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Motivators and deterrents of bicycling: comparing influences on decisions to ride

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Abstract In a survey of 1,402 current and potential cyclists in Metro Vancouver, 73 motivators and deterrents of cycling were evaluated. The top motivators, consistent among regular, frequent, occasional and potential cyclists, were: routes away from traffic noise and pollution; routes with beautiful scenery; and paths separated from traffic. In factor analysis, the 73 survey items were grouped into 15 factors. The following factors had the most influence on likelihood of cycling: safety; ease of cycling; weather conditions; route conditions; and interactions with motor vehicles. These results indicate the importance of the location and design of bicycle routes to promote cycling.

Keywords Bicycle · Survey · Infrastructure · Influence · Non-motorized transport

Introduction

With the rising pressures of climate change and illnesses related to physical inactivity (Katzmarzyk 2002; Colman and Walker 2004), there is increasing interest in shifting the automobile-dominated culture toward active transportation modes (Dora 1999; Sallis et al. 2004). Incorporating bicycling into daily travel patterns offers benefits for both individual and environmental health, with negligible economic cost (Cavill and Davis 2007). Furthermore, cycling is a feasible transportation mode: over 60% of Canadian adults have a bicycle, and more than 80% live within a reasonable cycling distance (<8 km) of at least

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one common destination (Go For Green 2004). Still, cycling mode share is low in North American cities, as compared to European centres (Pucher and Dijkstra 2003; Pucher and Buehler 2005). Evidence is needed on the types of initiatives that will create a supportive environment for cycling, and induce positive, long-term changes in travel behavior and physical activity patterns (Heath et al. 2006).

The friendliness of a city toward cycling is a function of the policies, programs, and facilities in place (Pucher and Buehler 2006, 2008). To determine which elements might be the most likely to influence cycling, we conducted a survey ("Cycling in Cities") of a population-based random sample of current and potential cyclists in Metro Vancouver, Canada. The focus was on those already cycling and those contemplating cycling (the "near market"), a strategic approach based on the Theory of Change used in many domains of health promotion (Prochaska and Velicer 1994, 1997), and previously used in cycling research (Accent Marketing & Research 2004; Gatersleben and Appleton 2007; Steer Davies Gleave 2008). The survey encompassed 73 items, a broad array of potential motivators and deterrents identified from other surveys, qualitative and quantitative research, and input from local policy makers and advocates. The results provide evidence on the relative importance of a wide range of items that could motivate or deter cycling.

Survey design and administration

The Cycling in Cities Survey was conducted in Metro Vancouver, British Columbia, an urban region of western Canada comprised of 22 municipalities that is home to approximately 2.1 million people (Metro Vancouver 2006). The region has widely varying neighbourhood characteristics and transportation infrastructure, with bicycle mode share estimated at 1.7% region-wide, and at 3.1% within the City of Vancouver (Translink 2004), a somewhat higher proportion of cyclists than other Canadian cities (Winters et al. 2007). The climate is conducive to cycling year-round, with all monthly average low temperatures above freezing, although the region receives substantial rainfall (over 1200 mm rain/year) (Environment Canada 2009). The regional bicycle route network has over 1,350 km of designated bicycle routes (Fig. 1), with about 170 of the bike routes off road. The road network has over 400 km of freeways and highways, 1400 km of arterial roads, 1500 km of collector roads, and 6500 km of local roads.

The survey was funded by the Transport Canada Moving on Sustainable Transport program, TransLink (the regional transit authority) and local municipalities. All study methods were reviewed and approved by the University of British Columbia's Behavioural Research Ethics Board. The survey was conducted in three seasonal waves in 2006 (February–April, May–July, September–December). This prevented bias based on the season of the survey, since weather, available daylight, and personal schedules might impact respondents' opinions about cycling. Details of the survey development and administration have been published elsewhere (Winters and Teschke in press). The survey instruments are available from the corresponding author. In brief, there were two questionnaires: a *telephone interview*, and a *self-administered survey* (either via the web or mail). The *telephone interview* filtered participants for eligibility and willingness, and collected demographic information, travel patterns and transport mode. The self-administered *follow-up* survey asked about use of and preference for bicycle route types (see Winters and Teschke in press) and about potential motivators and deterrents of cycling (the subject of this paper). In each survey period, a random sample of 4,000 names, addresses and telephone numbers was selected from the phone directory. Each selected household

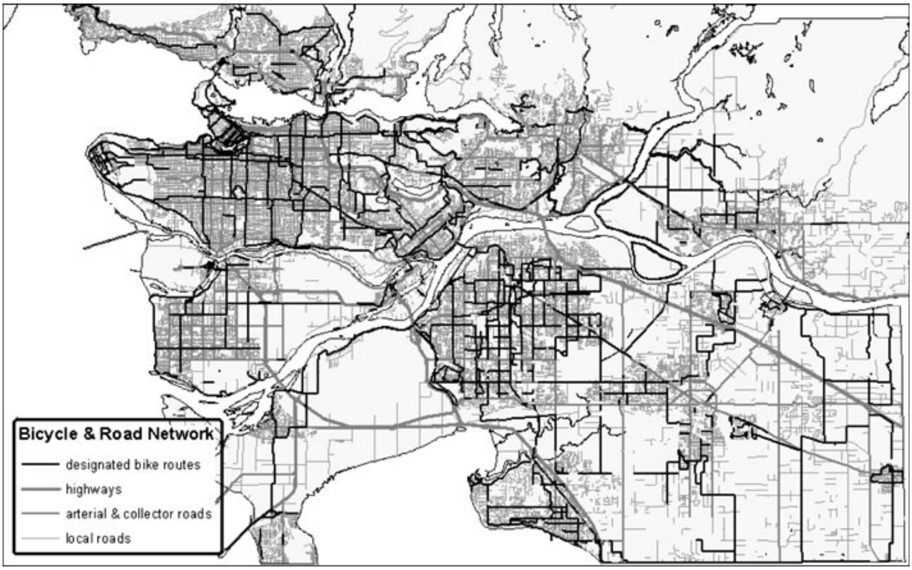

Fig. 1 Bicycle route and road network of Metro Vancouver

was mailed an introductory letter outlining the study purpose and the intended use of the information. In the second and third survey periods this was complemented by recruitment through random digit dialing to increase the numbers of participants. Given that the sampling frame was based on the telephone directory, the approximately 10% of the population who have only unlisted cellular telephone numbers would not be captured (representative of Telus, the landline carrier for the province of British Columbia, pers. comm, unpubl.).

The telephone survey had a contact rate for valid phone numbers of 40.3%. These respondents were screened for age, sex, regional representation and eligibility. To be eligible, respondents were required to be either *current* or *potential cyclists*, that is, they had to (1) have access to a bicycle and (2) either have cycled in the past year or be willing to consider cycling in the future. Of those contacted, 31% fit these criteria and were invited to participate in both portions of the survey. In total, 2,149 individuals completed phone interviews, and 65% of those ($n = 1{,}402$) completed the follow-up questionnaire. The population was categorized according to reported cycling patterns to identify differences in motivators and deterrents based on frequency of cycling. The groups were: *potential cyclists*, who had not cycled in the previous year, but had access to a bicycle and would consider cycling in the future; *occasional cyclists* (who cycled at least yearly, i.e., 1–11 trips/year); *frequent cyclists* (who cycled at least monthly, i.e., 12–51 trips/year); and *regular cyclists* (who cycled at least once a week, i.e., cycled $\geq$52 trips/year).

The extensive list of potential motivators and deterrents was compiled from transportation and health promotion literature on influences on bicycle use. The list was revised and refined by project partners (TransLink, the regional transportation authority, bicycle coordinators from the participating municipalities, members of cycling advocacy groups) and through pre-testing with focus groups. A total of 73 items were included in the follow-up questionnaire, presented under 13 general categories: vehicles; lane markings; intersections; distances, hills and connections; road surfaces and maintenance; aesthetics and access; coordination with transit; social interactions; safety; weather and darkness; legislation; and information and incentives. The survey questions asked "how would [item X] influence your decision to cycle?" with responses on a 5-category behavioral intent scale: much less likely to cycle (influence score = −1); less likely to cycle (score = −0.5); no influence on decision to cycle (score = 0); more likely to cycle (score = 0.5); much more likely to cycle (score = 1). 'Don't know' and refused responses (<4% for any item) were excluded from analyses.

Data summarization and analyses

Data from the telephone interviews was entered using a computer-assisted telephone interview (CATI) system. Web-based questionnaires were entered to an electronic database and paper-based surveys were entered to match the format of the web-based questionnaires.

SAS version 9.1 (SAS Institute, Cary, NC) statistical software was used for data management and analysis. Analyses included descriptive statistics (counts or proportions for categorical variables; means, standard errors, ranges, and frequency distributions for continuous variables). Responses were weighted to achieve results representative of the age, gender and geographic distributions of the region. Because of the large sample size, very small differences were statistically significant. Therefore rather than reporting the many statistically significant differences, standard errors are reported, so readers can make comparisons of importance to themselves. The discussion focuses on differences that are meaningful (i.e., differences of at least 5% for demographic characteristics, mean score differences of at least 0.35, consistent trends across cyclist experience categories).

Exploratory factor analysis (EFA) was done to identify underlying constructs among the 73 motivators and deterrents. We employed Proc Factor in SAS with the maximum likelihood option and orthogonal rotation to produce uncorrelated factors. Fifteen factors were extracted based on the scree plot and the Kaiser criterion (all factors with eigenvalues greater than one), and each was assigned a conceptual name based on the items that loaded on it.

Survey results

Of the 1,402 respondents who completed the follow-up survey, 197 were potential cyclists (weighted % = 13.8%), 617 were occasional cyclists (43.5%), 481 were frequent cyclists (34.6%), and 107 were regular cyclists (8.1%). Table 1 describes the demographic characteristics of the population, by cyclist type. Frequent and regular cyclists were more likely to be male (57.5 and 58.3%, respectively), and regular cyclists were less likely to have access to a car than other groups (only 78.4% had access, compared with 94% or more in other cyclist groups) and had more bicycles and fewer vehicles in their household, on average. As compared to the Metro Vancouver adult population, the "near market" population tended to be somewhat younger (53% of respondents between ages 35 and 54 in comparison with 43% of adults in this age group across the region) and were more likely to have some post-secondary education (87% of the near market versus 67% of overall population)(Statistics Canada 2006).

The mean scores for the 73 survey items ranged from a high of 0.79 to a low of −0.86, on the scale of +1 to −1, where positive scores indicated motivators and negative scores

Table 1 Demographic characteristics of respondents who completed the web/mail survey (n = 1,402) according to cyclist type[a]

	Cyclist type[a]				Overall[b]
	Potential	Occasional	Frequent	Regular	
Weighted % of total (n)	13.8 (197)	43.5 (617)	34.6 (481)	8.1 (107)	100 (1402)
Gender					
Male (%)	45.1	49.0	57.5	58.3	52.1
Age					
19–24 (%)	6.3	10.4	5.1	12.3	8.2
25–34 (%)	19.1	20.1	21.0	21.7	20.4
35–44 (%)	31.0	26.7	30.8	22.8	28.4
45–54 (%)	22.8	23.1	23.1	21.0	22.9
55–64 (%)	12.0	14.6	13.9	14.8	14.0
65 & older (%)	8.8	5.0	5.9	6.5	6.0
Education					
Some high school or less (%)	2.1	0.9	0.7	1.0	1.0
Graduated high school or less (%)	13.2	11.5	9.6	12.7	11.2
Some post-secondary (%)	82.9	86.4	88.5	85.5	86.6
Employment					
Full time (%)	51.9	54.9	56.2	52.1	54.7
Part time (%)	11.2	12.3	11.7	11.5	11.9
Self employed (%)	8.7	11.3	11.9	16.5	11.6
Student (%)	2.1	5.8	6.1	4.5	5.3
Retired (%)	14.4	7.6	9.5	7.3	9.2
Not employed (%)	8.8	6.4	3.3	5.3	5.6
Household income[c]					
<30,000 (%)	10.6	7.1	8.5	14.1	8.6
30–59,000 (%)	17.9	20.1	16.6	23.4	18.9
60–89,000 (%)	21.6	19.5	23.8	12.3	20.7
>90,000 (%)	30.3	32.7	30.0	33.2	31.5
Mean # of children/household	0.9	0.9	0.7	0.5	0.8
Access to car (% yes)	96.7	95.4	94.0	78.4	93.7
Mean # of motor vehicles/household	1.8	1.9	1.8	1.4	1.8
Mean # of bicycles/household	2.4	2.9	3.0	3.6	2.9

[a] Potential cyclists = never in past year; occasional cyclists = 1–11 one-way trips/year; frequent cyclists = 12–51 one-way trips per year; regular cyclists = 52 or more one-way trips per year

[b] The "near market" population was somewhat younger than the general population (across the region 53% of adults are between 35 and 54) and more educated (67% of the population have some post-secondary education) (Statistics Canada 2006)

[c] 20.3% of responses to household income were "refused/don't know"; all other variables had <2% "refused/don't know/other" responses

deterrents. Figure 2 shows the top 10 motivators and top 10 deterrents overall, as well as the distributions of responses to these items according to cyclist type. The top 10 motivators had mean scores ranging from 0.49 to 0.79. The strongest motivators were routes that were away from traffic, aesthetically pleasing, and easy to cycle. The top ten deterrents

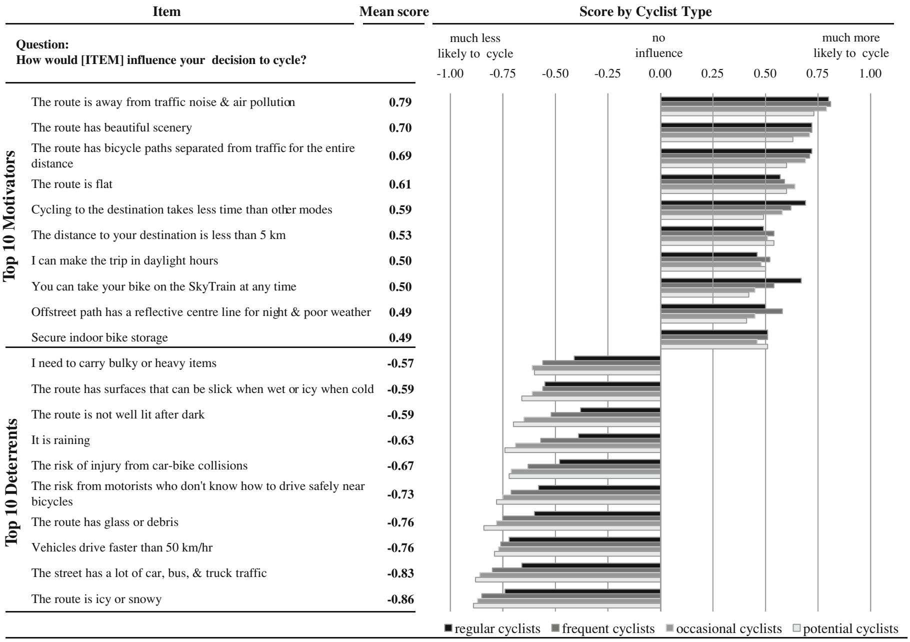

Fig. 2 Top 10 motivating and top 10 deterring influences on cycling, of 73 items asked of survey respondents ($n = 1{,}402$) (less than 4% missing responses for any item). Mean scores overall and as reported by each cyclist type (potential cyclists=never in past year; occasional cyclists = 1–11 one-way trips/year; frequent cyclists = 12–51 one-way trips per year; regular cyclists = 52 or more one-way trips per year)

had mean scores ranging from −0.57 to −0.86. The strongest deterrents were unsafe surfaces and interactions with motor vehicles.

Mean scores and rankings of the main motivators and deterrents were very similar across cyclist types (Fig. 2), and indeed across all 73 items (data not shown). Where important differences existed, mean scores were highest for regular cyclists (most easily motivated) and lowest for potential cyclists (least easily motivated), so differences were greatest between these groups. The following five items had the greatest differences by cyclist type. “The street is wide enough for motorists to safely pass cyclists” was perceived as a neutral influence for potential cyclists (mean score = −0.08), but a moderate motivator for regular cyclists (0.34). “The distance to your destination is 10–20 km” was a strong deterrent for potential cyclists (−0.50) but had no influence on regular cyclists (−0.10). “I need to buy groceries” was a moderate deterrent for potential cyclists (−0.33), but no influence for regular cyclists (0.07). “It is raining” was a stronger deterrent for potential cyclists (−0.74) than regular cyclists (−0.39), while “The weather is hot & humid” was a moderate deterrent to potential cyclists (−0.33), but had no influence for regular cyclists (0.06). These are all safety and comfort related items that would be expected to vary with cycling experience level and equipment.

Table 2 summarizes the mean scores and standard errors for all 73 survey items. The standard errors (SE) range from 0.007 to 0.017, so differences in mean scores of more than 0.03 to 0.07 (2*1.96*SE) have confidence limits that do not overlap. Given that mean scores range from −0.86 to 0.79, many are significantly different from each other.

In Table 2, the survey items are grouped by the 15 factors identified in factor analysis and ranked according to their strength of influence (either motivation or deterrence). The

Table 2 Means and standard errors for each survey item, and results of factor analysis. Items grouped by factor, and ordered from highest to lowest strength of motivation or deterrence (i.e., absolute value of mean influence on likelihood of cycling). Items and factors with absolute values of mean scores ≥0.5 in bold

Factor analysis		Survey items and influence scores			
Factors (eigenvalue)	Loading on factor	Items (individual motivators and deterrents)	Influence on likelihood of cycling: Mean[a] for Question	(SE[b]) for Question	Mean[c] for Factor
Safety (2.76)	0.75	The risk from motorists who don't know how to drive safely near bicycles	**−0.73**	(0.010)	**−0.58**
	0.75	The risk of injury from car-bike collisions	**−0.67**	(0.011)	
	0.64	The risk of bicycle theft	**−0.56**	(0.010)	
	0.68	The risk of violent crime when cycling	**−0.55**	(0.012)	
	0.53	The risk from cyclists who don't know how to ride safely	−0.37	(0.011)	
Ease of cycling (1.85)	0.46	The route is flat	**0.61**	(0.010)	**0.56**
	0.48	Cycling to the destination takes less time than traveling by other modes	**0.59**	(0.011)	
	0.65	The distance to your destination is less than 5 km	**0.53**	(0.012)	
	0.24	I can make the trip in daylight hours	**0.50**	(0.013)	
Poor weather and darkness (1.41)	0.47	The route is icy or snowy	**−0.86**	(0.007)	**−0.56**
	0.57	It is raining	**−0.63**	(0.010)	
	0.37	The route is not well lit after dark	**−0.59**	(0.011)	
	0.35	The weather is hot & humid	−0.16	(0.013)	
Pleasant route conditions (1.97)	0.70	The route is away from traffic noise & air pollution	**0.79**	(0.009)	0.48
	0.77	The route has beautiful scenery	**0.70**	(0.010)	
	0.26	The route is wide enough for cyclists to ride side-by-side	0.40	(0.011)	
	0.21	There are shops, banks, & grocery stores along the route[d]	0.34	(0.013)	
	0.23	I am making the trip with other people	0.18	(0.014)	
Interactions with motor vehicles (2.43)	0.69	The street has a lot of car, bus, & truck traffic	**−0.83**	(0.009)	−0.48
	0.67	Vehicles drive faster than 50 km/hr	**−0.76**	(0.010)	
	0.56	The street has on-street parking	−0.43	(0.012)	
	0.48	The street is wide enough for motorists to safely pass cyclists	0.10	(0.017)	
Route surfaces (2.92)	0.56	The route has glass or debris	**−0.76**	(0.008)	−0.43
	0.61	The route has surfaces that can be slick when wet or icy when cold	**−0.59**	(0.009)	
	0.72	The route has potholes or uneven paving	**−0.55**	(0.010)	
	0.23	There are bridges along the route where cyclists must share a narrow sidewalk	−0.34	(0.012)	
	0.67	The route has lots of fallen leaves	−0.29	(0.010)	
	0.57	The route surface is gravel or dirt	−0.25	(0.012)	
	0.47	The route has speed bumps	−0.25	(0.011)	

Table 2 continued

Factor analysis		Survey items and influence scores			
Factors (eigenvalue)	Loading on factor	Items (individual motivators and deterrents)	Influence on likelihood of cycling		
			Mean[a] for Question	(SE[b]) for Question	Mean[c] for Factor
Integration with transit (3.45)	0.74	You can take your bike on the SkyTrain at any time	**0.50**	(0.012)	0.42
	0.84	The bus has racks that carry bikes	0.45	(0.011)	
	0.77	There are secure bike lockers at transit stations	0.41	(0.011)	
	0.68	There are bike racks at transit stations	0.30	(0.011)	
Carrying loads (1.51)	0.79	I need to carry bulky or heavy items	**−0.57**	(0.013)	−0.40
	0.73	I need to buy groceries	−0.23	(0.014)	
Bike parking (1.19)	0.63	The destination has covered bike racks, to protect from rain	0.47	(0.011)	0.39
	0.59	The destination has outdoor bike racks	0.42	(0.011)	
	0.31	The destination has rental bike lockers[d]	0.27	(0.011)	
End of trip facilities (3.34)	0.48	The destination has secure indoor bike storage	0.49	(0.011)	0.37
	0.91	The destination has a place to store a change of clothing	0.38	(0.011)	
	0.84	The destination has a place to dry your cycling gear	0.36	(0.011)	
	0.87	The destination has showers	0.34	(0.011)	
	0.41	The destination has bike repair facilities	0.28	(0.010)	
Education, information, incentives (2.61)	0.41	Information about cycling routes to the destination is available	0.46	(0.010)	0.36
	0.41	A web-based trip-planning tool is available	0.45	(0.010)	
	0.57	I would be eligible to receive prizes or discounts such as savings on bike gear	0.35	(0.011)	
	0.80	Inexpensive or free short courses are available to help me learn how to fix my bike	0.30	(0.010)	
	0.77	Inexpensive or free short courses are available to help me improve my cycling skills	0.24	(0.010)	
Lane marking, signage (6.46)	0.36	The route has bicycle paths separated from traffic for the entire distance	**0.69**	(0.011)	0.34
	0.59	A 2-way off-street bike path has a reflective centre line for night & poor weather cycling	0.49	(0.014)	
	0.58	The route has bike signage, pavement markings & bike activated signals on residential streets	0.47	(0.012)	
	0.80	There is a consistent type of bike lane marking throughout the greater Vancouver area	0.41	(0.014)	
	0.54	The route has on-road bicycle lanes on major roads for the entire distance	0.36	(0.014)	
	0.51	Traffic calming on designated bike routes reduces the number of cars using the route	0.36	(0.013)	
	0.81	The bike lane has a different colour pavement than the road	0.35	(0.014)	

Table 2 continued

Factor analysis		Survey items and influence scores			
Factors (eigenvalue)	Loading on factor	Items (individual motivators and deterrents)	Influence on likelihood of cycling: Mean[a] for Question	(SE[b]) for Question	Mean[c] for Factor
	0.77	A bicycle is stenciled every 75 meters (250 feet) along the route	0.28	(0.013)	
	0.78	A solid white line is painted on both sides of the lane separating it from moving cars & from parked cars	0.26	(0.015)	
	0.73	The bike lane has one solid white line painted between moving cars & the bike lane	0.16	(0.014)	
	0.50	Bike lane markings end just before intersections	−0.13	(0.012)	
Physical challenge of trip (1.49)	0.37	The route has long steep sections	**−0.50**	(0.011)	−0.18
	0.71	The distance to your destination is 10 to 20 km	−0.37	(0.014)	
	0.71	The distance to your destination is 5 to 10 km	0.14	(0.015)	
	0.25	The route has a few small hills	0.02	(0.011)	
Intersections, traffic signals (1.72)	0.49	Cyclists have to stop at many stop signs on the route	−0.37	(0.010)	−0.10
	0.33	Designated bike routes on residential streets are used by cars because there are fewer stop signs	−0.31	(0.013)	
	0.51	The route has push-button-activated traffic signals for cyclists & pedestrians only	0.30	(0.013)	
	0.40	The route has rail crossings	−0.13	(0.009)	
	0.44	Many intersections on the route have traffic circles	−0.12	(0.013)	
	0.53	The route has regular traffic signals for all traffic (cyclists, pedestrians, cars & trucks)	0.01	(0.012)	
Laws related to cycling (1.65)	0.60	Cycling on sidewalks is not allowed	−0.22	(0.012)	0.00
	0.53	Cycling helmets are required	0.14	(0.013)	
	0.55	Lights are required for cycling after dark	0.13	(0.013)	
	0.65	Cycling side-by-side on roads is not allowed	−0.05	(0.010)	

[a] Weighted mean score, where +1 = much more likely to cycle, +0.5 = more likely to cycle, 0 = neutral, −0.5 = less likely to cycle, and −1 = much less likely to cycle

[b] Standard error of the mean

[c] Mean of weighted mean scores for each item in the factor

[d] Item could have been loaded on another factor: integration with transit

grouping factors with the strongest potential influence on cycling were safety, ease of cycling, poor route conditions and weather, pleasant route conditions, and interactions with motor vehicles. These five factors included the top 7 motivators and the top 7 deterrents. The following factors were likely to have more moderate influences on likelihood of cycling: route surfaces; integration with transit; carrying loads; bike parking; end of trip facilities; education, information, and incentives; and lane marking and signage. Factors with very little influence on cycling were laws related to cycling, intersections and traffic signals, and the physical challenge of a trip.

Discussion

This survey evaluated the relative importance of 73 potential motivators and deterrents of cycling among current and potential cyclists in the metropolitan area of Vancouver, Canada. This study contributes to the literature in the following ways: first, it captures opinions of a clearly delineated population-based sample, one most relevant to increasing modal share; second, it queries a wide array of characteristics not previously studied and compared in a single survey; and third, it illustrates that there are clear differences in the potential values of various policies, programs, and facilities for influencing cycling.

Transportation planners have categorized four “E’s” of cycling: engineering, education, encouragement, and enforcement (FHWA: US Department of Transportation Federal Highway Administration). This framework has been commonly adopted in municipal and regional bicycle planning in Canadian and US cities (e.g., Vancouver, BC, Boulder, CO and Madison, WI). Most of the 15 factors identified in our analysis can be mapped onto one of the four Es. Engineering would encompass “interactions with motor vehicles”, “route surfaces”, “lanes markings and signage”, and “intersections and traffic signals”. Encouragement would encompass “integration with transit”, “bike parking”, and “end of trip facilities”. Education would map to the factor “education, information and incentives”, and enforcement would map to “laws related to cycling”.

However, many of the factors with the most perceived influence in our analysis do not fit well in the 4E scheme. A fifth E—environment—would address the physical, safety and social environments that are often reported to influence physical activity, and cycling specifically (Giles-Corti and Donovan 2002; Hunt and Abraham 2007). The factors from our analysis that would fit here include “safety”, “ease of cycling”, “weather conditions and darkness”, “pleasant route conditions”, “carrying loads”, and “physical challenge of trip”. Many of these factors would be best addressed in the initial phases of route planning, when selecting the location of a cycling route, for example, locating routes away from noise and air pollution, along minimum grades, and in areas with aesthetically pleasing scenery. The importance of environmental conditions concurs with findings of the National Active Transportation Survey of Canadian adults, where better weather and increased safety in traffic were the 1st and 2nd ranked items (of 14) that would help them cycle more often (Go For Green 2004).

Key engineering items were related to bicycle facility location (away from high traffic speeds and volumes), design (i.e., bike paths separated from traffic; bike signage, pavement markings & bike activated signals on residential streets) and maintenance (smooth surfaces). These themes corroborate the results of the other part of our Cycling in Cities Survey on route types (Winters and Teschke in press), where the most preferred route types were off-street paths, cycle tracks along major roads but separated from traffic by a barrier, and designated bike routes on residential streets with traffic calming. The influence of traffic was also apparent in a recent stated preference survey on route choice trade-offs of Texan cyclists, where motorized traffic volumes and speeds were the most influential variables, when compared to on-street parking, bicycle route characteristics, and physical characteristics (hills and stops) (Sener et al. 2009). Route features were also mentioned in the National Active Transportation Survey (Go For Green 2004), where better designed on-road routes was the 4th ranked item, continuous routes to key locations was the 5th ranked item, and maintenance was the 7th ranked item. Our findings add to previous research by providing much more detail on the subtleties of route design. While particular engineering items were very strong motivators (“the route has bicycle paths separated from traffic for the entire distance", mean score = 0.69), others had little influence ("the bike lane has a solid white line painted between moving cars and the bike lane", mean score = 0.16).

The Cycling in Cities Survey had the benefit of a large sample size representative of the regional population of both current and potential cyclists. Sampling techniques for surveys have often focused on specialized populations such as students (Shannon et al. 2006), on recruitment from bicycle list-serves or clubs (Antonakos 1994; Moritz 1997; Stinson and Bhat 2004), or on regular cyclists (by stopping commuters or tagging locked bicycles) (Aultman-Hall and Hall 1998; Troped et al. 2001). A focus on students or those who cycle most often may not capture the motivators and deterrents important to women, adults with children, and older men, all of which are demographics under-represented among North American cyclists (Pucher and Dijkstra 2003; Pucher and Buehler 2005; Schneider et al. 2006). This survey excluded individuals without access to a bicycle, or who were not willing to cycle (69% of those contacted) but was representative of the remaining 31% of the population. The sampling approach was population-based, but focused resources on understanding the opinions of those currently willing to change travel behaviors; the "contemplating" population, or those with the greatest potential to increase mode share in the short to medium term. We included both current cyclists and potential cyclists as the "near-market" for cycling. Individuals in the regular cyclist group are avid commuters, cycling at least once per week. However, the other cyclist groups show great potential to increase their cycling patterns: frequent cyclists, cycling only monthly, and occasional cyclists, cycling only yearly, could certainly be encouraged to make more bike trips given the right conditions; and potential cyclists, who currently don't cycle but are willing to cycle more in the future, represent the greatest latent demand for cycling.

The reported influence of the 73 items included in the survey was similar across the regular, frequent, occasional, and potential cyclist groups. Any differences in influence scores varied most between the two extremes of cyclist type—the potential and the regular cyclists—but still the difference was rarely more than 0.2 on the scale of −1 to +1. Others have reported that cyclists are a non-homogenous group in terms of route choices and preferences. In an analysis of actual route choices, Aultman and colleagues (Aultman-Hall et al. 1997) suggested that there were two types of cyclists, those who are not averse to cycling on direct routes that may be major roads with traffic, and those who are willing to travel longer distances for better route options. In our population, long distances, proximity to motor vehicles, hot or rainy weather, and needing to shop had less deterrent effect for regular cyclists, than for the other groups. These different populations were evidence in the route type preferences observed in the other part of this survey (Winters and Teschke in press): regular cyclists scored routes along major roads higher than potential cyclists did (though both groups ranked paved off-street paths for cyclists only as their top route choice). The fact that there were so few differences between regular and potential cyclists is encouraging for planning: improvements related to the strongest motivators and deterrents have the potential to increase cycling of the whole near market population, not only a select subset.

Survey strengths and limitations

This survey of motivators and deterrents of cycling included a list of 73 potentially influential items developed based on previous literature and expert opinion. This broad range of items complements results from stated preference surveys on cycling, which quantify trade-offs between options (i.e., willingness to travel longer for a more desirable route type) but are limited in the number of comparisons they can make (Stinson and Bhat

2003; Krizek 2006; Sener et al. 2009). By capturing opinions on each item individually, components can be combined to optimize design. For example, off-street paths provide the desired separation from traffic, noise, and air pollution, but other strongly influential items should also be considered in the design; ideally such paths should also be flat, lit, and provide direct routes between common destinations. Still, some items were excluded during survey development in the interest of minimizing respondent burden. In many cases, these were subtle design features of interest to transportation engineers, but difficult to describe in a self-administered survey. In a survey of such scope, using pictures or videos of environmental or infrastructural items, or detailed descriptions for programs or incentives was not feasible. The questionnaire was pretested with cyclists, advocates, and the general public to ensure items were clearly written and understood, but respondents' responses were still subject to their own interpretation of each item.

We used mean scores to summarize study findings, based on a scale from $+1$ to -1, where positive scores were motivators and negative scores were deterrents. Mean scores averaged the ordinal scale responses (much more likely to cycle, more likely to cycle, neutral, less likely to cycle, much less likely to cycle). This approach assumes that the difference between any two adjacent categories is identical when in fact it may not be. In addition, a summary mean does not provide a picture of the underlying variability in responses. In the extreme case, a neutral mean score could result either if all individuals had a neutral response, or alternatively if half the population felt it was strong deterrent and the other half a strong motivator. Such extremes of opinion were not observed in this survey; only 1 item ("the street is wide enough for motorists to safely pass cyclists") had a bi-modal distribution.

This study was conducted in a single geographical location, but one that is comparable to many other cities in the western world. The Metro Vancouver region has a temperate climate that is similar to many European and North American centres influenced by coastal weather patterns. Its population density ($\sim$1000/people per km^2 in the region as a whole and $\sim$5000/km^2 in the City itself) spans the range of most North American and European cities with at least 100,000 population (Metro Vancouver 2006; Demographia 2009).

Finally, these findings are based on behavioral intent, not actual behavior. In other concurrent manuscripts, we have used GIS to conduct analyses of the actual travel behaviors made by this same study population, to determine how urban form affects mode choice between cycling and driving (Winters et al. under review), and also how it affects route choice for cyclists or drivers (Winters et al. in press). Such analyses, as well as those underway elsewhere (Dill and Gliebe 2008) will provide other sources of evidence about the types of infrastructure and environments that influence choice of cycling. Outcomes of these travel behavior studies can be used to test whether opinions are translated into actions, though they cannot provide relative rankings of the broad scope of items included in this survey.

Conclusions and policy implications

We quantified the relative impact of a wide-ranging set of items that could influence cycling behavior. The top motivators were: routes away from traffic noise and pollution; routes with beautiful scenery; and routes separated from traffic. The top deterrents were: ice and snow; streets with a lot of traffic; streets with glass/debris; streets with high speed traffic; and risk from motorists. These findings can direct transportation planners and public health officials to select urban planning and maintenance items that are likely to increase cycling rates. Certain items reported to be strongly influential, such as flat terrain, darkness, or poor weather, may not seem modifiable except via an individual's responsibility to have appropriate gear and a minimum fitness level. However, transportation engineers can make decisions that will mediate these for the entire population. Examples are to locate bicycle routes to minimize gradients, ensure that bicycle facilities are lit, and ensure that they are plowed and salted in winter weather.

While a comprehensive, multifaceted approach to bicycle promotion is likely to prove most effective, this study provides evidence on where to focus efforts to maximize changes in cycling mode share. Factors related to the built environment for cycling (separation from motor vehicles, ease of cycling, and pleasant route conditions) were the strongest perceived motivators and therefore most likely to make a dramatic impact on mode share. These factors could be addressed by building direct bicycle routes that are physically separated from motorized traffic and minimize gradients. Such designs may appear to be costly and reduce road space for motor vehicles, but one way to accomplish them with minimal impact on the road network is to develop cycle paths along old rail corridors. Such policies have been widely used in some North American cities but have not yet been fully exploited in many regions, including Metro Vancouver. Another approach that has met with wide success in Portland, Oregon is "bike boulevards", or bicycle routes along traffic-calmed neighbourhood streets. Detailed design guidelines are now available for implementation in other cities (Walker et al. 2009). In Vancouver these constitute a significant portion of the bicycle network and are referred to as "neighbourhood bikeways"; they are a highly ranked infrastructure by all types of cyclists (Winters and Teschke in press). Locally, the results of this survey have been used by Vancouver city planners to gain council approval for a $25-million plan for cycling including network improvements such as separated bicycle paths along arterial streets (City of Vancouver 2010), and to guide the development of an online bicycle route planner (Su et al. in press).

In a handful of cities where the built environment for cycling is already of high quality (i.e., Davis, California or Victoria, British Columbia), strategies related to education and encouragement may be effective to further increase already high bicycle mode shares. However the results of this study are likely to be informative in the majority of North American cities, where cycling modal share is low and the survey items reported to be stronger motivators and deterrents have not yet been adequately addressed.

Our findings support a shift in policy approach for the practice of bicycle infrastructure planning. In many jurisdictions, new route selection has been based largely on expediency; typically cycling routes are implemented on sections of roadway where adequate space already exists, where traffic volumes are low, or where there are developments in progress that allow for expansion of the road right of way. This paper supports a more rigorous approach to route selection that prioritizes safety, location, and environmental factors. Based on this research, key considerations for new routes should include the potential to physically separate bicycles from motor vehicles, to minimize slopes, to travel through aesthetically pleasing locations, and to serve popular destinations, including rapid transit lines. The engineering design of the facility should follow after the selection of route location, and should focus on construction of off-street paths, neighbourhood bikeways, and other designs allowing separation from traffic. Route lighting and smooth surfaces are important attendant features that should be included in both design and maintenance policies. This systematic approach would use evidence of the relative preferences of all subgroups of the "near market" cycling population, and should therefore serve to attract the highest number of users.

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