Measuring Racial Bias During Police Traffic Stops in Los Angeles, CA

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Abstract

With the “Black Lives Matter” (BLM) movement becoming an international phenomenon that put a glaring spotlight on the injustices and violence faced by the Black community in the U.S., research in disparate treatment based on race during police traffic stops is as relevant as ever to conduct. By utilizing two quantitative analysis methods, the Veil-of-Darkness test and Disproportionality Index, this paper explores Los Angeles city traffic stop and traffic collision data and measures potential racial bias during police-motorist interactions. Overall, both tests have suggested racial bias disproportionately and most noticeable against Black male motorists. To address this troubling finding, the report recommends that the Los Angeles Police Department vastly improve their audit division to keep the police department accountable in general, as well as reduce officer-motorist interactions via automated traffic enforcement and transfer of traffic enforcement responsibilities to a community organization composed of trained, unarmed professionals.

Introduction

In recent years, especially in 2020, there have been immense strides and civilian action taken in protest of disparate institutional and often violent treatment towards Black individuals in the United States, which has been identified as the "Black Lives Matter" (BLM) Movement. Especially after the video release of George Floyd begging for help as a police officer had his knee placed on Floyd's neck[1], which led to his eventual death, there has been an eruption of protests and an increased highlight on interactions between police officers and Black individuals. This has been shown by a recently rapidly growing awareness and movement to critique, defund, or abolish the police[2] (though the idea of police abolition is hardly new).[3]

According to the Bureau of Justice, being stopped while driving is the most common way for Americans to interact with the police.[4] Traffic stops are a reasonable source of data to review in order to research possible racial discrimination amongst police officers since they hold "the greatest potential for police racial bias, or perceptions of it."[5] Provided that is the case, it is significant to observe, analyze, and understand whether there legitimately exists racial bias during interactions between police officers and Black individuals during traffic stops. There have been countless stories that involve bloodied Black victims at the hands of allegedly bigoted police officers; however, without a way to soundly show that a racial bias exists during these interactions, there is a lacking foundational structure for implementing policy solutions to

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[1] Dreyer, Benard P., Maria Trent, Ashaunta T. Anderson, George L. Askew, Rhea Boyd, Tumaini R. Coker, Tamera Coyne-Beasley, et al. "The Death of George Floyd: Bending the Arc of History Toward Justice for Generations of Children." *Pediatrics* 146, no. 3 (2020). https://doi.org/10.1542/peds.2020-009639.
[2] Robinson, Paul H. "Why the Police Should See the 'Defund' Movement as a Golden Opportunity." *Newsweek*, July 21, 2020.
[3] Gimbel, V Noah, and Craig Muhammad. "Are Police Obsolete? Breaking Cycles of Violence Through Abolition Democracy." *Cardozo Law Review* 40, no. 1453 (2019): 91.
[4] Bureau of Justice Statistics. "Traffic Stops." Accessed October 26, 2020. https://www.bjs.gov/index.cfm?tid=702&ty=tp.
[5]Fridell, Lorie, Robert Lunney, Drew Diamond, Bruce Kubu, Michael Scott, and Colleen Laing. "Racially Biased Policing: A Principled Response." Police Executive Research Forum, January 1, 2001, 4.

prevent egregious actions performed disproportionately against Black individuals. Thus, this paper serves to utilize two different computational methods to measure racial disparities and suggestions of racial bias during police traffic stops, specifically the Veil-of-Darkness (VOD) test and Disproportionality Index, in the city of Los Angeles and to suggest policy recommendations that aim to minimize disparate treatment of different races during police traffic stops.

Background Information

I. "BLM"

Fear and hostility towards Black faces and especially Black males have fueled bias, prejudice, and discrimination against Black individuals in various ways. Beginning with the fatal shooting events where police officers, or members of authority, are responsible for the deaths of unarmed Black men such as Trayvon Martin and Michael Brown (it is significant to note that racism against Black individuals did not necessarily begin at this point, but the BLM movement began to seriously become more prominent after these events), the racism against Black individuals, individually and institutionally, has ultimately culminated into the BLM movement.[6]

BLM seeks to demand justice for Black individuals and raise awareness of institutional racism and policing.[7] Americans often associate Black individuals with the "Black-as-Criminal" stereotype, which is a term employed by Cynthia Lee, a law professor at George Washington University, that implies that Black individuals participate in criminal, violent, and dangerous

[6] Graff, Gilda. "Redesigning Racial Caste in America via Mass Incarceration." *The Journal of Psychohistory* 43, no. 2 (2015): 120–33.
[7] Chapple, Reshawna L, George A Jacinto, Tameca N Harris-Jackson, and Michelle Vance. "Do #BlackLivesMatter? Implicit Bias, Institutional Racism and Fear of the Black Body." *Ralph Bunche Journal of Public Affairs* 6, no. 1 (2017): 3–11.

activities.[8] In 1976, Birt Duncan at the University of California at Irvine found 75% of tested undergraduate students deemed a Black person shoving a White person as violent behavior, and 6% of subjects deemed the behavior as “playing around”. However, in the case of a White person shoving a Black person was deemed to be violent merely 17% of the time, with the behavior being described as “playing around” 42% of the time.[9] The study concluded that the threshold of being viewed as committing an act of violence is much lower for a Black person compared to a White person. The "Black-as-Criminal" stereotype applies to all Black individuals, but especially impacts young Black males.[10] There have also been various court cases where a White individual falsely accuses a Black man for having committed a crime, which is readily accepted by the criminal justice system, and later the White individual admits to lying or having committed the crime themselves:

> In 1989, Carol Stuart, who was seven months pregnant at the time, was shot and killed in an inner-city neighborhood of Boston, Massachusetts. Carol's husband, Charles Stuart, told police that a Black man had abducted them at gunpoint, robbed the couple, and then shot Carol in the head and Charles in the abdomen. Police arrested William Bennett, a Black man who had spent most of his life in trouble with the law and had served two terms in prison for threatening and shooting police officers. Later, Charles Stuart admitted to a family member that he killed his wife for the insurance money; Stuart then committed suicide.
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> Charles Stuart's false claim that a Black man murdered his wife is not the only case of its kind. In 1992, Jesse Anderson claimed two Black men attacked his wife by stabbing her in the face and neck. Anderson was later convicted of first-degree murder. In 1994, Susan Smith told police that a Black man took her car at gunpoint and kidnapped her two young boys. Smith later confessed to pushing her car into a lake and watching it sink with her two young children strapped inside, and was convicted of first-degree murder.[11]

These ideas of Black men in particular fuel society's lens that behavior and actions performed by Black men are violent and/or aggressive, even if that is not the case with White

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[8] Lee, Cynthia Kwei Yung. “Race and Self-Defense: Toward a Normative Conception of Reasonableness.” *Minnesota Law Review* 81, no. 367 (1996): 369–410.
[9] Birt L. Duncan, Differential Social Perception and Attribution of Intergroup Violence: Testing the Lower Limit of Stereotyping of Blacks, 4 J. Personality & Social Psychology. 590, 592 (1976).
[10] Lee, Cynthia. “Making Race Salient: Trayvon Martin and Implicit Bias in a Not Yet Post-Racial Society.” *North Carolina Law Review* 91 (2013): 59.
[11] Lee, “Race and Self-Defense”, 408-9.

men exhibiting the same behavior and actions and not being deemed violent and/or aggressive.[12] In fact, with White men, the same actions are often viewed as unintentional or out of one's control.[13] Thus, in the context of police interactions towards Black drivers, this paper seeks to examine whether the "Black-as-Criminal" stereotype is also exercised and results in disparate treatment to Black drivers in comparison to White drivers during traffic stops.

II. Racial Bias in Police Traffic Stops

Several studies have shown that racial minorities, especially Black individuals, are disproportionately affected when it comes to police stops, searches, citations, and arrests.[14] To name an example, Carroll and Gonzalez in 2014 analyzed all traffic stops in Rhode Island during 2006 and found that Black drivers were more likely than White drivers to be frisked and searched during a stop.[15] The Bureau of Justice also provides statistics that show while 9.8% of licensed drivers are Black individuals, they make up 11.6% of drivers that are stopped at least once by a police officer and 13.7% of drivers that are stopped more than once.[16] The "literature review" section of this paper also delves into more research papers that have found similar results. In regards to Los Angeles, Ayres and Borowsky found that per 10,000 residents, Black motorists were stopped 4,569 times compared to the 1,750 times White/other motorists were

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[12] Lawson, Tamara F. "A Fresh Cut in an Old Wound – A Critical Analysis of the Trayvon Martin Killing: The Public Outcry, the Prosecutors' Discretion, and the Stand Your Ground Law." *St. Thomas University School of Law* 23 (November 2012): 41.
[13] Richardson, L. Song, and Phillip Goff. "Self-Defense and the Suspicion Heuristic." *Iowa Law Review* 98 (2012): 293.
[14] Roh, Sunghoon, and Matthew Robinson. "A Geographic Approach to Racial Profiling: The Microanalysis and Macroanalysis of Racial Disparity in Traffic Stops," n.d., 53. https://doi.org/10.1177/1098611109332422.
[15] Carroll, Leo, and M. Lilliana Gonzalez. "Out of Place: Racial Stereotypes and the Ecology of Frisks and Searches Following Traffic Stops." *Journal of Research in Crime and Delinquency* 51, no. 5 (August 2014): 559–84. https://doi.org/10.1177/0022427814523788.
[16] Langan, Patrick A., Lawrence A. Greenfeld, Steven K. Smith, Matthew R. Durose, and David J. Levin. "Contacts between Police and the Public: Findings from the 1999 National Survey." Washington, D.C.: U.S. Department of Justice Office of Justice Programs, February 2001. https://www.bjs.gov/content/pub/pdf/cpp99.pdf.

stopped in 2008.[17] Black motorists were nearly 3 times as likely to be stopped. They also found that Black motorists were 166% more likely to be ordered out of their car, 127% more likely to be frisked, and 81% more likely to have a non-consensual search conducted during a police traffic stop compared to White motorists.

Though statistics may show that Black individual are disproportionately stopped by the police, that does not necessarily indicate that there is a pattern of race discrimination by police officers. The issue of "Driving While Black" (DWB), which is the existence of racial profiling (a person being suspected of committing an offense based on race solely as an indicator, or one of several indicators)[18] against Black individuals while driving, has been controversial for the past several years.[19] There have been arguments that claim there are other reasons/contributors to police traffic stops than racial profiling; one line of argument is the "out-of-place doctrine" (also known as racial incongruity), which is also applicable and legally used by police officers as reasonable suspicion.[20] Out-of-place policing contends that it is appropriate for a police officer to be suspicious of and to surveil and stop an individual who does not match the racial background of the area they are existing in at that moment.[21] For instance, it would be reasonable for a police officer to stop or arrest a White individual driving around in a predominantly Black neighborhood, according to out-of-place policing. There have been many studies that have

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[17] Ayres, Ian, and Jonathan Borowsky. "A Study of Racially Disparate Outcomes in the Los Angeles Police Department." Los Angeles: ACLU of Southern California, October 2008. https://www.aclusocal.org/sites/default/files/wp-content/uploads/2015/09/11837125-LAPD-Racial-Profiling-Report-ACLU.pdf.

[18] United States General Accounting Office. "Racial Profiling: Limited Data Available on Motorist Stops." Washington, D.C., March 2000. https://doi.org/10.1037/e543332006-001.

[19] Walker, Samuel. "Searching for the Denominator: Problems With Police Traffic Stop Data And an Early Warning System Solution." *Justice Research and Policy* 3 (1) (2001): 63–97. https://doi.org/10.3818%2FJRP.3.1.2001.63.

[20] Hannon, Lance, Malik Neal, and Alex R. Gustafson. "Out-of-Place and In-Place Policing: An Examination of Traffic Stops in Racially Segregated Philadelphia." *Crime & Delinquency*, June 1, 2020. https://doi.org/10.1177/0011128720926122.

[21] Fagan, Jeffrey, and Garth Davies. "Street Stops and Broken Windows: Terry, Race and Disorder in New York City." *Fordham Urban Law Journal* 28, no. 2 (2001): 457–64. https://doi.org/10.2139/ssrn.257813.

shown the existence of this policing method; for example, Gaston, Brunson, and Grossman in 2020 found Black individuals' risk of arrest was higher in neighborhoods inhabited by a majority of White and Hispanic residents, and the risk of arrest for White individuals in neighborhoods inhabited by a majority of Black residents was also increased.[22] Thus, an argument has been made that Black individuals may not necessarily be stopped merely because an individual is Black; the out-of-place policing phenomenon applies to both Black and White individuals. Instead of DWB referring to only Black individuals being impacted by police stops, out-of-place policing suggests that it is not necessarily about being Black but being a different racial background than the background of the area one is in.

Allegations of police officers racially profiling Black individuals during traffic stops have been especially contentious and discussed in many communities within the United States. Especially with the rise of the BLM movement, the implication of America's uniform-clad members holding racial bias when they are intended to uphold justice and maintain public safety is deeply unsettling. In a society striving for equal treatment, it is not acceptable for Black-Americans, just like any group of Americans, to feel unsafe around those who are intended to maintain safety within communities; without taking the time to determine whether police officers are exhibiting racial bias towards Black drivers, it is difficult to accurately assess whether race does play in a significant role in whether an individual is stopped or not while driving. Thus, it is important to create ways to assess racial bias during these interactions so that if there is a disparity in treatment between drivers based on race, this issue can be uncovered and dealt with accordingly.

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[22] Gaston, Shytierra, Rod K. Brunson, and Leigh S. Grossman. "Are Minorities Subjected to, or Insulated from, Racialized Policing in Majority–Minority Community Contexts?" *The British Journal of Criminology*, June 2020. https://doi.org/10.1093/bjc/azaa038.

III. Measuring Racial Bias Quantitatively

There are a variety of ways that racial bias may be measured, including the Outcome test, Disproportionality Index, Threshold test, and Veil-of-Darkness test. The Outcome test focuses on the "hit rate" of a driver, which is the likelihood of a search yielding a find of a contraband item.[23] So, in order to measure whether racial bias was involved in a search, even if it were the case that Black drivers are more likely to possess a contraband, if a Black driver has a less successful hit rate in comparison to a White driver then that would suggest that Black drivers are unjustly searched more than their White counterpart. *Figure 1*, displayed below, shows an example of conducting the test with stop and search percentages in Persico and Todd's 2006 study.

Table 1

(*a*) *Comparison of Stop and Search Percentages Against Population Benchmark*

	Percentage in Population*	Percentage of stops	Percentage of searches†
Black	11.4	21.45	32.65
Asian	4.0	2.81	2.09
White (incl. Hispanic)	75.2	73.90	63.61
White – NonHispanic	65.6	64.37	50.81
White – Hispanic	9.6	9.53	12.80
Native American	1.2	0.17	0.48
Other	8.2	1.68	1.17

Figure 1: Comparison of Stop and Search Percentages Against Population Benchmark[24], which displays overall more searches compared to stops for people of color and the reverse for White motorists.

[23] Engel, Robin S., and Rob Tillyer. "Searching for Equilibrium: The Tenuous Nature of the Outcome Test." *Justice Quarterly* 25, no. 1 (March 1, 2008): 54–71. https://doi.org/10.1080/07418820701717243.
[24] Persico, Nicola, and Petra Todd. "Generalising the Hit Rates Test for Racial Bias in Law Enforcement, with an Application to Vehicle Searches in Wichita." *The Economic Journal* 116, no. 515 (2006): F351–67.

The Disproportionality Index (DI), utilized by Bonner and Stacey in 2018[25] and originally created by the Dolan Consulting Group in 2016[26] builds off of the Outcome test by comparing the percentages of stops to a particular benchmark, which could be population or some indicator of driving behavior or proneness to illicit activities. The DI goes further by creating a proportion with the stop rates and the selected benchmark's rates; it creates a comparable numerical value that may be used to measure racial bias in police traffic stops for each race category.

The Threshold test is also built upon the foundations of the Outcome test (which had previously also been used to detect racial bias), but with the use of logistic regressions rather than proportions. In the Outcome test, the hit rates between Black and White males are compared; if Black male drivers have a lower hit rate than White male drivers, according to the Outcome test, there is a suggestion that the Threshold, or bar, to search Black male drivers is lower. If police officers had the Threshold for searching Black and White male drivers to be the same, then there would have been fewer Black male drivers searched, or more White male drivers searched in the first place. However, the Outcome test does not do enough to conclude racial bias due to infra-marginality[27]; if the average hit rate for Black male drivers is lower than for White drivers, that does not necessarily prove that the Threshold of the expected hit rate was lower for Black male drivers than for White male drivers. Though the Outcome test can show evidence of a disparity between the threshold of an officer's decision to search a White male driver versus a Black male driver, a disparity does not ensure unjustified behavior towards motorists based on race. The issue of infra-marginality is further discussed in the "Literature Review" section. Thus, in order to see whether a Black male driver is unjustifiably searched, one

[25] Bonner, 85.
[26] Johnson, Richard R. "Biased-Based Policing Reports Are Failing the Police and the Community." *Dolan Consulting Group*, September 2016, 5.
[27] Simoiu, Camelia, Sam Corbett-Davies, and Sharad Goel. "The Problem of Infra-Marginality in Outcome Tests for Discrimination." *The Annals of Applied Statistics* 11, no. 3 (September 2017): 1193–1216. https://doi.org/10.1214/17-AOAS1058.

may use the Threshold test, which would use a Bayesian regression model and serves to estimate race-specific search thresholds and risk distributions that are consistent with the observed search and hit rates.[28] The model is essentially a prediction, and it helps to more clearly see whether police officers' thresholds to search Black or White male drivers are unjustifiably different on the sole purpose of race. The Threshold test compares estimated search and hit rates generated by the Bayesian model. Thus, if it is found that the expected threshold of a police officer searching a Black male driver is lower than the expected threshold of searching a White driver, then there is a suggestion of racial bias during police traffic stops.

On the other hand, the Veil-of-Darkness (VOD) test compares the frequency in which drivers are stopped during sunlight and sundown; if Black male drivers make up less of the percentage of police stops during the night (or when the sun is down) compared to during the day (or when the sun is up, and drivers are more visible), that suggests racial bias against Black male drivers.[29] This test stems from the assumption that police officers will not be able to easily observe the race of drivers during the night in comparison to the day, since the darkness diminishes visibility of drivers in their vehicles. Thus, if there happens to be police officers that participate in racial profiling, then it would be expected for there to be a smaller percentage of Black male drivers that are stopped at night in comparison to the day. This text examines the specific times of the day that different drivers are stopped and determines at what time the sun is up or has set during that specific time of the year. It is important to keep the latter information in mind, for a specific time during a particular season could mean daylight, whereas the exact same time during another season could mean perceived darkness. Daylight and darkness are

[28] Simoiu, 1196.
[29] Grogger, Jeffrey, and Greg Ridgeway. "Testing for Racial Profiling in Traffic Stops From Behind a Veil of Darkness." *Journal of the American Statistical Association* 101, no. 475 (September 2006): 878–87. https://doi.org/10.1198/016214506000000168.

distinguished by how many degrees above or below the horizon the sun is. It is classified nighttime once the sun is at least six degrees below the horizon.[30] So that there is no room for confusion, the 30-minute time frame between sunset and dusk in the evening is not included so that there is an easier distinguishment between light and dark.

Literature Review

This literature review serves to examine existing publications and information that analyzes the topic of racial bias against Black drivers during traffic stops. Overall, much existing (quantitative and qualitative) research and literature have all generally shown a trend of disparate treatment towards Black drivers, especially in comparison to White drivers. Not only does there exist many, many accounts of police brutality against Black drivers during traffic stops that have made newspaper headlines (and countless more that have not reached the public eye), and these accounts are recognized nationwide, but there have also been many statistical analyses completed to grasp the actual numbers and measure the disparities that Black drivers face during police traffic stops. This literature review will delve into previous research that has used quantitative methods to demonstrate whether police officers did stop drivers with racial bias and the assumptions and issues that may exist with these methods. For context, this literature review will also include general information on racial bias against Black individuals/other research in regards to Black individuals disproportionately being stopped by police officers while driving. The articles examined in this literature review will be compared and analyzed based on their methodology and consideration to how the data collected or results found may have been

[30] Pierson, Emma, Camelia Simoiu, Jan Overgoor, Sam Corbett-Davies, Daniel Jenson, Amy Shoemaker, Vignesh Ramachandran, et al. "A Large-Scale Analysis of Racial Disparities in Police Stops across the United States." *Nature Human Behaviour* 4, no. 7 (July 2020): 736–45. https://doi.org/10.1038/s41562-020-0858-1.

impacted by factors other than racial bias. Especially since racial bias is an abstract concept that may not truly, objectively be measured, it is imperative that academic sources strive to measure it with the least amount of assumptions and account for any variables that may affect the outcomes resulting from the tests developed to measure racial bias.

I. General Racial Bias Against Black Individuals

As taught in UEP 310, movements and change are born from the point in which people decide that they are no longer willing to accept and endure the situations that they are put under. The killing of Trayvon Martin shook the United States by acting as the last straw that broke the camel's back in terms of how much racial injustice via abuse, killings, and more the Black community would stand for.

"Self-Defense and the Suspicion Heuristic" by L. Song Richardson and Phillip Atiba Goff published in the *Iowa Law Review* in 2013 discusses the importance of, and brings awareness to, the "suspicion heuristic", which is the idea that "non-conscious processes can lead to systematic and predictable errors in judgments of criminality — and influence subsequent behaviors — regardless of conscious racial attitudes."[31] Using previous scientific research and reports to support this claim, the paper comes to the conclusion that the law of self-defense should take into consideration the suspicion heuristic while assessing whether one claims the use of self-defense. This is a relevant topic to consider when reviewing the actions police officers take against Black individuals.

Heuristics themselves are mental shortcuts that are unconsciously utilized by all people. Despite actively or consciously believing in the idea that all individuals are created equal, there are still beliefs that are impossible to untangle within human unconsciousness that influence decision-making and judgment. It is efficient in terms of the mental energy that a person may use

[31] Richardson, 293.

to utilize heuristics, for if a person were to continuously go through thought processes for every little thing in their life, it would be extremely mentally draining. The ability to unconsciously and quickly make intuitive decisions has its advantages in daily life so that one may reach a conclusion without exhaustive research or thinking, which is critical to human survival. And usually, this ability has been advantageous and allows for deeper thinking in more important considerations.

However, the utilization of mental shortcuts allows for incorrect judgments to be made, even if one does not intend for them, thus contributing to implicit biases against particular races. With skilled ability in making quick decisions comes a hindrance in suppressing this quick decision-making process in everyday behavior, which unfortunately also includes significant behaviors, such as the way a police officer interacts with a Black individual or driver, or heavily suspecting a Black individual of wrongdoing despite potentially not having ever committed a crime. Going further than that, the decisions made with the help of mental shortcuts are often unquestioningly executed, leading to potentially harmful results, such as the shootings of (unarmed) Black men by police officers (though it may also be argued that there are cases where Black individuals are killed with not just heuristics involved but more ill intent towards Black lives). Especially with the “Black-as-Criminal" stereotype that Black individuals must face (the characterization that Black men perform criminal-like behavior and actions violently/aggressively),[32] the utilization of the suspicion heuristic may only serve to disadvantage Black lives whenever they interact with police officers.

This idea of heuristics impacting cognitive biases towards certain races is well researched; Tamborini et al. in 2007 found that race heuristics influence jury decision-making on

[32] Lee, 401.

court judgments.[33] Levinson in 2007 argued that the implicit biases of judges and jurors influenced the way that they encoded information about court cases, thus perpetuating racial stereotypes in case outcomes.[34] Jones and Kaplan in 2010 came to similar results that showed that heuristics led to "racial effects in judgment of trial defendants" in a courtroom setting.[35] Lastly, Parks poignantly writes in 2018 that implicit racial cognitive bias research has generally shown that people often have a connotation of positive concepts with White individuals and more negative concepts with Black individuals compared to their White counterparts.[36] There is a resounding understanding and backed research that shows the influence of mental shortcuts that ultimately lead to cognitive racial biases and physical, often tragic, outcomes to Black individuals.

Ultimately, the paper by Richardson and Goff concludes that the suspicion heuristic should be weighted, especially in cases where a person erroneously harms or kills a victim.[37] The paper expresses two conclusions: one, that a person that kills an individual based on the suspicion heuristic with the claim of self-defense should not be as severely punished as a person that kills an individual with active malice (fueled by racial bias), and two, since the suspicion heuristic makes it much easier for people to make erroneous judgments, all self-defense laws should acknowledge this by requiring the duty to retreat (where an individual may not harm another with self-defense as a reason if there is a possibility to retreat instead of using force).

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[33] Tamborini, Ron, Ren-He Huang, Dana Mastro, and Reiko Nabashi-Nakahara. "The Influence of Race, Heuristics, and Information Load on Judgments of Guilt and Innocence." *Communication Studies* 58 (November 6, 2007). https://doi.org/10.1080/10510970701648566.
[34] Levinson, Justin. "Forgotten Racial Equality: Implicit Bias, Decisionmaking, and Misremembering on JSTOR." *Duke Law Journal* 57, no. 2 (November 2007): 345–424.
[35] Jones, Christopher S., and Martin F. Kaplan. "The Effects of Racially Stereotypical Crimes on Juror Decision-Making and Information-Processing Strategies." *Basic and Applied Social Psychology* 25, no. 1 (February 1, 2003): 1–13. https://doi.org/10.1207/S15324834BASP2501_1.
[36] Parks, Gregory S. "Race, Cognitive Biases, and the Power of Law Student Teaching Evaluations." *University of California, Davis* 51:1039 (2018): 1046.
[37] Richardson, 293.

"Self-Defense and the Suspicion Heuristic" does a fair job at explaining and providing sufficient examples of how the suspicion heuristic may be applied in a general manner. However, the paper mentions police officers and how they are influenced by the suspicion heuristic while not at all addressing the elevated responsibility that comes with the status of being a police officer. The argument that a person who kills based on an error in judgment compared to active hostility should be punished less severely may be acceptable in a general sense, however, in the context of the person who kills being a police officer, it could be argued that police officers must be held to a higher standard. The paper itself does mention and suggest the idea that police officers could be required to undergo training that would reduce the effects of the suspicion heuristic, which would make the expectation of officers accepting the duty to retreat more so than a civilian. Thus, the paper recognizes the higher standard that police officers are expected to adhere to for the conclusion that self-defense laws should have a requirement of retreating if possible, however, it fails to also mention this standard for the conclusion regarding sentence severity. The paper still makes sensible points that are significant to consider, however, it does detract from the responsibility that police officers inherently hold to treat constituents fairly and without racial discrimination.

II. Tests to Quantitatively Measure Racial Bias

A significant amount of literature exists on measuring racial bias during police traffic stops; in 2002, Meehan and Ponder compared police officers' traffic-stopping behavior in predominantly White communities and predominantly Black communities in order to see if there is a disparity in how Black or White drivers are treated in both areas.[38] This study utilized data from a medium-sized suburban police department that policed a city of over 75,000 residents. Of

[38] Meehan, Albert J., and Michael C. Ponder. "Race and Place: The Ecology of Racial Profiling African American Motorists." Justice Quarterly 19, no. 3 (September 1, 2002): 399–430. https://doi.org/10.1080/07418820200095291.

these residents, 98% of them were White; this city also bordered a city with more than 75% Black residents, and the proximity between these two cities is utilized as a variable in this study. Meehan and Ponder took advantage of data that displayed the police officers' Mobile Data Terminal (MDT) queries (electronic requests officers input into in-car computers to gain instant access to national, state, and local databases displaying vehicular and driver information while observing and surveying vehicles during patrol shifts). They found that there was a disproportionate amount of queries on Black drivers that increased as drivers moved closer in proximity to the central area of the White-concentrated city. In regards to White drivers, they had an equal chance of being electronically queried by a police officer regardless of the area the White individual drove through.

In 2012, Novak and Chamlin reviewed traffic stops in Kansas City, Missouri, a large Midwestern city with a population of roughly 441,000 during the time the study was conducted.[39] The study analyzed 106,268 traffic stops that occurred in 2004 up till September 30, 2004, aside from stops that were investigatory (stops occurring due to motorists or vehicles matching a description for those who are wanted for police questioning). Thus, this study analyzed stops that were not investigatory and instead were proactive stops related to traffic law violations such as speeding, not turning on signals during lane changes, having a broken tailgate, etc. Novak and Chamlin found that the rate of police officers conducting a search on a driver increased for White drivers in areas of Kansas City that had a higher proportion of Black residents in comparison to White residents. Thus, this study shows that at some level, the environment, or surrounding population living in an area, affects an officer's decision-making during traffic stop searches, especially if the race of the driver does not match the race of the general surrounding population

[39] Novak, Kenneth J., and Mitchell B. Chamlin. “Racial Threat, Suspicion, and Police Behavior: The Impact of Race and Place in Traffic Enforcement.” Crime & Delinquency 58, no. 2 (March 2012): 275–300. https://doi.org/10.1177/0011128708322943.

in the area the driver was searched. This supports the out-of-place policing earlier mentioned in the "background information" section.

Carroll and Gonzalez in 2014 analyzed all traffic stops in Rhode Island during 2006 and found that Black drivers were more likely than White drivers to be frisked and searched during a stop.[40] During that year, troopers made 52,571 traffic stops; after combing through the data to remove duplication, stops not involving White or Black individuals, incomplete data, and other inconsistencies, the study reviewed 47,913 stops. On top of the aforementioned finding, the study concluded that Black drivers were significantly more likely to be frisked when stopped by a police officer in a White area. However, the rate at which White individuals were frisked did not match the disparity that Black drivers faced. Therefore, this study showed that out-of-place policing more heavily impacted Black drivers than White drivers.

Levchak's study in 2017 expresses similar results in New York; Black individuals had an increased risk of being frisked than White individuals.[41] In fact, the closer the proximity of a police officer frisking an individual to neighborhoods consisting of mostly Black residents, the higher the disparity between the increased risk of Black individuals being frisked to White individuals.

Lastly, "A large-scale analysis of racial disparities in police stops across the United States" by Emma Pierson, Camelia Simoiu, Jan Overgoor, Sam Corbett-Davies, Daniel Jenson, Amy Shoemaker, Vignesh Ramachandran, et al. is a comprehensive study published in 2020 in a monthly journal named *Nature Human Behavior* that utilizes nationwide data on police traffic stops to perform various tests to measure racial bias, such as the Outcome test, the Threshold

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[40] Carroll, Leo, and M. Lilliana Gonzalez. "Out of Place: Racial Stereotypes and the Ecology of Frisks and Searches Following Traffic Stops." *Journal of Research in Crime and Delinquency* 51, no. 5 (August 2014): 559–84. https://doi.org/10.1177/0022427814523788.

[41] Levchak, Philip. "Do Precinct Characteristics Influence Stop-and-Frisk in New York City? A Multi-Level Analysis of Post-Stop Outcomes." *Justice Quarterly* 34 (March 29, 2016): 1–30. https://doi.org/10.1080/07418825.2016.1162320.

test, and the Veil-of-Darkness test.[42] The article concludes that there *are* disparities between drivers based on race in the likelihood of being stopped by a police officer in traffic, and there is suggestion of racial bias against Black drivers (as well as Hispanic drivers) in comparison to White drivers during traffic stops across the United States.

The study carries out a variety of tests, one of them being the Outcome test. As a reminder, the Outcome test focuses on the rate at which a driver has a contraband item when searched; if there is a disparity in hit rates between Black and White drivers, the test claims that this suggests racial bias. The Outcome analysis in this paper found that when Hispanic drivers were searched, their "hit rate" was less successful than a White driver's rate; however, the comparison between hit rates of White and Black drivers was not as significant. Thus, the results show that police officers may be more biased against Hispanic drivers compared to White drivers, but there is not as strong of a connection with bias against Black drivers compared to White drivers. However, the Outcome test does come with some shortcomings; there is the issue of infra-marginality, meaning that if there are drivers with differences in variability around averages on the likelihood of carrying a contraband item, it is possible that the Outcome test incorrectly concludes biased searches against a specific race group, even if the test is administered in a race-neutral manner.[43]

[42] Pierson, 736.
[43] Simoiu, 1197.

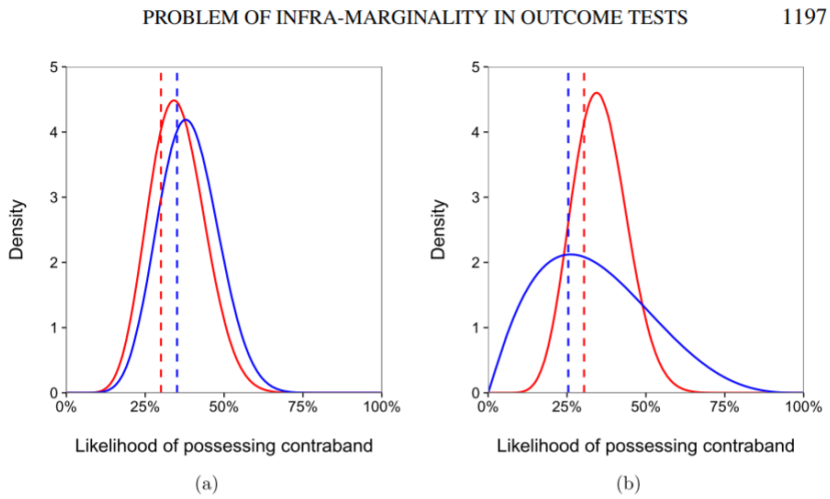

Figure 2: Problem of Infra-Marginality in Outcome Tests,[44] *which shows how groups may be viewed as being disproportionately searched when they are not.*

To more clearly display the issue of infra-marginality, these graphs show that the group represented in red is certainly disproportionately being searched, as shown by the higher height of the graph compared to the blue. For context, both graphs have the same hit and search rates, but how the drivers are distributed is different. Also for clarification, the search threshold is represented by the dotted lines. In the first graph, there is an implication that the red group is being searched disproportionately since the search threshold for the red group is lower than the blue group's, so everything matches what is expected. However, the next graph shows that those in the blue group have a lower search threshold compared to the red group, despite the red group being discriminated against. This result does not accurately depict the discrimination that the red drivers are facing, and in fact, gives the opposite result. So, when there are different amounts of drivers varying in their likelihood of possessing a contraband item, depending on how each graph is distributed, the lower or higher search threshold may not be representative of actual

[44] Ibid.

discrimination.

Thus, in order to address this issue, the Threshold test better represents a measurement of racial bias by taking into account both search rates and hit rates with a hierarchical Bayesian latent variable model, the Threshold test keeps in mind variances in different races being in possession of contraband items, unlike the Outcome analysis. As a reminder, the Threshold test aims to estimate race-specific probability thresholds in which officers search drivers. Even if two race groups have the same observed hit rate, the Threshold test may find that one group is searched on the basis of less evidence, indicative of discrimination. The Threshold test holds more weight than the Outcomes test since it solves the issue of infra-marginality, however, the test does not come without potential issues. For instance, there may be differences in search policies in different police departments throughout the United States, which may affect the results of the Threshold tests across the different geographic subdivisions within the nation. It is also possible that certain beats (a term that police use to refer to an area that an officer is responsible for) that police patrol are areas that disproportionately have more serious criminal activity than other beats, which may contribute towards an officer's decision-making in a search, thus not relating to racial profiling.[45] Thus, for a better understanding of whether there may be differences in these areas, more research would need to be done in this aspect.

The study also carried out the Veil-of-Darkness test, which is a common way amongst various researchers to measure racial bias.[46] [47] [48] This test, as mentioned in the "background information" section, compares the frequency in which Black drivers are stopped during sunlight

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[45] Pierson, 737.
[46] Taniguchi, Travis A., Joshua A. Hendrix, Alison Levin-Rector, Brian P. Aagaard, Kevin J. Strom, and Stephanie A. Zimmer. "Extending the Veil of Darkness Approach: An Examination of Racial Disproportionality in Traffic Stops in Durham, NC." *Police Quarterly* 20, no. 4 (December 1, 2017): 420–48. https://doi.org/10.1177/1098611117721665.
[47] Bonner, Heidi S, and Michele Stacey. "Measuring Disproportionate Treatment in Policing: One Department's Experience." *Journal of Criminal Justice and Law* 2, no. 2 (2018): 84–101.
[48] Hannon, 6.

and sundown; if Black drivers make up less of the percentage of police stops during the night (or when the sun is down) compared to during the day (or when the sun is up, and drivers are more visible), that suggests racial bias against Black drivers. The methodology does take into account different variables, such as time. If the research were to analyze data retrieved of stops during various points in time of the day, there would be many more variables that could be influencing potential disparities in those who are stopped by police officers. There may be different drivers being on the road during different times or other certain circumstances that only exist in the day or night that may never be noticed or accounted for. Thus, it is helpful that in this study, the researchers control for the time of day by looking at the beginning and ending of daylight-savings time, for at the same time during the beginning and ending, and there is light for one day at that time and darkness for the other. However, there still do exist other variables that may impact the veil-of darkness test; for instance, the street lamps in a neighborhood or area can make it so some places are more well-lit than others, which would vary the amount of light in different places during the nighttime. This problem may be ameliorated by controlling the locations of the stops that are being analyzed and taking measures that ensure that the locations of the stops have similar lighting conditions.

The paper “A large-scale analysis of racial disparities in police stops across the United States” does a good job at carrying out various tests to measure racial bias with rather consistent results, which provides more evidence towards their suggestion of Black male drivers facing racial bias from police officers during police stops. The study also does address issues and shortcomings clearly in their methodology and explains ways in which they have controlled for other variables, such as the infra-marginality issue in the Outcome test and the time of day for the Veil-of-Darkness test. Due to the large scale of the study, it makes sense that the researchers

did not take the time to further research and ensure that more detailed variables (such as different areas having different search policies for the Threshold test) were similar or accounted for while doing these tests.

III. Literature Review Conclusion

In summary, the academic papers address important and valid points in regards to police traffic stops; Richardson and Goff reviewed the basis of racial bias against Black individuals (assuming that people are not blatantly racist) with the suspicion heuristic, and the Pierson et al. strived to quantitatively measure with various tests whether police officers make decisions based on racial bias. Both papers similarly have a conclusion that Black individuals face more scrutiny/negative impact compared to other races, from both a psychological perspective and factual data-driven perspective. The first article comes to easily understood results padded with psychological research and real-life examples and explanations, however, there is an inconsistency in addressing the higher standard that police officers should be held to when it comes to being an individual that partakes in the suspicion heuristic. The second article is a significant piece of work in this field, especially due to its breadth in data across the United States over the course of a decade, utilizing a variety of tests intended to measure racial bias, and addressing the shortcomings of each test they carried out. A weakness is the lack of depth in addressing the shortcomings of some of the tests, which is understandable due to the massive amount of data analyzed.

The Outcome, Threshold, and Veil-of-Darkness test all work and serve to measure racial bias, however, there can be a variety of factors that affect the Outcomes of the tests that can make the results appear to be due to racial bias. For example, in the 1990s, the NYPD had focused on heavy marijuana enforcement, which led to a great increase in arrests against Black

and Latino individuals in New York.[49] Thus, there was a result of racial disparity, however, the reason for this disparity did not necessarily stem from a police officer's bias. There have also been conflicting studies that show differing driving behavior based on race; a study done by Kalinowsky, Ross, and Ross in 2017 with data from Massachusetts and Tennessee[50] showed that Black drivers speed less compared to White drivers, whereas a study done by MacDonald in 2001 with data from New Jersey showed that Black drivers were twice as likely to speed than White drivers.[51] The Outcome and Threshold tests also only work with large assumptions that the crime rates that are recorded by police officers reflect actual offending rates and that all police officers are motivated to maximize the number of stops or violations they participate in, which can lead to incorrect or misleading results. Ultimately, these tests rest on assumptions that cannot be solidly backed; it is clear to see disparities in the racial make-up of those who are stopped, however, that does not lend much help to determining whether a police officer racially profiles an individual. The tests bring society closer to understanding results that work with specific assumptions, but they are still imperfect and not resoundingly clear.

Further questions that may be asked would include consideration of police officers themselves/police culture/police policy or protocol in terms of stopping drivers. This would be a natural next step to take in order to address the clear disparities that most, if not all, research on police traffic stops have shown between especially Black and White male drivers. It is necessary to not only recognize and prove the racial bias if it does exist and is shown in results but to also

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[49] Starr, Sonja B. "Testing Racial Profiling: Empirical Assessment of Disparate Treatment by Police." *The University of Chicago Legal Forum* 2016, no. 12 (2016): 498.

[50] Kalinowski, Jesse, Stephen L. Ross, and Matthew B. Ross. "Endogenous Driving Behavior in Tests of Racial Profiling in Police Traffic Stops." Chicago, IL: Human Capital and Economic Opportunity Global Working Group, April 2020. http://humcap.uchicago.edu/RePEc/hka/wpaper/Kalinowski_Ross_Ross_2017_driving-veil-darkness_v3.pdf.

[51] Mac Donald, Heather. "The Myth of Racial Profiling." *City Journal*, 2001. https://www.city-journal.org/html/myth-racial-profiling-12022.html.

understand how the existing system within police departments allows this activity to occur and ameliorate the system to prevent or reduce racial bias during traffic stops. This research would not only impact specifically traffic stops, but also have larger implications for police brutality during pedestrian stops (such as the stop-and-frisk policy in New York) and even in general towards Black individuals, as well as societal views and behavior towards Black individuals in general. Traffic stops are the most common way that the public interacts with the police, and reducing racial bias in this area would certainly be a significant turning point and stepping stone for racial equity in the United States.

Methodology

To measure racial bias during traffic police stops, this project takes a quantitative approach with data acquired from the Stanford Open Policing Project and City of LA's Open Data Portal, and it strives to measure whether police officers in Los Angeles participate in racially profiling drivers during traffic stops with the Veil-of-Darkness (VOD) test and Disproportionality Index. The VOD test and Disproportionality Index were chosen due to 1) the fact that LA city provided enough open-sourced data on police traffic stops and data collision to allow for these analyses to be conducted, and 2) the DI complements the findings of the VOD test well due to the VOD test's vulnerability to the outcomes potentially resulting from difference in driving behavior via race (a topic which was been previously addressed in the "literature review" section), which would not suggest racial bias. Since the DI directly compares a benchmark for driving behavior (traffic collision rates), the DI results may also serve to provide more foundation to support a claim of racial bias with the VOD test.

This endeavor will be explored by utilizing Los Angeles Vehicle Stop Data and Los Angeles Traffic Collision Data. Data from the years 2011 to 2018 is analyzed since both tables provide complete sets of data for each of these years. Specifically male motorists will be analyzed due to research that shows especial disparate treatment towards Black male individuals in a criminal justice setting, which is further explained in the "background information" section. The data will be processed and analyzed in R, which is a software and programming language that is used most commonly with statisticians to analyze data and come to conclusions with the help of various graphs and models, such as line graphs and tables to display descriptive statistics and linear regression models. This paper utilizes the coding framework that the Stanford Open Policing Project has publicly provided for others to replicate for the VOD test,[52] as well as the concept of the Disproportionality Index provided by Bonner and Stacey in 2018.[53] Due to the limited information provided within the datasets (there are no records on whether searches were performed during traffic stops and no indication whether motorists possessed contraband items in the data tables), the Outcome and Threshold test cannot be done.

In order to carry out the VOD test, the dataset must include the time of the stop. There is additional information also necessary for the VOD test required that is not listed in the data but retrievable in R, such as knowing the times that the sun sets for each date, which is found using a downloadable package in R. More additional information that is required is the population of the areas being observed, so that there may be a total to compare the number of drivers stopped by police officers in a ratio, as well as the race and sex of the driver and the date of the stop. The VOD test employs the use of a binomial regression model; the code for the VOD test can be found in Appendix A.

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[52] Stanford. "The Stanford Open Policing Project." Accessed October 28, 2020. https://openpolicing.stanford.edu/.
[53] Bonner, 85.

In this code, the dataset is curated to only contain traffic police stops that occur during the inter twilight period so that there may be comparisons made between the number of Black male motorists and the number of White male motorists stopped in the daylight or darkness. This is done by taking the time of the traffic stops recorded and using R methods to determine whether the traffic stop occurred at a time of daylight or darkness and then using this subset of traffic stop data in the binomial regression model that includes natural splines with six degrees of freedom. The natural splines with six degrees of freedom are included in order to control for time, as well as provide robustness in regression utilized in the VOD test. The locations of the stops are also taken into account by factoring in the police division in the regression model to control for the case that certain areas may be policed more during the daylight and less so in the darkness. The summary of the VOD model displays the z-values and p-values of the regressions, which tells the statistical significance of the VOD test's findings. A p-value < 0.01 will be considered as statistically significant; Pierson et.al's study used a p-value < 0.001 to consider their findings statistically significant on an analysis of 200 million stops.[54] Since this study analyzes much fewer stops, roughly 4 million, a slightly larger p-value of 0.01 is employed.

In order to find the Disproportionality Index, a benchmark to compare the proportion of stopped Black drivers is required, which will be provided by the City of LA's Traffic Collision Dataset.[55] The Traffic Collision Dataset serves to indicate the driving behavior of respective races. This paper assumes that if the rates of traffic collisions are consistent with police traffic stop rates, then there is no indication of racial bias. However, if there are significant differences between the rates, then there is a suggestion of racial bias. For the DI, the traffic stop dataset must include the race and sex of the driver, as well as the date of the stop.

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[54] Pierson, 738.
[55] Los Angeles Open Data Portal. "Arrest Data from 2010 to 2019," 2019. https://data.lacity.org/A-Safe-City/Arrest-Data-from-2010-to-2019/yru6-6re4.

The disproportionality is calculated with the use of proportions and logarithms. The natural log of the proportion of a respective race being stopped by a police officer while driving is divided by the natural log of the proportion of a respective race being in a traffic collision. The equation is listed below:

```
DI = log(stops_prop)/log(traffic_collisions_prop)
```

Bonner and Stacey's original formula for DI does not include logs, however, the decision to include logs was made in order to account for the skewness of the data and display a more accurate representation of the resulting DI derived from the stops and collision proportions. When the original DI formula was calculated from the traffic collisions and traffic stops, there were inconsistencies in the results when the data points were too small. Thus, the DI was amended to account for this error.

Data Findings

After completing the Veil-of-Darkness (VOD) and Disproportionality Index (DI) analyses, the results overall show that there is a suggestion of racial bias against male motorists of color during police traffic stops, with the opposite being true for white male motorists. In regards to the VOD test, for every year from 2011 to 2018, as well as the aggregate, the results show a negative correlation for Black male motorists during traffic police stops. This suggests racial bias since it is more likely for Black male motorists to be stopped during the daytime, or in the sunlight, in comparison to the nighttime, or in darkness. In regards to the DI, overall, there is also a trend of male motorists of color having lower DI's in comparison to White male motorists; the findings suggest Black and Asian male motorists experienced racial bias, Hispanic male

motorists had an average amount of police interactions as expected, and White male motorists experienced significantly less traffic stops than expected, which may be advantageous racial bias.

The VOD test, for every year, consistently shows results that have a negative coefficient, which measures the influence of the stop occurring in the dark on whether the stopped motorist is Black. The numerical, absolute value of the coefficient displayed in the "VOD RESULT" column in *Figure 3* also shows a trend of increasing from 2011 to 2018. The greater the negative coefficient's absolute numerical value, the greater the influence of time of day/amount of light has on the stopped motorist's race being Black. If the coefficient is negative, then that indicates that when it is dark, fewer Black motorists are stopped; in other words, in the daylight, more Black motorists are stopped than in the darkness. This suggests racial bias, according to the VOD test. In the year 2011, the absolute, numerical value was roughly 0.09, whereas, in 2018, the value grew to 0.33. A greater absolute value represents a larger disparity, which indicates that over the years, more male Black motorists are experiencing racial bias over time during police traffic stops. All of the years excluding 2012 and 2018 are deemed statistically significant with a P-value < 0.01.

YEAR	VOD RESULT	STANDARD ERROR	Z-VALUE	PR(>|Z|)
2011	-0.07389564	0.03496924	-2.113	0.034587*
2012	-0.03273741	0.03604251	-0.908	0.36372
2013	-0.16483424	0.03806718	-4.330	0.0000149*
2014	-0.19569005	0.03747187	-5.222	0.00000077*
2015	-0.15304704	0.04641324	-3.297	0.000976*
2016	-0.37987601	0.04534951	-8.377	<.0000000000000002*
2017	-0.21859941	0.04295175	-5.089	0.000000359*
2018	-0.33606200	0.04247297	-0.791	0.428805

Figure 3: VOD Results that Display the Likelihood of a Male Motorist Stopped in the "Dark" being Black in Los Angeles City from 2011 to 2018, which seemingly increases over time.

For comparisons of different benchmarks for the DI, the racial proportions of the population, police traffic stops, and traffic collisions in Los Angeles City are studied. The population is provided for reference and has been used in research to compare to stops data,[56] but the actual DI is calculated using the police traffic stops and traffic collisions proportions, for traffic collisions are more useful and reflective of driving behavior than population numbers. In Los Angeles city, the population has not significantly changed between 2011 to 2018, as shown in *Figure 4*. In 2018, according to the American Community Survey (ACS), 48.9%, nearly half of the residents, were Hispanic, 27.8% of residents were White, 11.9% were Asian, and 8.4% were Black.[57]

[56] Bonner, 86.
[57] NHGIS."2011-2019 American Community Survey Data," 2019. https://www.nhgis.org/documentation/tabular-data

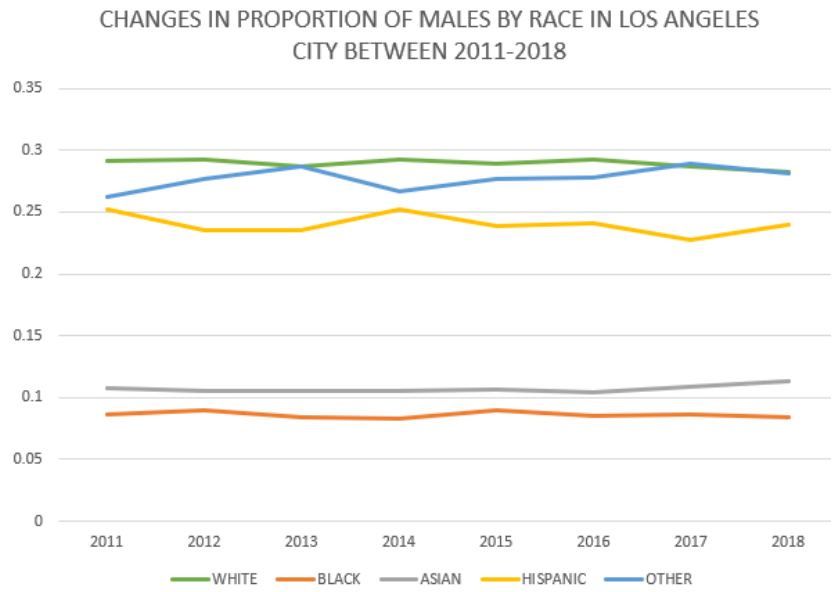

Figure 4: Proportions of LA City's Male Population By Race Between 2011-2018, which has not changed very much over time.

Source: The American Community Survey (ACS)[58]

RACE	COLLISIONS PROPORTION	STOPS PROPORTION
ASIAN	0.01623300	0.04477983
BLACK	0.15135767	0.22870255
HISPANIC	0.50512295	0.46631787
OTHER	0.01477215	0.05860766
WHITE	0.31251422	0.20159209

Figure 5: Overall Racial Proportions of Male Motorists in Traffic Collisions and Police Traffic Stops in Los Angeles City from 2011-2018, which shows Asian and Black male motorists having a higher proportion of stops compared to collisions, while Hispanic and White male motorists have the reverse.

[58] Ibid.

Source: Los Angeles Open Data Portal[59]

Based on all of the collisions and stops that have occurred between 2011 to 2018 shown in *Figure 5*, there is a pattern of non-White male motorists, or male motorists of color, having a lower traffic collision proportion than their stop proportion. However, for White male motorists, the reverse is true; the collision proportion is higher than their stop proportion. The most significant difference in proportions for male motorists of color comes from Black male motorists, with a difference of 7.73%. Despite making up 15.14% of traffic collisions in Los Angeles city, Black male motorists comprise a greater amount, 22.87%, of traffic police stops. The difference between the collisions and stops proportion for White male motorists is even greater in the opposite way with 11.09%; White male motorists comprise 31.25% of traffic collisions, while only making up 20.16% of police traffic stops.

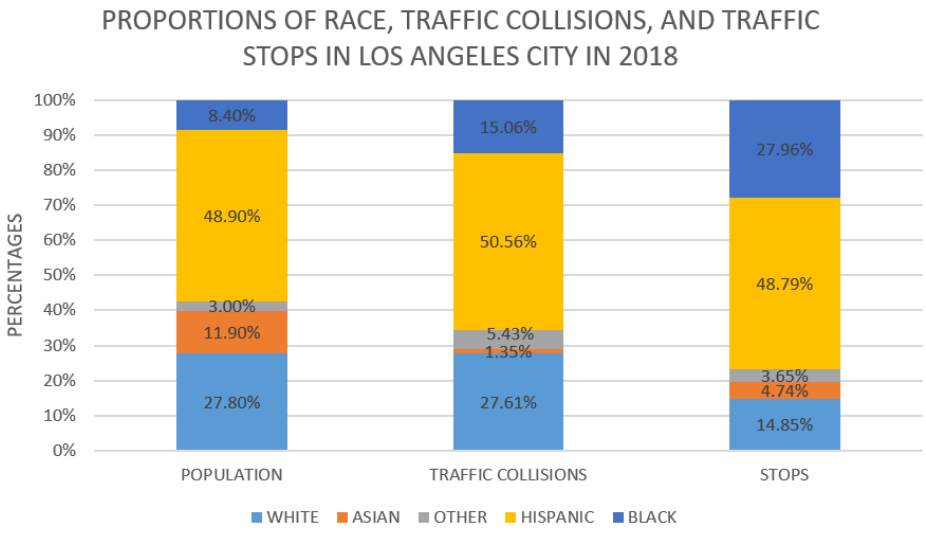

Figure 6: Racial Proportions of Male Motorists in Population, Traffic Collisions, and Police Traffic Stops in Los Angeles City in 2018, which shows higher percentages of stops for Black and

[59] Los Angeles Open Data Portal. "Vehicle and Pedestrian Stop Data 2010 to Present." Accessed February 12, 2021. https://data.lacity.org/Public-Safety/Vehicle-and-Pedestrian-Stop-Data-2010-to-Present/ci25-wgt7.

Asian male motorists, and lower percentages of stops for White and Hispanic male motorists, compared to traffic collisions, as well as population for reference.

Data Source: ACS, Los Angeles Open Data Portal[60]

Figure 6 graphically displays the racial proportions for all the male motorists in terms of the population, traffic collisions, and police traffic stops in 2018. Immediately, the trend of proportions increasing for Black individuals is noticeable; the Black population makes up 8.4% of Los Angeles city and accounts for 15.06% of traffic collisions, yet the percentage of police traffic stops that Black male motorists comprised of were 27.86%, which is nearly double their percentage for traffic collisions. For White individuals, their representation in the population and traffic collisions are similar, while the traffic collision and police traffic stop percentages are reversed compared to Black individuals. White male motorists make up a larger percentage of traffic collisions compared to Black male motorists (27.61% versus 15.06%), yet White male motorists only comprise 14.85% of police traffic stops, which is nearly less than double the percentage of traffic collisions. For Asian individuals, Asian residents make up 11.9% of the city, while only comprising 1.35% of traffic collisions, yet also comprising 4.74% of traffic police stops (which is nearly *quadruple* their percentage of traffic collisions). The numbers for those who are Hispanic are quite similar for all three categories (between roughly 48 to 50%), which suggests there are little differences in the proportions related to population, traffic collisions, and police traffic stops for Hispanic motorists.

With some framework provided by Bonner and Stacey and revisions made for increased accuracy, a DI that is 1.0 or lower suggests that police officers are stopping motorists from a particular race group more than expected, whereas a DI that is 1.0 or higher would indicate that

[60] Los Angeles Open Data Portal. “Traffic Collision Data From 2010 to Present.” Accessed February 12, 2021. https://data.lacity.org/Public-Safety/Vehicle-and-Pedestrian-Stop-Data-2010-to-Present/ci25-wgt7.

police officers are stopping less than expected. A DI > 0.95 does not indicate racial bias and may be attributed to chance. However, if there is a DI < 0.90, then there is suspicion of racial bias, or at the very least, certainly disproportionate treatment towards that race group.

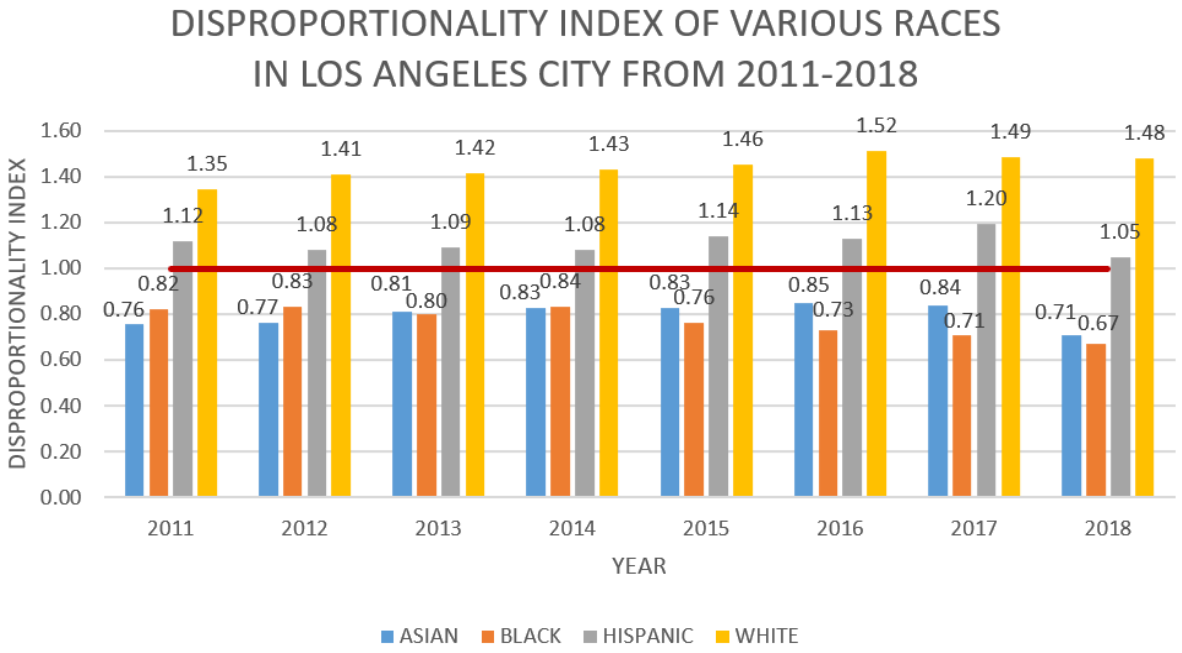

Figure 7: Graphic Representation of the Disproportionality Index Results for Various Races in Los Angeles city from 2011-2018, which shows Asian and Black male motorists having low DIs, Hispanic male motorists having slightly higher than expected DIs, and White male motorists having significantly higher DIs.

Figure 7 displays the DIs of various race groups, and the results show that consistently, White motorists have always been the smallest group to be stopped by police officers, despite representing a larger amount of traffic collisions. White motorists have the largest DIs. Hispanic motorists consistently have a DI slightly above the 1.0 benchmark and are the closest out of the race groups to having a DI near 1.0, which indicates regular treatment by police officers. Both

Black and Asian motorists consistently had a DI under 0.90. Initially, Asian motorists had a lower DI than Black motorists, however, over time, the DI for Black motorists decreased to become lower than the DI for Asian motorists. There also seems to be a trend that throughout the eight years, the DI for White motorists increased, and the DI for Black motorists decreased. The DI for White motorists started at roughly 1.35 in 2011 and was 1.48 in 2018. For Black motorists, their DI in 2011 was 0.82 and gradually decreased to 0.67 in 2018.

Discussion

The Veil-of-Darkness test consistently had the result of a negative coefficient, which shows that when it was dark, the likelihood of a Black male motorist being stopped in comparison to during daylight is lessened. In other words, the likelihood of a Black male motorist being stopped when their skin tone is visible increases. There had also been a trend of the negative coefficient's absolute value increasing as the years progressed, which indicates that the likelihood of a Black male motorist being stopped in the daylight compared to in the darkness has increased throughout the years. These results suggest discrimination against Black male motorists during police traffic stops in comparison to White male motorists.

The DI results showed that White motorists consistently had the highest DIs, which indicates that White motorists had higher odds of police interactions going to their own advantage (by having a lack of traffic stops, or being stopped less compared to their higher traffic collision rates). The DI for White motorists also increased over time, which indicates that the likelihood of a White motorist being stopped by a police officer (which already had been low, to begin with), became even lower over time.

Hispanic motorists consistently had DIs in the range of 1.0, which indicates that Hispanic motorists are close to being stopped at the rate that they are expected to be, but just slightly lower than expected. So Hispanic motorists are being stopped, according to the DI, at around a fair rate. Black motorists consistently had DIs less than 0.90. The DI of Black motorists decreased over time, which suggests increasing racial discrimination during police enforcement of traffic stops throughout the years. Like Black motorists, the DI for Asian motorists had been consistently less than 0.90, however, over time until 2017, the DI had been slightly increasing towards 1.0 (though never becoming larger than 0.90). However, in 2018, the positive trend stopped and dropped back to 0.71. It is somewhat surprising to observe disparities for Asian motorists since previous literature has not mentioned Asians, in particular, facing racial bias during traffic stops, however, it is worthy to note that to begin with, Asian male motorists are stopped or are in traffic collisions at extremely low rates compared to other races. Just a slight difference in rates is much more noticeable for such low numbers (as shown in *Figure 6*, Asian male motorists made up only 1.35% of traffic collisions and 4.74% of traffic collisions). Overall, the DI results strongly suggest racial discrimination towards Black, as well as Asian, male motorists, while Hispanic male motorists did not experience much difference in expected amounts of traffic stops, and White male motorists actually faced considerable privilege during traffic police stops.

Policy Recommendations

I. Police Department Audits

Public police department audits, specifically on the comprehensive process related to traffic police stops, can be an effective way to discover potential racial disparities or biases,

provide transparent information to the public, recommend improved practices to police departments, and incentivize police departments to address potential racial discrimination.[61]

The LAPD has an auditing division that claims to do yearly reviews of the police department, however, there is no specific audit process regarding police traffic stops. In 2019, the LAPD actually had requested the Office of the Inspector General (OIG) to do a review and make recommendations of police stops, essentially an audit on their traffic stop practices;[62] the report found that Black motorists were overrepresented during police traffic stops as well as post-stop activities in comparison to White and Asian motorists, and the report had a variety of recommendations, including a reduction in efforts towards pretextual stops that are based on minor infractions or violations and efforts more towards stops that promote public safety. However, this was just one report that did not seem to have any follow-up nor any impact once released. Also, despite the LAPD having an Auditing Division since 2001, there is a gaping lack of information on the police department audits, as well as a lack of the yearly audits themselves.[63] The actual website of the LAPD auditing division not only has a variety of visual errors but also is not currently updated and does not actually provide any auditing reports.[64]

Police department audits typically do have large amounts of research and analysis along with recommendations, however, it is not clear if police departments are held accountable with these audits. There are various examples of police departments nationwide having audits conducted with recommendations attached, however, little to none of the audits contain direct

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[61] Scanlan, Jeremiah. "Auditing Predictive Policing." *Brigham Young University Prelaw Review* 33, no. 4 (April 2019): 21.
[62] Smith, Mark P. "Review of Stops Conducted by the Los Angeles Police Department in 2019." Los Angeles: Office of the Inspector General, October 27, 2020. https://a27e0481-a3d0-44b8-8142-1376cfbb6e32.filesusr.com/ugd/b2dd23_d3e88738022547acb55f3ad9dd7a1dcb.pdf.
[63] Los Angeles Police Department. "Audits." Accessed March 2, 2021. https://www.lapdonline.org/audits.
[64] LAPD Audit. "LAPD Audit Division Website." Accessed March 2, 2021. https://www.lapdaudit.com.

repercussions for poor practices.[65] [66] In the case of the LAPD, the quality of the auditing division from the perspective of the public is also very poor; there is little effort put towards transparency of the police department auditing process. According to King and Schwartz, after investigating the impact of legal penalties on the quality of audits, when legal penalties exist, auditors put "greater changes in effort closer to the imposition of penalties", while they imposed "smaller changes as more periods go by without a penalty."[67] This suggests that enforcing penalties on low-quality audits incentivized auditors to put more effort into their work. Also, (not so) coincidentally, in the LAPD report done by the OIG, a few of their recommendations had included improved accountability measures, including internal audits and reviews of police traffic stops and consequences for violating police officers.[68] With more accountability measures placed on the police department's auditing division, the LAPD may work towards a more transparent and less discriminatory future.

Alternatively, it may be more beneficial for the LAPD to consistently employ third-party auditors to evaluate police traffic stops. The fact that the auditing division is connected to the police department internally may also factor towards the deficiencies of the division, and studies such as Stephens and Roszak's research have shown that third-party auditing is effective and beneficial to organizations belonging to a variety of sectors, which can include police

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[65] Bryson, Bridgette, and Zoe Thorkildsen. "Racial Bias Audit of the Niskayuna New York Police Department." Arlington, VA: CNA, 2021. https://www.niskayuna.org/sites/g/files/vyhlif4781/f/uploads/npd_racial_bias_audit_public_comment_report.pdf.

[66] Smith, 55-8.

[67] King, Ronald, and Rachel Schwartz. "Legal Penalties and Audit Quality: An Experimental Investigation*." *Contemporary Accounting Research* 16 (April 20, 2010): 685–710. https://doi.org/10.1111/j.1911-3846.1999.tb00601.x.

[68] Smith, 62.

departments.[69] The OIG conducted a comprehensive audit on the LAPD with sound recommendations, however, there was no follow-up included after that one report.

In order to keep the LAPD more accountable so that action is more likely to be taken after audits are processed, it is crucial for the audits to include incentives and penalties. In similar footsteps as the EPA's Audit Policy, this paper recommends adding incentives to the LAPD to encourage the police to search for and ameliorate issues within traffic stop interactions, such as funding for additional programs that promote career and learning opportunities for police officers, such as resources for pursuing a college education,[70] [71] as well as penalties in the case that the LAPD does not make any progress or take measures towards the audit recommendations, such as the removal of incentives, fines placed on the department, or overall budget reductions from the department. Initially, this paper aimed to recommend improved audits in order to improve the practices of police officers during police-motorist interactions, however, after further research in the pragmatic methods of diverting police traffic stops, this recommendation is no longer as necessary in the context of traffic stops if there is a diversion of police-motorist interactions to begin with. However, the upkeep and enforcement of audits within the LAPD would overall be beneficial so that there is more consistency, transparency, and accountability of the department, which is responsible for much more than simply traffic stops.

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[69] K, Stephens, and Marek Roszak. "A Study of the Role and Benefits of Third Party Auditing in Quality Management Systems." *Journal of Achievements in Materials and Manufacturing Engineering* 43 (December 1, 2010).
[70] US EPA, OECA. "EPA's Audit Policy." Other Policies and Guidance. US EPA, June 12, 2019. https://www.epa.gov/compliance/epas-audit-policy.
[71] Archbold, Carol Ann. "Career Paths of Police Officers." In *Policing: A Text/Reader*, 165–89. Thousand Oaks, CA: SAGE Publications, Inc, 2012. https://www.sagepub.com/sites/default/files/upm-assets/50820_book_item_50820.pdf.

II. Police Diversion from Traffic Stops

A more novel, but realistically implementable, solution to reduce racial disparities in police treatment of motorists is to reduce interactions between police officers and motorists in the first place for traffic infractions. The use of camera enforcement reduces the possibilities of a police officer stopping a vehicle (which may have been racially motivated), the pressure of interacting with a police officer, and the potential of being searched or having the situation escalated.[72] Nationwide, there are several cities that are moving towards or implementing policies and procedures to decrease police traffic stops with a variety of methods.[73] Oakland, California has intentionally decreased interactions between police and motorists by not enforcing low-level traffic violations since 2018. In Montgomery County, Maryland's County Council is currently considering the use of automated traffic cameras to reduce police-motorist interactions (Montgomery County also already has established a considerable amount of speeding and red-light cameras with plans to have more),[74] and Washington D.C. has already implemented automated traffic enforcement cameras that detect speed, red light, and stop sign violations while also having these operations under the responsibility of the District Department of Transportation (DDOT) rather than the police department.[75] Tangentially, not only will automated traffic enforcement reduce police-motorist interactions, which then reduces the number of motorists

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[72] Volokh, Eugene. "'The Cameras Are Watching -- And It's a Good Thing,.'" *Wall Street Journal*, March 26, 2002.
[73] Mercer, Marsha. "Police 'Pretext' Traffic Stops Need to End, Some Lawmakers Say." *Pew Charitable Trusts*, September 3, 2020. https://pew.org/3gToNRD.
[74] Konsmo, Sarah. "Speeding and Red-Light Cameras Are Doubling in Montgomery County." WUSA9, October 30, 2020. https://www.wusa9.com/article/traffic/montgomery-county-speeding-and-red-light-cameras-are-about-to-double/65-d039cc95-a3c1-4590-9060-cfd56062437e.
[75] DDOT. "DC StreetSafe: Automated Traffic Enforcement." Accessed March 3, 2021. https://ddot.dc.gov/page/dc-streetsafe-automated-traffic-enforcement.

disparately stopped due to race, but automated traffic cameras have been statistically proven to reduce the likelihood of vehicle crashes.[76]

Though, automated traffic enforcement via cameras has not come without backlash from motorists; there have been complaints regarding the inability of drivers to contest traffic citations, as well as issues of inability to pay for the citations, which adds further burden to those who are less financially stable.[77] One example of contention against traffic cameras is shown in the case motorists in Ohio requested against the town for having allegedly violated their due process rights with the use of speed cameras (which had been rejected by the judge in that county, Judge Michael A. Oster).[78] Motorists have also shown concern against traffic enforcement cameras due to suspicions of the government's intention behind using cameras as a way to garner revenue rather than keep public safety.[79]

In response to issues of due process, such as having a fair trial before being indicted, the photographs captured by traffic cameras serve as physical evidence that incriminates motorists; with the mailed traffic citation fine comes photos that show the motorist "in the driver's seat, plus [the] car's license plate and the precise place [the] car supposedly was when the light turned red",[80] which leaves little to no room for the process of being fined as unfair. However, the intention behind traffic camera use should be considered. According to Sheila Dunn, the Communications Director of the National Motorists Association, one in eight motorists in

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[76] Hu, Wen, and Anne T. McCartt. "Effects of Automated Speed Enforcement in Montgomery County, Maryland, on Vehicle Speeds, Public Opinion, and Crashes." *Traffic Injury Prevention* 17 (September 2016): 53–58. https://doi.org/10.1080/15389588.2016.1189076.

[77] Beck, Christina. "Are Traffic Enforcement Cameras Worth the Effort?" *Christian Science Monitor*, July 21, 2016. https://www.csmonitor.com/USA/Justice/2016/0721/Are-traffic-enforcement-cameras-worth-the-effort.

[78] Memorandum in Support of Jurisdiction of Appellant Village of New Miami (Supreme Court of Ohio May 5, 2016).

[79] NPR.org. "Two Drivers Are Suing D.C. Over A Single Speed Camera They Call 'Unconstitutional,'" March 11, 2020. https://www.npr.org/local/305/2020/03/11/814441302/two-drivers-are-suing-d-c-over-a-single-speed-camera-they-call-unconstitutional.

[80] Volokh, "The Cameras Are Watching"

Virginia drive with a suspended license because they are unable to afford traffic enforcement tickets.[81] Traffic citation fines more greatly impact the financial and overall general well-being of especially motorists with lower socio-economic status, who are those with the least ability to pay fines in the first place.[82] A way to ameliorate this issue would be to adjust traffic citations to fine motorists based on income level. With a standard ticket charge of say $200, this cost would be much more detrimental to a motorist working minimum wage compared to another that is more wealthy. More fines that work in proportion to income can serve as a way to alleviate the burden on less financially stable motorists and also show less focus on receiving standard amounts of fines by making them equitable.

It would also be remiss to not consider the utility that police officers provide during certain traffic encounters, such as traffic collisions and events where motorists are driving under the influence. Police officers are trained in various programs throughout their preparation in the police academy; the LAPD trains police officers in safe vehicle handling, stress management, tactical communications, strength and endurance, first aid, and more.[83] Especially in traffic incidents that are large in scale or include bodily harm, police officers are first responders to such events and are equipped to administer life-saving techniques,[84] they serve as arbitrators in situations where traffic collision faults may not be clear, or they may also serve as mediators when motorists during incidents become contentious or belligerent. However, cops are not the only solution in these situations. In Berkeley, California, the City Council also approved and adopted a policing measure to relieve police officers from enforcing traffic stop violations and

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[81] Beck, "Are Traffic Enforcement Cameras Worth the Effort?"
[82] Schierenbeck, Alec. "The Constitutionality of Income-Based Fines." *The University of Chicago Law Review* 85, no. 8 (December 2018): 1869.
[83] Los Angeles Police Department. "Academy Physical Training Program." Accessed April 4, 2021. https://www.joinlapd.com/events-prep/academy-physical-training-program.
[84] "LAPD Training To Use Combat-Style Trauma Kits." *CBS Los Angeles*, January 27, 2014. https://losangeles.cbslocal.com/2014/01/27/lapd-training-to-use-combat-style-trauma-kits/.

instead create a new Berkeley Department of Transportation division that will have unarmed, civilian employees enforce traffic laws,[85] [86] In Philadelphia, the city has employed "Public Safety Ambassadors" that are essentially unarmed officers patrolling the city who are trained in a variety of topics such as crime prevention, emergency first aid and CPR, and interpersonal relations, and they work in cooperation with other entities like the Drexel and Penn police departments, Amtrak, SEPTA, and more.[87] They provide vehicle services, such as assisting with jumpstarts or lockouts, escorting services, outreach and assistance for homeless individuals, as well as knowledge on the city's history and attractions. Though this position does not particularly focus on traffic enforcement, these ambassadors represent the ability of cities to have trained officers that may serve in places that police officers may have traditionally taken upon themselves.

There are efforts throughout the country that also have been implementing other forces to take over situations that police officers have traditionally dealt with. For 30 years in Eugene, Oregon, CAHOOTS has been collaborating with the local police department to answer 20% of 911 calls with trained crisis workers that have handled roughly 24,000 calls in 2019 without any weaponry.[88] Lastly, the LAPD is *also already* implementing solutions that divert police officers from other divisions in order to reduce police-civilian interaction; in February of 2021, the department began a program with Didi Hirsch Mental Health Services to have a trained response

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[85] Ravani, Sarah. "Berkeley Adopts Sweeping Police Reforms Including Taking Cops off Routine Traffic Stops." San Francisco Chronicle, February 23, 2021. https://www.sfchronicle.com/bayarea/article/Berkeley-to-consider-sweeping-police-reforms-15971071.php

[86] Mercer, Marsha. "Police 'Pretext' Traffic Stops Need to End, Some Lawmakers Say."

[87] University City District. "Maintaining Clean and Safe Streets," September 1, 2011. https://www.universitycity.org/safe.

[88] Shapiro, Ari. "'CAHOOTS': How Social Workers And Police Share Responsibilities In Eugene, Oregon." NPR.org, June 10, 2020. https://www.npr.org/2020/06/10/874339977/cahoots-how-social-workers-and-police-share-responsibilities-in-eugene-oregon.

team that prioritizes de-escalation when dispatched for certain 911 calls.[89] Thus, the ability to divert police during traffic stops is realistically implementable, given that this has already been accepted and put into practice for 911 calls in LA.

This paper recommends that the LAPD divert the responsibility of enforcing traffic violations to a combination of automated traffic cameras that provide income-adjusted fines and working in conjunction with a community organization with trained professionals in de-escalation and other pertinent programs, in the same way that there are trained professionals in CAHOOTS or Didi Hirsch, to handle traffic enforcement and collision events. Given that automated traffic cameras are more efficient and effective than police officers in catching motorists speeding or running lights, funds generated from the fines can help to support the dedicated task force.

Conclusion

With the rise of public awareness and media attention to Black Lives Matter, it has become especially relevant to provide quantitative/statistical backing towards BLM to further galvanize action towards justice for Black individuals. Previous studies have consistently shown with tests such as the Outcome test, Disproportionality Index (DI), Threshold Test, Veil-of-Darkness (VOD) test, and many more not mentioned that suggest racial bias consistently permeates during police-motorist interactions during traffic stops. This research paper worked to find answers on racial disparities and suggestions of racial bias in Los Angeles city police traffic

[89] City News Service. "LAPD Launches Program for Mental Health Clinicians to Respond to Some Calls." *NBC Los Angeles* (blog), February 10, 2021. https://www.nbclosangeles.com/news/local/lapd-launches-program-for-mental-health-clinicians-to-respond-to-some-calls/2523190/.

stops using the Veil-of-Darkness test and the Disproportionality Index, both of which have been derived from previous literature that provides the methodology of their quantitative tests.

Much of previous research in measuring racial bias in police traffic stops have shown that there is a strong suggestion of racially motivated disparate treatment towards male motorists of color, particularly Black male motorists, and this report further illustrates that. From 2011 to 2018, the VOD test consistently resulted in a lower likelihood of a Black male motorist being stopped in the darkness than in the daylight. The regression model used for the VOD test was relatively robust, with all but two years statistically significant. According to the DI, Black male motorists had, on average, the lowest DI value. Notably, Asian male motorists had comparable DI values to Black male motorists, Hispanic male motorists experienced no racial bias during the stops, and White male motorists gained significant privilege during police traffic stops. These findings from the DI further support the VOD test results, since the DI shows that there are still racial disparities when controlling for the variable of driving behavior, so the VOD test results are more robust against being attributed to races having differing driving behavior.

After researching the audit history of the LAPD, this paper recommends the department, for general purposes, to dramatically improve their auditing division to provide more transparency to the public and enforce accountability measures within the department. Since this may prove to be difficult due to the inherent relationship between police officers and the audit division within the department, it may be more prudent for LAPD to have yearly third-party audits for further padding towards transparency. Specifically for traffic stops, this paper recommends the reduction in police officers on the streets enforcing traffic violations via use of a traffic enforcement camera system with equitable ticket fines and a collaboration with a community organization with trained, unarmed professionals, which would be in line with many

U.S. cities that have or are currently working to have their departments of transportation or other organizations to have alternatives to police interactions with civilians.

Unfortunately, due to lack of stop information, more quantitative measurements of data could not be tested, such as the Threshold test, which required knowing whether a stopped motorist had been searched or had a contraband item. Thus, this research was limited to performing tests that could be conducted with the data provided by LA city. However, it is still useful that the city provides this data to the public in the first place; various cities and counties have state policies mandating the collection of such police information, but many more do not have these policies.

To further this research, more studies should be done on the driving behavior of different races. Though this paper found that the justification of races having differing driving behavior did not hold, there have been other studies that suggest otherwise. If driving behavior truly does differ between races, then the assumptions made in the VOD test fall apart. Other next steps to explore would be further researching racial bias against Asian motorists during traffic police stops; research in quantitatively measuring police officer behavior during traffic police stops overall does not find disparate treatment against Asian motorists, so it would add in unique literature in the field to see whether this phenomenon is specific to Los Angeles and what its implications are.

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Appendix A

Veil-of-Darkness Code, derived from Pierson et al.'s research

```
library(tidyverse)
library(lubridate)
library(lutz)
library(suncalc)
library(splines)

#load the stops into R
stops <- read.csv("stop.csv", fileEncoding="UTF-8-BOM")

#change the latitude and longitude to fit california
lat <- 34.055623909664455
lon <- -118.29657446507176

tz <- lutz::tz_lookup_coords(lat, lon, warn = F) #gives the
timezone of the state

#function that helps to format the time neatly
time_to_minute <- function(time) {hour(hms(time)) * 60 +
minute(hms(time))}

#format dates properly
stops$date <- as.Date(stops$date, "%Y-%m-%d")

#getting the sunset time for each date in dataset
sunset_times <- stops %>% mutate(lat = lat, lon = lon) %>%
select(date, lat, lon) %>% distinct() %>% getSunlightTimes(
data = ., keep = c("sunset", "dusk"), tz = tz) %>%
mutate_at(vars("sunset", "dusk"), ~format(., "%H:%M:%S")) %>%
mutate(sunset_minute = time_to_minute(sunset), dusk_minute =
time_to_minute(dusk),
date = ymd(str_sub(date, 1, 10)) ) %>% select(date, sunset, dusk,
ends_with("minute"))

sunset_times %>% filter(dusk == min(dusk) | dusk == max(dusk))
```

```
vod_stops <- stops %>% left_join(sunset_times, by = "date") %>%
mutate(minute = time_to_minute(time), minutes_after_dark = minute -
dusk_minute, is_dark = minute > dusk_minute, min_dusk_minute =
min(dusk_minute), max_dusk_minute = max(dusk_minute), is_black =
subject_race == "BLACK") %>%
#filter to get only the inter twilight period
filter(minute >= min_dusk_minute, minute <= max_dusk_minute,
!(minute > sunset_minute & minute < dusk_minute),
#remove ambiguous period between sunset and dusk
subject_race %in% c("BLACK", "WHITE")) #compare only white and
black drivers

#filter the data to only look between sunset period and dusk period
vod_stops %>% filter(time > hm("19:00"), time < hm("20:30")) %>%
group_by(is_dark) %>% summarize(prop_black = mean(is_black))

#creating the binomial regression model
vodmodel <- glm(is_black ~ is_dark + splines::ns(minute, df = 6) +
as.factor(division), family = binomial, data = vod_stops)

#get the summary of the results
summary(vodmodel)
```

Appendix B

P-Values of the Cubic Natural Splines with 6 Degrees of Freedom from the VOD test

SIGNIFICANT DIGITS	KEY
0.000	***
0.001	**
0.010	*
0.050	.
0.100	

P-Values < 0.000 are indicated by "***". P-Values < 0.001 are indicated by "**". P-Values < 0.05 are indicated by ".". Any P-Value greater does not have a symbol.

DEGREES OF FREEDOM	Z-VALUE	PR(>|Z|)	SIGNIFICANT DIGITS
Overall	-2.113	0.034587	*
1	3.733	0.000189	***
2	2.205	0.027460	*
3	3.454	0.000553	***
4	2.742	0.006103	**
5	2.711	0.006716	**
6	1.769	0.076877	.

VOD Test Values for 2011

DEGREES OF FREEDOM	Z-VALUE	PR(>|Z|)	SIGNIFICANT DIGITS
Overall	-0.908	0.36372	
1	2.269	0.02324	*
2	1.886	0.05927	.
3	2.381	0.01729	*
4	2.051	0.04028	*
5	1.408	0.15926	
6	2.866	0.00416	**

VOD Test Values for 2012

DEGREES OF FREEDOM	Z-VALUE	PR(>|Z|)	SIGNIFICANT DIGITS
Overall	-4.330	0.0000149	***
1	2.128	0.0333730	*
2	3.090	0.0020010	**
3	3.434	0.0005940	***
4	3.934	0.0000835	***
5	2.015	0.0438860	*
6	4.208	0.0000257	***

VOD Test Values for 2013

DEGREES OF FREEDOM	Z-VALUE	PR(>|Z|)	SIGNIFICANT DIGITS
Overall	-5.222	1.770e-07	***
1	2.497	1.251e-02	*
2	1.783	7.465e-02	.
3	2.472	1.343e-02	*
4	2.851	4.350e-03	**
5	3.193	1.410e-03	**
6	5.034	4.790e-07	***

VOD Test Values for 2014

DEGREES OF FREEDOM	Z-VALUE	PR(>|Z|)	SIGNIFICANT DIGITS
Overall	-3.297	0.000976	***
1	-0.405	0.685587	
2	-0.770	0.441432	
3	1.480	0.138920	
4	2.613	0.008972	**
5	-0.240	0.910171	
6	0.989	0.322595	

VOD Test Values for 2015

DEGREES OF FREEDOM	Z-VALUE	PR(>|Z|)	SIGNIFICANT DIGITS
Overall	-8.377	2.00000e-16	***
1	1.546	1.22096e-01	
2	3.072	2.12300e-03	**
3	2.409	1.60090e-02	*
4	3.983	6.80000e-05	***
5	3.345	8.22000e-04	***
6	4.560	5.12000e-06	***

VOD Test Values for 2016

DEGREES OF FREEDOM	Z-VALUE	PR(>|Z|)	SIGNIFICANT DIGITS
Overall	-5.089	3.590e-07	***
1	3.108	1.884e-03	**
2	2,772	5.564e-03	**
3	3.204	1.357e-03	**
4	3.508	4.510e-04	***
5	2.862	4.206e-03	**
6	3.637	2.760e-04	***

VOD Test Values for 2017

DEGREES OF FREEDOM	Z-VALUE	PR(>|Z|)	SIGNIFICANT DIGITS
Overall	-0.791	0.4288050	
1	1.475	0.1402740	
2	4.000	0.0000113	***
3	1.673	0.0943170	.
4	3.682	0.0002310	***
5	2.443	0.0145460	*
6	1.184	0.2364110	

VOD Test Values for 2018