How Signs, Markings, and Hazards Impact Motorist Assessment of Cyclist Lane Placement

Mary L. Still
Old Dominion University

Jeremiah D. Still
Old Dominion University

Human factors research has led to safer interactions between motorists through redesigned signage, roadway designs, and training. Similar efforts are needed to understand and improve interactions between cyclists and motorists. One challenge to safe motorist-cyclist interactions are expectations about where cyclists should be on the road. In this study, we utilize more directive signage and additional lane markings to clarify where cyclists should ride in the travel lane. The impact of these signifiers was examined by having motorists indicate where cyclists should ride in the lane, how difficult it was to determine the correct lane position, and how safe they would feel if they were in that lane position. Results indicate that more directive signage – “bicycles take the lane” - and painted hazard signifiers can change motorists’ expectations, so they are more aligned with safer cyclist positioning in the lane.

INTRODUCTION

Although bicycling is considered an environmentally friendly mode of transportation and can provide health benefits, several factors limit their regular use. Safety is one of those limiting factors. Between 2006 and 2015, fatality rates for vulnerable road users in the United States increased by 5% despite the creation of new infrastructure (NHTSA, 2018). When it comes to cyclists, 2016 data show that 95% of traffic fatalities involve a motor vehicle.

In addition to the risk for injury, near misses occur as frequently as 1.8 times for every hour of riding (Aldred, 2016). The diary study conducted by Aldred (2016) further indicated that 40% of the near misses reported were “very annoying,” and an additional 14% were classified as “very scary.” When asked how they changed their riding behavior in response to these near misses, cyclists in the study reported they would ride closer to the center of the lane (i.e., “Take the lane”), find alternative routes if available, or quit cycling completely. Similarly, a survey study by Chataway, Kaplan, Nielsen, and Prato (2014) found a positive correlation between cyclists who were more fearful of riding in traffic and general cycling avoidance (i.e., avoiding specific routes or parts of routes and avoiding cycling when they felt unsafe).

When cyclists in Aldred’s (2016) study reported that they would take the lane, their actions were consistent with the common knowledge instruction that taking the lane increases cyclist safety, particularly on narrow roads. Moving to the center of the lane, increases visibility, decreases chances of being hit by a door from a parked vehicle (a.k.a., “doored” or “dooring”), and increases lateral space vehicles give when passing (Harkey & Stewart, 1997 but see Hatfield et al., 2018 and Walker, 2007 for contradictory evidence). Even with the knowledge that taking the lane is a reasonable action to pursue, cyclists report concerns that motors will become angry or irritated if they take the lane (Aldred, 2016; Hatfield et al., 2018).

Misunderstandings between motorists and cyclists are a legitimate concern. There is evidence that some motorists have negative attitudes toward cyclists and taking the lane could be seen as an additional irritation. An example of this can be found in Australia. Haworth, Heesch, and Schramm (2018) indexed the relationship between motorist characteristics and reactions to the adoption of Minimum Passing Distance (MPD) in Queensland Australia (at least 1 meter at 60km/h or less; at least 1.5 meters at 60+ km/h). The data indicated that approximately 33% of respondents did not comply with the MDP. Further, this behavior was related more to attitudinal factors than typical demographic factors like gender and age. While the majority of motorists felt they could make accurate judgments to execute the MDP and they were not annoyed by the new regulations, almost half felt that the new passing minimums made it more difficult to pass cyclists. Perhaps more concerning is the finding that those who did not comply with the MPD were more likely to be opposed to the rule, to report witnessing little change in response to the rule (i.e., other motorists are not giving more space), to find it difficult to determine the appropriate passing distance, to believe the rule was ineffective (i.e., it does not improve cyclist safety), and to believe the 1.5m MPD at higher speeds was annoying.

Beyond attitudinal factors, Still and Still (2019) found basic misunderstandings among young motorists of state laws and guidelines for sharing the road. For instance, 76% of their motorist sample believed cyclists are required to ride within three feet of the curb, 43% believed cyclists should ride on the sidewalk when available, and only 33% knew that a shared lane marking indicates that the cyclist should take the lane.

Ultimately, a cyclist could know they can and should take the lane, but if a motorist does not realize the cyclist can and should take the lane, the tension between motorists and cyclists will persist. The purpose of this study was to examine how signage and road markings might guide motorists’ expectations about where a cyclist should be on the roadway.

Traffic Signs

According to Hess and Peterson (2015), effective signage communicates the rights and duties of cyclists. This knowledge, available to both cyclists and motorists has the potential to reduce accident rates and could facilitate more predictable and less stressful interactions between motorists and cyclists. In their survey, Hess and Peterson compared the effectiveness of three indicators (signs and road marking) that communicate cyclists' right to take the lane. One condition used the "Share the Road" sign - subject of a pervasive educational campaign in the United States. A second condition used a sharrow (shared-use arrow) road marking, and a third condition used a "Bicycles May Use Full Lane" sign. The control condition was an unmarked, unsigned lane.

Results demonstrated somewhat graded comprehension across the conditions (Hess & Peterson, 2015). The "Share the Road" condition produced results comparable to the unmarked control condition suggesting that "Share the Road" itself is ambiguous, not communicating the specific rights of cyclists. Compared to the control condition, the sharrow condition produced better comprehension in that respondents were more likely to agree that cyclists are allowed in the center of the lane. Also, when the scenario indicated more space was available (e.g., four-lane roads instead of two-lane roads), respondents were more likely to agree that cyclists do not have to move out of the way of the following vehicle and agreed that the center of the lane was a safe place to ride.

The "Bicycles May Use Full Lane" sign was most effective showing greater comprehension across all items. Specifically, respondents were more likely to agree that cyclists could ride in the middle of the lane, they do not have to move over to let traffic pass, the middle of the lane was a safe position, and motorists had to wait for the appropriate time to pass. Hess and Peterson (2015) explained this result, saying this signage provides a direct and unambiguous message regarding how cyclists should use the travel lane. Even with this clear signage, approximately 7% of respondents disagreed with the statement "the bicyclist is permitted to ride in the center of the lane".

The message "Bicycles May Use Full Lane" is more direct than the message to "Share the Lane," but the message could be changed to even more directly communicate optimal lane placement. Specifically, the word *may* implies a permission schema where the cyclist has the choice to use the full lane but is not necessarily required or instructed to do so. Motorist annoyance and frustration of being "stuck" behind a cyclist may be further increased if they believe the cyclist could just as easily be riding near the edge of the road allowing them to pass. Further, some studies examining motorist attributes of cyclists reveal that cyclists may be seen as being irresponsible, unaware of their surroundings, reckless, arrogant, and as getting a special privilege at the cost of other road users (e.g., Aldred, 2013; Basford, Reid, Lester, Thomson & Tolmie, 2002; Goddard, 2017).

Given this collection of characterizations, we believe a more explicit version of the "Bicycles May Use Full Lane" message could be effective in guiding motorist expectations. We test one potential variant – "Bicycles Take the Lane" – in comparison to the traditional "Share the Road" message. We also test one variant of roadway markings as they also provide guidance as to where cyclists should position themselves in the lane.

Lane Markings

Bike lanes provide one solution for indicating where to expect cyclists on the road. Even with a bike lane, cyclists are still at risk if vehicle parking spaces are adjacent to the bike lane. Namely, parked vehicle doors can open obstructing a portion of the bike lane. Buffered bike lanes can help alleviate this problem. The painted buffer on the buffered bike is intended to preserve an open space between the bike lane and the adjacent travel lane or parking lane. When used with a parking lane, the buffer encourages cyclists to stay out of the door zone (National Association of City Transportation Officials NACTO – Urban Bikeway Design Guide).

Nevertheless, having space to accommodate a bike lane has become more challenging. A typical narrow lane may only be 12 feet wide. That space is quickly exceeded when the motorist considers that an average vehicle is greater than six feet wide and needs padding to accommodate travel, a cyclist needs four feet of operating space (AASHTO, 2012), and the typical MPD in the United States is three feet. That amounts to a *minimum* of 15 feet needed to share a lane. A related consideration is increasing vehicle size. In addition to requiring more operating space in the travel lane, larger vehicles in an adjacent parking lane may encroach on the travel lane (Furth, Dulaski, Buessing, & Tavakolian, 2010).

When the roadway is too narrow for a bike lane and is too narrow to share, cyclists are often encouraged to take the lane (e.g., Hatfield et al., 2018). Experienced cyclists are more likely to take the lane, and those with that preference report fewer "doorings" (Hatfield et al., 2018). Nevertheless, the results of a more naturalistic study suggest that as a cyclist moved closer to the center of the lane, motorists passed with less clearance (c.f., Walker, 2007), thereby increasing the chances of having a close call or near miss.

In these cases, a sharrow (shared-use arrow) might be used. A sharrow is a roadway marking that indicates where in the lane a cyclist should ride. That positioning can be used to help direct cyclists away from hazards such as grates or drains on the side of the road and door zones of parked vehicles (Hunter, Thomas, Srinivasan, & Martell, 2010; Pein, Hunter, & Stewart, 1999;). Site studies suggest that the majority of cyclists ride in the sharrow location after they are installed, they are more likely to position themselves toward the center of the lane, and, in some cases, are less likely to ride on the sidewalk (Hunter et al., 2010; Pein et al., 1999). For motorists, the sharrow serves as a reminder that cyclists belong on the road but also provides some indication of where the motorist should expect to see cyclists on the roadway (similar to bike lane markings, Pein et al., 1999). In some cases, motorists give more lateral space when passing cyclists after sharrows have been introduced (Hunter et al., 2010).

Even with these positive results, it is clear that sharrows do not fully communicate cyclists' right to the road or necessarily communicate their role in hazard avoidance. We believe that additional signifiers are needed. Signifiers are an important communication device providing valuable cues about how an operator may effectively navigate within a complex environment (Norman, 2008). For instance, cyclists ought to know that a door from a vehicle in an adjacent parking lane could open at any time. Therefore, they should proceed by giving the appropriate lateral space. However, a variety of factors could cause cyclists to ignore or discount the threat of being "doored." For instance, they may not notice a reduction in lane width; they may forget their training about the dangers of dooring; they may feel pressure to stay right to let other traffic pass. A visual hazard signifier could serve as a just-in-time reminder to increase lateral space. It is also possible that these signifiers would more clearly communicate to motorists why the cyclist has taken the lane.

Present Study

In this study, static scenarios were used to examine how signage, road markings, and presence of hazards (e.g., parked vehicles), impact motorists' determination of the best location for a cyclist in that particular lane. In addition to "placing" the bicycle, motorists rated how difficult it was to determine the best location for the bicycle and rated how safe they would feel in that location.

One set of scenarios used a signage manipulation that compared motorist responses associated with the message "Share the Road" to "Bicycles Take the Lane". The second set of scenarios used a sharrow along with a hazard signifier manipulation. In this case, the hazard signifier was a hazard strip that resembles the "buffer" on a buffered bike lane. The hazard signifier is used with a similar intention in that it provides a visual reminder that cyclists should not ride in the door zone on sharrows.

An additional manipulation across scenarios was the presence of a parked vehicle. When asked to rate the safety of different infrastructures, cyclists rate scenarios with parking lanes as being less safe (e,g., Chataway et al., 2014). We predicted the direct and unambiguous message, "Bicycles Take the Lane" and the hazard signifier would guide motorists to expect bicycles in a more central lane position.

METHOD

Participants (*N* = 73) were traditional university students (90% 18-23 years of age, 78% female) who completed the survey for course research credit. All participants were licensed to operate a motor vehicle in the state of Virginia, with 74% reporting that they drive regularly. Only 10% reported regular cycling experience, but even for them, the yearly mileage was well below the expert level (between 100 and 2000 miles per year).

The paper-and-pencil survey was completed in a laboratory setting, allowing participants to ask clarification questions as they completed the survey, although none did.

The scenarios reported in this study were part of a larger survey that included demographic questions along with items assessing knowledge of local bicycle law, opinions about appropriate motorist passing behavior, and appropriate placement at intersections. The order of the scenarios in the survey was fixed, but they were presented such that the novel manipulations – "Bicycles Take the Lane" sign and hazard strip – were completed after the familiar scenarios – "Share the Road" signage and no hazard strip.

Signage Scenarios

Four scenarios were constructed to examine how motorists use signs and potential hazards to assess cyclist lane placement. Two independent variables were manipulated: sign ("Share the Road", "Bicycles Take the Lane") and hazard type (vehicle in a parking lane or occluded side roads).

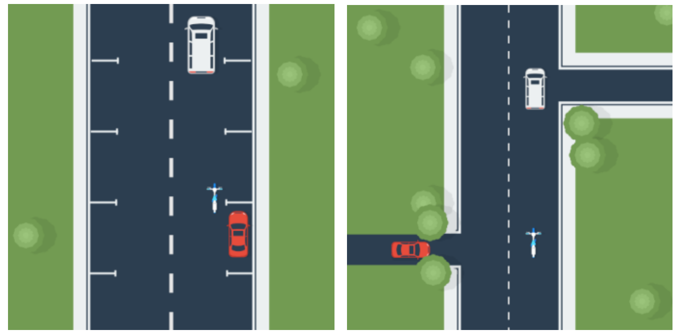


Figure 1. Examples of the two hazard types used in the signage scenarios. Note that the signs were not included in the image, they were provided in the scenario instructions for context.

Lane Marking Scenarios

Four scenarios were constructed to examine how motorists use hazard strips and potential hazards to assess cyclist lane placement. Two independent variables were tested: hazard strip (presence or absence) and hazard type (presence or absence of a vehicle in a parking lane). All four scenarios depicted a two-lane road with a sharrow marking on the roadway as depicted in Figure 2.

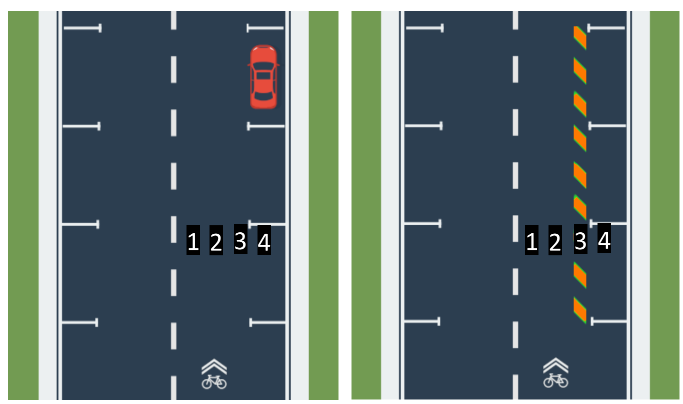


Figure 2. Examples of a scenario with the parked car hazard and a scenario that included a hazard strip. Note that each of these scenarios includes the sharrow lane marking.

Three dependent measures were collected in each scenario: the motorist selected one pre-determined position as the best position for a bicyclist then rated how difficult it was to determine that position and rated how safe they feel in that position. Both ratings were completed using a scale of 1 (Strongly Disagree) to 4 (Strongly Agree).

RESULTS

All statistical tests were performed as two-tailed tests using an alpha level of 0.05. All dependent measures were ordinal and nonparametric statistical tests were used. Friedman's Q was used to test differences in mean ranking across several conditions (e.g., do the average rankings differ across conditions). The McNemar-Bowker test for consistency was used to examine change in participant-level responses across conditions. This measure tests for patterns in how responses change while discounting cases where responses do not change.

Signage Scenarios

Bicycle placement. The McNemar-Bowker test for consistency was used to examine how motorist's responses changed with the signage used in the scenario description. Overall, motorists tended to indicate that the cyclist should be in the position closest to the curb. When the sign "Bicycles Take the Lane" was used instead of "Share the Road," motorists were more likely to place the cyclists further from the curb in a more optimal lane position (the middle position of the three options). This trend occurred both when the parked vehicle was the hazard, χ^2 (3) = 12.275, p = .006, and when the occluded adjacent roads were the hazard, χ^2 (2) = 24.148, p < .001.

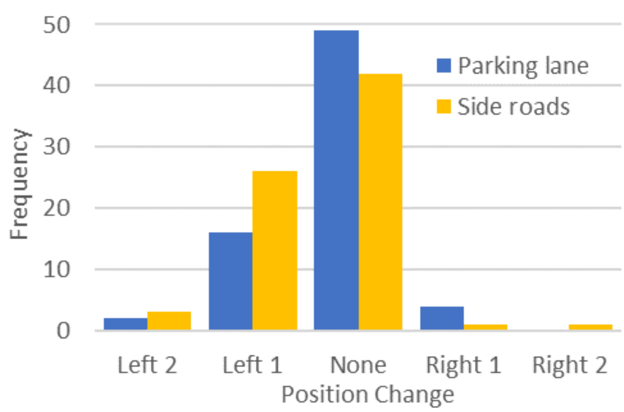


Figure 3. Change in motorist bicycle placement going from a "Share the Road" sign to a "Bicycles Take the Lane" sign.

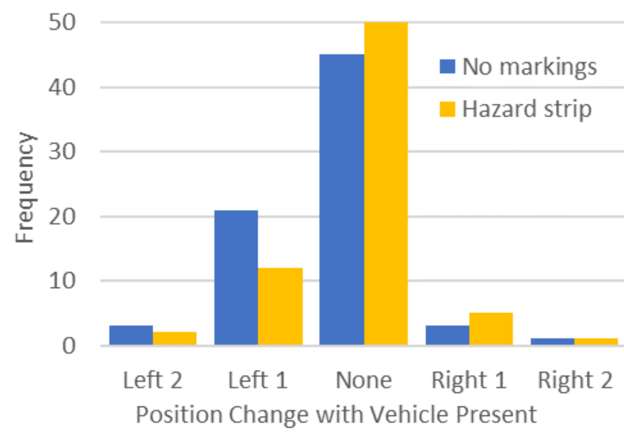
Difficulty rating. When the sign "Bicycles Take the Lane" was used instead of "Share the Road" the McNemar-Bowker test revealed no statistically significant shift in how difficult it was to determine where the cyclist should be placed in the lane. This was true for both the parked vehicle (p = .471) and occluded-roads (p = .282) scenarios.

Safety rating. Based on the McNemar-Bowker test, there was no shift in motorist ratings of how safe they would feel in their particular lane position based on different signage. This was true for both the parked vehicle (p = .506) and occluded-roads (p = .465) scenarios.

Lane Marking Scenarios

Bicycle placement. Across the four scenarios, the presence or absence of a parked vehicle and presence or absence of a hazard strip impacted motorists' placement of the bicycle in the scenario, Friedman's Q (3) = 55.091, p < .001. Planned comparisons revealed significant differences between scenarios that included the hazard strip and those that did not. When the hazard strip was present, motorists tended to choose lane positions closer to the centerline than when it was not included. This was true whether the parked car was absent (p < .001) or present (p = .051).

The McNemar-Bowker test for consistency mirrored these findings showing that when motorists changed the bicycle positioning across scenarios, they tended to place the bicycle more to the left when the hazard strip was present, χ^2 (5) = 24.958, p < .001. The same trend emerged when a parked vehicle was present, χ^2 (3) = 18.619, p < .001.



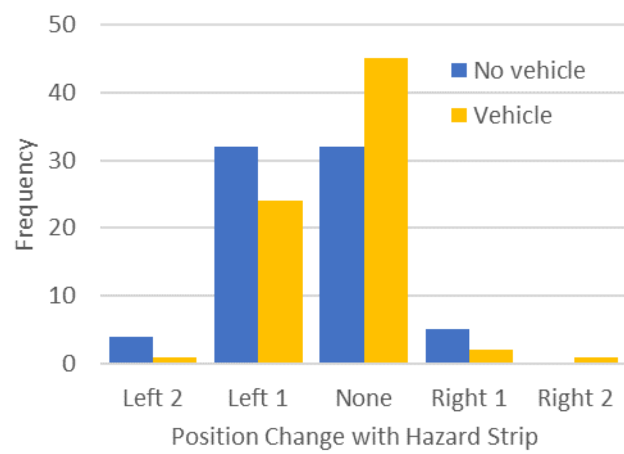


Figure 4. Change in motorist bicycle placement in response to the presence of a parked vehicle (top) and in response to the presence of a hazard strip (bottom).

Difficulty rating. Across the four scenarios, the presence of a parked vehicle and presence of a hazard strip impacted motorists' rating of how difficult it was to determine the best position on the road for the bicycle, Friedman's Q (3) =

22.824, $p < .001$. Planned comparisons revealed a significant difference between the scenario with the hazard strip and the scenario without the strip when there was no parked vehicle, ($p = .057$). The McNemar-Bowker test for consistency mirrored these findings showing that motorists tended to rate the bicycle placement task as being more difficult when the hazard strip was present, χ^2 (6) = 17.879, $p = .007$. A similar pattern of results was obtained when a parked vehicle was present, χ^2 (6) = 13.702, $p = .033$.

Safety rating. Across the four scenarios, the presence or absence of a parked vehicle and presence or absence of a hazard strip impacted motorists' rating of how safe they would feel in that location on the road, Friedman's Q (3) = 30.796, $p < .001$. Planned comparisons revealed a significant difference between scenarios that included the hazard strip and those that did not. When there was no parked vehicle, motorists felt less safe when the hazard strip was present than when it was not ($p = .051$). The McNemar-Bowker test for consistency mirrored these findings, χ^2 (5) = 17.902, $p = .003$. Further, a similar non-significant trend was observed when a parked vehicle was present, χ^2 (6) = 10.702, $p = .098$. The McNemar-Bowker test for consistency was used to further examine the impact of the presence of a parked vehicle; it resulted in a marginal decrease in safety ratings, χ^2 (4) = 9.600, $p = .048$

DISCUSSION

The results of this study indicate that motorists' expectations about where a cyclist should be positioned in a travel lane can be guided by direct signage and by the presence of hazard signifiers. Specifically, motorists were more likely to "place" a bicycle in a safer, more central lane position in the context of the message "Bicycles Take the Lane" compared to "Share the Road." They were also more likely to place a bicycle in that more central position when a hazard strip was included with the sharrow. One unexpected result was the relatively small position change associated with the presence of parked vehicles.

These results provide a conceptual extension of Hess and Peterson's (2015) finding that the "Share the Road" sign and sharrow markings are not as effective in communicating cyclists' right to the road as the more direct "Bicycles May Use Full Lane" signage.

In addition to creating signs and signifiers that provide unambiguous direction, motorist attitudinal factors must be considered as they may interact with their interpretation of the situation. Indicating that a cyclist may use the full lane, for instance, does not necessarily communicate the safety concerns that warrant taking the lane. We believe safety concerns can be communicated using a hazard signifier. Additional research will be needed to examine how motorists would interpret and respond to hazard signifiers *in situ* and how those reactions would change over time.

It is unclear why participants rated the bicycle placement task as being more difficult when the hazard signifier was used. One possibility is that the difficulty rating served as a proxy for uncertainty. For instance, motorists were more likely to place the bicycle further left in the lane, toward the centerline, when the hazard signifier was present; these are also positions they would typically avoid. That conflicting feeling arising from placing the bicycle in an "uncomfortable" position may have been interpreted as "difficulty." Alternatively, the hazard strip might be highlighting the increased risk of riding near parked vehicles.

Signs and signifiers are needed to communicate appropriate bicycle positioning, particularly when appropriate positioning may be ambiguous. Taking the lane can improve safety, but it also communicates that there is not enough room to share the lane. Importantly both cyclists and motorists must be aware of this information because it indicates how motorists and cyclists should interact.

REFERENCES

AASHTO (2012). *Guide for the development of bicycle facilities (4th Ed.).* American Association of State Highway and Transportation Officials, Washington, DC.

Aldred, R. (2013). Incompetent or too competent? Negotiating everyday cycling identities in a motor dominated society. *Mobilities*, *8*, 252-271.

Aldred, R. (2016). Cycling near misses: Their frequency, impact, and prevention. *Transportation Research Part A*, *90*, 69-83.

Basford, L.., Reid, S., Lester, T., Thomson, J., & Tolmie, A., (2002). *Drivers' perceptions of cyclists.* (TRL Report 549). Wokingham, UK: Transport Research Laboratory.

Chataway, E. S., Kaplan, S., Nielsen, T. A. S., & Prato, C. G. (2014). Safety perceptions and reported behavior related to cycling in mixed traffic: A comparison between Brisbane and Copenhagen. *Transportation Research Part F*, *23*, 32-43.

Furth, P. G., Dulaski, D. M., Buessing, M., & Tavakolian, P. (2010). Parking lane width and bicycle operating space. *Transportation Research Record: Journal of Transportation Research Board*, *2190*, 45-50.

Goddard, T. (2017). Drivers' attitudes and behaviors toward bicyclists: Intermodal interactions and implications for road safety. *Dissertation and Theses*. Paper 3645.

Harkey, D. L, & Stewart, J. R. (1997). Evaluation of shared-use facilities for bicycles and motor vehicles. *Transportation Research Record* 1578, 111-118. Transportation Research Board, Washington, DC.

Hatfield, J., Poulos, R. G., Rissel, C., Flack, L. K., Grzebieta, R., McIntosh, A. S., Murphy, S. (2018). Factors associated with cyclists' self-reported choice of lane position. *Transportation Research Part F*, *55*, 403-414.

Haworth, N., Heesch, K. C., & Schramm, A. (2018). Drivers who don't comply with a minimum passing distance rule when passing bicycle riders. *Journal of Safety Research*, *67*, 183-188.

Hess, G. & Peterson, M. N. (2015). "Bicycles may use full lane" signage communicates U.S. roadway rules and increases perception of safety. *PLoS ONE*, *10*(8): e0136973

Hunter, W. W., Thomas, L., Srinivasan, R., & Martell, C. A. (2010). Evaluation of shared lane markings (Report No. FHWA-HRT-10-041). Washington, DC: Government Printing Office.

National Highway Traffic and Safety Administration's National Center for Statistics and Analysis (2018). Traffic Safety Facts 2016 Data: Bicyclists and Other Cyclists. (DOT Publication No. HS 812507). Washington, DC: Government Printing Office.

Norman, D. A. (2008). Signifiers, not affordances. *ACM Interactions,* November + December, 18-19.

Pein, W.E., Hunter, W.W., & Stewart, J.R. (1999). *Evaluation of the Shared-Use Arrow*, Florida Department of Transportation, Tallahassee, FL.

Still, M. L. & Still, J. D. (2019). *Sharing the Road: Experienced Cyclist and Motorist Knowledge and Perceptions.* In: Stanton N. (eds) Advances in Human Factors of Transportation. AHFE 2019. Advances in Intelligent Systems and Computing, vol 964. Springer, Cham.

Walker, I. (2007). Drivers overtaking bicyclists: Objective data on the effects of riding position, helmet use, vehicle type and apparent gender. *Accident Analysis and Prevention*, *29*, 417-425.