Explaining Gender Difference in Bicycling Behavior

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Although men and women bicycle at relatively equal rates in industrialized countries such as the Netherlands, Germany, and Denmark, research has consistently found that in the United States men's total bicycle trips surpass women's by a ratio of at least 2 to 1. Current evidence, though limited, suggests that women are affected to greater or lesser degrees than men by certain factors. The purpose of this study is to provide insight on gender differences with the factors that influence the decision to use a bicycle, with the intent of supporting policy development aimed at increasing bicycle ridership, particularly among women. Bicycle use in six small cities in the western United States is examined to determine how gender interacts with individual factors and social and physical environments to influence bicycle behavior. Analysis of data from an online survey using a binary logistic regression approach shows strong interaction of gender with individual factors such as safety perception and household responsibilities and, to a lesser degree, with social and environmental factors to influence bicycle behavior.

In light of volatile gas prices and concerns over climate change, bicycling is seeing a resurgence of popularity in the United States. From Los Angeles, California, to New York City, bicycle stores are experiencing higher bicycle sales than usual, especially for commute purposes (*1–3*). But if current cycling patterns hold, men will be doing much more bicycling than women. Research has consistently found that in the United States, men's total bicycle trips surpass women's by a ratio of at least 2:1 (*4*). What explains this imbalance by gender in U.S. bicycling rates?

Garrard et al. (*5*) were motivated to study female bicycle behavior by the observation that industrialized countries such as the Netherlands, Denmark, and Germany, with higher rates of bicycling for both transportation and recreation, have equal or higher rates of female cyclists than males, in contrast to the far greater proportion of male to female cyclists in Australia and the United States. This difference has been attributed to the strong automobile culture of Australia and the United States, where low bicycling and walking rates are still the norm in many communities (*5*). In the United States, emphasis on the automobile in infrastructure design has resulted in less focus on bicyclists' needs for both safe and efficient access to destinations by public roads, creating a situation that discourages bicycling for less confident riders, (*5–8*).

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In this paper, data from a 2006 survey of residents of six small cities in the western United States are used to explore differences between men and women in the factors that explain their bicycle use. Bicycle use in these cities is examined in an effort to determine how gender interacts with individual factors and social and physical environments to influence bicycle behavior. Providing empirical insight on how gender influences the decision to use a bicycle should support planners and policy makers attempting to increase bicycle ridership in their communities, particularly among women.

CONCEPTUAL BASIS AND LITERATURE REVIEW

The conceptual model for this study is based on the ecological model commonly used in physical activity research in the public health field to explain individual behavior (*9*). This model suggests that individual behavior is influenced by factors at multiple levels, including individual, social environment, and physical environment. Individual factors include attitudes, preferences, and beliefs, as well as confidence in one's ability to engage in the behavior (known in the field of public health as self-efficacy). Social environment factors include the cultural norms of the community as evidenced by the collective behaviors of its residents. Interpersonal relationships, including those within households, are also considered social environment factors. Physical environment factors depend on the nature of land use patterns and transportation infrastructure. The ecological model was chosen over the more traditional model of travel behavior that focuses on utility maximization and does not readily account for attitudes or social environment factors.

Research explaining gender differences in bicycle rates is limited, with the few existing studies focusing on female bicycling behavior specifically; this is understandable, considering the low rate of female cyclists compared with that of males. The limited available evidence suggests that women are affected to greater or lesser degrees than men by factors at each level of the model. Two factors that cut across the levels of the model emerge as especially relevant to explaining gender differences in bicycling: concern for safety and household responsibilities.

Concern for Safety

A number of studies, mainly aimed at increasing women's participation in bicycling, indicate that female cyclists have different perceptions of safety and different trip needs than male cyclists, regardless of whether they are advanced or less experienced cyclists (*4, 5, 10*). Studies by Garrard (*11*) and Garrard et al. (*5, 12*) studies in Australia concluded that female cyclists' concerns for safety—from the perspective of road safety and driver behavior—were the main factors that discouraged them from bicycling. Women are more risk averse than men and tend to perceive negative consequences of sharing roads with vehicular traffic more than men do (*13*).

Although this concern for safety is an individual level factor, it is influenced by both the social and physical environments in which the cyclists operate. The probability of fatal injuries for bicyclists increases dramatically on roads where vehicular speed is over 30 mph or approximately 48 km/hr; this is a definite concern in both Australia, where the residential speed limit is approximately 31 mph or 50 km/h, and in the United States, where residential speed limits range from 25–35 mph or 40–55 km/h (*14*). In their 2006 observational study of cyclists in Melbourne, Australia, Garrard et al. (*5*) found that female cyclists preferred off-road paths that were separated from traffic; this finding is consistent with other studies of bicycling behavior in which women were more likely than men to prefer bicycling separated from vehicular traffic by on-road lanes designated for bicycle use or by off-road paths (*4, 8, 10, 15, 16*).

Household Responsibilities

Research examining the influence of household responsibilities on travel behavior has found that women tend to make more trips for household and family support activities than do men (*17, 18*). Since many of these activities require the transport of goods or passengers, women may prefer the convenience of driving over bicycling to fulfill these activities, especially if they are also using trip chaining to carry out these responsibilities. Although a preference for driving over bicycling is an individual level factor, it is heavily influenced by household and family relationships, which are considered a part of the social environment.

McGuckin and Nakamoto (*19*) analyzed data from the 1995 Nationwide Personal Transportation Survey and the 2001 National Household Travel Survey and found that American men's trip chaining increased to twice that of women's from 1995–2001, mainly for the purpose of buying food and coffee. American women's trip chaining was more for shopping and family errands than was men's, with women in two-working-parent families making twice as many weekday trips as men to pick up or drop off household children under the age of 14 years. Such responsibilities are likely to restrict the viability of bicycling.

When it is possible for women to bicycle for these chores, bicycling rates go up. In Germany, the Netherlands, and Denmark, where the share of female cyclists is equal to or greater than the share of male cyclists, shopping trips account for 20%–25% of overall bike trips versus 5% of all bike trips in the United States (*20*). However, a 2002 survey of more than 400 women, conducted by the San Francisco, California, Bicycle Coalition, found that 37% of the respondents felt that it was impossible to transport children or groceries on a bicycle (*10*). This perception could be, in part, because of a lack of cyclist role models in San Francisco engaging in these tasks. Portland, Oregon, addresses this misperception by offering a "shopping by bike" class in order to teach residents how to carry their groceries by bicycle (*21*).

METHODOLOGY

The data used in this study were obtained from an online survey conducted in 2006 in six small cities in the western United States. To ensure variation in potential explanatory variables, Davis, California, and five communities that are similar to Davis in size, topography, and weather but differ from Davis with respect to bicycle infrastructure and culture were selected for the survey—three in California (Turlock, Chico, and Woodland), one in Oregon (Eugene), and one in Colorado (Boulder). Davis was chosen as the relevant model because of its high level of bicycling, not only encouraged by its flat terrain, moderate weather, and large university but also supported by a city council that has invested in bicycle infrastructure as far back as 1966 (*22*). In recognition of its strong bicycling tradition, Davis was named the first platinum-level U.S. Bicycle Friendly City by the League of American Bicyclists in 2005.

Five comparison communities were selected for the study based on several factors. Woodland, Chico, and Turlock were chosen as comparison cities that differ from Davis with respect to bicycle culture and infrastructure but are geographically close to Davis. Chico is a two-hour drive north of Davis and has a reputation of being pro-bicycles, while Woodland is about 10 miles or 16 km north of Davis and has twice the bicycle lane mileage as Chico. Turlock is a three-hour drive south of Davis and has little bicycling or bicycle infrastructure. Eugene and Boulder were chosen because they have extensive bicycle infrastructure and enjoy reputations as bicycling communities nearly comparable to that of Davis. This set of cities ensured reasonable comparability with respect to control variables but ample variation in key explanatory variables.

For each of the six communities, a random sample of 1,500 residents, along with an additional sample of 1,000 residents for Davis (to capture residents who had recently moved to Davis), were each mailed a letter in June 2006 inviting them to participate in the online survey. This was followed up by two postcard reminders and an offer to send participants a hard copy of the survey if requested. Of the original 10,000 addresses, more than 2,000 proved to be incorrect, as evidenced by the number of returned surveys. After accounting for bad addresses, a response rate of more than 10% was achieved for every city except Turlock, where the response rate was only 7.2%; the highest response rate was 18.8% in Davis. The final sample size was 965, with an overall response rate of 12.6%. A follow-up phone survey conducted in Davis in May 2008 to assess nonresponse bias yielded bicycling levels that were statistically indistinguishable from those in the online survey [see Xing et al. (*23*) for more details]. In this paper, only those respondents who reported owning a bicycle are included in the analysis.

Variables

The dependent variable is the binary variable of whether the respondent reported bicycling or not in the last week before the survey, with discrete values of 1 for "bicycled in the last 7 days" and 0 for "did not bicycle in the last 7 days." The conceptual model defines three categories of relevant explanatory variables in this context: individual factors, social environment factors, and physical environment factors. This study uses variables developed and tested by Xing et al. (*24*). Three additional variables were included in this study: "assisted children" (presence of children requiring travel assistance), "bike repair skill" (index for perceived bicycle repair capability), and "limitations on biking" (existence of a physical condition that seriously limited or prevented riding a bicycle). In this study, all the variables in Xing et al.'s (*24*) paper, plus the three additional variables, were tested for gender-specific effects using interaction terms. The potential explanatory variables are shown in Table 1.

TABLE 1 Description of Variables in Models

Variable	No. of Item (range)	Description
Dependent variable: bike or not	1 (0,1)	0 = owns a bike and did not bike in past 7 days, 1 = owns a bike and biked during past 7 days
Individual factor: sociodemographics		
Age	1 (17,73)	Age in years
Female	1 (0,1)	1 = female, 0 = male
Education level	1 (1,6)	Highest level of education: 1 = grade school or high school, 2 = high school diploma, 3 = college or technical school, 4 = four-year degree or technical school certificate, 5 = some graduate school, 6 = completed graduate degree(s)
Household size	1 (1,6)	Number of persons living in household
Income	1 (1,125)	Continuous, in thousand dollars
Car ownership	1 (0,1)	0 = does not own or have regular access to car, 1 = owns or has access to car
Home ownership	1 (0,1)	0 = rents, 1 = owns
White	1 (0,1)	1 = white, not of Hispanic origin, 0 = all others
Limit on biking	1 (0,1)	0 = does not have conditions that limit biking, 1 = has conditions that limit biking
Child assistance	1 (0,1)	0 = child(ren) do not need assistance traveling, 1 = child(ren) do need assistance
Individual factor: attitudes		
Biking comfort	6 (1,3)	Average comfort biking on an (1) off-street path or (2) quiet street, (3) two-lane-local-street with or (4) without bike lane, (5) four-lane-street with or (6) without bike lane, on 3-point scale where 1 = uncomfortable and I wouldn't ride on it, 2 = uncomfortable but I'd ride there anyway, 3 = comfortable
Safety concern	5 (1,3)	Average concern of being (1) hit by a car, being (2) hit by another bicyclist while biking, (3) being bitten by a dog, being (4) mugged or attacked, or (5) crashing because of road hazards on 3-point scale where 1 = not at all concerned, 2 = somewhat concerned, 3 = very concerned
Like biking	1 (1,5)	Agreement that "I like riding a bike" on 5-point scale[a]
Like driving	1 (1,5)	Agreement that "I like driving" on 5-point scale[a]
Need car	1 (1,5)	Agreement that "I need a car to do many of the things I like to do" on 5-point scale[a]
Limit driving	1 (1,5)	Agreement that "I try to limit driving as much as possible" on 5-point scale[a]
Like walking	1 (1,5)	Agreement that "I like walking" on 5-point scale[a]
Like transit	1 (1,5)	Agreement that "I like taking transit" on 5-point scale[a]
Environmental concern	1 (1,4)	Importance of environmental benefits when choosing mode, on 4-point scale where 1 = not at all important, 2 = somewhat important, 3 = important, 4 = extremely important
Proexercise	2 (1,5)	Average agreement that "it's important to get regular physical exercise" and "I enjoy physical exercise" on 5-point scale[a]
Good health	1 (1,5)	Agreement that "I am in good health" on 5-point scale[a]
Biked in youth	1 (0,1)	Ever rode a bicycle when about 12 years old, 0 = no, 1 = yes
Self-selection	5 (0,1)	A good community for cycling is important, at least not less important than any other reason, for choosing a residential location. 0 = not important, 1 = important
Bike repair	6 (1,3)	Average response reflecting the capability of repairing bike: (1) "fix flat," (2) "pump air," (3) "AdjSeat," (4) "AdjBrake," (5) "OilChain," and (6) "FixAnything" on a 3-point scale where 1 = not at all capable, 2 = somewhat capable, 3 = very capable
Social environment		
Good driver attitude	4 (1,5)	Average agreement that (1) "most drivers [do not] seem oblivious to bicyclists," (2) "most drivers yield to bicyclists," (3) "most drivers watch for bicyclists at intersections," (4) "most people [do not] drive faster than the speed limit" on 5-point scale[a]
Biking is normal	2 (1,5)	Average agreement that (1) "bicycling is a normal mode of transportation for adults in this community" and (2) "it is [not] rare for people to shop for groceries on a bike" on 5-point scale[a]
Children bike	1 (1,5)	Agreement that "kids often ride their bikes around my neighborhood for fun" on 5-point scale[a]
Bikers poor	1 (1,5)	Agreement that "most bicyclists look like they are too poor to own a car" on 5-point scale[a]
Bikers spend	1 (1,5)	Agreement that "most bicyclists look like they spend a lot of money on their bikes" on 5-point scale[a]
Bikers not concerned	1 (1,5)	Agreement that "many bicyclists appear to have little regard for their personal safety" on 5-point scale[a]
Physical environment		
Bike infrastructure	8 (1,4)	Average perceived that (1) "major streets have bike lanes," (2) "streets without bike lanes are generally wide enough to bike on," (3) "stores and other destinations have bike racks," (4) "streets and bike paths are well-lighted," (5) "intersections have push-buttons or sensors for bicycles or pedestrians," (6) "the city has a network of off-street bike paths," (7) "bike lanes are free of obstacles," (8) "the bike route network does not have big gaps" on 4-point scale where 1 = not at all true, 2 = somewhat true, 3 = mostly true, 4 = entirely true
Hilly topography	1 (1,4)	Perception that "the area is too hilly for easy bicycling" on 4-point scale where 1 = not at all true, 2 = somewhat true, 3 = mostly true, 4 = entirely true
Safe destinations	5 (1,3)	Average perception of safety bicycling to "your usual grocery store," "the nearest post office," "the local elementary school," "a restaurant you like," "the nearest bike shop" on 3-point scale where 1 = comfortable, 2 = uncomfortable but I'd ride there anyway, 3 = uncomfortable and I wouldn't ride there
Distances	6 (1,4)	Average perception of distances from home to "your usual grocery store," "the nearest post office," "a restaurant you like," "a bike repair shop," "your workplace," "the local elementary school" on 4-point scale where 1 = less than a mile, 2 = 1–2 miles, 3 = 2–4 miles, 4 = more than 4 miles
Transit access	1 (0,1)	There is bus or train service within a 5-minute walk of home. 0 = no, 1 = yes

[a]1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.

Multivariate Analysis

The original data set ($N = 965$) was narrowed down to a data set of $N = 912$ cases by excluding 53 cases that did not specify whether the respondent was male or female. As an initial analysis step, using the $N = 912$ data set, the statistical significance of differences between men and women was analyzed for all potential explanatory variables (Table 2). The substantial differences between genders on many variables suggested that market segmentation (i.e., segmenting pooled data into two subgroups, male and female) was appropriate. The pooled data were then disaggregated into two subsamples: female ($n = 401$) and male ($n = 511$). Based on Xing et al. (*24*), these subsamples were further filtered to include in the models only respondents who were bike owners, yielding a final working data set ($n = 657$) of two subsamples, with $n = 272$ for female and $n = 385$ for male.

TABLE 2 Variable Mean Scores, Female Versus Male

	Mean		
Variable	Female	Male	*P*-Value
Dependent variables: bicycled or not in past seven days	0.37	0.43	.063
Individual factor: sociodemographics			
Age (years)	**47.54**	**50.65**	**.002**
Education level	4.36	4.51	.122
Household size	**2.27**	**2.52**	**.001**
Income ($1,000)	**62.49**	**78.15**	**.000**
Car ownership	**0.95**	**0.98**	**.019**
Home ownership	**0.30**	**0.20**	**.002**
White	0.76	0.77	.894
Limit on biking	**0.15**	**0.09**	**.004**
Child assistance	**0.15**	**0.10**	**.038**
Individual factor: attitudes			
Biking comfort index	**2.29**	**2.47**	**.000**
Safety concern index	**1.75**	**1.60**	**.000**
Like biking	**2.53**	**2.64**	**.016**
Like driving	**2.38**	**2.58**	**.000**
Need car	2.76	2.82	.096
Limit driving	**3.54**	**3.32**	**.001**
Like walking	**4.11**	**3.90**	**.000**
Like transit	2.61	2.61	.947
Environmental concern	**0.55**	**0.44**	**.001**
Pro-exercise index	4.26	4.24	.828
Good health	3.95	3.87	.205
Biked in youth	0.96	0.97	.383
Self-selection index	0.33	0.30	.315
Bike repair index	**1.66**	**1.28**	**.000**
Social environment			
Good driver attitude index	2.98	3.00	.665
Biking normal index	**2.96**	**2.62**	**.000**
Children bike	3.41	3.49	.206
Bikers poor	2.00	2.04	.488
Bikers spend	2.81	2.88	.228
Bikers not concerned	**2.83**	**2.98**	**.042**
Physical environment			
Bike infrastructure index	**3.25**	**3.06**	**.000**
Hilly topography	1.37	1.28	.120
Safe destinations index	**1.68**	**1.51**	**.000**
Distances index	2.81	2.79	.595
Transit access	0.82	0.79	.258

NOTE: Boldface indicates a significant difference, $P < .05$ (one-way analysis of variance); valid $N = 912$ includes all cases where respondents stated yes or no to whether they "owned or had regular access to a bicycle (in working condition)" and specified their gender.

Because of the large number of potential explanatory variables (see Table 1) and the even larger number of potential interaction terms, the analysis approach consisted of three major steps: (*a*) the gender-specific models consisted of two separate models using female and male subsamples, respectively, to explore variables for potential interaction terms in a pooled model; (*b*) the pooled model was a combined model for men and women using pooled data; and (*c*) the pooled model with interaction terms started from the "best" pooled model obtained from the preceding step and added potentially valuable interaction terms indicated by the two gender-specific models to form the best combined model. With a comparison of the final specifications of the two gender-specific models, variables could be identified that appeared in one model but not the other, or that appeared to have significantly different coefficients according to *t*-tests. These variables were then included in the final model as interaction terms with either male or female. If the interaction term was significant in the final model, the conclusion was drawn that the effect of that variable differed by gender.

A binary logistic regression was used to estimate the models because it allows the prediction of a discrete outcome, such as that analyzed in this study. To find the best sets of explanatory variables, the same procedure used in Xing et al. (*24*) was followed: for each model, sociodemographic factors, individual attitudinal factors, social environment factors, and physical environment factors were entered as sets sequentially, then insignificant variables were deleted in a backwards stepwise process for each set of variables. This procedure helps to overcome the practical limitations of fitting a model with a large number of potential explanatory variables and the potential loss of cases due to missing values. The best gender-specific models and pooled model (as defined by relative goodness-of-fit and interpretability) derived from Steps (*a*) and (*b*) are presented in Table 3, while the final pooled model with interaction terms is shown in Table 4.

RESULTS AND ANALYSIS

Of the 657 valid respondents who owned a bicycle, 55.9% reported bicycling within the past week and 44.1% did not. Of these 367 respondents who reported bicycling, 59.7% were men versus 40.3% women. As anticipated, the share of bicyclists who are women is higher than in national surveys. Of the 272 female respondents who owned a bicycle, 148 (54.4%) reported bicycling, as did 219 (56.9%) of the 385 male respondents who owned a bicycle. Previous research has found that communities with higher levels of bicycling tend to have a higher ratio of female to male bicyclists; Davis, Boulder, and Eugene have bicycle commuting rates (14.4%, 6.9%, and 5.5%, respectively) much higher than the national U.S. average of 1% (*25*), and therefore would be expected to follow the trend of European countries discussed earlier that have more gender equity in bicycling levels (*20, 25, 26*).

Men and women diverged significantly on many of the explanatory variables (see Table 2); this difference suggests that the factors influencing bicycle use might differ for men and women even if their level of bicycling was not significantly different. For example, women report at a higher rate than do men physical limitations that prevent bicycling (15% versus 9%, respectively) and agree less, on average, that they like bicycling (2.53 versus 2.64, respectively, on a 5-point scale). However, multivariate analysis is needed to assess the relative importance of these factors in explaining male and female bicycle

TABLE 3 Logistic Regression Models for Bicycled or Not, Female Model, Male Model, and Pooled Model

	Model 1: Female Model		Model 2: Male Model		Model 3: Pooled Model	
Variable	Coefficient	OR	Coefficient	OR	Coefficient	OR
Constant	–6.436	0.002	–9.018	0.000	–6.752	0.001
Individual factor: sociodemographics						
Age	–0.035**	0.966				
Education level	0.266**	1.304	0.159*	1.172	0.235***	1.265
Home ownership					–0.609**	0.544
Limit on biking					–1.868**	0.154
Child assistance					0.684**	1.982
Individual factor: attitudes						
Biking comfort	1.325***	3.764			0.776**	2.174
Like biking	1.227***	3.411	1.354***	3.871	1.306***	3.693
Need car	–0.481**	0.618			–0.351**	0.704
Like transit	0.919***	0.399	–0.269*	0.764	–0.443***	0.642
Environmental concern	0.449**	1.566				
Good health	0.370**	1.447	0.254*	1.289	0.306***	1.358
Biked in youth			1.338**	3.810		
Self-selection			0.655*	1.925		
Social environment						
Good driver attitude	0.635***	1.886				
Biking is normal			0.271*	1.311		
Bikers poor					–0.313**	0.731
Physical environment						
Safe destinations					0.370*	1.448
Transit access			1.085***	2.960	0.791***	2.205
Valid *N*	254		369		587	
Pseudo-R^2	.331		.269		.312	
Model chi-square	249.478		389.714		587.427	

NOTE: OR = "odds ratio," representing the proportional change in the odds of bicycling for a one-unit increase in the variable.
*10% significance level, **5% significance level, ***1% significance level.

behavior. Furthermore, it is possible that the importance of the factors, not just their values, differ for men and women. The analysis that follows addresses these issues.

Initial Models: Gender-Specific Models and Pooled Model

The purpose of the two gender-specific models was to identify factors significant for men or women that potentially should be included as interaction effects. The female model was run with 272 survey cases; the male model was run with 385 cases; and the pooled model was run with all 657 cases that identified as male or female. The results are shown in Table 3.

Sociodemographics

Age was significant only in the female model: the older the respondent, the lower the odds that they reported bicycling, by a factor of 0.966 for every year increase in age. Significant to all three models was educational level, with both men and women who had higher education levels being more apt to bicycle. In the pooled model, three other sociodemographic factors were associated with greater odds of bicycling: not owning a home, having no physical or psychological conditions that limit bicycling, and having a child or children requiring assistance traveling.

Attitudes

Individual attitude factors play a leading role in explaining whether men and women bicycled in the week before the survey. Three factors were unique to the female model. Women who agreed with the statement "I need a car to do many of the things I like to do" had lower odds of bicycling by a factor of 0.618 for every unit increase in agreement. The second factor unique to the female model was a positive effect of concern for the environment on bicycling (odds ratio = 1.566). Third, women with high comfort index scores were more likely to have ridden than women scoring low on this comfort index. For each step on the comfort scale, the odds of biking increased by 3.764.

As in the female model, individual attitude factors play a leading role in explaining whether or not men bicycled in the week before the survey. Two factors were unique to the male model. First, having bicycled as a youth (defined as around 12 years old) increased the odds of bicycling by a factor 3.810. Second, if bicycling was a relatively important factor in residential location choice, the odds of bicycling were 1.925 times higher.

Of the three significant factors that only appeared in the female model, two were also significant in the pooled model: "bicycling comfort" and "need car." Neither individual factor that was significant in the male model but not the female model ("biked in youth" and "self-selection") was significant in the pooled model. Agreement with the statements "I like biking" and "I am in good health" were positive determinants of both male and female bicycling behavior in

TABLE 4 Logistic Regression Model for Bicycled or Not, Pooled Model with Interaction Terms

Variable	Pooled Model with Interaction Terms: Coefficient	OR
Constant	−7.899	0.000
Individual factor: sociodemographics		
Education level	0.241***	1.272
Home ownership	−0.681***	0.506
Limit on biking	−1.379*	0.252
Child assistance	0.744**	2.105
Individual factors:attitudes		
Like biking	1.370***	3.935
Like transit	−0.488***	0.614
Good health	0.265**	1.304
Biking comfort_female[a]	1.952***	7.046
Need car_female[a]	−0.537***	0.585
Biked in youth_male[b]	1.637***	5.138
Self-selection_male[b]	0.844**	2.326
Social environment		
Bikers poor	−0.320**	0.726
Physical environment		
Safe destinations	0.321*	1.379
Transit access_male[b]	1.046***	2.847
Valid *N*		590
Pseudo R^2		.327
Model chi-square		577.599

*10% significance level, **5% significance level, ***1% significance level.
[a]Interaction term with female
[b]Interaction term with male

all three models. In contrast, agreement with the statement "I like transit" decreased the odds of bicycling in all three models and suggests a substitution effect between bicycling and transit.

Social Environment

In the female model, women's perception that drivers in the community behave safely toward cyclists, as measured by the "good driver" index, had a positive effect on bicycling (odds ratio = 1.886). This factor was not a significant influence on men's bicycling behavior and did not appear in the pooled model. One social environment factor influenced men's bicycling behavior; a one-unit increase in the "biking is normal" index increased the odds of bicycling by a factor of 1.311. The only social factor that was a significant influence in the pooled model was the perception that bicyclists are poor; it was not significant, however, in either gender-specific model.

Physical Environment

There were no significant physical environment factors in the model for women. However, the physical environment may have an indirect influence through its impact on bicycling comfort.

Significant in both the male model and the pooled model was the transit access factor. In the male model, men who lived within a five-minute walk of bus or transit service had increased odds of bicycling versus men who lived more than five minutes away (odds ratio = 2.960), while for the pooled model, the odds increased by 2.205. The likelihood of bicycling increased if respondents felt safe bicycling to neighborhood destinations such as the post office, elementary school, grocery store, and restaurant or bike repair shop, an influence that was only significant in the pooled model.

Final Model: Pooled Model with Interaction Terms

The final model, shown in Table 4, was developed by starting from the final pooled model (Table 3) and adding potentially significant interaction terms suggested by the two gender-specific models. The significant interaction terms point to important differences in the factors that influence bicycling for women versus men.

Sociodemographics

The same four sociodemographic factors that were significant in the pooled model are significant in the final pooled model, with interaction terms "education level" and "child assistance" both having positive effects; and "home ownership" and "limit on biking" having negative effects. No interaction terms were significant, suggesting that the effects of these variables are they same for men and women.

Attitudes

Three gender-neutral attitude factors appeared in the final model: "like biking" and "good health," with positive effects; and "like transit," with negative effects. This result was robust across the models, and liking biking was one of the most important determinants of bicycling in all models.

Two male-specific and two female-specific attitude factors were significant in the final model. Men placing strong emphasis on living in a community that is good for bicycling were more likely to bicycle, suggesting a self-selection effect for men but not for women. In other words, the higher level of bicycling among men is partly related to a prior preference for bicycling that leads men to choose a community that is good for bicycling. Conversely, women are equally likely to bicycle in these cities regardless of whether they chose their city because of its bicycling environment. The fact that self-selection is not significant for women suggests a greater potential for the physical environment to influence women's than men's bicycling independently of preferences.

In addition, the odds of bicycling for male respondents who had biked in their youth was higher by a factor of 5.138, making it one of the most significant influences on bicycling in the final model. There have been few studies that have conducted gender-specific analysis of physical activity in children and how it correlates to adult physical activity. A number of social and environmental influences could be involved with this variable; research has found that males are more active than females in youth (*27*) and are allowed by their parents to roam farther spatially than female youths, suggesting that girls are more restricted in their bicycling than boys (*28–30*).

Female respondents who agreed that they need a car were less likely to bicycle, with a decrease in odds by a factor of 0.585 for every unit increase in agreement. Since this variable does not differentiate what the car is needed for (e.g., work, household tasks, or recreation), this result could have multiple interpretations. The negative influence could be partially explained by research discussed earlier that has found that women in two-working-parent families make many more stops for pick up, drop off, and errands (*19*). However, potentially the most important determinant of bicycling for women was their level of comfort bicycling, with an odds ratio of 7.046, the highest in all four models.

To understand better the gender difference with respect to the influence of bicycling comfort, the mean scores for each of the survey questions used to create the comfort index were examined (Table 5). These questions asked about comfort bicycling on six types of bicycling facilities using a three-point scale (1 = "uncomfortable and I wouldn't ride on it," 2 = "uncomfortable but I'd ride there anyway," and 3 = "comfortable"). Men were more comfortable on average than women on all types of facilities except a "quiet street." Women were generally comfortable on off-street paths, though somewhat less comfortable than men, perhaps because of a concern over personal safety on segregated and potentially less visible facilities, suggesting a possible trade-off between safety from traffic and safety from attacks; both men and women are less comfortable on off-street paths than quiet streets. Both men and women become less comfortable as the size of the street increases and if bike lanes are absent, but the decrease is more significant for women than men. On average, women would not ride on four-lane streets without bike lanes, while men would despite feeling uncomfortable. These results are not entirely consistent with observations by both Garrard et al. (*12*) and Krizek et al. (*4*) that women have a stronger preference for bicycling on facilities that are separated from traffic than do men. Of note, neither Garrard et al. nor Krizek et al. provided a facility preference choice in their surveys that satisfied both the need for safety from traffic and from assault, which the "quiet street" choice in our survey seemed to provide to survey respondents.

Social Environment

Only one social variable, the perception that bikers are poor, is significant in the final model. Social environment effects did not differ for men and women. It is notable that positive perceptions of the bicyclists in the community (e.g., bicycling is normal for adults) were not significant predictors of bicycling.

TABLE 5 Biking Comfort Variable Mean Scores for Gender Difference

Variable	Female Mean[a]	Male Mean[a]	P-Value
Biking comfort index	**2.29**	**2.47**	**.000**
Off-street path	**2.74**	**2.85**	**.002**
Quiet street	2.91	2.92	.658
Two-lane-local-street with bike lane	**2.70**	**2.84**	**.000**
Two-lane-local-street without bike lane	**1.65**	**1.97**	**.000**
Four-lane-street with bike lane	**2.38**	**2.59**	**.003**
Four-lane-street without bike lane	**1.36**	**1.63**	**.000**

NOTE: Boldface indicates a significant difference, $P < .05$ (one-way analysis of variance)
[a]3-point scale, with 1 = "uncomfortable and I wouldn't ride on it," 2 = "uncomfortable but I'd ride there anyway," and 3 = "comfortable."

Physical Environment

Two variables in this category were significant: "safe destinations" and the interaction term of "transit access" for males, both positively associated with bicycling. A perception of safe destinations to bicycle to in the respondent's neighborhood increased the likelihood of bicycling regardless of gender. However, this variable is only marginally significant ($0.05 < P < .10$) and has a much smaller effect than that of bicycle comfort. The male-specific "transit access" variable could perhaps be serving as a proxy for a set of neighborhood characteristics: denser neighborhoods that are easier to access by bicycle may also have more transit facilities.

CONCLUSIONS

This analysis offers new insights into the factors that explain gender differences in bicycling. Study results show that individual, social, and physical factors all play an important part in determining bicycle use and that these influences are often the same for men and women. However, they also highlight important differences in the factors that matter to men and women.

Individual factors were the most important influences, both for the gender-specific samples and the pooled sample. Consistent with Xing et al. (*24*), one of the most important gender-neutral factors was agreement with the statement "I like biking." Gender-specific influences were potentially stronger determinants of bicycle use, however. Biking in youth had a strong positive association with men choosing to bicycle. As discussed earlier, more research to determine why bicycling in youth is associated with men but not women choosing to bicycle as adults is required. The significance for men of a preference for a bicycling community suggests an indirect role for bicycle facilities in attracting residents who prefer to bicycle. Feeling comfortable using bicycle facilities was strongly positively associated with women's bicycle use, a finding that is supported by previous research on gender differences in bicycling. This finding, in conjunction with the significant positive influence of perception of bicycling safety to selected neighborhood destinations, also suggests an indirect effect of bicycle facilities on bicycle use through their influence on perceptions of bicycling safety.

This study suggests that gender differences in perceptions of bicycling safety combined with the effect of bicycle facility type could help explain different cycling rates for men and women. These results point to a need for gender sensitivity in the bicycle planning process and a reevaluation of the definitions of "experienced" versus "nonexperienced" bicyclist categories that guide U.S. bicycle infrastructure design (*31, 32*). Currently U.S. Federal Highway Administration (FHWA) guidelines are based on the assumption that experienced bicyclists are those who are comfortable riding under most traffic conditions: this assumption is found in both the design bicyclist categories and the Bicycle Compatibility Index (BCI) used by FHWA as important guidelines for bicycle infrastructure design and assessment (*31, 32*).

However, neither of these guidelines explicitly takes into account gender differences in bicycling behavior. FHWA classifies bicyclists into three standardized categories: (*a*) Group A, advanced bicyclists: experienced riders who operate under most traffic conditions, (*b*) Group B, basic bicyclists: casual or new adult and teenage riders who are less confident of their ability to operate in traffic without specific provisions for bicycles, and (*c*) Group C, children (*32*). Similarly, in a study by Harkey et al. on which the BCI is based, experienced riders were defined as “comfortable riding under most traffic conditions, including major streets with busy traffic and higher speeds” (*31*).

Both these guidelines assume that with enough experience bicyclists will become comfortable riding in traffic. However, research indicates that not only female bicyclists but also many male bicyclists of all levels of experience show a marked preference for bicycle facilities—bike paths and bike lanes—that separate them from vehicular traffic (*4, 15, 16*). But studies have also found that extensive bicycle path networks do not always create a strong bicycle community (*8, 16, 33*). Perhaps the FHWA bicycle design guidelines are partially responsible for this phenomenon: following them may result in facility design that creates conflict between bicyclists’ desire for safety and their preference for routes that are convenient to services. Because traffic-separated bicycle facilities in the United States are often designed for the FHWA-defined “inexperienced” bicyclist, there is less emphasis on incorporating these facilities into the community transportation network because it is assumed that bicyclists using these facilities are using them more for recreation than transportation purposes (*8, 16, 33*). If, as research suggests, women prefer to use traffic-separated facilities even as experienced bicyclists, does the use of these facilities that are usually designed for the “inexperienced” cyclist (*31, 32*) actually discourage women from bicycling because these facilities are often not as convenient for getting to services (*4, 8*)?

Although providing bicycle facilities that equally support the needs of both male and female bicyclists is an important step toward increasing U.S. bicycling levels, there are a number of other approaches that should be combined with bicycle facility design for a more comprehensive program. FHWA (*34*) suggests a joint approach of engineering, education, enforcement, and promotion of bicycling (*35*) to increase the U.S. bicycling rate. These approaches, combined with an understanding of how gender differences affect bicycling rates, could form the basis for strategies to increase bicycling among women. This will first require further research to demonstrate how the combination of gender differences interacts with individual, social, and physical factors to affect bicycling levels. The high rates of bicycling for women in other countries suggest much room for improvement in the United States.

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DISCUSSION

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The question the paper asks is, What explains this imbalance by gender in U.S. bicycling rates? To answer this question, the paper analyzes the results of an online survey of bicycle owners in six small cities in the western United States, including Davis, to find the correlation between how much they bicycled and various characteristics of the responders. The paper states, "For each of the six communities, a random sample of 1,500 residents, along with an additional sample of 1,000 residents for Davis (to capture residents who had recently moved to Davis), were each mailed a letter in June 2006 inviting them to participate in the online survey." The paper notes that the each city is about the same size but does not give the population or the number of bicycle owners in each city. The paper describes how nonresponses were handled: "A follow-up phone survey conducted in Davis in May 2008 to assess nonresponse bias yielded bicycling levels that were statistically indistinguishable from those in the online survey [see Xing et al. (*23*) for more details]." Finally, "in this paper, only those respondents who reported owning a bicycle are included in the analysis."

Several questions arise from this process:

1. How was the random sample of residents to receive letters selected?
2. Were only residents with listed telephone numbers included in the sample?
3. Were only residents with listed telephone numbers included in the follow-up phone survey?
4. Given that the number of letters sent to each city was not proportional to the population of the city, do the authors claim that the responses to the online survey represent a random sample of all residents in the six cities combined?
5. Was the question that the individual owned the bicycle or that the household owned one?
6. Given that the number of letters in each city was not proportional to the number of bicycle owners in the city, do the authors claim that the responses to the online survey represent a random sample of all bicycle owners in the six cities combined?
7. Do the authors claim that the results of their study can be extended to a population beyond the six small cities that were included in the survey?

The paper states that the six cities were selected "[t]o ensure variation in potential explanatory variables." Since all cities are about the same size and all are in the western United States, how does the selection of those cities ensure variation in potential explanatory variables? During the analysis of the survey, did the authors check whether it had achieved this goal?

It is notable that the respondent's city was not one of the explanatory variables. Did the authors explore how the responses varied among cities?

The paper states, "Of the 657 valid respondents who owned a bicycle, 55.9% reported bicycling within the past week." Yet the percentages of both female and male respondents who reported bicycling (37% and 43%) were lower than 55.9%. How can this be?

In describing the multivariate analysis, the paper states, "If the interaction term was significant in the final model, the conclusion was drawn that the effect of that variable differed by gender." But in several cases, the variable was not significant in either gender-specific model. If a variable is not significant in either gender-specific model, is it reasonable for the same variable to suddenly appear as significant in the final model?

In Table 1, the paper describes one of the statements under the section on bike infrastructure as "streets without bike lanes are generally wide enough to bike on." This question appears to show a bias by the authors, specifically that bicyclists are expected to stay out of the way of cars, even on a street without bike lanes for which the travel lanes are too narrow for a bicycle and vehicle to travel safely side-by-side within the lane.

Also in Table 1, the paper describes two of the statements under the good driver index as "most drivers [do not] seem oblivious to bicyclists" and "most people [do not] drive faster than the speed limit." Did a higher numbered response indicate stronger agreement with the original or the reversed meaning of the statement?

In Table 2, the paper reports that the mean ages of women and men respondents who owned a bicycle were 47.54 and 50.65 years, respectively. The mean age of all respondents, whether they owned a bicycle or not, was not reported. Did the authors attempt to compare statistics for all respondents with census or other data to check on the representativeness of their sample?

Also in Table 2, the mean scores of women and men on the "biked in youth" question were only 0.04 and 0.03, respectively. Does this mean that only 4% of women and 3% of men reported bicycling in their youth?

The paper states that in the pooled model, sociodemographic factors associated with greater odds of bicycling included "having a child or children requiring assistance traveling." Is this statement correct? If so, it is opposite to the expectation expressed in the beginning of the paper.

It is notable that the paper states that "agreement with the statement 'I like transit' decreased the odds of bicycling in all three models and suggests a substitution effect between bicycling and transit." This is in agreement with studies from Europe that found levels of bicycling dropping with increased transit usage.

The paper states that although "[t]here were no significant physical environment factors in the model for women . . . the physical environment may have an indirect influence through its impact on bicycling comfort." This appears to be a speculative statement. Have the authors explored ways of testing its truth?

The paper states, "The odds of bicycling for male respondents who had biked in their youth was higher by a factor of 5.138, making it one of the most significant influences on bicycling in the final model." But, as noted earlier, only 3% of male respondents reported bicycling in their youth. Is it possible to make a statement about the correlation between such a low positive "biked in youth" response among men and whether they bicycled in the past week?

In its conclusion, the paper states, "More research to determine why bicycling in youth is associated with men but not women choosing to bicycle as adults is required." But the multivariate regression reported in the paper expresses only a correlation, not cause and effect. Are the authors claiming a cause and effect relationship between men bicycling in their youth and whether they bicycled in the past week?

Also, in its conclusion, the paper states, "Feeling comfortable using bicycle facilities was strongly positively associated with women's bicycle use." Again, are the authors claiming a cause and effect relationship where they have only shown a correlation?

Regarding the same statement, even if a cause and effect relationship could be established between women feeling comfortable using bicycle facilities and the amount they bicycled, how do the authors know that improving bicycle facilities is the best way to increase the amount of bicycling? Perhaps their perception of the safety of the roads could be affected by education into the real hazards of bicycling in mixed traffic compared with that on bicycle facilities.

The paper states that its results "point to a need for gender sensitivity in the bicycle planning process and a reevaluation of the definitions of 'experienced' versus 'nonexperienced' bicyclist categories that guide U.S. bicycle infrastructure design." Indeed, the paper notes that both experienced and nonexperienced bicyclists prefer bike lanes and bike paths over mixed traffic, which makes one question what experience has really been gained. Perhaps real skill comes not from the number of years a person has bicycled but in his or her ability to operate as the driver of a bicycle in traffic. It is notable that the survey asked only about perceptions of safety and not whether the respondent had taken a class given by the League of American Bicyclists or a similar class to learn how to bicycle in mixed traffic and what the real dangers are. The perceptions and preferences of people who have taken such classes differ greatly from people who have not.

Education is mentioned only in the context of combining facility design with a more comprehensive program in the last paragraph of the paper. I agree that further research is needed to explore how gender differences interact with individual, social, and physical factors to affect bicycling levels, but I would hope that education, enforcement, and equality would be given more weight than they are in this paper.

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