$p < 0.05$.
[b]$p < 0.001$.

Descriptive Statistics

There are expectedly more bicyclists on trails and roadways on BTWD than on normal summer days (Nordback 2013; Pucher et al. 2010). Our understanding of the composition and motivation of these individuals remains limited. Are these increases in counts around BTWD breakfast stations or other event-specific locations due simply to existing cyclists altering their routes to take advantage of BTWD amenities? Alternatively, are these individuals who would not normally cycle on other days? To understand who participates in BTWD, and what their standard bicycling behavior is, survey participants were asked to self-identify as either: year-round commuters (i.e., daily), frequent commuters (i.e., summer, spring, and fall), occasional commuters (i.e., commute by bike when it is convenient), and those who ride only on BTWD. The first step was to classify respondents into these four groups.

Impact of Bike-to-Work Day

To better understand the impacts of BTWD on different groups of cyclists, the authors examined descriptive statistics of self-reported behavior preevent and postevent. Survey respondents were asked to recall the 3 months preceding BTWD and the 3 months following BTWD. They were then asked to recall how frequently they rode to work (days per month) and how many nonwork bicycle trips (trips per month) they estimate they completed during those two time periods. The authors employ paired sample t-tests to assess mean differences before and after the event (Table 1).

Behavior change measures before and after BTWD show modest increases in bicycling after the event. Notwithstanding reliability concerns regarding self-report recollections of behavior at two distinct points in time (rather than a repeat, cross-sectional measure pre-BTWD and post-BTWD), bicycling to work and nonwork bike trips each significantly increased across the full sample populations after BTWD. Among all behavioral categories that ride at least occasionally to work, there were increases after the event. Frequent and occasional bicycle commuters report increases in nonwork travel as well (but as with work travel, those individuals who "only ride on BTWD" did not report increases in nonwork travel).

The descriptive statistics suggest that previous studies may be missing unique impacts of the event across distinct cyclist types. For instance, 17% of the sample population consists of individuals who are capable of riding to work, as evidenced by their reporting of a few nonwork bicycle trips per month (3–4), but choose not increase their cycling after BTWD. At the other extreme of the bicyclist behavior spectrum, year-round commuters make up 20% of the sample population and report modest behavior change after the event (an additional 0.4 bicycling trips to work after BTWD). Distinctions between these groups are explored further by examining reasons for participation in the event as well as an examination of demographic characteristics of each behavioral group.

Motivation to Participate and Influence of Participation

Survey respondents were asked to consider two aspects of why they participated in BTWD. Responses to the first question, "which one of the following reasons best describes why you decided to register for BTWD" is shown in Table 2. Results for a second question, "which one of the following statements best describes how BTWD has influenced you" is in Table 2. Descriptive statistics are provided in cross-tabulated tables indicating responses to each question across bicycling behavior categories as well as the full sample. In both cases, responses are strongly correlated with an individual's behavior category (see values for Cramer's V at the bottom of each table; values between 0.15 and 0.25 indicate a strong correlation).

The motivation to participate, as well as the impact of the event, varies most drastically at the ends of the behavioral spectrum (e.g., those who cycle more frequently and less frequently). The majority of year-round cyclists (55.7%) state that they participate to "raise awareness [about bicycling to work]," while 58.6% of those who only ride on BTWD state they participate in the event because it is "a fun thing to do" (Table 2). Additionally, majorities in each of these behavioral categories also reported that

Table 2. Reason for Participating in the Event (Self-Report)

Reason for participation	Reason for participating in Bike-to-Work Day				
	Year-round commuter (%)	Frequent commuter (%)	Occasional commuter (%)	Only on BTWD (%)	Full sample (%)
Try bike commuting	0.0	0.0	9.3	11.1	5.2
Commute more often	12.5	22.9	26.8	3.7	18.9
A fun thing to do	21.4	25.9	35.8	58.6	33.7
Compete in business challenge	6.3	2.0	3.5	8.0	4.4
Raise awareness	55.7	44.4	22.0	17.3	34.9
Win prizes	3.6	4.0	2.6	1.2	3.0

Note: Cramer's $V = 0.261$; $p < 0.001$.

Table 3. Influence of Event on Participant (Self-Report)

Influence of Bike-to-Work Day					
Influence of BTWD	Year-round commuter (%)	Frequent commuter (%)	Occasional commuter (%)	Only on BTWD (%)	Full sample (%)
Motivated me to commute more often	4.5	19.4	33.8	11.2	19.6
Motivated me to travel by bike more for all trips	32.7	34.2	37.2	30.8	34.3
No influence	62.9	46.4	28.7	53.8	45.4
Less motivated to commute by bike	0	0	0.3	4.1	0.8

Note: Cramer's $V = 0.207$; $p < 0.001$.

Table 4. Descriptive Statistics ($n = 1{,}018$)

Descriptive statistics		
Variable	Sample population	City of Denver (ACS 2012)
Education category	Bachelor's or graduate degree (mean = 5.15)	n/a
Median age (years)	44	33.7
Household size	2.63	2.22
Income category	\$50,000–99,999; \$100,000–149,999 (mean category = 3.5)	\$77,900 (mean)
	\$50,000–99,999 (median category = 3.0)	\$58,244 (median)
Gender (% male/% female)	62/38	50/50
Race (% white)	83.3	68.9

participation in BTWD had "no influence" on their behavior (62.9% of year-round commuters and 53.8% of those who only ride on BTWD) (Table 3). Responses are more varied across the frequent and occasional commuter populations, which further support the notion that BTWD motivates and impacts different groups of cyclists differently. The next step in the descriptive analysis is to determine the extent to which these behavioral groups differ across demographic characteristics.

Demographics across Behavior Groups

The authors employed analysis of variance (ANOVA) to identify significant differences across behavior groups. Table 4 provides descriptive statistics of event participants, and Table 5 presents the ANOVA results of BTWD participants across self-identified behavior groups. Years of participation, income, and education are ordered categorical variables (years of participation in BTWD: 1 = first time, 2 = 2–5 years, 3 = 5 or more years; income and education use six categories from low income or education to high income or education), while gender is a binary variable (1 = male, 2 = female). Trip distance is reported in miles, household size includes number of people (including minors) in the home, and age is reported in years.

Across all groups, age, number of children, income category, and educational attainment did not differ significantly. However, among those who report more frequent bicycle commuting, years of participation was higher and one-way trip distance was lower than those who commute by bicycle less or only on BTWD. Higher proportions of males report more frequent bicycle commuting. Because of the sampling frame employed in data collection, it is unsurprising that the sample population is fairly homogenous across demographic categories like age, income, and education. In comparison to the population of the City of Denver, the sample population is older (median age = 44 compared to 33.7), somewhat larger household size (2.63 persons compared to 2.22), higher income (approximately \$100,000 household income compared to a mean \$77,900 in Denver), and less diverse (higher percentage of whites and males participated in the survey) (Table 4). Despite demographic similarities, BTWD attendees encompass a wide range of bicycling behaviors and motivations, as well as diverse impacts of the event.

Table 5. ANOVA Results

ANOVA results					
Variable	Year-round bike commuter ($n = 202$)	Frequent bike commuter ($n = 305$)	Occasional bike commuter ($n = 317$)	Only commutes on BTWD ($n = 169$)	F
Number of years participating	2.25_1 (0.69)	$2.12_{1,2}$ (0.70)	2.07_2 (0.71)	1.95_2 (0.74)	5.549^a
One-way trip distance (mi)	7.23_1 (7.75)	$8.68_{1,3}$ (6.44)	$9.84_{2,3}$ (7.05)	12.02_4 (9.38)	13.734^b
Education category	2.35_1 (0.68)	2.22_1 (0.68)	2.26_1 (0.68)	2.18_1 (0.74)	2.275
Age (years)	43.07_1 (11.71)	43.89_1 (11.60)	43.78_1 (10.99)	45.97_1 (11.07)	1.789
Household size	2.68_1 (1.25)	2.63_1 (1.37)	2.67_1 (1.27)	2.50_1 (1.33)	0.608
Income category	3.36_1 (1.09)	3.52_1 (1.05)	3.54_1 (0.96)	3.56_1 (0.88)	1.360
Gender	1.22_1 (0.41)	1.38_2 (0.48)	1.40_2 (0.49)	1.53_3 (0.50)	12.002^b
Safety and infrastructure factor	-0.07_1 (0.98)	0.06_1 (0.95)	-0.03_1 (1.03)	0.02_1 (0.96)	0.941
Convenience and climate factor	-0.86_1 (0.85)	-0.18_2 (0.85)	0.34_3 (0.76)	0.70_4 (0.84)	136.833^b
Cost and concerns factor	0.03_1 (0.88)	-0.17_1 (1.01)	-0.02_1 (1.00)	0.31_2 (0.93)	9.397^b

Note: Standard deviation appears in parentheses following means; means with differing subscripts within rows differ significantly at $p < 0.05$ based on Tukey's honestly significant difference post hoc comparison.
[a]$p < 0.05$.
[b]$p < 0.001$.

Table 6. Principal Components Analysis

Factor	Variable[a]	Loading[b]
Factor 1: safety and infrastructure	Worries about road safety (with regard to traffic)	0.767
	Street conditions (potholes, cracks, snowy bike lanes, etc.)	0.729
	Not enough light on existing bicycle facilities at night	0.582
	Too few bike lanes	0.821
	Lack of connections between bike lanes and paths	0.749
Factor 2: convenience and climate	Driving is more convenient than riding my bike	0.759
	Transit is more convenient than riding my bike	0.550
	Too much cargo to carry	0.471
	Weather (rain, snow, heat, wind, etc.)	0.434
	Too hilly	0.503
	Biking to work takes too long	0.748
	Can't get sweaty before work	0.531
Factor 3: cost and concerns	Fear of bike theft or vandalism	0.716
	Problems taking bike on transit	0.432
	Can't afford a good bike	0.413
	No available storage for a bicycle at work	0.755

[a]Variables coded on a 4-point Likert scale (1 = strongly disagree; 4 = strongly agree).
[b]Cut-points for factor loadings > 0.4.

Barriers to Bicycling

The data provide unique insight into factors that may support increased commute cycling. The survey includes 17 variables measuring general barriers to bicycle commuting, not only barriers to bicycling on BTWD (Table 6). A principal components analysis (PCA) with an orthogonal (i.e., varimax) rotation was conducted on these variables to reduce the dimensionality of the data, creating a manageable subset of factors. The factors are then modeled as independent variables in a regression model. Linking specific barriers to cycling behavior to provide insights for policymakers interested in specific, actionable approaches to increasing commuter cycling.

The PCA yielded three factors encompassing *safety and infrastructure*, *convenience and climate,* and *cost and concerns* (Table 6). The safety and infrastructure factor includes variables like "worries about road safety" and concerns such as the number of bike lanes and infrastructure connectivity. The convenience and climate factor encapsulates concerns regarding the convenience of cycling relative to other modes, weather, terrain, and commute time. The cost and concerns factor is made up of variables around bicycle cost, challenge of bringing a bike on transit, adequate bike storage, and concerns of theft and vandalism. Taken together, these three factors account for 45.8% of the variance in the data subset (safety and infrastructure = 26.8%, convenience and climate = 11.2%, cost and concerns = 7.8%).

The three-factor solution was arrived at through a Scree test (Johnson and Wichern 2007; Kim and Mueller 1978) and careful assessment of the resulting factors by the research team. A conservative factor loading cut-point was used for interpretation (Grimm and Yarnold 1995): considering factor loadings >0.40 (0.4 indicates the variable and corresponding eigenvector share 16% of their variance). One measure, "must transport children to school or daycare," did not load higher than 0.27 on any factor (likely owing in part to the fact that 52.4% of the sample reported not having children under 16), and has been omitted from the results (Table 6). *Convenience and climate* and *cost and concerns* factors differed significantly across bicycle behavior groups (Table 5). The methodology for determining the magnitude and direction of these factors impact on bicycling category is detailed in the next section.

Statistical Methodology

An ordered logit model was used to identify the probability that an individual would belong to each of the bicycling behavior categories. Ordered logistic regression, an extension of the binary logit model to an ordered categorical dependent variable (McCullagh 1980; Norusis 2010; Winship and Mare 1984), is commonly expressed as

$$\ln \frac{\text{prob(event)}}{1 - \text{prob(event)}} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_k X_k \quad (1)$$

where ln = logit; prob = probability of the outcome; X_1 = independent predictor variable; α = intercept; and β = coefficient for effect of the independent variable.

The left-hand side of the equation represents the log odds of an event occurring, while the right side informs how much the logit changes based on the values of the predictors. To account for the ordinal nature of a dependent variable, the probability of all possible outcome categories is defined by the probability of that outcome as well as all outcomes ordered before it (Norusis 2010). For example, the dependent variable in our model is cyclist behavior category (1 = year-round commuter, 2 = frequent commuter, 3 = occasional commuter, 4 = commutes only on BTWD)

$$\theta_1 = \text{prob(score of 1)}/\text{prob(score} > 1)$$

$$\theta_2 = \text{prob(score of 1 or 2)}/\text{prob(score} > 2)$$

$$\theta_3 = \text{prob(score 1,2, or 3)}/\text{prob(score} > 3)$$

The fourth category (commutes only on BTWD) is the reference category in the model and does not have an associated probability since the probability of scoring up to and including the last score is 1 (Norusis 2011).

The extension of the binary logit model to an ordinal outcome is (Norusis 2011)

$$\ln(\theta_j) = \alpha_j - (\beta_1 X_1 + \beta_2 X_2 + \ldots \beta_k X_k) \quad (2)$$

where values of j are from 1 to the number of total categories minus 1.

The final model for this study, using the following predictors, took the form:

$$\begin{aligned}\ln(\text{behavior category}) = \alpha_j - (&\beta_1 \text{ years participating} \\ &+ \beta_2 \text{ trip distance} + \beta_3 \text{ education} + \beta_k \text{ age} \\ &+ \beta_k \text{ household size} + \beta_k \text{ income} \\ &+ \beta_k \text{ gender} + \beta_k \text{ safety and infrastructure} \\ &+ \beta_k \text{ convenience and climate} \\ &+ \beta_k \text{ cost and concerns}) \quad (3)\end{aligned}$$

Results

Ordered Logistic Regression

Regression results indicate that a number of sociodemographic variables, as well as two of the *barriers to bicycling* factors were significantly correlated with bicycling behavior category (Table 7). Log-odds coefficients are interpreted such that a unit change in the explanatory variable corresponds to an expected change in the dependent variable by the explanatory variable's log-odds coefficient (when holding all other variables in the model constant). For example, a one-unit increase in one-way trip distance (i.e., an additional mile of trip distance) corresponds to an expected 0.052 increase in the log-odds of commuting less by bike (i.e., a *higher* level of the dependent variable) when all other variables in the model are held constant. In other words, longer trip distances are associated with less commuting.

In the case of sociodemographic characteristics [gender (1 = male, 2 = female)], women are associated with an expected 0.796 increase in the log-odds of commuting less by bicycle. Age is associated with an 0.019 increase in log-odds of reduced cycling to work. Similarly, higher income is associated with reduced bicycle commuting (log-odds = 0.204). However, smaller household size is correlated with more frequent commuting by bicycle (log-odds = −0.134).

Significant independent variables that may be of most interest to practitioners and event organizers include years of participation (in BTWD), convenience and climate factor, and the cost and concerns factor. The log-odds of expected bicycle behavior category suggest that as number of years of participation in BTWD increases, the ordered logit for being in a higher behavioral category (i.e., reduced commute bicycling) is −0.425 less with each unit increase in years of participation. Thus, the longer an individual participates in BTWD, the higher the odds of their being a year-round commuter.

Interpreting the barriers to cycling factors drawn from the PCA (convenience and climate factor and the cost and concerns factor) involves accounting for both the coding of the original Likert-scale variables they represent as well as the log-odds coefficients. Higher values on the original variables equal *strong agreement* with a given barrier statement; in turn, higher factor scores equal increased concern that the barriers represented by the factor are important to the survey respondent. For example, higher scores on the convenience and climate factor (i.e., enhanced concern that the variables this factor represents are barriers to increased cycling) are associated with a 1.103 log-odds increase in an individual commuting less by bicycle. Similarly, the ordered logit for being in a higher behavior category and commuting less by bicycle is 0.336 greater as cost and concerns regarding bicycling to work increase. Two final points should be stressed when interpreting model results: first, the factors arrived at through PCA are standardized (mean = 0, standard deviation = 1) scores that do not correspond to a *real-world* measure of perceived barriers; second, while the overall model formulation operationalizes all independent variables as predictors, results only provide evidence of correlation.

The authors' literature review identified sociodemographic factors as significant correlates of bicycling behavior, and that barriers to bicycling may vary across demographic characteristics. As such, 12 interaction terms (age, household size, gender, and income by each of the three factors) were included in the initial ordered logit model formulation. The resulting model offered little additional explanatory power (Chi-square = 276.480, $df = 22$, $p < 0.001$; Nagelkerke psuedo-$R^2 = 0.40$). Upon reducing the total number of predictors by removing insignificant interactions, no interaction terms maintained statistical significance (at $p < 0.05$). Further details, caveats, and implications of this model (and the preceding descriptive statistics) are discussed in the following section.

Discussion

The results illustrate that reasons for participation and the impact of the BTWD event are largely predicated on the participants existing bicycle behavior category. While data limitations preclude robustly connecting BTWD in particular to behavior change, the event itself offers an opportunity to better understand the diverse factors impacting different types of cyclists. Perhaps one of the most compelling aspects of BTWD events is their ability to draw participants from across a wide spectrum of bicycling behavior. Our results illustrate the significance of this opportunity in identifying the relative impact of specific barriers to bicycling on increasing commuter cycling. Implications of this work for bicycle policy and planning are described below, as are opportunities and future directions for improved research evaluating the impact of BTWD in particular.

Reasons for Participation and Influence of the Event

The behavioral impacts of BTWD, the motivation behind participation, and influence on participants varies by type of bicyclist. Comparing results from the extremes of bicycling groups—year-round riders and those who only commute on BTWD—provides a stark contrast. A majority of responses within each of these groups suggest they participate in the event for different reasons (the former to raise awareness and the latter because it is a fun thing to do). Across these two groups, there is no evidence

Table 7. Factors Influencing Bicycle Behavior Category

Variable category	Variable	Log-odds coefficients (standard error)
Cut-points (dependent variable = bicycling behavior category)	Year-round commuter ($y = 1$)	−0.261 (0.719)
	Frequent commuter ($y = 2$)	1.639 (0.721)
	Occasional commuter ($y = 3$)	3.776 (0.737)
Explanatory variables	# years participating	−0.290[a] (0.127)
	One-way trip distance (mi)	0.052[b] (0.012)
	Education category	−0.119 (0.091)
	Age (years)	0.019[a] (0.008)
	Household size	−0.134[a] (0.063)
	Income category	0.204[a] (0.091)
	Gender	0.796[b] (0.178)
	Factor 1: safety and infrastructure	0.011 (0.081)
	Factor 2: convenience and climate	1.103[b] (0.098)
	Factor 3: cost and concerns	0.336[b] (0.085)

Note: Chi-square $(df = 10) = 262.428^b$; Psuedo R^2 (i.e., Nagelkerke) = 0.394.
[a]$p < 0.05$.
[b]$p < 0.001$.

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of significant behavior change. A self-reported year-round commuter, it is assumed, likely already commutes as much as possible by bicycle. For those who report they only cycle on the day of the event, some element of the event is a prerequisite for commuting by bicycle. Participation in the event across the two extremes of bicyclist behavior groups appears to be predicated on social aspects (it is fun), or perceived social impacts (to raise awareness) of the event.

Differences between frequent and occasional commuters are less obvious than among the extremes of bicycling behavior groups. These populations report somewhat more diverse motivations for participation in the event, and diverse influences of the event on their behavior (Tables 2 and 3, respectively) than the year-round or only day-of behavioral groups. Frequent and occasional cyclists do not differ significantly in average number of years participating in BTWD, average one-way distance to work, or gender (Table 5). These groups warrant closer examination as similarities across groups may be less pronounced with more precise measures of bicycling frequency. Individuals who occasionally commute may be gradually changing their behavior, or they may be making gradual lifestyle and residential or work location changes that facilitate bicycle commuting. For this group, BTWD may be an important factor reinforcing a multiyear behavior change process. Our findings indicate that the role of BTWD in promoting bicycling is diverse and long term and requires further evaluation.

Factors Influencing Bicycle Behavior Category

The regression analysis (Table 7) provides actionable directions for increasing commuter cycling. First, a number of sociodemographic variables were significantly correlated with bicyclist category, including age, household size, income, and gender. Consensus within the existing literature on cycling finds that bicycling behavior is influenced by sociodemographic and household characteristics, but findings are unclear (Heinen et al. 2010). Targeting outreach around BTWD events to women, families, and older individuals may increase attendance at events and also help to spur longer-term travel behavior changes.

The second category of significant variables includes two barriers to bicycling factors: (1) convenience and climate, and (2) cost and concerns. The barriers represented by these factors may be partially mitigated with more attention to secure bicycle parking and enhanced integration of bicycling with transit. Bicycle route planning that avoids significant elevation change and prioritizes access to destinations over recreational routes can make bicycling more convenient relative to other modes. Convenience may also be closely associated with at work amenities. An enhanced focus on amenities like showers and bike storage can significantly impact bicycling to work (Geus et al. 2007; Pucher et al. 2011) and may offer an important solution for addressing barriers across both significant factors in our analysis.

The safety and infrastructure factor was not significant among BTWD attendees. This result is in contrast the long-standing planning goal of improving bicyclist and pedestrian safety (Southworth 2005; Bowman et al. 1994). Indeed, safety has been identified as a primary concern for short -distance travel in general (Zhou et al. 2010), and among bicyclists in particular (Allen-Munley and Daniel 2006). While research supports the role of perceived safety (Schneider 2013) and quality infrastructure (Krizek et al. 2009a) on the decision to bicycle, such factors appear less relevant to BTWD participants. It may be that these factors are relevant to those who do not cycle at all, but less so among the subset of the population who can cycle to work, and do so at least once a year on BTWD. This assertion requires further research, but implies that barriers to bicycling in the first place may be distinct from barriers to *regular* bicycling.

Limitations and Future Directions

The impact of event-based interventions such as Bike-to-Work Day is varied and confounded by numerous factors. Our results are bolstered by the site selection and a large number of significant variables in the regression model, but also illustrate the need for additional study (ideally employing a longitudinal panel study research design). The City of Denver is representative of many mid-sized U.S. cities (particularly in the western United States) in its history of auto-oriented planning. But in recent years, Denver has been making strides toward reducing automobile reliance with increased investments in bicycle infrastructure and light rail transit. The result of this shift toward multimodal travel, and the increasing popularity of BTWD-style events, has implications for many similar U.S. cities. At this point, the present research findings are limited by data constraints (i.e., cross-sectional in nature), and as such they should be considered exploratory. However, they do provide numerous directions for event-based intervention evaluation in particular and encouraging commuter cycling in general.

The available data is not ideal for identifying behavior change over time, as behavior measures are self-reported. The overall accuracy of the self-reported trip rates likely suffers from some measurement error, calling into question the magnitude of reported effects. Our ability to introduce control variables is somewhat limited; however, the influence of weather was considered. The Denver region experienced an unusually mild and dry spring 2012 [average monthly rainfall from March–September 2012 was between 0.0 and 5.6 cm (0.0 and 2.2 in.); average monthly temperatures were between 53.0 and 79.4°F: March, 53.0°; April, 57.3°; May 64.0°; June, 78.0°; July, 79.4°, August, 76.8°; September, 68.2° (NOAA 2013)].

Available research on the effect of weather is mixed. Bicycle counts reveal some of the highest number of cyclists July through October (Nordback et al. 2013). Other studies find the magnitude of weather's effect to be modest (Amiri and Sadeghpour 2012), and chiefly affects discretionary travel (Nankervis 1999; Thomas et al. 2013). The extent to which weather may impact journey-to-work travel also varies across different types of commuter cyclists (Bergström and Magnusson 2003) and may significantly impact uptake of bicycling as a new behavior (dell'Olio et al. 2014). Because of the cross-sectional nature of this data set, the authors are unable to specifically account for the impact of weather in our study, but this remains an outstanding issue that may be addressed with longitudinal research designs.

This work would be significantly strengthened through a longitudinal panel study with a control population. Unfortunately, due to privacy concerns expressed by the Denver Regional Council of Governments (who led participant registration efforts and administered the survey), the authors were unable to administer follow-up surveys after the event, or cultivate an annual panel survey. Thus, the authors stress that the first step to more robust evaluation is some form of multiple observation approach applied to a panel of participants before and after the *treatment* (i.e., event participation). It is also advisable to carefully select a control population for observation to avoid overestimating behavior impacts solely due to BTWD. That is, external factors such as evolving social norms and/or changes to the built environment may be positively impacting bicycling rates. The impact of these factors may be observed during BTWD, but inadequately accounting for such impacts will overestimate the event's effectiveness.

Future research to understand the impacts of BTWD should focus on multiyear effects, causal versus corollary relationships between events and parallel programs, policies, and trends, and changes to the character of the event itself. For example, winter BTWD events are gaining in popularity (winterbiketoworkday.org). Bike-to-Work Month is also becoming more common (bikeleague .org/content/national-bike-month). Our results do not necessarily support the conclusion that more frequent BTWD events (twice, or even four times per year, for example) would have a greater impact on daily cycling. Though, the impact of extending the event itself (e.g., a month-long event) is unclear and deserves further study. Future evaluation should consider how the frequency or length of event-based promotional strategies impacts efficacy. More generally, BTWD should be conceptualized as one component in a complex system rather than a discreet event with a direct impact.

Conclusion

Bike-to-Work Day and similar event-based promotional activities potentially hold promise for communities looking for low-cost means to encourage bicycling. On-street bicycle treatments in much of the United States are modest compared to those in many European cities with high bicycle mode shares (Pucher and Buehler 2008), and outside of an event day, novice cyclists may feel intimidated on U.S. streets. Dispersed land uses, inconsistent connectivity, and a lack of bicycle infrastructure may also be factors for some cyclists (Marshall and Garrick 2010). However, the social aspect of the event (i.e., *it's fun*) may help to trump some of these barriers and draw out those who do not cycle to work on any other day.

While previous research has focused solely on behavioral impacts of BTWD events, this study uses BTWD as an opportunity to better understand the diverse population of cyclists who can, but often do not, bicycle to work. Of particular relevance to practice is that safety concerns do not significantly predict bicycling behavior among BTWD attendees. It is possible that BTWD provides an enjoyable opportunity for individuals to try cycling that may in turn work to dispel safety concerns. Indeed, this research indicates that cities interested in promoting bicycling in general should focus on straightforward aspects of mode choice decisions such as the cost and convenience of cycling relative to other mode choices. In practice, expensive bicycle infrastructure may be less important than bicycle-supportive policies. Relative cost and convenience of bicycling may be best addressed through multimodal transportation policies, bicycle-friendly workplaces (including showers and secure parking facilities), and better integration of bicycling with transit.

Programs and policies aimed at promoting bicycling are traditionally judged by their impact on behavior, but this approach may be shortsighted when evaluating BTWD. Event-based promotional events serve a unique purpose among bicycle-promotion strategies. Diverse groups of cyclists all attend the same event, but they do so for distinct reasons. It may be more appropriate to conceptualize event-based promotion as both an opportunity to identify issues impacting local cycling populations, and as one approach to encouraging cycling that is reciprocally related to broader policies and the built environment. The present results provide a useful benchmark to help communities who have been investing, and continue to invest, in bike-to-work related events, but the degree to which BTWD is a symptom or a cause of other factors remains unclear at this point. This research confirms that BTWD participants are a diverse group, that cyclists, even those who share sociodemographic characteristics, are a diverse group with specific motivations and barriers impacting their travel behavior decisions. However, future research is needed to help us understand how such promotional strategies may either support or deter an individual's movement along a bicycling behavior spectrum.

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