Exploring Racial Disproportionality in Traffic Stops Conducted by the Durham Police Department

REPORT

Prepared for

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Executive Summary

Recent research has generated questions regarding the Durham Police Department's (DPD) use of race as a proxy for criminal behavior. For example, Baumgartner and Epp's (2012) analysis of DPD traffic stop data suggested racial bias in traffic enforcement. Critically, Baumgartner and Epp used census population estimates to establish a benchmark for the driving population. Census estimates, however, demonstrate only where people reside and therefore serve as a poor proxy for the actual driving population.

The DPD, in an effort to promote transparency and achieve an improved understanding of its operations and their impact on the community, provided RTI International with access to 6 years of traffic stop data. In turn, RTI proposed a series of analyses that would address the methodological limitations noted above. This research was funded internally by RTI to serve the community and to contribute to a growing body of scientific research on this topic. The study was conducted independently, and the DPD provided no financial support for the project.

Data

We analyzed data from 151,701 traffic stops conducted by the DPD from January 2010 through October 2015. The stop data analyzed here were sourced directly from the DPD and included additional information (e.g., the unit assignment of the officer that conducted the stop) not routinely included in the traffic stop data submitted to the state. The data include traffic stops enforced by several different units, including traffic enforcement, patrol, High Enforcement Abatement Team (HEAT), and interdiction units.

Analytical Approach

To study the racial distribution of traffic stops in Durham, we used the "veil of darkness" (VOD) approach, which is based on the logic that police officers are less likely to be able to ascertain the race of a motorist after dark than they are during daylight (Grogger & Ridgeway, 2006). This method takes advantage of the fact that there is seasonal variation in the amount of daylight at certain times of the day. Using this method, the existence of racial disproportionality can be assessed by comparing the race of drivers stopped during daylight with the race of drivers stopped after dark during the intertwilight period (roughly between 5:30 p.m. and 9:30 p.m.). The analysis is limited to stops that occur in the late afternoon and early evening hours to reduce the variation in travel patterns that are dependent upon time of day.

Results

Results indicate that Black drivers are disproportionally stopped during daylight hours. Overall:

- The odds that a stopped driver was Black were 12% higher when the stop occurred during daylight hours than when it occurred in darkness. Put another way, at night, when officer visibility is limited, we predict 146 Black drivers stopped for every 100 White drivers. During daylight, when officer visibility is better, the predicted number of Black drivers stopped increases to 164.
- Among traffic stops involving male drivers, the odds that a stopped driver was Black were 20% higher when the traffic stop occurred during daylight than when it occurred in darkness. Put another way, for every 100 White males stopped during night hours, we predict 124 Black male drivers. This number increases to 149 Black males during daylight hours.
- No evidence of racial disproportionality was found when the analysis was restricted to traffics stops involving female drivers.

- The relationship between lighting and driver race was dependent upon the agency unit assignment. Black males in particular were overrepresented during daylight hours in the traffic stops conducted by the HEAT and patrol. For the HEAT, the odds that a stopped male driver was Black were 44% higher during daylight than in darkness. For the patrol unit, the odds that a stopped male driver was Black were 17% higher during daylight than in darkness. There was no evidence of overrepresentation among traffic stops conducted by the dedicated traffic unit.
- The relationship between lighting and driver race was also conditional upon year. Evidence suggests that racial disproportionality is decreasing over time. For the years 2014 and 2015, we found little evidence to suggest that Black drivers are overrepresented in traffic stops conducted by the DPD.

Discussion

We found evidence of racial disproportionality in traffic stops conducted by the DPD. However, the evidence further suggests that this effect is limited to male drivers, suggesting that there is a race-sex interaction and that it is Black males specifically who are more likely to be stopped during daylight, when race is more discernible. In addition, subsequent analyses found that the relationship between lighting and driver race was also conditional upon unit assignment. For instance, we did not find evidence of racial bias among traffic stops conducted by dedicated traffic units.

Introduction

Recent research has generated questions regarding the Durham Police Department's (DPD) use of race as a proxy for criminal behavior. Specifically, Baumgartner and Epp's (2012) analysis of DPD traffic stop data, and the reports that followed, strongly suggested racial bias in the traffic enforcement conducted by the DPD. This claim was based on two statistics: (1) a comparison between the percentages of Black motorists stopped in the city limits and the percentage of Black individuals who reside in the city and (2) the disproportionate number of Black individuals subjected to searches after having been stopped.

The results of these two comparisons have been used to suggest the existence of widespread racial bias in the DPD. The analyses conducted by Baumgartner and Epp (2012) are methodologically limited and provide insufficient information to fully understand the nature of disproportionate minority contact. Critically, Baumgartner and Epp employed census population estimates in an attempt to establish a suitable benchmark for the driving population. Census estimates, however, demonstrate only where people reside and, as such, may serve as a poor proxy for the actual driving population.

The DPD, in an effort to promote transparency and achieve a better understanding of its operations, provided access to its traffic stop data to RTI International to allow for an independent and objective analysis. In turn, RTI proposed a series of analyses that would address the methodological limitations noted above. This research was funded internally by RTI to serve the community and to contribute to a growing body of scientific research on this topic. The study was conducted independently, and the DPD provided no financial support for the project.

Various approaches have been developed to provide more reliable estimates of the impact of race on traffic stops. One such approach is the "veil of darkness" (VOD) method, which takes advantage of seasonal variation in the amount of daylight to examine whether the race of drivers stopped varies as a function of ambient lighting. The underlying assumption is that reduced lighting hinders the ability of officers to determine the race of drivers—and thus suggests the amount of racial bias, either implicit or explicit, in initiating the stop. This method compares the racial composition of traffic stops during the intertwilight period (a time of day when it is sometimes light and sometimes dark, depending upon the time of year) over the course of the year. Accordingly, the VOD method avoids the complex issue of controlling for the driver activity base rate.

Data

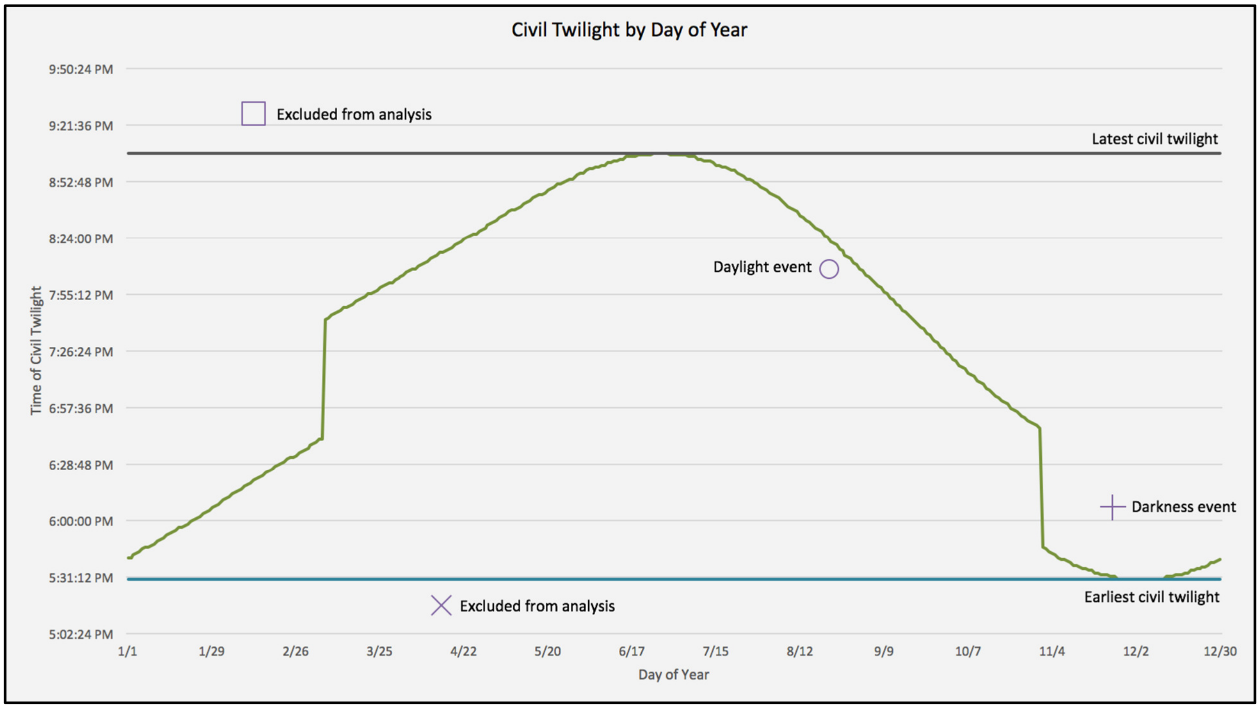
The analyses detailed below were performed on data describing 151,701 traffic stops conducted by the DPD from January 2010 through October 2015. State law requires law enforcement agencies to document the demographic characteristics, stop characteristics, and stop outcomes of all traffic stops. The stop data analyzed here were sourced directly from the DPD and included additional information (e.g., the unit assignment of the officer that conducted the stop) not typically provided in the traffic stop data submitted to the state.[1]

[1] The North Carolina state legislature passed Senate Bill 76 in 1999 to require state law enforcement officers to collect traffic stop statistics. This requirement was later expanded to include local law enforcement officers. An amendment to the bill in 2009 specified that each law enforcement officer making a stop would be assigned an anonymous identification number by the officer's agency, and this number would be reported to the Division of Criminal Statistics along with other types of traffic stop data required by the bill.

Analytical Method

To study the racial distribution of traffic stops in Durham, we used the VOD approach, which is based on the logic that police officers are less capable of determining the race of a motorist after dark than they are during daylight. Using this method, the existence of racial bias can be assessed by comparing the race distribution of stops made during daylight to the race distribution of stops made after dark. The analysis is limited to stops that occur during the intertwilight period (between 5:29 p.m. and 9:07 p.m.) to reduce the variation in travel patterns that are conditional on time of day. ***Figure 1*** graphically depicts the intertwilight period.

Figure 1: Civil Twilight by Day of Year



- ☐ Events above the black line occurred *after* the latest civil twilight—always in the dark. These events are excluded.
- X Events below the blue line occurred *before* the earliest civil twilight—always during daylight. These events are excluded.
- O Events between the blue and black lines occurred after the earliest civil twilight and before the latest civil twilight. Events under the green curve occurred before civil twilight of that day and are considered daylight events.
- \+ Events outside of the green curve occurred after civil twilight for that day and are considered darkness events.

The VOD method was developed and first employed by Jeffery Grogger and Greg Ridgeway in an analysis of traffic stops in Oakland, California, in 2006 (Grogger & Ridgeway, 2006) and Cincinnati, Ohio, in 2009 (Ridgeway et al., 2009). The method has also been used in studies focusing on the nature of traffic stops in Minneapolis, Minnesota (Ritter & Bael, 2009), Syracuse, New York (Worden, McLean, & Wheeler, 2010), San Diego, California (Burks, 2015), and a variety of jurisdictions in the state of Connecticut

(Pazniokas, 2015). Evidence of racial disproportionality was identified using this method in Minneapolis and for several jurisdictions in Connecticut.

Our models incorporate one enhancement from these previous studies: We use a random intercepts model to control for differences between officers. By doing so, we recognize that officers may have inherent differences in the percentages of Black motorists they are likely to encounter. These differences may be caused by factors such as geographic deployment, unit assignment, or individual characteristics (e.g., unique decision-making processes).

One benefit of the VOD approach is the simple interpretation of results. A statistically nonsignificant daylight indicator suggests that daylight was not associated with the race of the driver who was stopped. Alternatively, a statistically significant, positive daylight indicator suggests that Black motorists are more likely to be stopped during times when visibility is higher. Evidence of racial bias is present if minority drivers are over-represented during daylight hours compared with during times of darkness.

We processed the DPD's traffic stop data for 2010–2015 and incorporated information on civil twilight, collected from a public database maintained by the U.S. Naval Observatory. Using the VOD method, we explored four areas of interest:

1. The relationship between light visibility and race of the driver stopped
2. The relationship between light visibility and race of the driver stopped among female drivers only
3. The relationship between light visibility and race of the driver stopped among male drivers only
4. The relationship between light visibility and race of the driver stopped among different kinds of unit assignments (male motorists only)

Descriptive Statistics for Traffic Stops

This section describes the stop data used in this analysis. Descriptive statistics from all the stops in the time range (January 2010 through October 2015) are provided along with those for the subset of events that are used in the VOD analysis (intertwilight period).

Table 1 displays frequency distributions and percentages for the reasons for traffic stops. The first set of columns represents all 151,701 traffic stops that occurred in the time period studied. The shaded columns display frequency distributions and percentages for only the 19,801 traffic stops that occurred during the intertwilight period. Among the reasons for all traffic stops, the most likely was a speed limit violation (31% of all stops). Large percentages of stops were also identified for vehicle regulatory violations (23.3%) and vehicle equipment violations (13%). Perceptions of the driver's being impaired, seat belt violations, and checkpoints were less common reasons for traffic stops (<4% each). Similar patterns are observed during the intertwilight period. Specifically, speed limit violations, vehicle regulatory violations, and vehicle equipment violations were the top three reasons for stops. One noteworthy difference is that speed limit violations make up a smaller percentage of stops during the intertwilight period than they do for all stops, whereas vehicle equipment and regulatory violations make up larger percentages of stops during the intertwilight period.

Table 1: Reasons for Stop

	All stops (*N* = 151,701)		ITP stops (*n* = 19,801)	
Reason	Frequency	Percent	Frequency	Percent
Checkpoint	4,726	3.12	418	2.11
DWI	439	0.29	34	0.17
Investigation	11,757	7.75	1,481	7.48
Other motor vehicle violation	4,974	3.28	650	3.28
Safe movement violation	12,619	8.32	1,813	9.16
Speed limit violation	47,027	31.00	4,536	22.91
Seat belt violation	4,341	2.86	469	2.37
Stoplight/sign violation	10,587	6.98	1,631	8.24
Vehicle equipment violation	19,836	13.08	3,424	17.29
Vehicle regulatory violation	35,395	23.33	5,345	26.99
Total	151,701	100.00	19,801	100.00

Notes: ITP = intertwilight period.

Table 2 shows descriptive statistics for reasons for the traffic stop by the officer's unit assignment. Shaded columns present results specifically during the intertwilight period. More than half (54%) of all stops were conducted by officers assigned to the patrol unit, and about a fifth (22%) were conducted by officers assigned to the traffic unit. Within the High Enforcement Abatement Team (HEAT) unit, vehicle regulatory and equipment violations and investigation were the most common reasons for stops, although safe movement and speed limit violations each accounted for 9% of all traffic stops conducted by the HEAT. Seventy percent of stops conducted by the traffic unit were related to the speed limit. Stops conducted by the patrol unit mostly pertained to equipment, regulatory, and speed limit violations. Highly similar patterns are observed for stops that occurred during the intertwilight period. Most (74%) stops during the intertwilight period were conducted by the patrol or traffic units. Within the HEAT, vehicle regulatory and equipment violations and investigation were the most common reasons for stops. Seventy percent of stops conducted by the traffic unit related to the speed limit, whereas stops conducted by the patrol unit mostly pertained to equipment and regulatory violations.

Table 2: Reasons for Stop by Officer Assignment

Reason for stop	HEAT		Traffic		Patrol		All else		Total	
	All	ITP	All	ITP	All	ITP	All	ITP	All	ITP
Checkpoint	688	183	458	11	3,093	173	487	51	4,726	**418**
	(5%)	(7%)	(1%)	(0%)	(4%)	(2%)	(2%)	(2%)	(3%)	(2%)
DWI	16	2	100	8	285	22	38	2	439	**34**
	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)
Investigation	1,695	330	1,064	91	7,947	924	1,051	136	11,757	**1,481**
	(14%)	(12%)	(3%)	(2%)	(10%)	(8%)	(4%)	(6%)	(8%)	(7%)
Other motor vehicle violation	547	103	467	57	3,176	395	784	95	4,974	**650**
	(4%)	(4%)	(1%)	(2%)	(4%)	(4%)	(3%)	(4%)	(3%)	(3%)
Safe movement violation	1,161	204	1,046	142	7,195	1,150	3,217	317	12,619	**1,813**
	(9%)	(8%)	(3%)	(4%)	(9%)	(10%)	(13%)	(13%)	(8%)	(9%)
Speed limit violation	1,129	179	23,068	2,623	12,563	1,101	10,267	633	47,027	**4,536**
	(9%)	(7%)	(70%)	(70%)	(15%)	(10%)	(43%)	(26%)	(28%)	(23%)
Seat belt violation	333	74	2,051	142	1,375	170	582	83	4,341	**469**
	3%)	(3%)	(6%)	(4%)	(2%)	(2%)	(2%)	(3%)	(3%)	(2%)
Stoplight/sign violation	571	142	990	156	7,649	1,104	1,377	229	10,587	**1,631**
	(5%)	(5%)	(3%)	(4%)	(9%)	(10%)	(6%)	(9%)	(7%)	(8%)
Vehicle equipment violation	3,083	726	758	151	13,849	2,194	2,146	353	19,836	**3,424**
	(25%)	(27%)	(2%)	(4%)	(17%)	(20%)	(9%)	(14%)	(13%)	(17%)
Vehicle regulatory violation	3,270	702	2,898	371	25,068	3,726	4,159	546	35,395	**5,345**
	(26%)	(27%)	(9%)	(10%)	(30%)	(34%)	(17%)	(22%)	(23%)	(27%)
Total	12,493	**2,645**	32,900	**3,752**	82,200	**10,959**	24,108	**2,445**	151,701	**19,801**
Percentage of total stops	8%	13%	22%	19%	54%	55%	16%	12%		

Notes: HEAT = High Enforcement Abatement Team; ITP = intertwilight period. *N* for all stops = 151,701; *n* for ITP stops = 19,801; approximate column percentages are in parentheses.

Table 3 displays reasons for traffic stops by the time of day for stops that occurred during the intertwilight period. Results show some variation in the number of stops that occurred during these 30-minute increments. For instance, 20% of stops occurred between 8:30 and 9:00 p.m., whereas only 3% occurred between 9:00 and 9:30 p.m. However, in general, each reason for stop typically makes up the same approximate percentage of all traffic stops in each time slot. For instance, speed limit violations made up about 23% of stops during each time period, and there were only minor fluctuations in the percentage of stops that were speed limit violations over time. Likewise, the percentages of stops that were stoplight/sign violations did not differ substantially throughout the overall time period, ranging from 7% to 9% of all stops in each time slot. One exception was vehicle equipment violations, which showed a small spike starting during the 8:00–9:30 timeslot (from approximately 14% of all stops before 8:00, to 20% of all stops during the 8:00–8:30 time slot, up to 24% of stops during the 8:30-9:30 time slot). The percentage of all stops that pertained to vehicle regulatory violations peaked between 6:30 and 7:00 p.m. at 32%, but dropped to 24% of all stops by 8:00–8:30.

Table 3: Reasons for Stop by Time of Day During Intertwilight Period

Reason for stop	5:30–6:00	6:00–6:30	6:30–7:00	7:00–7:30	7:30–8:00	8:00–8:30	8:30–9:00	9:00–9:30	Total
Checkpoint	97	42	29	39	63	65	70	13	418
	(5%)	(3%)	(1%)	(2%)	(2%)	(2%)	(2%)	(2%)	(2%)
DWI	0	2	2	2	6	8	13	1	34
	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)
Investigation	157	89	194	225	245	251	286	34	1,481
	(8%)	(6%)	(7%)	(9%)	(8%)	(8%)	(7%)	(6%)	(7%)
Other vehicle violation	75	61	84	75	108	105	130	12	650
	(4%)	(4%)	(3%)	(3%)	(3%)	(3%)	(3%)	(2%)	(3%)
Safe movement violation	217	164	255	227	249	298	353	50	1,813
	(11%)	(10%)	(10%)	(9%)	(8%)	(9%)	(9%)	(8%)	(9%)
Speed limit violation	493	409	541	609	714	800	828	142	4,536
	(25%)	(26%)	(21%)	(23%)	(23%)	(24%)	(21%)	(24%)	(23%)
Seat belt violation	67	70	81	84	70	52	38	7	469
	(3%)	(4%)	(3%)	(3%)	(2%)	(2%)	(1%)	(1%)	(2%)
Stoplight/sign violation	127	118	229	220	267	295	326	49	1,631
	(7%)	(7%)	(9%)	(8%)	(9%)	(9%)	(8%)	(8%)	(8%)
Equipment violation	199	206	372	354	521	661	971	140	3,424
	(10%)	(13%)	(14%)	(14%)	(17%)	(20%)	(24%)	(24%)	(17%)
Vehicle regulatory violation	521	416	850	758	874	790	991	145	5,345
	(27%)	(26%)	(32%)	(29%)	(28%)	(24%)	(25%)	(24%)	(27%)
Total	1,953	1,577	2,637	2,593	3,117	3,325	4,006	593	19,801
Percentage of total stops	(10%)	(8%)	(13%)	(13%)	(16%)	(17%)	(20%)	(3%)	

Notes: All times are in the afternoon and evening (p.m.). n = 19,801; approximate column percentages are in parentheses.

Table 4 presents frequencies for the purposes of stops by the race of the motorist. Races other than Black and White made up a very small percentage of the number of traffic stops. For instance, Asian, Native American, and motorists with an unknown race, combined, accounted for 3% of all stops, both overall and during the intertwilight period. For all stops, speed limit violations were the most common reason for the traffic stop for all racial groups, and vehicle regulatory violations were second. Although these patterns are generally true during the intertwilight period, we note a few exceptions. Particularly among Black drivers, vehicle equipment and regulatory violations each made up a larger percentage of all reasons for stops than did speed limit violations. Among Native American motorists, the most common reasons for the stop were speed limit and safe movement violations.

Table 4: Reasons for Stop by Race of Driver

Reason for stop	Asian		Black		Native American		White		Unknown		Total	
	All	ITP	All	ITP	All	ITP	All	ITP	All	ITP	All	ITP
Checkpoint	17	1	2,486	192	13	2	2,192	222	18	1	4,726	418
	(1%)	(0%)	(3%)	(2%)	(1%)	(2%)	(4%)	(3%)	(3%)	1%	(3%)	(2%)
DWI	2	0	156	14	3	0	277	20	1	0	439	34
	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)	(0%)
Investigation	103	7	6,943	877	26	3	4,638	587	47	7	11,757	1,481
	(4%)	(2%)	(8%)	(7%)	(3%)	(3%)	(8%)	(8%)	(7%)	(10%)	(8%)	(7%)
Other motor vehicle violation	50	8	3,046	399	20	1	1,827	239	31	3	4,974	650
	(2%)	(2%)	(3%)	(3%)	(2%)	(1%)	(3%)	(3%)	(5%)	(4%)	(3%)	(3%)
Safe movement violation	283	48	7,170	1,003	101	23	4,981	729	84	10	12,619	1,813
	(11%)	(13%)	(8%)	(8%)	(11%)	(20%)	(9%)	(10%)	(13%)	(14%)	(8%)	(9%)
Speed limit violation	1,273	164	24,466	2,312	431	49	20,651	1,991	206	20	47,027	4,536
	(48%)	(44%)	(27%)	(19%)	(49%)	(43%)	(35%)	(27%)	(32%)	(28%)	(31%)	(23%)
Seat belt violation	39	2	2,909	347	19	4	1,347	115	27	1	4,341	469
	(1%)	(0%)	(3%)	(3%)	(2%)	(4%)	(2%)	(2%)	(4%)	(1%)	(3%)	(2%)
Stoplight/sign violation	278	45	5,824	933	95	15	4,329	633	61	5	10,587	1,631
	(11%)	(12%)	(7%)	(8%)	(11%)	(13%)	(7%)	(9%)	(9%)	(7%)	(7%)	(8%)
Vehicle equipment violation	220	47	13,865	2,355	65	8	5,623	1,004	63	10	19,836	3,424
	(8%)	(13%)	(16%)	(20%)	(7%)	(7%)	(10%)	(14%)	(10%)	(14%)	(13%)	(17%)
Vehicle regulatory violation	371	54	22,371	3,427	111	9	12,433	1,841	109	14	35,395	5,345
	(14%)	(14%)	(25%)	(29%)	(13%)	(8%)	(21%)	(25%)	(17%)	(20%)	(23%)	(27%)
Total	2,636	376	89,236	11,859	884	114	58,298	7,381	647	71	151,701	19,801
Percent of total stops	2%	2%	59%	60%	1%	1%	38%	37%	0%	0%		

Notes: ITP=intertwilight period; approximate column percentages are in parentheses. *N* for all stops = 151,701; *n* for ITP stops = 19,801.

Table 5 shows descriptive statistics for the sex and race of drivers for the overall sample and separately for stops that occurred during the intertwilight period. Traffic stops more commonly involved men than women in both the overall sample and in stops limited to the intertwilight period. The racial composition between all traffic stops and traffic stops occurring in the intertwilight period was relatively consistent. For instance, the majority of motorists in both samples were Black. As shown also in Table 4, Asian, Native American, and motorists of an unknown race were involved in only a small percentage of all traffic stops, both overall and those occurring during intertwilight.

Table 5: Race and Sex of People Stopped

Characteristic	Overall (*N* = 151,701)		ITP stops (*n* = 19,801)	
	Frequency	%	Frequency	%
Sex				
Male	93,486	61.63	12,516	63.21
Female	58,215	38.37	7,285	36.79
Total	151,701	100.00	19,801	100.00
Race				
Asian	2,636	1.74	376	1.90
Black	89,236	58.82	11,859	59.89
Native American	884	0.58	114	.58
Unknown	647	0.43	71	.36
White	58,298	38.43	7,381	37.28
Total	151,701	100.00	19,801	100.00

Notes: ITP = intertwilight period.

There are a few differences between the reasons for stops for males and females (*Table 6*). For all stops, females were more likely to be stopped for speed limit violations (35% female and 29% male) and vehicle regulatory violations (25% female and 22% male). Females were stopped for most other reasons at lower rates than males were. These patterns are generally mirrored in the intertwilight period.

Table 6: Reason for Stop by Sex of Driver

Reason	All stops (*N* = 151,701)			ITP stops (*n* = 19,801)		
	Frequency			Frequency		
	Male	Female	Total	Male	Female	Total
Checkpoint	3,108 (3%)	1,618 (3%)	4,726 (3%)	280 (2%)	138 (2%)	418 (2%)
DWI	368 (0%)	71 (0%)	439 (0%)	30 (0%)	4 (0%)	34 (0%)
Investigation	8,248 (9%)	3,509 (6%)	11,757 (8%)	1,061 (8%)	420 (6%)	1,481 (7%)
Other motor vehicle violation	3,370 (4%)	1,604 (3%)	4,974 (3%)	440 (4%)	210 (3%)	650 (3%)
Safe movement violation	8,503 (9%)	4,116 (7%)	12,619 (8%)	1,191 (10%)	622 (9%)	1,813 (9%)
Speed limit violation	26,720 (29%)	20,307 (35%)	47,027 (31%)	2,824 (23%)	1,712 (24%)	4,536 (23%)
Seat belt violation	3,056 (3%)	1,285 (2%)	4,341 (3%)	370 (3%)	99 (1%)	469 (2%)
Stoplight/sign violation	6,350 (7%)	4,237 (7%)	10,587 (7%)	972 (8%)	659 (9%)	1,631 (8%)
Vehicle equipment violation	12,844 (14%)	6,992 (12%)	19,836 (13%)	2,158 (17%)	1,266 (17%)	3,424 (17%)
Vehicle regulatory violation	20,919 (22%)	14,476 (25%)	35,395 (23%)	3,190 (25%)	2,155 (30%)	5,345 (27%)
Total	93,486 (62%)	58,215 (38%)	151,701	12,516 (63%)	7,285 (37%)	19,801

Notes: ITP = intertwilight period; approximate column percentages are in parentheses.

Veil of Darkness

The overall model suggests that daylight was significantly associated with driver race (***Table 7***). The odds of the driver's being Black were 12% higher when the stop occurred during daylight than when the stop occurred during darkness.[2]

Table 7: Overall Veil of Darkness Analysis

Model specification	*n*	Odds Ratio
Model 1—All intertwilight stops	19,801	1.12***

Notes: Results presented as odds ratios. Models also controlled for day of week, year, and time of stop as linear and quadratic terms. These coefficients are omitted for brevity. Models were specified as generalized linear mixed models where officer ID was treated as a random effect. ***p < 0.001.

[2] A likelihood ratio test was performed to test the time control-only model (day of week, year, and time of stop indicators) against the fully fitted model that added the dark/light indicators. Models including the day/light indicator resulted in a statistically significant improvement in model fit.

An assessment of the predicted probabilities for this model showed that stops conducted during daylight had a 62% chance of involving a Black motorist, whereas stops occurring during darkness had a 59% chance of involving a Black motorist.[3] Put another way, we expect officers to stop 146 Black drivers for every 100 White drivers during night hours, when officers are less capable of determining driver race. During daylight hours, when visibility of the driver is higher, we expect officers to stop 164 Black drivers for every 100 White drivers. This increase in Black drivers stopped during daylight hours is indicative of racial disparity in traffic stops.

Race-Sex Interaction

Models were respecified to explore the effect of driver sex on the relationship between available lighting and driver race (***Table 8***). The VOD method was applied to the subsample for males only and for females only. In the male-only subsample, the odds of the driver's being Black were 20% higher when the traffic stop occurred during the daylight hours of the intertwilight period than when it occurred during the dark hours of the intertwilight period. We did not find a significant relationship between lighting and driver race among the female subsample.[4]

Table 8: Veil of Darkness Analysis Subset by Sex

Model specification	*n*	Odds Ratio
Model 2—Male only	12,516	1.20***
Model 3—Female only	7,285	0.988

Notes: Results presented as odds ratios. Models also controlled for day of week, year, and time of stop as linear and quadratic terms. These coefficients are omitted for brevity. Models were specified as generalized linear mixed models where officer ID was treated as a random effect. ***$p < 0.001$.

The predicted probabilities of this model suggest that during darkness there was a 55% chance that the motorist was a Black male. During daylight hours, this chance increased to 69%. Stated another way, we expect officers to stop 124 Black male drivers for every 100 White male drivers during dark hours. This figure increases to 149 Black male drivers during daylight hours.

Veil of Darkness Analysis by Unit Assignment

Separate analyses on traffic stops involving male drivers conducted by different unit assignments indicated evidence of racial disproportionality in stops by the HEAT and patrol units (***Table 9***). The relationship between lighting and race of driver was statistically nonsignificant for the traffic enforcement unit.

[3] This was calculated by taking 1/(1 - mean) for that condition. Odds were calculated using the LSMEANS command in SAS. All other model variables were set to their means.
[4] The intraclass correlation for the male-only model was 10.3%.

Table 9: Veil of Darkness Analysis Subset by Unit Assignment, Male Drivers Only

Model Specification	*n*	Odds Ratio
Model 4—HEAT	1,777	1.44**
Model 5—Traffic	2,285	1.11
Model 6—Patrol	6,824	1.17**

Notes: Results presented as odds ratios. Models also controlled for day of week, year, and time of stop as linear and quadratic terms. These coefficients are omitted for brevity. Models were specified as generalized linear mixed models where officer ID was treated as a random effect. HEAT = High Enforcement Abatement Team. **p < 0.01.

For the HEAT, the odds of the motorist's being Black during daylight hours were 44% higher than the odds during darkness. An assessment of the predicted probabilities for this model shows that stops conducted by the HEAT during darkness had a 69% chance of involving a Black male motorist, compared with a 76% chance in daylight. On the basis of these results, for every 100 White male motorists stopped by the HEAT during darkness, we would predict 220 Black male motorists stopped; for every 100 White male motorists stopped during daylight, we would predict 319 Black male motorists stopped.[5]

Results from the subsample analysis of the patrol unit indicated that the odds of daylight stops' involving a Black male driver were 17% higher than the odds during darkness. More specifically, stops during darkness had a 55% chance of involving a Black male driver, compared with a 58% chance in daylight.[6] Furthermore, during darkness, for every 100 White males stopped by the patrol unit, we would predict 120 Black males to be stopped; during daylight, for every 100 White males stopped, we would predict 141 Black males to be stopped.[7]

Estimation of Long-Term Temporal Trends

In ***Table 10*** we explore the relationship between lighting and driver race over time. These models include an interaction term between lighting and year in addition to all other covariates specified in the models that were previously discussed. The interaction term was created by multiplying the indicator representing daylight by the year variable and is included to assess whether the effects of daylight on the odds of the motorist's being Black were stronger or weaker over time.

[5] The intraclass correlation for the HEAT was 16.6% and for patrol was 9.1%.
[6] All predicted probabilities for the night/day indicator were calculated while holding the other variables in the model at their means.
[7] We explored how the impact of lighting changed when the outcome variable was specified as 1 = Black Male, 0 = everyone else rather than subsetting the analysis to males only. Results showed only small differences from those presented in Tables 8 and 9. For example, the point estimate for the night/day indicator when predicting the odds of the driver's being a Black male was 0.1821, and the odds ratio was 1.20.

Table 10: Veil of Darkness Analysis With Year-Daylight Interaction

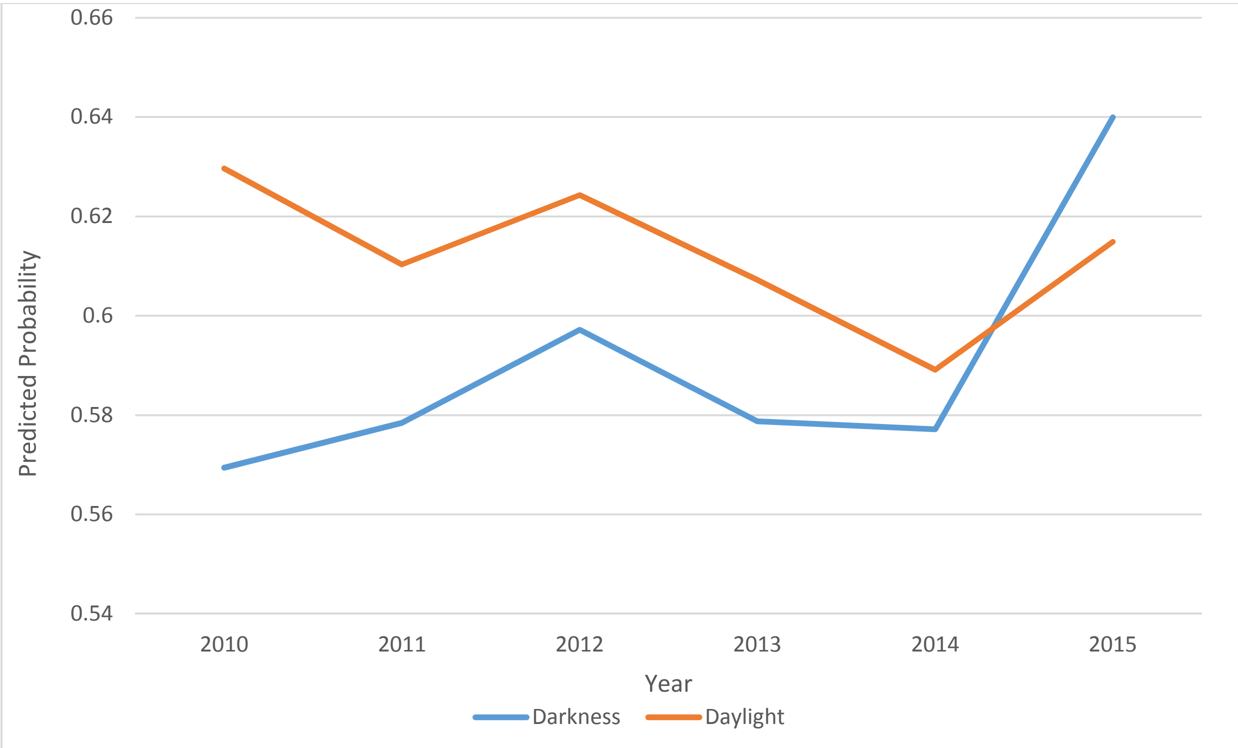
Model Specification	*n*	Odds Ratio
Model 7—Overall	12,516	
Daylight	--	1.359***
Year	--	1.038*
Year-Daylight Interaction	--	0.944**
Model 8—Male only	7,285	
Daylight	--	1.397***
Year	--	1.055**
Year-Daylight Interaction	--	0.956†

Notes: Results presented as odds ratios. Models also controlled for day of week and time of stop as linear and quadratic terms. These coefficients are omitted for brevity. Models were specified as generalized linear mixed models where officer ID was treated as a random effect. . † p<0.10; *p<0.05; **p<0.01; ***p < 0.001.

The interaction term is statistically significant and negative in direction for the Model 7 (coefficient=-.057; odds ratio=.944), indicating that the relationship between daylight and the odds of the motorist's being Black was weaker over time. To better interpret the relationship between the year and daylight, we calculated predicted probabilities of the driver's being Black by year for light and dark times in the intertwilight period (***Figure 2***). In 2010, daylight stops had a 63% chance of involving a Black motorist, compared with a 57% chance in darkness. In 2011, daylight stops had a 61% chance of involving a Black driver, compared with just under 58% chance in darkness. Similar patterns are found in 2012 and 2013. The gap is considerably smaller in 2014, with only about a 1% difference in the predicted probabilities for daylight and darkness. The year 2015 is unique from previous years in that the percent chance of the driver's being Black during darkness was higher than the percent chance during daylight. Supplementary analysis was conducted to further understand how racial disproportionality in traffic stops has changed over time. Specifically, separate logistic regression models were run for each year of data (not shown). Results indicated that the relationship between daylight and the odds of the traffic stop's involving a Black driver was not statistically significant in 2014 and 2015.[8]

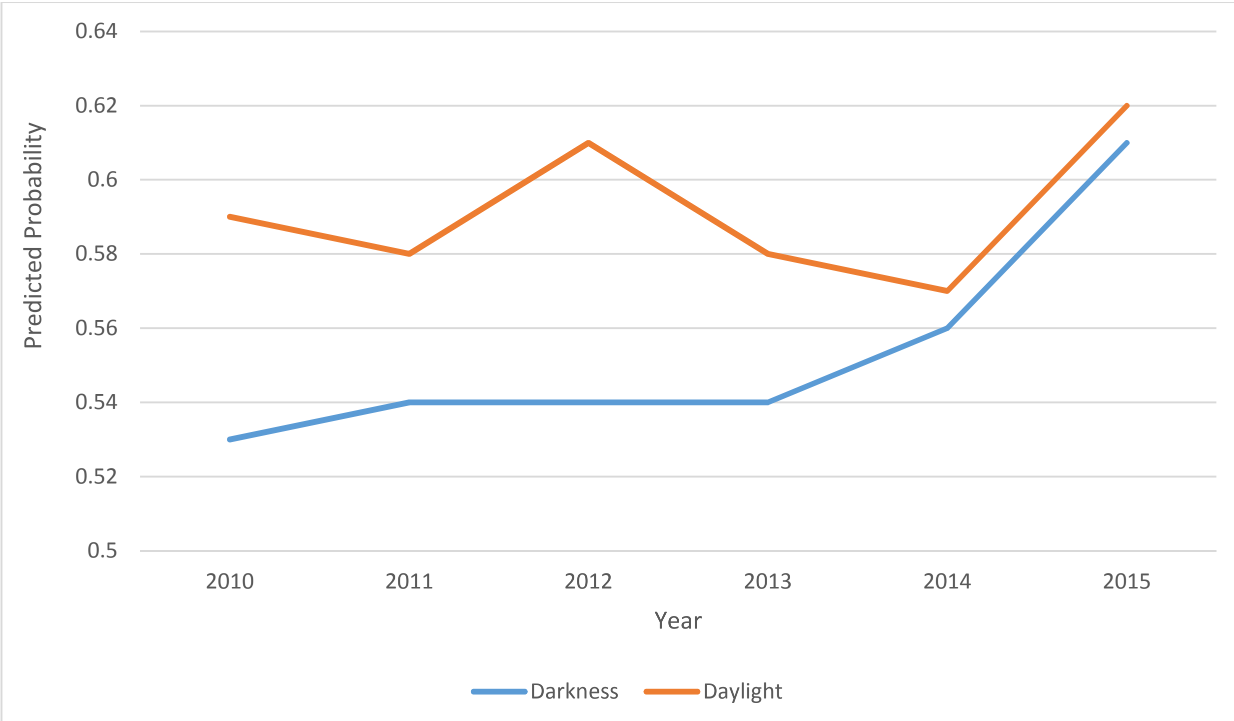
[8] At the time of the analysis, RTI did not have complete data for traffic stops occurring in 2015 (traffic stops in November and December of 2015 had not yet occurred, representing approximately 1,000 traffic stops). Once complete data became available, all analyses were rerun. The results for all analyses showed only slight differences from the results presented here.

Figure 2: Effect of lighting on the racial composition of drivers, over time for the overall sample in the intertwilight period (n=19,801)



Results from Model 8, which is restricted to traffic stops involving male drivers, show that the interactive term for year and daylight was statistically significant only at a relaxed p-value cutoff point of .10. ***Figure 3*** displays predicted probabilities of the driver's being Black during daylight and darkness from 2010 to 2015. In 2010, there was a 59% chance that the traffic stop involved a Black male driver if the stop occurred during daylight, compared with a 53% chance during darkness. In 2011, there was a 58% chance the driver was a Black male during daylight, compared with a 54% chance during darkness. The disparity was largest in 2012; there was a 61% chance the driver was a Black male during daylight, compared with a 54% chance during darkness. The disparity between predicted probabilities during daylight and darkness in 2013 is very similar to that in 2011. As shown, in 2014, the chance of the driver's being Black during daylight was only about 1% higher than during darkness. Similar to the overall sample, although the predicted probability for the traffic stop involving a Black driver in daylight increased in 2015 (relative to 2014), so did the predicted probability for the traffic stop's involving a Black driver during darkness. Thus, much like 2014, the disparity between daylight and darkness stops is small (a 1% difference). Separate logistic regression models were also run for each year of data (not shown). Results indicated that the relationship between daylight and the odds of the traffic stop's involving a Black driver was not statistically significant in 2014 or 2015.

Figure 3: Effect of lighting on the racial composition of drivers, over time for traffic stops involving males (n=12,516)



Interagency Comparison

The DPD is not the only North Carolina agency at which claims of racial bias have been leveled. A recent *New York Times* article highlighted the racial disproportionality in traffic stops in both Greensboro and Fayetteville (LaFraniere & Lehren, 2015). That article is only the most recent in a long line of media claims that racial bias exists in traffic stops in these cities.

Racial bias has also been a long-running claim in Raleigh. News reports going back to 2000 claim racial bias in traffic stops, based on the difference between the racial composition of stopped motorists and the racial composition of the city (Associated Press, 2000). The problems with this method and the limitations of this comparison were previously noted.

Greensboro, Fayetteville, and Raleigh have socioeconomic and demographic characteristics that are similar to those of Durham. This makes them reasonable comparisons for understanding whether the relationships found in Durham hold in different jurisdictions. ***Table 11*** displays the demographic characteristics of comparison cities.

Table 11: Demographics of Comparison Cities

City	Population[a]	% Black[b]	% White[b]	Median Household Income[c]
Durham	251,893	41.0	42.5	$49,585
Raleigh	439,896	29.3	57.5	$54,581
Fayetteville	203,948	41.9	45.7	$44,514
Greensboro	282,586	40.6	48.4	$41,518

Notes: Sources: [a] 2014 census population estimates. [b] 2010 census summary file. [c] 2010–2014 American Community Survey 5-year estimates.

Analyses using the VOD approach were conducted on the state-sourced traffic stop data from these three cities; results are shown in ***Table 12***. We controlled for time (day of week, year, and within-day) but omitted these variables from the tables.

Table 12: Comparison City Analysis

	Raleigh		Fayetteville		Greensboro	
Model	*N*	OR	*N*	OR	*N*	OR
Model 9—Overall	52,114	1.025	30,733	1.015	37,125	0.988
Model 10—Males only	32,248	1.028	18,133	1.024	21,796	1.051
Model 11—Females only	19,866	1.016	12,600	1.002	15,329	0.891***

Notes: Results presented as odds ratios. Models also controlled for day of week, year, and time of stop. Model fit tests for the analysis of traffic stops in Greensboro indicated a statistically significant improvement in model fit when a quadratic term for time of stop was also included in the model. Assessments for Raleigh and Fayetteville indicated that quadratic terms did not improve model fit and therefore those models controlled for time of stop as a linear term only. Coefficients for all control variables are omitted for brevity. Models were specified as generalized linear mixed models where officer ID was treated as a random effect. ***$p < 0.001$.

In the overall models, we did not find evidence of racial bias in Raleigh, Fayetteville, or Greensboro (Model 9). Given that the largest effect in Durham was for males, we reran the models, restricting the analysis to males only (Model 10) and females only (Model 11). In all but one instance, we did not find a statistically significant relationship between lighting and the race of the driver. The one exception was traffic stops involving female drivers in Greensboro, where the odds of the driver being black were 11% *lower* during daylight than in darkness.

Limitations

First, the VOD approach assumes that there are no seasonal differences in risk of drivers' being stopped that are conditional upon daylight or darkness. Certain conditions (e.g., large population changes based on a university schedule or large seasonal changes in population) may invalidate this assumption. To test this assumption, we modeled events that occurred within 30 days before and after the switch to Daylight Saving Time. These models, which are reported in Appendix 2, demonstrated no substantive differences from the results presented above.

Second, the VOD method is sensitive to factors that reduce the correlation between presumed visibility and darkness. Two situations are worth discussing. First, street lighting may alter the ability of officers to detect the race of drivers in darkness (Horrace & Rohlin, 2014). The extent to which this artificial lighting enhances officers' abilities to detect driver race will negatively affect the assumptions underlying the model. Second, adverse weather conditions may make it darker earlier than indicated by the day's civil twilight. We note, however, that under both of these conditions, the exclusion of this ancillary information biases results toward null findings and that the inclusion of these ancillary data should *strengthen* the ability to detect a relationship between visibility and driver race. The results presented here are thus a *conservative* estimate of the impact of lighting on the race of driver stopped.

Third, the VOD addresses only the question of racial bias that may be occurring during the intertwilight period. Because the method requires variations in lighting during the same times, we are unable to assess racial bias in time periods when it is always day (e.g., 3:00 p.m.) or always dark (e.g., 11:30 p.m.). Although these results are suggestive, it would be inappropriate to extrapolate our findings to times outside of our analysis window.

Fourth, the VOD approach explores only the patterns of traffic stops and the racial composition of the drivers. We make no claims about the reasons, causes, or other factors that may influence the officer's decision to make a traffic stop. Relatedly, the VOD approach tells us nothing about other important stop characteristics, including the length of the stop, the outcome, or decisions to search. This approach also does not consider the impact of passengers on the decision to stop.

Finally, a lack of location information of the stop in the data for 2010–2014 prevented us from exploring the district-level variance in the relationship between lighting and driver race. Instead, we controlled for officer-level variance as a proxy for natural differences in the likelihood of stopping Black motorists that can be influenced by factors such as location and unit of assignment.

Discussion

The VOD approach to analyzing traffic stops is powerful because it does not need an external benchmark to model the driving population at risk. Instead, natural variation in lighting that occurs over time throughout the year is used to identify periods when it is dark at some times of the year and light during other times (e.g., 7:30 p.m. in July will be light, whereas 7:30 p.m. in December will be dark). This natural variation creates changes in the ability of officers to determine driver race, while avoiding the issue of comparing different times that may have different driving populations at risk. For these reasons, the VOD approach has received widespread and increasing acceptance in the criminal justice field in recent years.

The results of these analyses suggest that Black motorists are overrepresented in the Durham traffic stops that occurred between 5:29 p.m. and 9:07 p.m. during January 2010–October 2015. The overrepresentation of Black motorists in daylight traffic stops is confined to Black males. The analysis did not find a statistically significant relationship between lighting and Black female drivers. This suggests that there is a sex-race interaction. We find evidence that the overrepresentation of Black drivers is present in most, but not all, unit assignments. Most notably we found that the HEAT and patrol units stopped more Black males during daylight hours than during the hours when it was dark. Traffic stops made by the dedicated traffic unit, however, did *not* display evidence of racial disproportionality.

Overall, we predict that officers will stop 146 Black drivers for every 100 White drivers during night hours, when officers are less capable of determining driver race. During daylight hours, when visibility is higher, we predict that officers will stop 164 Black drivers for every 100 White drivers. When examining males only, these numbers change to 124 Black drivers for every 100 White drivers during dark hours and 149 Black drivers for every 100 White drivers during daylight hours.

Further analysis of the impact of daylight on Black male motorists was done by analyzing the unit assignment of the officer making the stop. These subset analyses were conducted for the HEAT, patrol, and traffic units. For the HEAT, for every 100 White male motorists stopped at night, we predict that 220 Black male motorists will be stopped; for every 100 White male motorists stopped during the day, we predict that 319 Black male motorists will be stopped. For patrol, for every 100 White males stopped by the patrol unit, we would predict that 120 Black males will be stopped; during daylight, for every 100 White males stopped, we would predict that 141 Black males will be stopped.

Despite the consistency of these findings, we note that the traffic enforcement unit showed no evidence of racial disproportionality. We also note that the strength of the disproportionality varies considerably between units. More research is needed to understand the underlying factors that drive this variability.

There was also evidence of longer-term trends in the data. Racial disproportionality was larger in the earlier years of analysis. By 2014–2015 we saw a convergence of the predicted probabilities for light times and dark times. This suggests that there is little evidence of Black overrepresentation during these 2 years. The causes for this convergence are unknown and warrant further study.

Note that the proportion of Black drivers stopped during dark hours is not the key indicator of disproportionality. It is assumed that the lack of available lighting during the dark hours prevents officers from reliably determining the race of the driver before initiating the traffic stop. The overrepresentation of Black motorists during the dark hours may be driven by the natural differences in the driving population, differences in the driving population at risk of being stopped (i.e., differences in driving behaviors), or differences in police deployment strategies that influence risk of being stopped (e.g., officers being assigned to high-crime areas that correlate with larger minority populations). The differences between Black and non-Black driver risk during dark hours highlights why analyses that have focused on the difference between the racial compositions of those stopped and the racial compositions of the jurisdiction's population are highly problematic and potentially misleading.

We conducted similar analyses on other North Carolina cities that have also had claims of racial bias in traffic enforcement. Raleigh, Fayetteville, and Greensboro have each had long-term media attention on the racial composition of the motorists stopped by those departments. Our analyses of traffic stops in these other cities failed to identify evidence of racial bias. We note that media attention and benchmarks against census population are insufficient to reliably identify racial disparity in traffic stops.

The results of these analyses also demonstrate the importance of capturing additional contextual details in the traffic stop dataset. Our analyses demonstrate that organizational unit is a key factor in exploring racial bias. This information is not available in the state-level data. Without this information, we would have been unable to determine that the traffic unit shows no evidence of racial disproportionality in traffic stops. We also find the lack of location information in most traffic stop data to be problematic. Others have used this information to subset analyses by geography (Grogger & Ridgeway, 2006) or to control for features of the built environment (Horrace & Rohlin, 2014). This information could be used to better specify models and to control for potential spatial effects.

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Appendix 2—Sensitivity Analysis

Several variations in the VOD methodology have the potential to alter findings (***Table 13***). These variations are more restrictive in the time ranges that are used in the analysis.

Table 13: Additional Model Specifications

Model Specification	Overall		Male		Female	
	n	OR	*n*	OR	*n*	OR
Model A—Exclude the period of sunset to intertwilight	17,414	1.125**	11,003	1.218***	6,411	0.971
Model B—Events within 30 days of switch to Daylight Saving Time, exclude sunset to intertwilight	6,015	1.245*	3,761	1.258*	2,254	1.209
Model C—Exclude drivers that were Hispanic, other than White/Black	16,578	1.166***	10,085	1.256***	6,493	1.015
Model D—Include controls for month	19,801	1.128*	12,516	1.221**	7,285	.935

Notes: Results presented as odds ratios. Models also controlled for day of week, year, and time of stop as linear and quadratic terms. These coefficients are omitted for brevity. Models were specified as generalized linear mixed models where officer ID was treated as a random effect. $*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

Model A recognizes that the time between sunset and intertwilight (roughly 30 minutes) is difficult to classify as light or dark. Therefore, Model A dropped events that occurred between sunset and intertwilight. Results were substantively the same.

Model B considers only events that occurred within 30 days before or after the switch to Daylight Saving Time. The switch causes a well-defined difference in available lighting at the same time of day and limits the amount of variance that could be caused by seasonal differences in traffic patterns. Furthermore, we excluded cases that occurred between sunset and intertwilight for the reasons discussed previously. Model B can be thought of as the strongest theoretical test of the effect of lighting. Although we dropped a substantial number of cases, the results were largely the same. There were minor changes in the odds ratios, but the overall findings were consistent with the less-restrictive models presented above.

Model C dropped events that involved drivers who were Hispanic, Asian, Native American, or of unknown race. Results were substantively the same.

Model D included dummy variable controls for month of year. The model also contained standard temporal controls (time of day, day of week, and year). No noteworthy changes were observed from the primary models (Models 1, 2, and 3).

An alternative scenario that may invalidate these findings is systematic underreporting of traffic stops that involve Black drivers. Given the lower confidence interval of the primary model (Model 1), DPD officers would have to systematically underreport stops of Black drivers by 4.54% during dark hours (for example, if officers reported 100% of traffic stops involving Black drivers during daylight, they would have to report 95.46% of stops involving Black drivers during dark hours). Given state laws mandating this reporting, and the DPD's internal audits and checks on stop data submission, this level of systematic underreporting by officers is unlikely.