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Is the three-foot bicycle passing law working in Baltimore, Maryland?

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A B S T R A C T

Maryland (MD) recently became one of fourteen states in the United States to enact a traffic law requiring motor vehicles to pass bicyclists at a distance of greater than three feet. To our knowledge, motorist compliance with the law has never been assessed. This study measured the distance between overtaking motor vehicles and cyclists [*e.g.* vehicle passing distance (VPD)], to develop baseline metrics for tracking implementation of the three-foot passing law in Baltimore, MD and to assess risk factors for dangerous passes. During September and October 2011, cyclists ($n = 5$) measured VPD using a previously published video technique (Parkin and Meyers, 2010). Cyclists logged a total of 10.8 h of video footage and 586 vehicle passes on 34 bicycle commuting trips. The average trip lasted 19.5 ± 4.9 min and cyclists were passed on average 17.2 ± 11.8 times per trip. VPDs of three feet or less were common when cycling in standard lanes (17%; 78 of 451 passes) and lanes with a shared lane marking (*e.g.* sharrows) (23%; 11 of 47 passes). No passes of three feet or less occurred in bicycle lanes (0 of 88 passes). A multiple linear regression model was created, which explained 26% of the variability in VPD. Significant model variables were lane width, bicycle infrastructure, cyclist identity, and street identity. Interventions, such as driver education, signage, enforcement, and bicycle infrastructure changes are needed to influence driving behavior in Baltimore to increase motorist compliance with the three-foot law.

1. Introduction

On October 1, 2010, a three-foot passing law took effect in Maryland (MD), United States (US) to protect bicyclists from motorists on roadways. Similar to laws in 13 other US states (Smith, 2009), the MD law requires motor vehicles to pass cyclists with a clearance of greater than three feet (Maryland General Assembly, 2010). Motorized vehicular traffic can be intimidating for cyclists and close passes are physically destabilizing. If a heavy vehicle traveling at 64 km/h (40 mph) passes a cyclist with a clearance of three feet, the cyclist is pushed by lateral forces of ~13 N (3 lbs force) (Khan and Bacchus, 1995), which may divert that cyclist from his or her course, increasing risk for a collision with traffic or parked vehicles. In addition to the physical effects, Parkin and colleagues found that cyclists perceive risks related to traffic volume, speed, and motor vehicle composition (Parkin et al., 2007). Creating space between vehicles and bicycles may be the reason why individuals prefer cycling in bicycle lanes over streets with no bicycle facilities (Kroll and Sommer, 1976; Stinson and Bhat, 2003) as a risk reduction strategy.

Cycling is not without risks; cyclists are 12 times more likely to be killed compared to motorists per kilometer traveled in the US (Pucher and Dijkstra, 2003). There are also health benefits of bicycle commuting from increased physical activity (Oja et al., 1998), and some research suggests greater net health benefits compared to risks (from traffic accidents and air pollution) among cyclists *versus* motorists (de Hartog et al., 2010; Rojas-Rueda et al., 2011). The public health benefits of commuting to work by bicycle extend beyond personal physical health. Commuting by bicycle is associated with improved psychological health (Ohta et al., 2007), and reduced communiting costs compared to commuting by car. One of the authors of this paper calculated an annual saving of $5,500 by not owning a car for daily commuting; a calculation that used current rates of automobile insurance in Baltimore, MD parking costs at the Johns Hopkins Medical Campus (JHM) and at the author's condominium, the cost of a low-end car amortized over ten years, and fuel and maintenance costs.

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The benefits of bicycle commuting also extends to the wider community. Compared to motorized forms of transit, commuting by bicycle produces modest reductions in air pollution emissions associated with negative public health outcomes and also reduces greenhouse gas emissions implicated in anthropogenic climate change. There are also less tangible,well-studied benefits to cities and communities with larger populations of bicycle commuters, including social and group cohesion, perception of neighborhood safety, and improved urban 'livability' standards that are increasingly recognized as important for planning long term urban sustainability.

Baltimore, like many US cities, has experienced an increase in cycling over the past two decades (Pucher et al., 2011). Nearly 2000 cyclists were counted during morning and evening commutes on September 13th to 15th, 2011 at eight locations in Baltimore. This number reflects a 5.7% increase from counts recorded during the same month in 2010 (Evans, 2011). To encourage bicycling in Baltimore and to enhance public safety, City officials enacted a bicyclists' bill of rights in 2010 (City Council of Baltimore, 2009), are actively expanding miles of bicycle lanes, and have implemented a state-enacted three-foot law. While the three-foot law is a positive step toward improving cyclist safety, the study authors found that data gaps exist in monitoring and enforcement of the three-foot law, unless vehicular passing results in a vehicle–bicycle collision. As of December 2011, the three-foot law has been enforced twice in MD, both after vehicle–bicycle collisions. Hence, under normal circumstances not involving a collision, there is no measurement tool for compliance with the three-foot law. Therefore, the aims of this study were to assess compliance with the three-foot law, to provide a baseline measure of overtaking motor vehicle passing distance (VPD) in Baltimore, and to examine risk factors associated with close vehicle passes.

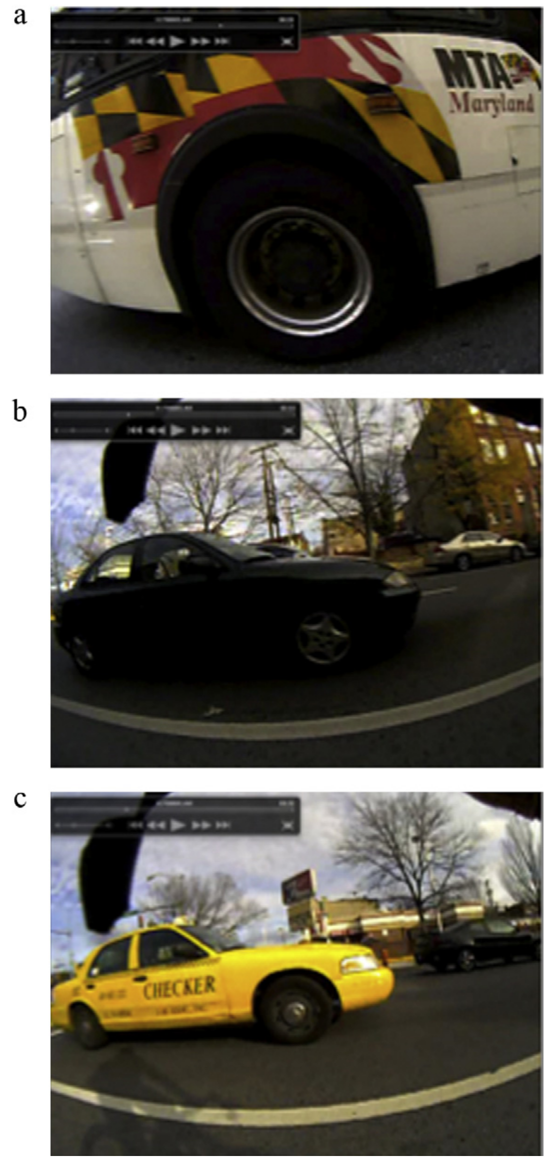

Fig. 1. Example footage of vehicles passing a bicyclist; top to bottom frames show 3-ft, 5-ft, and 7-ft passes.

2. Methods and materials

2.1. Study design and VPD measurement

Cyclists ($n = 5$; 4 male, 1 female) recorded their morning and evening bicycle commutes during September and October 2011 in Baltimore using video recording methods previously described (Parkin and Meyers, 2010). A video camera (Drift X170, http://driftinnovation.com/) was attached to the underside of each bicycle seat, with the lens facing perpendicular to the direction of travel. The first shot of each trip was a calibration image of a tape measure extended on the ground to provide a scale with which to measure distance from the bicycle in 1-ft intervals from 2 to 10 ft of bicycle clearance.

Cyclists' video-recorded trips were uploaded to a computer for video playback and each cyclist measured VPD passes in his or her own video relative to the initial calibration frame. A cross-validation of passing distance measurements was performed during an instructional period for cyclists in the study. During video playback, VPD was measured on-screen as the point where the front right tire of a motor vehicle crossed the perpendicular plane of the bicycle. The range of potential VPD measurements were ≤3, 4, 5, 6, 7, 8, 9, or ≥10 ft. Example screen shots of ≤3-ft, 5-ft, and 7-ft passes are presented in Fig. 1. A correction factor was applied to each measurement to subtract the distance between the left bicycle handlebar, as the closest point to an overtaking vehicle, and the camera. Other variables that were recorded during video playback were: date; time; rider; street and cross street identity; bicycle lane (*e.g.* yes, no, sharrow); and overtaking motor vehicle type (*e.g.* bus, commercial vehicle, taxi, car, other). All bicycle lanes in the study were 5-ft wide. Additional information on lane width was collected using Google Earth. Parking lanes in Baltimore are 7-ft to 9-ft wide, and for simplicity we assumed 8-ft wide parking lanes in this study.

2.2. Data analysis

The data were stored in Google Documents, analyzed using R software (R Development Core Team, 2011), and plotted in R and Prism (Graph Pad). A multiple linear regression model was developed for VPD by forward addition using variables of lane width, bicycle lane (present, absent, sharrow), cyclist identity, and street identity, and tested using ANCOVA. Plots of VPD by lane width were fitted using LOWESS trend lines. Two sided *T*-tests were performed for comparisons of VPD within a single street corridor, with a level of significance of 0.05.

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3. Results and discussion

3.1. Video data

A total of 10.8 h of video were recorded during 34 bicycle commuting trips (Table 1). A convenience sampling approach was used where each cyclist videotaped his or her route from home to work and back, with routes beginning and ending in Baltimore neighborhoods of Hampden, Charles Village, Mount Vernon, and Pigtown; work destinations were JHM or Johns Hopkins Homewood Campus (JHH). Bicycle routes traversed 37 streets and 101 cross streets. Some overlap existed in routes used by cyclists 1 and 3, and by cyclists 2 and 4; all final destinations were JHM. Cyclist 5 was the only rider with JHH as a destination. The average trip duration was ~20 min, with a range of 14–24 min, by cyclist.

3.2. Modeling vehicle passing distance

Participants recorded a total of 586 motor vehicle passes. A multiple linear regression model for VPD was developed ($p < 0.0001$), which explained 26% of the variance in VPD (*i.e.*, adjusted $R^2 = 0.26$). Coefficients in the VPD model were lane width, bicycle infrastructure, cyclist, and street identity, each discussed individually below.

3.2.1. Lane width

Lane width was a significant variable ($p < 0.0001$), explaining 9% of the variance in the VPD model. Increasing lane width increased VPD as seen by LOWESS trend lines (Fig. 2). The average VPD on a standard 10-ft wide lane was 4.8 ft and VPD increased to 5.0 ft and 5.8 ft on standard 11-ft wide and 12-ft wide lanes, respectively. An average VPD of 6.3 ft was measured for cyclists riding in a bicycle lane adjoining an 11-ft lane, and VPD increased to 7.7 ft for bicycle lanes adjoining 13-ft wide lane. Too few sharrow lanes were included in the study for an analysis of the effects of sharrow lane width.

A Florida study generated a similar finding that lane width had a large effect on VPD (Harkey and Stewart, 1997). Bicycle lane width was constant in Baltimore—although adjoining lane width did vary—while in other study sites VPD increases as a function of increasing bicycle lane width (Harkey and Stewart, 1997; Hunter et al., 1999).

3.2.2. Bicycle infrastructure

Bicycle infrastructure was a significant variable ($p < 0.0001$), explaining 8% of the variance in the VPD model. Compared to standard lanes, bicycle lane streets significantly increased VPD ($p < 0.0001$), while sharrows did not ($p = 0.28$) (Fig. 2). Vehicle passes three feet or less were common in standard lanes or sharrows, but not in bicycle lane streets. In standard lanes, 17% of vehicle passes (78 of 451 passes) were three feet or less. In sharrows, 23% of vehicle passes (11 of 47 passes) were three feet or less. None of the 88 passes that occurred in bicycle lane streets were three feet or less.

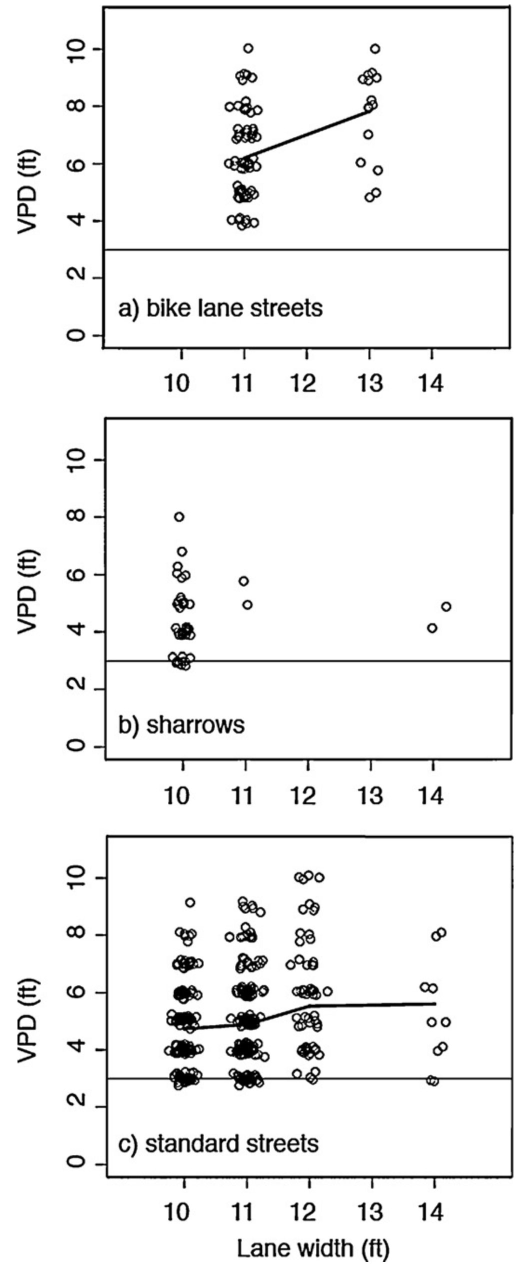

Fig. 2. Vehicle passing distance by lane width: (a) bicycle lane streets, (b) sharrows, and (c) standard lanes. LOWESS trend lines reported. The legal passing distance is marked on the *y*-axis. Random jitter applied to data points.

Our finding that streets with bicycle lanes are safer for cyclists than standard lanes of the same width is strongly supported by past research performed in multiple cities. Bicycle lanes reduce the frequency of bicycle–motor vehicle crashes (City of Eugene, 1980; Herrstedt et al., 1994), increase VPD (Hunter et al., 1999), reduce variability in VPD (*i.e.* from wide swerves or close passes) (Kroll and Ramey, 1977; Harkey and Stewart, 1997) compared to streets without bicycle lanes, and increase ridership by making cyclists feel safer on urban streets (Parker et al., 2011). One exception is on high-speed roads (>40 mph); VPD was greater on streets without bicycle lanes than streets with bicycle lanes (Parkin and Meyers, 2010). On high-speed roads, motorists stay within the boundaries of their own marked lanes, with minimal attention to provision of safe passing distance to cyclists in adjacent lanes (Parkin and Meyers, 2010). Most roads in our study had posted speed limits of 25–35 mph, so the findings by Parkin and Meyers could not be confirmed.

Our observation that VPD did not differ between sharrows and standard lanes does not agree with a study in San Francisco that found sharrows increase VPD by two feet over standard lanes (Alta Planning and Design, 1994). Sharrow road markers in this study were placed on the right edge of the travel lane and in some cases partially hidden underneath parked vehicles. These markers may not be as effective as sharrow markers placed closer to the middle of the travel lane that encourage cyclists to claim the entire lane. Further research could be performed to address the effects of sharrow placement on VPD and cyclist distance to the curb.

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Table 1
Summary of vehicle passing data.

Rider	Route	Number of trips	Trip duration (min)		Motor vehicle passes			
			All trips	Average trip duration ±st. dev.	All passes		Passes 3 ft or less	
					N	Mean passes per trip ±st. dev.	*N*	% of total
1	Hampden–JHM	3	64	15.7 ± 1.8	29	9.7 ± 5.5	1	3%
2	Hampden–JHM	10	239	23.9 ± 4.5	304	30.4 ± 11.3	29	10%
3	Mt. Vernon–JHM	5	70	14.0 ± 3.9	69	14.0 ± 4.5	14	20%
4	Charles Village–JHM	7	110	21.3 ± 4.0	32	4.6 ± 2.1	9	28%
5	Pigtown–JHH	9	179	19.9 ± 1.9	152	16.9 ± 4.6	38	25%
Total or average		34	648	19.5 ± 4.9	586	17.2 ± 11.8	91	16%

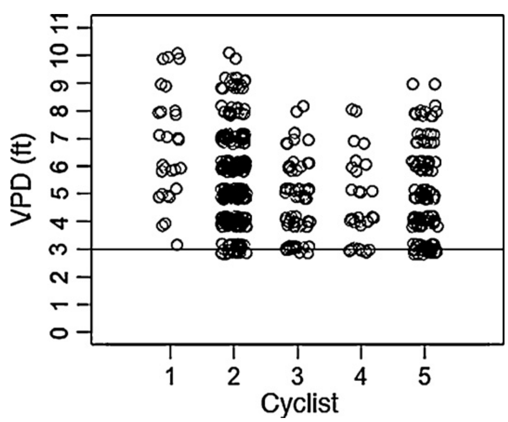

Fig. 3. Vehicle passing distance by cyclist. The legal passing distance is marked on the *y*-axis. Random jitter applied to data points.

3.2.3. Cyclist

Cyclist identity was a significant variable ($p < 0.0001$), explaining 7% of the variance in the VPD model. The VPD distribution for each cyclist is presented in Fig. 3, with a mean VPD ranging from 4 ft to 6 ft. VPD did not differ significantly between cyclists ($p = 0.1–0.6$). The passing rate, as the average number of passes per minute, was variable among the five cyclists: cyclist 2 (1.3 ± 0.5 passes per minute), cyclist 3 (1.1 ± 0.7 passes per minute), cyclist 5 (0.9 ± 0.2 passes per minute), cyclist 1 (0.4 ± 0.2 passes per minute), cyclist 4 (0.3 ± 0.2 passes per minute). Each cyclist was passed three feet or less during the study, ranging from 3% to 28% of all passes, by cyclist (Table 1). Cyclist's traits and behaviors were not a focus of this study, although others have examined this topic.

Walker (Walker, 2007) bicycled with and without a helmet, in various riding positions, and dressed as a male and female, and found that motorists are more likely to provide additional passing distance if a cyclist appears to be female, is not wearing a helmet, or is riding closer to the road's edge. Walker suggests that drivers modify their VPD behavior based on the perceived vulnerability of cyclists, with helmet-wearing riders and cyclists riding closer to the middle of the roadway perceived as more experienced and predictable. Only one cyclist in our study, rider 1, was female, and she had the lowest percentage (3%) of passes three feet or less of all riders in this study, which is suggestive of an effect of gender but certainly not conclusive. Helmet use in this study was also not conclusive due to the low number of cyclists studied, with only cyclist 5 not wearing a helmet.

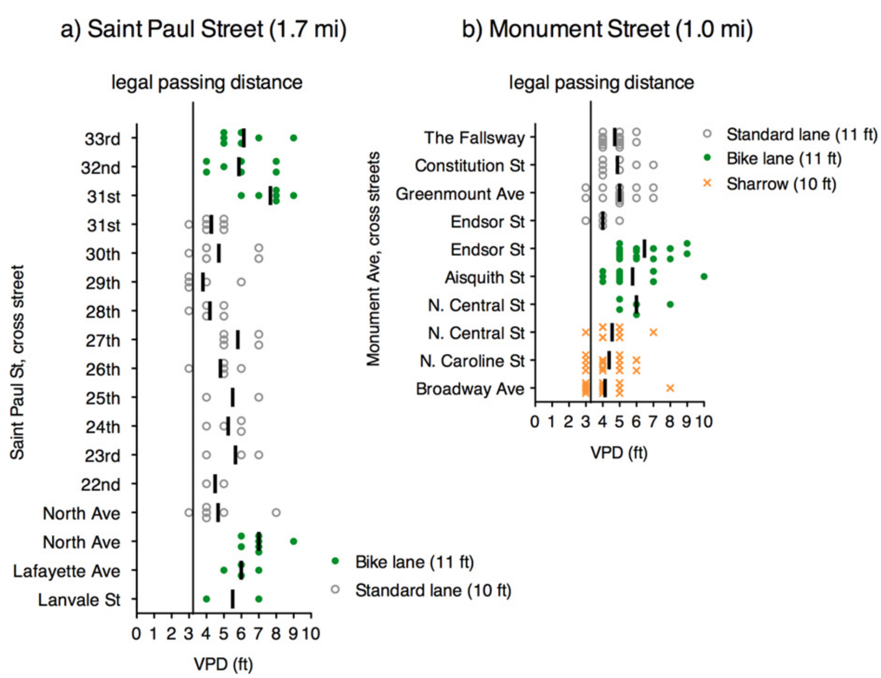

Fig. 4. Vehicle passing distance (VPD) on (a) Saint Paul Street and (b) Monument Street in Baltimore, MD. The legal passing distance is marked on the *x*-axis. Random jitter applied to data points. Bars represent mean values.

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3.2.4. Other factors

Street identity was a significant variable ($p = 0.0001$), explaining 10% of the variance in the VPD model. Of the 37 streets in the study, Bonaparte Street ($p = 0.02$), Clipper Mill Road ($p = 0.002$), and Falls Road ($p = 0.0004$) had significant coefficients in the model. Motor vehicle type was not a significant variable in the VPD model. Eighty-nine percent of passing vehicles ($n = 521$ passes) were personal vehicles, and the remaining passes were by commercial vehicles ($n = 25$), taxis ($n = 23$), buses ($n = 15$), and police vehicles ($n = 2$). Other studies indicate motor vehicle type affects VPD (Walker, 2007; Parkin and Meyers, 2010), but this was not the case in our model.

Traffic volume and speed, cyclist distance to the curb, time-of-day, and the presence of driveways are variables that other studies have identified as important to VPD (Harkey and Stewart, 1997; Hunter et al., 1999; Walker, 2007), but were not measured in this study due to the limited field of view of the video camera and non-standardized timing of rides. Another limitation of the study was its focus on overtaking motor vehicles, which accounts for only 8.6% of crashes reported in MD and other states (Hunter et al., 1997). The predominant type of collisions are side-swipe crashes that often occur at intersections (Wang and Nihan, 2004) and were not addressed in this study. Overtaking crashes are still important because of the severity of crash outcomes; 28% of cyclists involved in overtaking crashes sustained serious or fatal injuries (Hunter et al., 1997).

3.3. Vehicle passing distance along street corridors

VPD was plotted along two street corridors to illustrate actual conditions where lane widths and bicycle infrastructure types vary over a length of roadway (Fig. 4). On a 1.7-mile portion of Saint Paul Street, a major north-south Baltimore street, bicycle lanes exist for 4 blocks, then disappear for 13 blocks and reappear for 4 blocks. VPDs on Saint Paul Street were greater in bicycle lane streets than in standard streets ($p < 0.0001$), although this finding may be biased by the fact that the bicycle lane had an adjoining 11-ft wide lane, while the standard lane was narrower, at 10-ft wide. On a 1-mile portion of Monument Street, standard lanes become bicycle lanes and then become sharrow lanes. VPD differed significantly by type of bicycle infrastructure on Monument Street ($p < 0.0001$); 11-ft lanes adjoining a bicycle lane had significantly greater VPDs than either a standard 11-ft lane without a bicycle lane or a 10-ft lane with a sharrow ($p < 0.0001$, both). Again, this difference may be biased by compounding effects of lane width and bicycle infrastructure. A single cyclist collected video on Saint Paul Street (cyclist 2), therefore controlling for the effect of cyclist was not needed. Video on Monument Street was collected by two cyclists (cyclists 2 and 3) whose VPDs were strongly and positively correlated ($R^2 = 0.90$), indicating that controlling for cyclist was also not needed.

4. Conclusions

Cyclists in Baltimore, MD were routinely passed at a distance of three feet or less while cycling during morning and evening commutes, which indicates that the three-foot law is not being followed and cyclist safety may be compromised. Risk factors for dangerous passes by motorists were decreasing lane width and the absence of bicycle lanes. Interventions and strategic education campaigns are needed to influence motorists' driving behavior in Baltimore, to cultivate norms for passing cyclists, and to enhance enforcement and compliance around the three-foot law. The construction of bicycle lanes is a transportation infrastructure solution that would engineer out deficiencies in motorist behavior toward cyclists.

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