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Estimated car cost as a predictor of driver yielding behaviors for pedestrians

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A R T I C L E I N F O

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A B S T R A C T

Introduction: Pedestrian crashes are not equitably distributed; people of color and males are overburdened. The aim of this study was to examine if driver yielding behavior differed based on gender and skin color of the pedestrian, and the estimated car cost at two midblock crosswalks in the Las Vegas metropolitan area.
Methods: One white and one black female and one white and one black male crossed the intersection in a similar, prescribed manner. Crossings were video recorded. Driver yielding behavior was documented. The cost of car was estimated by cross referencing manufacturing websites and averaging the high and low values of estimated private sale. Generalized linear mixed model was applied, nesting within crossing attempt and within streets.
Results: Of 461 cars, 27.98% yielded to pedestrians. Cars yielded more frequently for females (31.33%) and whites (31.17%) compared to males (24.06%) and non-whites (24.78%). Cost of car was a significant predictor of driver yielding (OR = 0.97; p = 0.0307); odds of yielding decreased 3% per $1000 increase.
Discussion: Driver yielding differed by cost of cars. Given previous findings, future research is needed to further examine gender and racial disparities in pedestrian crashes. Findings are significant for public health and pedestrian safety, especially given the upward trend in crash rates.

1. Introduction

In 2017, nearly 200,000 pedestrians were injured by cars (Centers for Disease Control and Prevention, National Center for Injury Prevention and Control (CDC, NCIPC), 2017) and another 5,977 were killed making pedestrian crashes a major public health concern (National Highway Traffic Safety Administration, 2018). Over the last decade, pedestrian fatalities have seen an upward trend (National Highway Traffic Safety Administration, 2018). Pedestrian fatality rates are highest in urban areas, which comprised 80 percent of the total pedestrian fatalities in 2017 (National Highway Traffic Safety Administration, 2018). Additionally, counties with high rates of urban sprawl are at increased risk, as it has been found to be directly related to pedestrian fatalities, with more sprawling counties having higher fatality rates (Ewing, Reid & Hamidi, 2015; Ewing, R., Schieber and Zegeer, 2003).

Health disparities are population specific differences in health outcomes, including disease, injury, or death rates, for example.

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Health disparities are present in pedestrian crash rates. In 2017, the age adjusted pedestrian fatality rate was 2.99 per 100,000 population for African Americans and 3.99 for American Indian/Alaska Natives, compared to 1.83 for whites. Additionally, the fatality rate was 2.53 per 100,000 population for those of Hispanic ethnicity compared to 1.80 for non-Hispanics (CDC, NCIPC, 2017). A study conducted in Las Vegas, NV found that communities with a high percentage of Hispanic populations had higher rates of pedestrian crashes (Pharr et al., 2013). Males are also over burdened by pedestrian crashes, comprising 70 percent of all fatalities (National Highway Traffic Safety Administration, 2018). One study examining national death-rate ratios found the pedestrian death rate per person-year to be 2.3 times higher for males compared to females (Zhu et al., 2013). Driver bias related to race and gender may be one understudied factor in the higher pedestrian crash rates in these populations.

Two field experiments found that driver yielding differed by pedestrian race. One field experiment in downtown Portland, Oregon examined driver yielding behaviors at crosswalks and found that drivers yielded less often for black male pedestrians compared to white male pedestrians at a crosswalk (Goddard et al., 2015). A similar study was conducted in Las Vegas, Nevada, which, contrary to downtown Portland, has an urban design that is characteristic of sprawl. This study examined only female pedestrians, and in addition to race, this study also compared driver yielding behaviors at a high income and low income neighborhood crosswalk. It was found that significantly more cars passed through the crosswalk while a black female pedestrian was in the roadway compared to a white female pedestrian at the high income crosswalk, while drivers were less likely to yield to the white female pedestrian while she waited at the curb (Coughenour et al., 2017). Failing to yield increases the risk for all pedestrians; however, failing to yield while a pedestrian is in the roadway is of greater concern. Findings from both studies support the idea that pedestrians of color may be exposed to increased traffic risks. In both studies, the participants were comprised of only one gender, highlighting the need to examine differences in yielding behaviors by gender.

Class bias is another understudied factor that may play a role in disparate pedestrian crash rates. Gino & Pearce confirmed their hypothesis that wealth induces unethical behavior in experimental environments, while Piff and colleagues (Gino and Pierce, 2009; Piff, P. K., Stancato, Cote, Mendoza-Denton and Keltner, 2012) used multiple experimental and naturalistic methods to examine ethical behavior. In all seven studies they found that people from the upper-class were more likely to behave unethically than people from a lower-class. Specifically in relation to the current study, two naturalistic experiments examined if upper-class individuals behaved more unethically while driving. They found that upper-class individuals (as indicated by vehicle status – make, age, and appearance) were more likely to violate California state law and cut drivers off at a 4-way intersection (Piff et al., 2012). In a separate study they also found that upper-class individuals were more likely to violate California state law and cut pedestrians off at a marked intersection (Piff et al., 2012). Previous findings have confirmed that socioeconomic characteristics are associated with car type and characteristics (Lansley, 2016; Muller, 2011).

It is important to understand the factors that might influence disparate pedestrian crash rates in order to best intervene and minimize the associated negative health implications. This study aimed to examine how driver yielding behavior differed based on gender and skin color of the pedestrian, as well as the estimated cost of the car at two midblock crosswalks in the Las Vegas metropolitan area. Given previous findings and data that demonstrates unequal crash rates, it was hypothesized that drivers would yield less frequently for males and for African American pedestrians, and that drivers of more expensive vehicles would yield less frequently to pedestrians overall.

2. Material and methods

2.1. Setting

The Las Vegas metropolitan area is located in the southwestern United States. The urban design is very characteristic of sprawl including auto-dominated development with separated land uses, such as residential areas separated from retail or entertainment districts, numerous high speed arterial streets with large block distances. One result of this design characteristic is that it leads to large distances between crosswalks. With large distances between crosswalks, pedestrians are more likely to cross the street outside of a crosswalk at random and unpredictable locations (Federal Highway Administration, 2006). In an effort to facilitate non-intersection crossings, midblock crosswalks are frequently used (Federal Highway Administration, 2006). For this study, two midblock crosswalks were chosen at locations that were matched on street design (zebra-striped, non-signaled midblock crossing, street speed of 35mph, and 4 vehicle lanes with a center turn lane) and income characteristics (~$30–37,000 median household income (U.S. Census Bureau, 2013)). Additionally, each midblock crosswalk was located within one mile of an elementary school. Though our field experiments took place on weekend days, the proximity to a school was chosen in an attempt to improve the likelihood that local drivers would be accustomed to the presence of pedestrians in that particular location.

2.2. Pedestrian crossing

Pedestrian crossing methodology followed that of Coughenour et al. (2017). Four research participants, one white and one black female and one white and one black male, acted as pedestrians attempting to cross the street at the marked intersection locations. Participants were provided instruction about how to approach the crosswalk and cross the roadway in a similar manner. Additionally they were briefed on a safety protocol that mandated the participant not to enter the roadway until they were sure that the oncoming vehicle in the nearest lane was going to yield. When approaching traffic reached a selected roadway marker (i.e. a fire hydrant or street tree) that was located approximately 200 yards from the crosswalk, the pedestrians would approach the crosswalk and step at least one foot off of the curb to indicate a clear intent to cross the roadway. The participant would then attempt to make eye contact with the driver and observe the speed of the approaching vehicle. If they were sure the vehicle was going to yield, they would then enter the roadway into the marked crosswalk, continuing to ensure that all approaching traffic from subsequent lanes also yielded. All pedestrians wore a matching red t-shirt. Research participants only crossed when no other pedestrians were present and when no cross traffic was present. All field experiments took place between 10a.m. and 12p.m. on a Saturday and a Sunday in June 2016. The number of crossing *attempts* (regardless of driver yielding behavior) made by each of the participants at each of the two midblock crosswalks were as follows: street 1–22 crossings by the black female, 29 crossings by the white female, 29 crossings by the white male, and 0 crossings by the black male; street 2–30 crossings by the black female, 23 crossings by the white female, 27 crossings by the black male, and 30 crossings by the white male. While each pedestrian made 30 crossings, lack of video data occurred due to battery failure as a result of the ambient outdoor temperature exceeding 100^{o}F (street 1) and timing synchronization errors resulting in fewer crossing attempts being captured via video.

2.3. Driver yielding by cost of car

Video data that had been recorded during the pedestrian crossings were analyzed to assess the general cost of each vehicle and whether or not each vehicle yielded for the pedestrian. The cost of each car was estimated using various pricing categories from the Kelly Blue Book (KBB). This consisted of using the video data to determine the vehicle make, model, year, and overall condition. The year of the vehicle was estimated by cross referencing each manufacturer's website to compare body styles. To estimate the overall cost of the vehicle, the low end and high end price estimates from private sale were averaged. This methodology was similar to that used by Piff and colleagues (Piff et al., 2012), but was modified to average vehicle cost from the low and high end of the KBB category.

Using the video data, driver yielding behaviors were documented while the pedestrian was in the same half of the roadway. Reasoning for recording each half of the roadway individually stems from language in the Nevada Revised Statutes (NRS 484B.283, 1969), which states:

When official traffic-control devices are not in place or not in operation, the driver of a vehicle shall yield the right-of-way, slowing down or stopping if need be so to yield, to a pedestrian crossing the highway within a crosswalk when the pedestrian is upon the half of the highway upon which the vehicle is traveling, or when the pedestrian is approaching so closely from the opposite half of the highway as to be in danger (NRS 484B.283, 1969).

2.4. Analysis

We applied the generalized linear mixed model to evaluate whether the average cost of cars observed (in thousands), pedestrian gender (female and male), pedestrian race (white and non-white), and street location (street 1 and street 2) were associated with whether or not vehicles yielded to the pedestrian at two midblock crosswalks. The rationale for using this modeling approach is to take the clustering effect within crossings into account based on a multilevel structure. Because most crossings observed multiple cars, we assumed that the car effect is nested within crossings. Similarly, the crossing effect is nested within streets. Therefore, we defined level 1 as cars, level 2 as crossings, and level 3 as streets. Accordingly, by defining Y_{ijk} as a binary variable where 1 means car i yielding to a pedestrian while crossing j and street k, and 0 means otherwise, the model equation is expressed as follows:

$$Logit\left(Y_{ij}=1\right)=\alpha+\alpha_{j(k)}+\alpha_k+\beta_1\times Cost_{ijk}+\beta_2\times Gender_{ijk}+\beta_3\times Race_{ijk},$$

where α is a fixed intercept, $\alpha_{j(k)}$ is a random intercept among crossings nested within streets, and α_k is a random intercept of streets. The estimated coefficients ($\widehat{\beta}_1, \widehat{\beta}_2, \widehat{\beta}_3$) was transformed by an exponential function to explain the odds ratio (OR) of yielding in terms of the cost of car ($Cost_{ijk}$), pedestrian's gender ($Gender_{ijk}$), and pedestrian's race ($Race_{ijk}$).

Data cleaning, management, and analyses were conducted using SAS v9.4 (SAS Institute, Cary, NC). The significance level was set by 5%. The study protocol was approved by the University of Nevada, Las Vegas Office of Research Integrity.

Table 1
Descriptive statistics of driver yielding behavior at two midblock crosswalks in Las Vegas, NV.

		Yielding (N = 129; 27.98%)		Not-yielding (N = 332; 72.02%)	
		Mean	SD	Mean	SD
Cost of car (in thousands)		5.92	4.67	7.82	6.53
		N	**%**	**N**	**%**
Pedestrian gender	Female	78	31.33	171	68.67
	Male	51	24.06	161	75.94
Pedestrian race	Non-white	57	24.78	173	75.22
	White	72	31.17	159	68.83

SD = standard deviation.

3. Results

Among a total of 461 cars observed in this study, only 27.98% (N = 129) of them yielded to pedestrians. Table 1 shows full descriptive statistics by yielding, where the average cost was lower for cars that yielded to pedestrians. Cars yielded more frequently for females (N = 78; 31.33%) and whites (N = 72; 31.17%) compared to males and non-whites, respectively.

Table 2 shows that only the cost of car was a significant predictor of driver yielding (OR = 0.97; 95% confidence interval = 0.94, 0.99; P-value = 0.0307), meaning that the odds of yielding decreased around 3% (i.e., (0.97–1) × 100%) when the car cost increased by one thousand dollars.

By using the estimated variances of residuals and two random intercepts $\alpha_{j(k)}$ and α_k, which are 0.12, 1.81, and 0.12, respectively, the conditional correlation between yielding on two cross attempts of the same street was 0.09 (i.e., 0.18/(0.12 + 1.81+0.12)). Meanwhile, of the variability in yielding that was not explained by the covariates, 9% was caused by unobserved street-specific attributes. In addition, the conditional correlation between the yielding of two cars on the same crossing was 0.95 (i.e., (0.18 + 1.81)/(0.12 + 1.81+0.12)), meaning that 95% of the variability of yielding was caused by unobserved crossing-specific attributes.

4. Discussion

We examined driver yielding behaviors at two midblock crosswalks in Las Vegas, NV. We found that the average estimated car value was lower for cars which yielded to pedestrians, and that estimated cost of the car was a significant predictor for driver yielding. Though very few studies have examined this phenomenon in natural experiments, current findings are consistent with Piff et al. (2012) who reported that drivers of "higher status" vehicles were less likely to yield to pedestrians. Our findings are also consistent with previously published studies in that cars yielded less frequently for African American pedestrians (Coughenour et al., 2017; Goddard et al., 2015), though our results did not reach statistical significance. Our findings are significant for public health and pedestrian safety, as pedestrian crash rates have seen an upward trend.

Given the nature of this study, simply observing yielding behavior without the ability to interview drivers, it is not possible to understand the underlying reason for lack of yielding (Coughenour et al., 2017; Goddard et al., 2015). However, it is important to note that personal characteristics may be related to driving behaviors. For example, younger drivers and male drivers are more apt to take risks while driving (Rhodes and Pivik, 2011; Turner and McClure, 2003). Similarly, socioeconomic characteristics may play a role. Prior research has shown that wealth is associated with more unethical behavior (Gino and Pierce, 2009). Greater wealth enables individuals more control over their life and a greater sense of self-focus (Kraus et al., 2009; Piff, 2014). In a series of four studies, Piff confirmed that "higher social-class standing was positively associated with increased feelings of entitlement and narcissism" (Piff, 2014). Therefore, one potential explanation may be that drivers of higher value cars were displaying some of these characteristic traits through their lack of yielding behavior; e.g. felt a sense of superiority over other road users. Similarly, individuals of lower socio-economic status (SES) may empathize more with the pedestrians. Kraus, Côté, and Keltner studied individuals of both high and low SES groups and found that those of low SES were more able to accurately interpret the thoughts and feelings of others (Kraus et al., 2010). Kraus and Keltner reported that in face-to-face interactions, high SES individuals were less likely to engage with strangers and were more likely to disengage with strangers than low SES individuals (Kraus and Keltner, 2009). Disengagement and a lower ability to interpret thoughts and feelings of others along with feelings of entitlement and narcissism may lead to a lack of empathy for pedestrians among higher SES drivers which may result in lower yielding behaviors.

Drivers of higher cost cars may have been less accustomed to and ill prepared to yield for pedestrians, as higher SES is associated with lower rates of active transportation (Agrawal and Schimek, 2007; Doescher et al., 2017). However, the roads were relatively low speed at 35mph and the researchers made their intent to cross obvious with more than enough time for drivers who were paying attention to stop. Even if it was the case that the drivers who failed to yield did so because they failed to anticipate a crosswalk or the presence of pedestrians, it does not bode well for pedestrian safety, as the Las Vegas metropolitan area has numerous midblock crosswalks.

Another finding was that driver yielding behavior differed on the two roadways even though they were similar in design, household income, and proximity to a public elementary school. It may be, again, that drivers were less accustomed to seeing pedestrians at one location compared to the other. But as stated above, the nature of crossing attempts in this study provided more than ample time for cognizant drivers to recognize and yield to the pedestrian. Another explanation may be that drivers fell victim to social pressure, meaning that if the first car did not yield, neither did the following cars or vice versa (if the first car yielded so did subsequent cars). This phenomenon is supported by the data, as the yielding behaviors of the drivers for the pedestrian on the same crossing attempt

Table 2
Odds ratios of yielding at two midblock crosswalks in Las Vegas, NV.

		OR	95% CI	P-value
Cost of car (in thousands)		0.97	(0.94, 0.99)	0.0307
Gender	Female	1.35	(0.80, 2.28)	0.2560
	Male (Reference)	1.00	–	
Race	Non-white	1.06	(0.62, 1.80)	0.8302
	White (Reference)	1.00	–	

Abbreviation: OR = odds ratio; CI = confidence interval.

were more similar to each other than were the yielding behaviors of drivers for different crossing attempts on the same street. Goddard et al. (2015) also found that whether or not the first car yielded did not differ by pedestrian race, but that black pedestrians were twice as likely to have to wait for subsequent cars to yield as the white pedestrian.

Failure to yield because of social pressure may still decrease safety, as perceived pedestrian inconvenience is correlated with dangerous behaviors (Xu et al., 2018). Liu, Li and Sun found that the bearable amount of time pedestrians will wait to cross an intersection is 90 s (Liu et al., 2009), and Quistberg and colleagues found that a longer pedestrian-specific signal duration was associated with higher collision risk (Quistberg et al., 2014). When pedestrians are forced to go out of their way to cross the street at a marked crosswalk, but that *safe* behavior is not rewarded (e.g. drivers fail to yield), they may be more likely to cross outside of the crosswalk, sometimes called “darting.” If this behavior leads them to the desired outcome, getting to their destination on the opposing side of the street safely, this learned behavior is likely to be repeated. Thus, although darting pedestrians receive a safe outcome on most occasions by avoiding collisions with vehicles, the rare circumstance in which they do not is likely to be catastrophic. Policy makers should consider the public health implications that may result from the observed lack of yielding and work to enhance enforcement of existing policy to improve yielding and enhance pedestrian safety.

Overall the average yielding rate was just less than 28%. This is similar to Fitzpatrick and colleagues, who found a driver yield rate of about 30% at midblock crosswalks with high visibility markings (Fitzpatrick et al., 2007). Of note, however, they also found a yield rate as low as 15% for streets with a 35 mph speed limit. Similarly, Bertulis and Dulaski used the 85th percentile speed, or the speed at which 85% of vehicles travel under free-flowing conditions, and found yield rates between 9 and 19% on roads with 85th percentile speeds of 38 mph and 37 mph, respectively (Bertulis and Dulaski, 2014). Given that over 70% of drivers failed to yield in the current study is concerning, especially because the majority of minor and major arterial roads in the Las Vegas metropolitan area have posted speed limits of 35 mph or greater. Perhaps even more concerning, the built environment of the majority of roadways in the study area is such that drivers feel comfortable driving at speeds much higher than the posted speed limit. This phenomenon not only decreases pedestrian safety, but also perceived pleasantness and livability (Dumbaugh and Gattis, 2005). Public health and transportation practitioners should consider these impacts when designing and retrofitting the built environment.

While cars yielded less frequently for both males and African American pedestrians, our results did not reach statistical significance. Given that findings are not consistent with other published literature (Coughenour et al., 2017; Goddard et al., 2015), the lack of statistical significance may be due to a low sample size. Specifically, the lack of crossing data due to video error in this study likely played a role. Further analysis is necessary to determine if disparate rates of pedestrian injuries in these groups is related to driver yielding behavior.

The study has some limitations. First, we applied the estimated model to calculate two conditional correlations, revealing that the study needs more covariates related to crossing-specific attributes to explain yielding, e.g. typical pedestrian volume. The lack of crossing data due to video error in this study for the black male pedestrian on street 1 may result in underestimated coefficients. The study may lack generalization because we only examined two crosswalks in the Las Vegas metropolitan area, and both locations were low income neighborhoods. Additional field experiments and observational studies in various metropolitan areas and neighborhoods which differ demographically will provide a better understanding of pedestrian risk and driver yielding behaviors. All field experiments were conducted on a weekend day, so our findings may not reflect the same scenario of yielding behaviors during weekdays. We cannot ascertain any driver characteristics, feelings or beliefs given the nature of the study. We also cannot assume that drivers in either neighborhood resided there. Additionally, cost of car was a best estimate based on the average high and low values of year, make, and model.

This study has implications for public health, as pedestrians are overrepresented in motor vehicle crashes, making up 16% of fatalities, but only 12% of all trips (League of American Bicyclists, 2018). Interventions aimed at educating drivers of policies which mandate that they yield right of way to pedestrians may impact driver yielding behaviors. Drivers simply may not know that they are legally required to yield to pedestrians. However, increasing knowledge alone is unlikely to be effective at changing behavior. Behavior change is much more likely to occur when it is coupled with other efforts (Marteau et al., 2015). For example, injury prevention focuses on the three E’s, education, enforcement, and engineering. Built environment changes that will enhance safety of pedestrian travel and crossing without the need for a conscious effort by drivers or pedestrians themselves is likely to be more effective. Built environment changes could mean lower speed streets, narrowing roadways, more signalized crossing locations, or some combination of multiple environmental changes (Cairns et al., 2014; Retting et al., 2003). Additionally, an attitudinal shift may be necessary to change the culture in the Las Vegas metropolitan area and other similar sprawling cities. Currently priority is given to motor vehicles and other forms of travel are somewhat stigmatized (Lubitow et al., 2017; Wellman, 2015). Major efforts are necessary to make walking for transportation and use of public transit more convenient, equitable, and less stigmatized.

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Disclaimer

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Declaration of competing interest

None.

CRediT authorship contribution statement

Courtney Coughenour: Conceptualization, Methodology, Supervision, Resources, Writing - original draft, Project administration. **James Abelar:** Methodology, Investigation, Writing - review & editing, Project administration. **Jennifer Pharr:** Conceptualization, Writing - review & editing. **Lung-Chang Chien:** Data curation, Formal analysis, Software, Visualization, Writing - review & editing. **Ashok Singh:** Data curation, Formal analysis, Software, Writing - review & editing.

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