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Seen to be done

A graphical investigation of peremptory challenge

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Preface

This work would be nowhere near as polished or complete without the effort of Prof. Dr. Marloes Maathuis to ensure I was performing analysis with a clear direction and purpose. I would like to thank her for finding time in her busy schedule to allow for weekly meetings. The group meetings organized by her Ph.D. student Marco Eigenmann were also critical in the development of more nuanced analysis and intuitive visualizations. I thank Marco Eigenmann for organizing them, and Jinzhou Li, Armin Fingerle, Sanzio Monti, and Qikun Xiang for attending my presentations and listening attentively. A special thanks is extended to Cédric Bleutler and Leonard Henckel, both of whom were especially engaged and participated in lengthy discussions both during and outside of the group meetings.

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Abstract

The legal practice of peremptory challenges is described, outlining its past and present racial controversies as well as defences provided in its favour. These defenses are analyzed statistically, and novel visual tools including the mobile plot and the positional boxplot are developed to explore three data sets (Wright, Chavis, and Parks (2018), Grosso and O'Brien (2012), and Baldus, Woodworth, Zuckerman, and Weiner (2001)) and test whether race is a determining factor in peremptory challenge exercise. Mulitnomial regression models motivated by these visualizations are fit and used to generate precise parameter estimates which indicate the dominance of race in peremptory challenge decisions. Trial level summaries are produced and discussed.

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Notation and Terms

0.1 Terms

In order to facilitate clarity despite brevity, a list of terms used in this paper is presented here.

Prosecution/State The legal representation which argues for conviction

Defence The legal reperesentation which argues against conviction

Court Reference to the judge, prosecution, and defence

Venire The population sample from which a jury is selected (according to Mirriam-Webster (2019a) derived from the latin *venire facias*: "may you cause to come")

Jury The final group of (usually) twelve chosen venire members which judge the guilt or innocence of the accused/defendant

Accused/Defendant The individual on trial for a crime

Voir dire From old French "to speak the truth" (see Mirriam-Webster (2019b)), this is the questioning process used by the court to assess the suitability of a venire member to sit on the jury

Struck In the context of a venire member being rejected from the jury, struck indicates removal by peremptory challenge or challenge with cause

Litigants The accusor and the accused

Disposition The outcome of a venire member in the jury selection process: either kept, struck with cause, struck by prosecution, or struck by defence

0.2 Variables

Across data sets and analyses, the variable names and mathematical notation will be as follows. Note that the use of a capital letter indicates a random variable and a lowercase letter a particular realization of a random variable.

- $\mathbf{x}_i = (r_i, e_i, p_i, g_i, s_i)^T$: the variable combination for a particular venire member
- $d \in \{1, 2, 3, 4\}$: indicator of disposition, with the levels corresponding to kept, struck with cause, struck by defence, and struck by prosecution respectively

- $r \in \{1, 2, 3\}$: indicator of venire member race, with the levels corresponding to black, other, and white respectively
- $e \in \{1, 2, 3\}$: indicator of defendant race, with levels as for the venire member race
- $p \in \{1, 2, 3, 4\}$: indicator of venire member political affiliation, with levels Democrat, Independent, Libertarian, and Republican respectively
- $g \in \{1, 2\}$: indicator of venire member gender, with levels female and male respectively
- $s \in \{1, 2\}$: indicator of defendant gender, with levels as for the venire member
- $\pi_{i|jklmn} \in [0, 1]$: the probability of disposition i given factor levels $jklmn$, may be written as π_i for convenience
- $y_{ijklmn} \in \mathbb{N}$: the count of venire members with $\mathbf{x} = (i, j, k, l, m, n)^T$

This work also uses hat notation for estimates (i.e. the estimate for π is $\hat{\pi}$ and the estimator for π is $\tilde{\pi}$).

Chapter 1

Introduction

The Gerald Stanley murder trial was noteworthy for all of the wrong reasons. The first reason was the crime itself. The rural region around Biggar, Saskatchewan (Quenneville (2018)) is not known for crime, indeed, the crime statistics collected by Statistics Canada suggest it is one of the safest in the province (Statistics Canada (2018)). Any murder at all would be worthy of attention and subject to plenty of drama. But beyond the damage this trial has done to the community, this trial is noteworthy because it led to a significant re-examination of the legal jurisprudence surrounding the jury selection process culminating in the proposition of Bill C-75 by the Canadian government in March of 2018 (42nd Parliament of Canada (2018a)), less than two months after the trial's verdict (Quenneville and Warick (2018b)).

Bill C-75, in part, aims to ameliorate one of the critical points of contention about the Gerald Stanley case: the use of peremptory challenges in jury selection. The outsized impact of the case was due, in large part, to it's racial aspect. Gerald Stanley, a white man, was accused of second degree murder in the killing of Colten Boushie, a First Nations man. Given Canada's troubled history with First Nations groups, this alone would have been enough to make the trial a flash point for race issues, but that was not the worst aspect of the trial. Rather, it was the alleged use of peremptory challenges to strike five potential jurors who "appeared" to be First Nations, resulting in an all-white jury, that proved to be the most controversial and influential facet of the entire affair (Harris (2018), MacLean (2018)).

With Bill C-75 currently moving through the Canadian parliamentary system, having completed its second reading in June 2018 (42nd Parliament of Canada (2018b)), a close re-examination of the practice of peremptory challenge is warranted. A great deal of ink has already been spilled on both sides of the debate (see Hasan (2018), Zinchuk (2018), and Roach (2018)), but startlingly little of this discussion has been based on any hard evidence on the impact of peremptory challenge in jury selection. This paper aims to provide analysis and evidence to illuminate the topic further by analyzing three separate peremptory challenge data sets collected in the United States, namely Wright et al. (2018), Grosso and O'Brien (2012), and Baldus et al. (2001). While this data cannot tell us if challenges were racially motivated in the Stanley trial, stepping back from this fraught legal episode to take a wider view of the practice of peremptory challenge provides a more sober place to start the discussion of its place in modern jury trials.

Moreover it is still relevant today, as the affected communities have held on to this trial as

emblematic of the greater problems they face in their relations to each other, as discussed by Cuthand (2019).

This paper will proceed in five parts. Chapter 2 provides a brief history of the practice of peremptory challenges in jury trials, in particular explaining their original motivation, past implementations, and how they have developed in the United States, the United Kingdom, and Canada. Chapter 3 proceeds to discuss the three data sets obtained, explaining the sources and collection methods before detailing the cleaning and preprocessing. Chapter 4 then provides the details and results of the analysis performed on the different data sets. It begins discussing the Jury Sunshine data set, which was used as a 'test' set of sorts, where analysis could be flexibly performed before the final analysis methods were turned to the other two data sets. The results of this analysis are compared to previous works in Chapter **??**. Finally, the results and findings are summarized in **??**, and recommendations based on the observations obtained here are provided.

1.1 A Note on Palette Choice

The analysis and presentation of results in this paper is primarily visual, utilizing graphs and figures rather than tables to communicate patterns and estimates. In order to make these visual presentations of the data as accessible as possible, the colours and palettes used were very deliberately chosen to be visibly different for as many individuals as possible, including the large minority of colour blind individuals. Choosing such colours and palettes was made much simpler by the `RColorBrewer` package in R (Neuwirth (2014)) and Wong (2011), both of which provide suggested colour-blind safe palettes and recommendations. Additionally, most colours are redundantly encoded by position or order where possible, to make the main results of the paper clearer.

Chapter 2

Peremptory Challenges

The focus of this text is the practice of peremptory challenges in a jury trial system, a highly specific practice in a particular context which may not be known in detail to the reader. As a consequence, a brief exploration of their history, motivation, and current use is presented here. It is not meant to be exhaustive, but rather to provide context and references for an interested and motivated reader to learn more. Indeed, many details have been omitted from the summary of the history in particular.

2.1 Jury Selection Procedures

Before reviewing the history, it is best to give some context and an explanation for readers unfamiliar with the jury system and general courtroom procedures. While the process of jury selection varies by jurisdiction and crime severity, the general steps shared by jury trials are outlined below. More detail and a discussion of the diversity of jury selection procedures can be found in Ford (2010), Hans and Vidmar (1986), and Van Dyke (1977). To select a jury:

i.) Eligible individuals are selected at random from the population (using a list known as the *jury roll*) of the region surrounding the location of the crime, the sampled individuals are called the *venire*

ii.) The venire is presented to the court, either as a group or sequentially (borrowing the names of Ford (2010): the "struck-jury" system and the "sequential-selection" system, respectively)

iii.) The presented venire member(s) are questioned in a process called *voir dire*, which can result in three possible outcomes for each venire member:

(a) The venire member is removed with cause, the cause provided by either the prosecutor or defence lawyer and admitted by the judge

(b) The venire member is removed by a *peremptory challenge* by the prosecutor or defence lawyer, where no reason need be provided to the court; such privileged rejections of a venire member are limited in number for both lawyers (in Canada a maximum of 20 such challenges per side per defendant are allowed [Government of Canada (1985)])

(c) The venire member is accepted into the jury, and so becomes a juror

iv.) Steps i-iii are repeated until the prosecution and defence fail to reject the desired number of jurors.

As mentioned above, the details in this process can vary greatly by region. One of the greatest sources of this variation is the creation of jury rolls. In the United States the method is somewhat homogeneous: they are typically selected using lists of registered voters (see Van Dyke (1977) chapter two and Hans and Vidmar (1986) page 53), but in Canada their creation is far more varied. Ontario uses a combination of municipal voter lists and First Nations band lists (see Ministry of the Attorney General of Ontario (2018)), while in Saskatchewan - the province of the Gerald Stanley trial - the jury roll is created from the data in the central government health insurance agency in accordance with Government of Saskatchewan (1998).

Clearly, the variation in these methods will create differences in the universe of the sampled jury rolls relative to the population they are meant to reflect. Such differences are no doubt important to the coverage of the population which is present in the jury selection process (see Iacobucci (2013)), but these differences are not of primary interest to this paper. Rather, the steps presented afterwards are those to be investigated.

This leads to the two presentation methods presented in step ii, Ford (2010) and Van Dyke (1977) both note that the predominant method in the United States and Canada is the sequential-selection system. This is perhaps due to the relative efficiency of the method, as it is clear that in the sequential system voir dire need not be performed on the entire venire, only a subset. Contrast this with the struck-jury system, where the entire venire must be reviewed in every trial.

Finally, the scope of voir dire is radically different in the United States and much of the British Commonwealth. Van Dyke (1977) notes on page 143 that Canada and the United Kingdom do not allow questions in areas of "non-specific" bias, or bias which is not directly related to the case before the court. That is to say, while it would be perfectly valid to ask a venire member for a murder case about their work history in the United States, such a question would only be allowed in Canada or the United Kingdom if occupation was specifically related to the crime.

This difference in procedure creates a far greater emphasis on the voir dire process in the United States, as noted by Hans and Vidmar (1986). Hans and Vidmar go further than this, and surmise that the key reason for this marked departure in procedure is a difference in philosophy. To borrow a quote from page 63 of Hans and Vidmar (1986):

> In Canada... the courts have said that we must start with an initial presumption that "a juror will perform his duties in accordance with his oath"

This doctrine places a responsibility on the jurors themselves to overcome their biases and accept arguments in spite of them. This stands in stark contrast to the American attitude implied by the emphasis on expansive voir dire: that certain prejudice cannot be overcome by jurors themselves. The public statements of the Stanley trial critics indicate that they subscribe to this viewpoint more than to the Canadian philosophy.

2.2 The Role of the Jury

Such a difference in viewpoint is especially relevant given the purpose of the jury. The central function of a jury in a jury trial system is to judge the innocence or guilt of an accused in light of the presented evidence, a function which has had drastically different forms throughout history. In the distant past, von Moschzisker (1921) and Hoffman (1997) report that the central function of the jury was to collect evidence, essentially assuming the role commonly performed today by police detectives. Such a role justified the archaic practice of selecting only the most "trustworthy" individuals of some renown.

This is contrasted by the modern jury, which performs no collection of evidence. It is, ideally, a panel of peers or "equals" of the accused sampled at random from the population, an idea which did not develop until 19th century Britain (see page 28 of Hans and Vidmar (1986)) and was not applied using random sampling until some time later (see Hoffman (1997), page 29 of Hans and Vidmar (1986), and page 16 of Van Dyke (1977)). The modern jury is meant to apply the law, as told to them by the judge[1], to the case at hand. Evidence of the guilt of the accused is presented to the jury by the prosecutor, while evidence meant to exonerate is presented by the defence.

The jury listens to the evidence, considers the law as presented by the judge, and must (typically) reach a unanimous decision of guilt or acquittal. Such a decision cannot be overturned by the judge of the court, and the judge must then determine sentencing based on the decision of the jury and the letter of the law[1]. It should be clear that the jury therefore has tremendous power in the judgement of any case. The philosophical and ethical justification for such power is well explained by Woolley (2018), and best summarized by a quote from Supreme Court of Canada (1991):

> The jury, through its collective decision making, is an excellent fact finder; due to its representative character, it acts as the conscience of the community; the jury can act as the final bulwark against oppressive laws or their enforcement; it provides a means whereby the public increases its knowledge of the criminal justice system and it increases, through the involvement of the public, societal trust in the system as a whole.

While such enthusiastic support for juries has not been expressed by all countries which practice them, the justification is entirely consistent with the histories and discussions presented by Hoffman (1997), von Moschzisker (1921), Hans and Vidmar (1986), Van Dyke (1977), and others. This suggests that the Supreme Court of Canada (1991) lionization of the jury system is a fair representation of the perceived role of the jury throughout those countries which use them.

2.3 Modern Peremptory Challenge Controversy

If the general utility and importance of the jury is clear, the same cannot be said for peremptory challenges. The privileged removal of a venire member[2] without any justification has seen persistent allegations of abuse, often around the use of these challenges by

[1] Hans and Vidmar (1986) note that this system actually varies throughout the US, though the jury and judge powers described here are consistent across Canada.

[2] To be replaced by another, *randomly selected* venire member

state prosecutors.

In the United States, the criticism has focused on racial discrimination, and has led to significant changes in their allowed use, through cases such as *Swain v. Alabama* (Supreme Court of the United States (1965)) and *Batson v. Kentucky* (Supreme Court of the United States (1986)). The first of these cases, *Swain v. Alabama*, established in 1965 that the systematic exclusion of venire members of a particular race would be unconstitutional discrimination under the Fourteenth Amendment, but argued that a *"prima facie"* (or "based on first impression") argument of discrimination was not adequate to prove this[3]. This placed a significant burden on the side taking issue with a particular peremptory challenge to demonstrate that the choice had been discriminatory.

However, this ruling was overturned only 21 years later in the 1986 case *Batson v. Kentucky*, which allowed the party objecting to a challenge to use a *prima facie* argument which must be countered by a race-neutral reason that satisfies the judge. If no such reason can be supplied, the challenge would not be allowed. This created a new challenge which could be used to keep a venire member despite the use of a peremptory challenge: the so-called "Batson Challenge". While the effectiveness of this system of additional challenges is questionable both practically and in abstract (see Page (2005) and Morehead (1994), and a particularly strong response in Hoffman (1997)), it has only been extended to allow Batson challenges for both the sex and race of venire members[4].

In Canada, the controversy has also had a racial component. Racial bias in Manitoba against First Nations venire members was alleged in 1991 in a report produced after an inquiry by the provincial government (see Roach (2018)). More damning still was the Iacobucci Report on First Nations representation in juries. This report proposed an explicit restriction to the practice when it recommended:

> an amendment to the Criminal Code that would prevent the use of peremptory challenges to discriminate against First Nations people serving on juries.

Despite these recommendations and allegations, there had not been a significant political effort to reform the peremptory challenge system until the Gerald Stanley trial culminated in the tabling of Bill C75 42nd Parliament of Canada (2018b), which would abolish the peremptory challenge outright. As of the writing of this paper, the bill has not been approved by the Government of Canada, but it seems likely to become law in the near future.

In doing so Canada would join the United Kingdom. Significant controversy around the use peremptory challenges in the United Kingdom has already resulted in the abolition of the practice by the Criminal Justice Act of 1988. The specific controversy was the result of the Cyprus spy case in the late 1970s, which led to a "sustained campaign in Parliament and in the press alleging that defence counsel were systematically abusing it" (see Hoffman (1997))[5].

[3] In the actual case, not a single black juror had sat in Kentucky in the previous 15 years, despite composing 26% of the jury-eligible population. In Swain's trial, six of the eight black venire members were rejected by state prosecutor peremptory challenges, and the other two removed for cause, leaving not a single black juror to judge Swain, a black man. This was the prima facie argument presented by Swain's defence team against the state prosecutors of Alabama, and it was rejected as insufficient to prove discrimination

[4] The use of Batson Challenges for sex was established in Supreme Court of the United States (1993)

[5] It should be noted that this did not abolish the use of "standing-aside" by the Crown, although the practice was restricted to national security trials and heavily curtailed, with strict guidelines to its use

2.4 The Role of the Peremptory Challenge

Despite these legal changes, recommendations, and a great deal of articles providing analysis against the practice (see, for example, Hoffman (1997)), the topic of the peremptory challenge remains controversial. The modern motivation and justification for the practice in spite of all of the controversy was perhaps best described by Justice Byron R. White in Supreme Court of the United States (1965):

> The function of the challenge is not only to eliminate extremes of partiality on both sides, but to assure the parties that the jurors before whom they try the case will decide on the basis of the evidence placed before them, and not otherwise. In this way, the peremptory satisfies the rule that, "to perform its high function in the best way, justice must satisfy the appearance of justice."

Such a justification is reminiscent of the now famous words of Lord Chief Justice Hewart in *R. v. Sussex Justices* in 1924: "Justice should not only be done, but should manifestly and undoubtedly be seen to be done" (as reported in Richardson Oakes and Davies (2016)). While these words originally only referred to the pecuniary interest of court staff involved in the case, they have since come to express the idealized expectation that both the defence and prosecution find the judge and jury acceptable, as explored by Richardson Oakes and Davies (2016)[6].

This defence suggests two modern justifications for the peremptory challenge. The first is that of removing venire members with "extreme" bias, and the second is the creation of a jury which is composed of jurors mutually acceptable to both the defense and the prosecution. Those who defended the practice of peremptory challenges in Canada after the Gerald Stanley trial, including Hasan (2018) and Macnab (2018), seem to use this defence or some variant of it to argue in favour of keeping the practice. However philosophically appealing these two claims are, in light of all of the controversy surrounding the peremptory challenge, perhaps a critical and empirical examination of these assertions is warranted.

2.5 History

Such an analysis most appropriately begins with a historical explanation of the peremptory challenge. Roughly, the presentation of the history of jury trials here follows the comprehensive and exhaustively referenced description provided by Hoffman (1997). Two of the references Hoffman uses extensively, Hans and Vidmar (1986) and Van Dyke (1977), provided useful context while specific details provided by von Moschzisker (1921), Forsyth (1994), Brown, McGuire, and Winters (1978), and Brown (2000) helped to create a clearer picture of particular periods of jury history. Information regarding the history of the Canadian system was provided by Brown (2000) and Petersen (1993). For an excellent exploration of the nineteenth century, a formative time for the development of challenge law, see Brown (2000).

outlined by Attorney General's Office of the United Kingdom (2012).

[6]Such grand generalizations and myth-making can also be seen in the common belief that the right to a trial by jury was originally established in the Magna Carta, an idea which is not supported by the relevant historical evidence (see Hoffman (1997) and Van Dyke (1977) for a detailed discussion and more accurate history).

It must be noted that certain important trials in the development of the peremptory challenge system have been excluded from the summary provided here. This was done deliberately, as the history presented here is only meant to explore the practice of peremptory challenges throughout history in broad terms. All of the sources listed above are much more thorough, by merit of their singular focus on the analysis of the practice from a legal and historical perspective, while this work devotes more to empirical and statistical analysis.

2.5.1 Pre-English History

Although precise timelines are hard to establish, there is evidence that jury trials have occurred in some form or another since antiquity. The concept, that of judgement by a group of peers, is so ancient that it is prevalent not only in historical records, but in myth. As Hoffman (1997) indicates, both Norse and Greek mythology feature groups of individuals assessing the guilt or collecting evidence about the actions of a peer.

Outside of the realm of myth, Hoffman (1997) reports that there is evidence of the use of juries in Ancient Egypt, Mycenae, Druid England, Greece, Rome, Viking Scandanavia, the Holy Roman Empire, and Saracen Jerusalem. It should be noted that in none of these areas was the jury trial the primary form of conflict resolution practiced. Nonetheless, it is clear the jury trial has a broad and long history of use.

Something similar to the modern peremptory challenge does not appear until Rome, however. The Roman *Judices* were groups of senators selected to judge the guilt of the accused in a legal case. According to Hoffman (1997), 81 Senators would be chosen to sit on one of these *Judices*, after which the litigants were permitted to remove fifteen of these Senators each. This egalitarian reduction of the jury size seems analogous to the modern peremptory challenge system, as it places the power of removal with the litigant and suggests no justification is necessary for their removal.

2.5.2 In English Law (1066–1988)

Peremptory challenge did not reach is modern form, as outlined in 2.1, until it was established in the English legal system. It should be noted that despite some previous debate on the topic, the most modern historical evidence suggests that the basis of the English practice was not related to the system used in the selection of *Judices* in Rome. The English system appears to be its own beast entirely.

The dominant historical interpretation is presented by von Moschzisker (1921) and Hoffman (1997): that the jury system was introduced to England during the Norman conquest of 1066 by William the Conqueror. The practice, however, was not made official until the Assize of Clarendon in 1166 by Henry II, and it was not until the outlaw of trials by ordeal (the most common method of trial at that time) in 1215, that peremptory challenges began to appear in England in the late thirteenth century. The challenges were officially recognized in 1305 when Parliament outlawed their use by the Crown, only to replace them with an analogous system of so-called "standing-aside"[7].

[7] For a detailed explanation of this system see Hoffman (1997) and Brown (2000)

It should be noted here that although the challenges issued between the Assize of Clarendon and this 1305 act are called "peremptory," they may not have served the same purpose, nor shared the same justification, as the modern challenges. Indeed, as Hoffman (1997) argues convincingly, these challenges may have been closer to modern challenges with cause. The argument hinges on the paradigm of royal infallibility and absolutism which was present in the late medieval period when the peremptory challenge first appeared (see Burgess (1992)).

Under royal absolutism and infallibility the argument for peremptory challenges is quite simple. If the king cannot be wrong in his judgement and he has some reason to feel that a venire member cannot serve on the jury, then he need not say why he thinks that is so, as his judgement is correct in any case. Indeed, asking for an explanation would be disrespectful and providing one undignified. The Crown prosecutors, as representatives of the king, would be similarly shielded from criticism.

Such an argument is further supported by the abolition of their royal use in 1305, the language of which suggests that peremptory challenges were originally the privilege of the Crown (see Hoffman (1997) and Van Dyke (1977)), with none being granted to the defence. Hoffman (1997) suggests that as royal infallibilty grew out of favour, peremptory challenges were granted to the defence rather than being removed entirely.

Whatever the logic of the expansion of these challenges to the defence, their legal limits are recorded more precisely[8]. From a maximum of 35 challenges allowed at their peak in the fourteenth century, the number of challenges allowed only decreased over time until their abolition in 1988 (discussed in 2.4).

2.5.3 In American Law (ca. 1700–1986)

von Moschzisker (1921), Hoffman (1997), and Van Dyke (1977) all agree that the early English colonists that came to North America accepted the jury system with peremptory challenges as common law well before the establishment of the United States of America. Hans and Vidmar (1986) note, however, that the difficulty of ocean travel and the overall indifference of appointed Crown representatives in the colonies led to an increased importance of the jury trial and the role of challenges to these early colonists as a way to exercise some degree of community control in the face of laws drafted in a distant country and implemented by unsympathetic authorities[9].

It is somewhat interesting then, that the United States constitution makes no mention of the practice of peremptory challenges. The Sixth and Seventh Amendments specify a great deal of the jury system, including the right to public defense and an impartial jury drawn from the district of the crime, but make no mention of a right to the exercise of peremptory challenges, or any challenges whatsoever (see Constitution of the United States (1788)).

[8] see Brown (2000) for a detailed examination of the case law developing around challenges in the nineteenth century

[9] For more detail on this development among the early colonists, it is instructive to read about the Zenger trial of 1734 (described on pages 33-35 of Hans and Vidmar (1986)). Not only does this trial say a great deal about the attitudes of the colonists at the time, but it also presents the idea of a jury assessing guilt and "wrongness" using their own conscience rather than just settling fact. The precept of the modern jury trial in Canada (see Woolley (2018)) is based on this very idea

As Hans and Vidmar (1986) report on page 37, an original draft of the Sixth Amendment expressly included challenges for cause, but the debate around their inclusion resulted in the removal of their mention. They continue to say that at the time, even some proponents of the challenge considered the reference unnecessary, as the practice was implied by the text which remained, referring to a trial by an "impartial" jury. Another result of these debates was the adoption of the extensive voir dire process which allows questions of general bias[10].

Critically, there appears to have been no discussion around the inclusion of peremptory challenges (see Hans and Vidmar (1986) and Hoffman (1997)). Despite the clear importance of the jury trial to the drafters of these amendments, it would seem the peremptory challenge was not considered to have anywhere near the same significance as judgement by an impartial jury of local peers[11].

Regardless of this, as Brown (2000) notes, the importance and use of challenges increased in the United States in the nineteenth century following American independence due to a desire to prevent the tyranny of the state. This desire also led to the adoption of a limited number of peremptory challenges for the prosecution, rather than the possibly unlimited stand-asides that were allowed under British law to prosecutors (see Van Dyke (1977), page 150).

While the specific numbers of peremptory challenges allowed to both sides and the required motivation of challenges for cause have varied over time (see Hoffman (1997) and Brown (2000)), they have remained a feature of the American legal system, and numerous Supreme court cases (detailed by Hoffman (1997)) have merely served to make the use of challenges more specific and codified. It was not until *Batson v. Kentucky* in 1986 that this system of challenges was drastically changed with the introduction of Batson challenges (described in 2.3).

2.5.4 In Canadian Law (ca 1800–2018)

Canadian law, inspired by a close relationship to both the British Crown and the United States, seems to have adopted elements of both legal systems in its development of peremptory challenges in the nineteenth century. As discussed by Brown (2000), Canada adopted the American practice of replacing prosecutorial stand-asides in favour of a more egalitarian limited number of peremptory challenges to both sides. Despite this, the Canadian voir dire process remains limited and much more similar to the British one, as does the system of challenges for cause (see page 48 of Hans and Vidmar (1986)).

One perfect demonstration of this departure is the Canadian constitution. As in the United States, the Canadian consitution fails to mention challenges. The British North America Act of 1867 (see Constitution of Canada (1982)), which established Canada's independence from England, makes no mention of legal rights of the accused, indicating a deference to legal precedent in England. It is not until the Charter of Rights and Freedoms

[10] This is described on page 37-38 of Hans and Vidmar (1986), though Brown (2000) notes that 1807 Burr trial was also highly significant in the development of general voire dire in the United States

[11] Indeed, as *Batson v. Kentucky* and *Swain v. Alabama* have both shown (Supreme Court of the United States (1986) and Supreme Court of the United States (1965)), the modern interpretation of "impartial" may preclude the use of peremptory challenges altogether

in 1982[12] that such rights were guaranteed in a legal Canadian document. Notably, its language is considerably more vague than the United States Sixth and Seventh Amendments, guaranteeing only "the benefit of trial by jury" (see Constitution of Canada (1982)).

This "eclectic" incorporation of both American and English case law, to borrow the term used by Brown (2000), led to a system somewhere between the English and American systems, but decidedly closer in operation to the English system. It should be noted, however, that as Canada grew more populous in the twentieth century and developed a greater legal precedent and more experienced judges of its own, this reliance upon its former colonial master and its more powerful southern neighbour seems to have diminished in importance. Viewing Supreme court rulings from recent decades reveals a great deal of reference to Canadian legal precedent rather than to the precedent of the other two countries.

2.6 Summary

The peremptory challenge, a practice of much controversy in the English-speaking world, seems to have started in its modern form as a privilege of the King of England in the thirteenth century. After its conception, it spread with English conquest and colonization, with new colonies and local governments accepting the practice based primarily on the adoption of English legal precedent. Though it was abolished in England in 1988, it remains a fixture of American jury trials, and is accompanied there by a thorough and invasive voir dire process which is not seen in Canada nor the United Kingdom.

Though the practice has historical longevity, it is not guaranteed by the constitutions of Canada or the United States, and has been a practice of considerable legal debate and significant change throughout its history. In England this culminated in the Cyprus spy trial, in the United States in *Batson v. Kentucky* and *Swain v. Alabama*, and in Canada in *R. v. Stanley*: the Gerald Stanley murder trial. As a consequence, the broad agreement of the importance and propriety of a jury has conferred little consensus on the place peremptory challenges in the selection of juries.

Indeed, it seems increasingly impossible for the jury to function in a way consistent with its demanding ideals with the peremptory challenge still present. Its spotted history and use to exclude certain minorities may undermine its purported use as a tool to ensure the acceptance of a trial's outcome by both litigants. The three court cases mentioned above are a demonstration how the peremptory challenge can be used to create a jury which is actually unacceptable to one litigant in the case.

[12] This was the year of patriation of the Canadian constitution. As independence was granted by the Britsh Parliament, the British North America Act outlining Canada's laws was a British law and changing it was the prerogative of the British Parliament rather than the Canadian one. It was not until the Consitution Act of 1982 that the Canadian constitution became a Canadian law. For a more detailed history see Sheppard (2018)

Chapter 3

Data

Without data, performing an analysis that incorporated more than the history and legal argumentation presented in Chapter 2 is impossible. This proved problematic. While the motivation of this text was a Canadian case, no comprehensive Canadian data sets which exmained jury selection in Canada could be found. The increased prominence of the jury selection process in the United States garnered a more fruitful search.

The author is heavily indebted to Wright et al.; Grosso and O'Brien; and Baldus et al.. These authors shared their data freely with the author, providing him with a wealth of data to analyse empirically. As a consequence of the multiple separate data sets, however, care must be taken to describe each of the data sets separately in order to capture adequately the different methodologies and sources they represent. Critically, it should be noted that each of these papers represents effort on the part of the authors. As Wright et al. (2018) notes:

> limited public access to court data reinforces the single-case focus of the legal doctrines related to jury selection. Poor access to records is the single largest reason why jury selection cannot break out of the litigato's framework to become a normal topic for political debate

Currently, the collection of jury data is difficult, as many courtrooms have not digitized past records and concerns over privacy limit the release of those records, which are stored as paper documents in the case file (see Wright et al. (2018)). This limits the ability of an individual to ask for summaries across numerous trials or to view the jury selection process on a scale beyond the basis of one case. Thus, to gather aggregate data the authors of these papers necessarily used different collection techniques dictated by the scope of collection desired and the procedures of the court systems from which data was collected.

3.1 Jury Sunshine Project

3.1.1 Methodology

The Jury Sunshine Project (Wright et al. (2018)), so named as it was carried out in order to shed light on the jury selection process, is the most extensive data set which was provided to the author. It endeavoured to collect jury data for all felony trial cases in

North Carolina in the year 2011, which ultimately resulted in a data set that detailed the simple demographic characteristics and trial information of 29,624 individuals summoned for jury duty in 1,306 trials. Note that not all entries were complete.

Due to the scope of the project, there are a number of problems which had to be solved by the authors. The first of these was simply identifying which court cases went to trial in 2011, in order to direct resources effectively. This was accomplished by downloading publicly available case data from the North Carolina Administrative Office of the Courts (NCAOC)[1] and determining the case numbers and counties of cases which went to trial. Wright et al. state that this likely missed some cases which went to trial, but that they were confident that a "strong majority" of trials was collected, which did not systematically differ from those excluded.

This list was then used to perform a pilot study to refine recording practices before undertaking a more general survey where "law students, law librarians, and undergraduate students" (called *collectors* for convenience) visited court clerk offices to collect the relevant case data, including the presiding judge, prosecutor, defence lawyer, defendant, venire members, charges, verdict, and sentence. The case files also included data about whether a venire member was removed by cause or peremptorily, and the party which challenged in the peremptory case. Using public voter databases, bar admission records, and judge appointment records, these collectors were able to determine demographic (race, gender, and date of birth) and political affiliation data for the venire members, lawyers, defendants, and judges. This data set was stored stored in a relational database provided to the author by Dr. Ronald Wright.

The analysis of the data provided in Wright et al. (2018) was limited to aggregate summaries of the trends at the venire member level. That is to say, they examined the strike trends for both the defence and the prosecution, conditioning on some additional variables. There was also spatial analysis performed, were different urban counties were directly compared. These analyses were not statistical in nature, and were displayed using contingency tables. Regardless the stark differences between prosecution and defence with regards to race were a key finding when the aggregate data was analyzed.

3.1.2 Cleaning

Flattening the Data

For greater expediency of analysis, the relational database of the Jury Sunshine Data was first flattened. The relational database was read into Microsoft Excel and the `readxl` package (Wickham and Bryan (2018)) was used to read the excel file into the programming language R . A wrapper for the `merge` function was developed which provided simple a simple output detailing failed matches in an outer join in order to ensure that the flattening of the data into a matrix did not miss important data due to partial incompleteness. The code for this wrapper can be seen in D.1.

[1] The link provided in the Jury Sunshine Paper to the specific source (http://www.nccourts.org/Citizens/SRPlanning/Statistics/CAReports_fy16-17.asp) does not appear to be working as of January 2019, however the NCAOC seems to provide an API functionality at https://data.nccourts.gov/api/v1/console/datasets/1.0/search/

This wrapper revealed only a small number of irregularities in the data, which are detailed in B.1:

i.) Twenty-nine charges missing trial information such as the presiding judge (all of trials with IDs of the form 710-0XX)

ii.) Twenty-six prosecutors not associated with any trials and missing demographic data

iii.) One trial missing charge information

Ultimately, the jurors for trial ID 710-01, the trial missing a charge from above, were included in the data as their records were complete otherwise. The prosecutors and charges which could not be joined were excluded from any future analysis, as they could have easily been included by collectors by accident. Due to the small relative size of these inconsistencies relative to the size of the data set, they did not cause concern.

Uninformative Columns

Of course there were other irregularities in the data than the obvious ones that arose in the flattening process. There were a handful of likely sources for these errors. The first of these is the anonymization of the data for public use. The private data includes a wealth of privileged data such as juror name and address, and these were removed in the data given to the author.

As a consequence of this anonymization as well as the inclusion of rarely used columns such as those for additional notes, some columns of the data contained only NA values. Most baffling of these was the `BirthDate` variable in the `Jurors` table, as there was no clear reason for this data to be missing. Thankfully, none of the missing columns were relevant to the joins performed in flattening, and they would have been only secondary in data analysis. As a consequence, these uninformative columns were simply removed from the data.

Coding Inconsistencies

Related to this problem was the issue of inconsistently coded variable levels. An example of these inconsistencies would be levels recorded as both lower and upper case letters, or the presence of "?" instead of "U" for unknown values. It is very likely this inconsistency was a direct result of the data collection method which used many data collectors working independently in different places at different times. Thankfully, Wright et al. provided the codebook used by data collectors, which served as the authoritative reference for the admissible factor levels of demographic variables. Solving this problem was as simple as setting all demographic variable levels to be uppercase and replacing obviously misspecified levels.

One specific inconsistency which should be noted is that of the outcome, which had a handful of entries recorded as "HC", an inadmissible level not defined by the codebook. It is quite possible that this level represented a typo, as the "H" and "G" keys are adjacent on the American QWERTY keyboard layout, and "GC" was the code for 'guilty as charged', but out of a desire to be conservative with the data the occurrence of this outcome was replaced with U instead. Additionally, the inadmissible level "G" was replaced by GC.

Swaps

A more difficult problem of level misspecification was the presence of what appeared to be columns with swapped values, frequently occurring with the gender column (the admissible levels of which are "M", "F", and "U") and the political affiliation column (the admissible levels of which are "D", "R", "I", or "U"). The aformentioned "swaps" appeared as records in which, for example, the gender was recorded as "R" and political affiliation as "M". More complicated swaps of three columns also occurred. To address this problem, the `IdentifySwap` function was written (see line 108 in D.1).

The `IdentifySwap` function accepts two arguments: a data frame with named columns and a named list of vectors of the acceptable levels for some of the column names. It then performs vectorized checks of the specified column names and presents any rows which may have swaps or errors interactively to the user, along with a suggested reorder to "un-swap" the row. The user can press enter to accept the suggested reordering, enter some other reordering, or enter 0 to indicate that the row was not a true swap, but simply an error. The un-swapped entries are then returned to the data, and the rows with errors have the erroneous values replaced by "U", the universal code for "Unknown" within all data variables[2].

The source of these swaps is also most likely the data collection method. The codebook provided specifically notes that the data collection was meant to record the race (R), gender (G), and political affiliation (P) data in the form RGP, but it is not inconceivable that it would occasionally have been recorded or entered in some other ordering in the tedium of data entry. In any case, this problem affected only 431 records of the nearly 30,000, suggesting that the recorded error rate was not unacceptably large.

Charge Classification

Perhaps the least regular data in this data set was that of the charge text. Due to the lack of any codebook guidance about the standard way of recording a charge in a trial, identical charges were recorded in numerous ways. The first method used to combat this was removing non-alphnumeric characters, extra spaces, and converting all charges to lower case. This still left a considerable variation, however. Consider the charge of breaking and entering, for example, even with this simple preprocessing performed the entries varied significantly (e.g. "break or enter", "breaking andor entering", "breaking and or entering", etc.).

As a consequence, the processing was more involved. First the most common versions of the charge text for the charges were all regularized to be identical (see `StringReg` in D.1. Next, a regular expression classification tree was developed, which would also account for specific features of a charge. When identifying murder, for example, it seemed important to ensure attempted murder was separated from murder itself, and separating first and second degree was also desired. This tree would, when presented with a charge, apply the regular expressions at each node to the charge. If the charge matched the expression at a node, the regular expressions of that node's children were applied to the charge until it was classified to some leaf node, each of which had a standardized value which replaced

[2]One notable exception to this insertion of "Unknown" was the case of the judge Arnold O Jones II, whose gender was not recorded in the data, but who was identifiable as a man using a quick Google search of his unique name

the charge. A small example of this structure is displayed in Figure 3.1, and the full tree is visualized in B in Figure B.1.

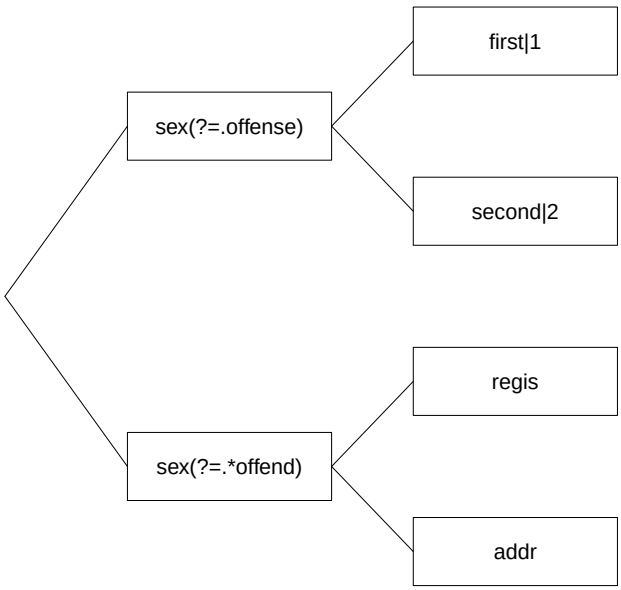


Figure 3.1: A example of a simple charge classification tree to separate the sexual offenses from charges leveled against previously known sex offenders. A charge would be classified from most general on the left to most specific on the right.

By performing regularization using this charge tree, regularized charges were guaranteed. The cost of this regularization was the inability to classify all crimes, however. Of the 1407 charges present in the data, the tree provides regularization for 1209. With additional time and inspection of the failed matches, the tree could conceivably be axpanded to regularize all charges. As this was not the primary investigation of the report, however, such effort was not expended.

Instead, a number of helpful aggregation and extraction functions were developed to allow for the charges to be further simplified, as seen in D.1. In this report, they were aggregated by intuitive classes: sex-based offenses, thefts, murders, drug charges, violent offenses not otherwise classified, and driving charges. However, other classes, such as the North Carolina felony classes themselves (as provided by North Carolina Sentencing and Policy Advisory Commission (2017)), may provide a more informative classification rationale.

Variable Level Renaming

The final step of the data cleaning process was to convert the uninformative codes used to indicate variable values to more intuitive and clear names (for example to convert “I” in the political affiliation variable to “Ind”, a clearer indication of independent). Certain variables which were already clear, such as gender (codes “M”, “F”, “U”), were not renamed due to the clarity of the one letter representations.

3.1.3 Variable Synthesis

In order to expand the possible analysis and visualization potential, a number of variables were synthesized from the Jury Sunshine data set. They are detailed below.

Race Match A logical variable which is true for a venire member if they are the same race as the defendant, and false otherwise. This variable was motivated in particular by the Gerald Stanley trial, in which the implicit contention of those who have taken issue with peremptory challenge is that the First Nations venire members were removed by the defence as their race did not match that of Stanley in the racially charged trial.

Guilty Logical indicator indicating whether the trial outcome was guilty or not

Visible Minority Logical indicator of non-white venire member race

Race of Striking Party Factor variable which gives the race of the prosecution if the venire member was struck by the prosecution, the race of the defence if the venire member was struck by the defence

Simplified Race Due to the scarcity of the other minority races, this variable simplified the race provided to white, black, or other for the venire member

Simplified Defendant Race The same as the simplified race for the defendant races

Simplified Disposition This variable combined the categories "Foreman" and "Kept" in the original disposition variable into a variable "Kept"

3.2 Stubborn Legacy Data

3.2.1 Methodology

Grosso and O'Brien (2012) also provided data to the author, albeit a more limited set. This study, also based in North Carolina, focused on the trials of inmates on death row as of July 1, 2010, yielding a total of 173 cases. In each proceeding, the study examined only those venire members not excluded for cause, and critically the analysis of the study focused only on prosecutorial peremptory challenges. Besides collecting demographic data as in the Jury Sunshine Case, this study also collected attitudinal data for the venire members. This attitudinal data for the venire members is somewhat more detailed than the political affiliation data provided in the Sunshine data, including attitudes about the death penalty, employment information, and opinions on the trustworthiness of law enforcement.

Staff attorneys from the Michigan State University College of Law were responsible for the data collection in this study. The work was performed similarly to the Jury Sunshine Data, using case files to collect information about the court proceedings such as the peremptory challenges used, presiding judge, prosecutor, and defence lawyer. Detailed verdict and charge information was not collected, as the preselection criteria of death row inmates made the verdict clear, and the death penalty can only be applied for certain crimes.

To collect demographic and attitudinal data, the juror questionnaire sheets were con-

sulted[3]. These sheets are typically used as a component of voir dire, in order to make the process more efficient and determine venire members categorically ineligible for jury duty. As a result, they inquire about opinions on the death penalty, for example, as well as demographic questions. As not all jury questionnaires were available, additional information was collected from jury roll lists to determine the races of the final jury members. It should be noted that this collection was done blind and to high standards of proof, and a reliability study carried out in Grosso and O'Brien (2012) indicated that under this system the race coding was 97.9% accurate when the standards were met. Those for whom the standards were not met were marked as "Unknown."

The lack of an examination of political affiliation by this study, instead choosing to input far more detailed data on venire member viewpoints, serves as a barrier to the comparison of this data to the Sunshine data on an identical basis. However, the racial data for the two is recorded in a very similar way, so this effect can, at least, be compared. A comparison of the estimates of racial impacts controlling for political affiliation in the Sunshine data to those generated controlling for much more specific may be also of interest.

3.2.2 Cleaning

The data provided to the author was already exceptionally clean, and so no cleaning was required. There was no variable synthesis performed on the data, rather variables were used and combined to generate analogous measures to those recorded by the Sunshine data. These combinations included using indicators of strike status to make a disposition variable analogous to that provided in the Sunshine data, and combining certain racial indicators into the more universal white/black/other coding.

3.3 Philadelphia Data

3.3.1 Methodology

Baldus et al. (2001) presents a similar data set collected using similar means. Court files such as the juror questionnaire, voter registration, and census data were all used to complete juror demographic information for 317 venires consisting of 14,532 venire members in Philadelphia capital murder cases between 1981 and 1997[4]. It should be noted that this data included only those jurors kept or peremptorily struck, venire members struck for cause were not included in the data. The procedure used to determine race using the census and voter registration polls was quite complicated, but was rigorously performed using accepted census methods to a standard of 98% reliability[5].

[3] As Grosso and O'Brien (2012) observe, self-identified race may be the most accurate source of racial group identification.

[4] This study took into account the sampling error by reweighting venires based on the year of the trial and the defendant race, as court records showed that the sample coverage varied over these factors.

[5] Additionally, imputation was only performed in a small minority of cases.

3.3.2 Cleaning

One interesting quirk of the Philadelphia data set was missing values. While the codebook describing the data explicitly stated a number of variables should be recorded as binary values. In the provided data files, however, these variables were missing for a majority of the observations. In the case of the "FINLJURY" variable for example, an indicator of whether the jury member was included in the final jury, there were 4626 records with a value of 1, 3 with a value of 0, and 12890 missing values. These missing values were assumed to be zero, as using this assumption created a data set which was consistent with that reported in Baldus et al. (2001). As with the Stubborn data, the only variable synthesis performed was completed to create analogous variables to the Sunshine data.

Chapter 4

Analysis

With this data cleaned and processed, questions can now be posed and addressed through analysis. A few obvious questions come to mind, considering the previous work done on this subject and the modern controversy surrounding it. First, there is the obvious question of possible racial imbalance of peremptory challenge use and how this potential imbalance changes with the race of the defendant. In the Gerald Stanley trial, for example, the critical aspect of the trial was not the use of peremptory challenges in abstract, but how their use interacted with the race of Stanley.

Aside from these investigations, we may wonder whether the most common arguments posed in favour of peremptory challenge are satisfied in this data. As discussed in 2.4, there are two primary arguments. The first is the argument that the peremptory challenge is necessary to remove the "extremes of partiality" present in the venire for both sides; that is to remove the most extremely biased jurors. This goal is complemented by the ability of the judge to remove jurors with cause, which is also designed to remove those jurors with extreme bias. The second argument is the creation of a jury which is mutually acceptable to both parties in the trial.

4.1 Extremes of Partiality

While creating a quantitative judgement on the acceptability of a jury is somewhat difficult, measuring the extremality or abnormality of observations is a critical function of statistics. With this in mind, a very simple calculation was performed. The central claim of the advocates of the use of peremptory challenge is that it is only used to remove extreme cases of bias. If that is so, then the proportion of venire members removed by peremptory challenge should reflect this concept.

Of course, this cannot be rigorously tested, as there is no way of knowing the true distribution of bias among jurors. That does not mean nothing can be said, however. Each individual in the population will have opinions which imbue a bias for a given case. The relevant opinions across all individuals in the population will form some distribution of bias ranging from individuals biased heavily for conviction before seeing evidence to individuals biased heavily against conviction before seeing evidence. Viewing the rate at which venire members are rejected in the data allows inference of what proportion of the

population is 'too extreme' to judge the average trial. A distributional assumption refines this proportion into a measure of distance for a symmetric rejection rule.

As Nisbett and Kunda (1985) notes, there is a tendency for people to assume a normal distribution normal when asked to guess the distribution of social attitudes. This is unsurprising. The ubiquity of the normal distribution throughout science gives it a central position in the way the typical person conceptualizes any distribution. Such reasoning is supported by Nisbett and Kunda (1985) and suggests that when the average person hears of extremality in a distribution, their view is reasonably assumed to be the tails of a normal distribution. It is therefore not unreasonable to assume that the proponents of peremptory challenge may view the distribution of bias in the population as normally distributed.

Additionally, mathematical constraints such as the Chebyshev inequality (see Weisstein (2018)) provide an upper limit to the dispersion of any distribution. The Chebyshev limit gives an estimate of the proportion of observations above a given distance from the mean given a maximally dispersed distribution. In case bias terms the proportion of individuals further from the mean, "unbiased" opinion, than some standard distance in a population which is maximally biased both for and against.

Table 4.1 provides a summary of the rejection rates of the different data sets and the implied distances from the mean, in standard deviations, that these imply for symmetric rejection. Note that two rows are provided for the Sunshine data, the first for the entire data set of jury trials and the second for first degree murder[1]. This was done to facilitate comparison, as both the Stubborn Legacy and Philadelphia dataset only addressed capital cases[2].

Table 4.1: The implied statistical extremity bound for symmetric rejection in the datasets given different distributional assumptions

Data	Rejection Rate	Normal	Chebyshev Limit
Sunshine	0.434	0.781	1.517
Sunshine Capital	0.639	0.470	1.251
Stubborn	0.659	0.442	1.232
Philadelphia	0.736	0.337	1.166

The normal rejection bounds are visualized in Figure 4.1, where the areas shaded red give the rejection regions for the correspoding data sets. From left to right in the negative distances, the areas correspond to the full Sunshine, Sunshine capital, Stubborn, and Philadelphia data sets.

The narrowness of the implied acceptance regions, indicated by the white region for the Philadelphia data and the lighter red regions for all other data sets, suggests that the peremptory challenge is not being used exclusively to remove extreme individuals from the population. Indeed, as the rejection bounds are typically less than or near one standard deviation from the mean, this suggests that the average individual sampled from the population is "extremely partial" in the eyes of the court. Such rejection is inconsistent

[1]The only sentence with the potential of a death penalty, as informed by the sentencing guidelines provided in North Carolina Sentencing and Policy Advisory Commission (2017).

[2]It should be noted that there is still some difference in studied populations, as the previous studies looked at individuals sentenced to death, while no individuals in this data set were sentenced to death.

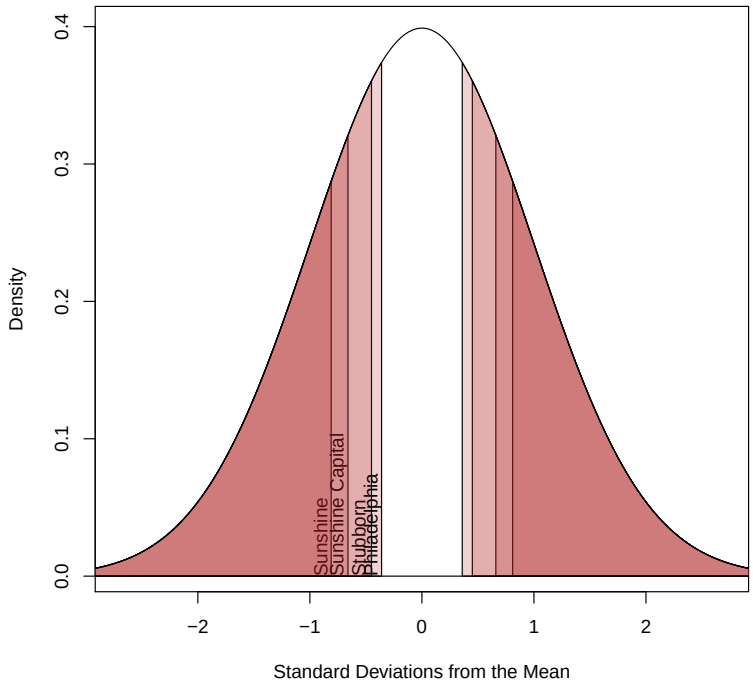


Figure 4.1: The rejected areas for each data set given the observed proportion of struck venire members and assuming a normal distribution.

with the concept of a jury as the "conscience of the community," one of the core philosophies of a jury trial, and implies the overuse of rejections by the court in some way.

Obviously, the above reasoning has some flaws. It is not possible to comment with authority on the presence of partiality in the population. Critically, if the population has a tendency to be biased as a whole, *i.e.* the "unbiased" opinion is not the mean of the population distribution, the above arguments on symmetric extremity break down, and such high rejection rates may very well be appropriate to find the unbiased jurors.

Such criticism may be supported by the increased use of peremptory challenges for the capital cases in the data. As is clear viewing historical Gallup polls on the topic (?? (gal)), opinions on the death penalty and murder trials are far more polarized and have varied greatly over time in the United States. At times the population has been biased as a whole to favour the death penalty for murder trials by a very wide margin. In the case of murder trials, then, perhaps only a minority of the population holds reasonable unbiased views on the subject.

Consequently, the rejection rates are suggestive, but may be misleading. It is impossible to conclusively state whether more individuals are being rejected from serving on the jury than the proper amount. Indeed, the concept of the "appropriate" amount of rejection is unclear given the lack of detailed knowledge of the population bias as a whole on a case-by-case basis. However, given the history of peremptory challenges and the legally successful arguments of their over-utilization on certain groups, further investigation on the venire members for which data exists is warranted.

4.2 The Impact of Race

The racially-motivated controversy surrounding peremptory provides one hypothesis in the pattern of venire member rejection which may be so investigated. To begin, a simple marginal investigation was performed to explore the impact of the simplified race on the peremptory strike probability. The result of this investigation is displayed in Table 4.2. Of particular interest is whether any race is far more likely to be struck by peremptory challenge than the others, as this might suggest that race is the target of the over-use of strikes.

Table 4.2: The conditional probability of a venire member being struck peremptorily by the simplified venire member race across data sets. These values are smaller than the values presented in the extremity analysis as only the individuals which were identifiably removed by peremptory challenge are counted in this table. Regardless, the comparisons remain similar if the unattributed removals are included. Note that the Philadelphia trial data only indicated black and non-black venire members and so only two numbers can be reported.

Data	Black	Other	White
Sunshine	0.23	0.24	0.25
Sunshine Capital	0.22	0.27	0.27
Stubborn	0.65	0.36	0.66
Philadelphia	0.67	0.68	

These probabilities are different, but not greatly so. Indeed, the trend of higher probabilities for the removal of white jurors across all data sets is perhaps counter-intuitive given the history of peremptory challenge controversy in the United States. In any case, the small magnitude of these differences seems to suggest that there is no strong racial bias at the aggregate level, whether or not the results are statistically significant[3]. Perhaps there is a more interesting race-dependent relationship to be uncovered. Taking inspiration from *Swain v. Alabama*, *Batson v. Kentucky*, and *R. v. Stanley*, viewing the relationship between venire member race and defendant race could be informative. This relationship is displayed in Figure 4.2.

A detailed description of this plot and its development which includes a discussion of the principles of graphics and perception which were used to devise its form is presented in A[4]. Henceforth in the paper, plots of this type for visualizing three way relationships of categorical variables will be referred to as "mobile plots." The most interesting patterns visible in this particular mobile plot will be discussed here.

First, a small explanation of this mobile plot. This mobile plot displays the relationship between three categorical variables: venire member race, defendant race, and disposition (whether a venire member is struck and by whom). The vertical axis corresponds to the conditional probability of the disposition given a race and defendant race combination[5]. Racial combinations are placed along the horizontal axis, and each combination corresponds to one horizontal black line in the plotting area. The length of these lines is

[3] Consider the numerical impact of a statistically significant difference of a few percent when the jury size is 12 for each trial.

[4] Here it suffices to mention that much of its design was motivated by the philosophy of Tufte (2001) and the results of Cleveland and McGill (1987) on the accuracy of visual perception.

[5] Generally, any three categorical variables can be displayed using a mobile plot, as the mobile plot is used to display the distribution of a categorical variable given the combinations of the other two. Mathematically it displays $X_3|X_1, X_2$.

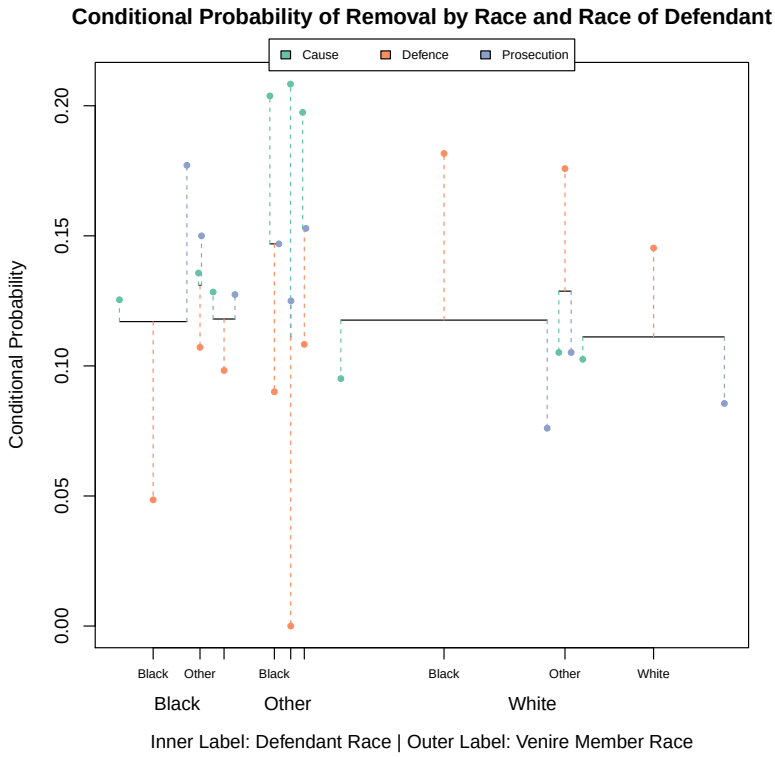


Figure 4.2: The conditional probability of successful challenges given the venire member and defendant race, with the expected value represented by the horizontal black line, and the observed values represented by the point at the end of the dotted line. Each horizontal black line corresponds to a particular venire member and defendant race combination, with a length proportional to the number of venire members with that combination. The dashed vertical lines, coloured by challenge source, start at these horizontal lines and end at points which show the observed probability of a challenge by that source for the given racial combination.

proportional to the number of venire members in the data with the corresponding racial combination, and their vertical positions are the mean conditional probability of a venire member being removed by a challenge, causal or peremptory, for that particular combination. The dashed vertical lines, coloured by disposition, start at this mean line and extend to the observed conditional probability of the corresponding disposition for the relevant racial combination. As a consequence, this plot can be viewed as a visualization of the test of a specific hypothesis:

$$D|D \in \{2,3,4\}, R, E \sim Unif(\{2,3,4\}) \tag{4.2.0.1}$$

Where D, R, E are random variables representing the disposition, venire member race, and defendant race respectively as outlined in 0.2. In words: the conditional distribution of the disposition given both rejection and the racial combination is uniform. This implies that causal challenges, defence strikes, and prosecution strikes occur with the same probability for each racial combination, though they may differ between racial combinations. Such a hypothesis allows for certain racial combinations to experience a higher strike rate generally, but constrains the strike rate to be the same for all parties, which would imply that all parties in the court pursue an identical strike strategy across all venire member and defendant race combinations.

Clearly, Figure 4.2 casts some doubt on this hypothesis. While the horizontal black lines tell a very similar story to Table 4.2, with little variation between them except for in small population subsets, a number of other striking patterns are visible. The first, and most obvious of these, is the main effect of venire member race. While the aggregate removal rates do not seem to depend on the race of the venire member, it is clear that the defence and prosecution pursue radically different strategies. The defence seems biased towards a jury with more venire members from visible minorities. All orange points are below the horizontal lines for the black and other venire members, indicating these groups are less likely to be struck by the defence than expected, while the points are above the lines for the white venire members, indicating a higher than expected probability of defence removal for white venire members. The prosecution seems to mirror this tendency, striking the white venire members at a lower rate than expected and the black venire members more often than expected. The prosecution seems to show no deviation from expectation for the venire members of other races, and otherwise always deviates from expectation in the same direction as the prosecution.

The addition of defendant races shows another interesting trend. It would seem that the aforementioned tendencies of the prosecution and defence are strongest for black defendants, which have the strongest departure of the conditional probabilities from the expectation. The defense and prosecution seem to have slightly more similar habits when the defendant is white, despite their opposite tendencies in all cases. Finally, it would seem that the removals with cause have tendencies similar to the prosecution, as the points representing the conditional probability of a venire member being removed with cause are always on the same side of the expected line, an event which would occur with probability $2^{-9} \approx 0.002$ under the hypothesis of independent uniform strike rates. Further discussion of the agreement of these two strike tendencies can be found in 4.4.

While Figure 4.2 is quite suggestive, the widths of certain horizontal black lines, in particular those for venire members with a race other than white or black, suggest that perhaps some of the more extreme tendencies are simply a result of the well-known higher variation of samples with small sizes. In order to see the true nature of the noted departures some incorporation of the variation one expects from each observed value is required. This is accomplished by the addition of approximate 95% simultaneous multinomial confidence intervals using the `MultinomialCI` package in R , which implements simultaneous confidence intervals for multinomial proportions following the method presented in Sison and Glaz (1995). These confidence intervals can be seen in Figure 4.3.

As suspected, some of the results for the smaller sample sizes do not seem to be significant. The results for the larger groups, in particular for white venire members or black defendants, are significant, however. It should be noted that these simultaneous confidence intervals do not constitute a proper statistical test of the impact of race, they are rather a way of visually providing a viewer some sense of the expected variability in the data over repeated sampling. More rigorous testing requires controlling the impact of confouding factors, as done by the modelling in 4.4.

4.2.1 In the Stubborn and Philadelphia Data

With the patterns for the entire Sunshine data set examined, it is important to see how general this pattern is. It is entirely possible that the Sunshine data simply shows a particularly bad year in North Carolina, and so seeing whether this pattern is present over

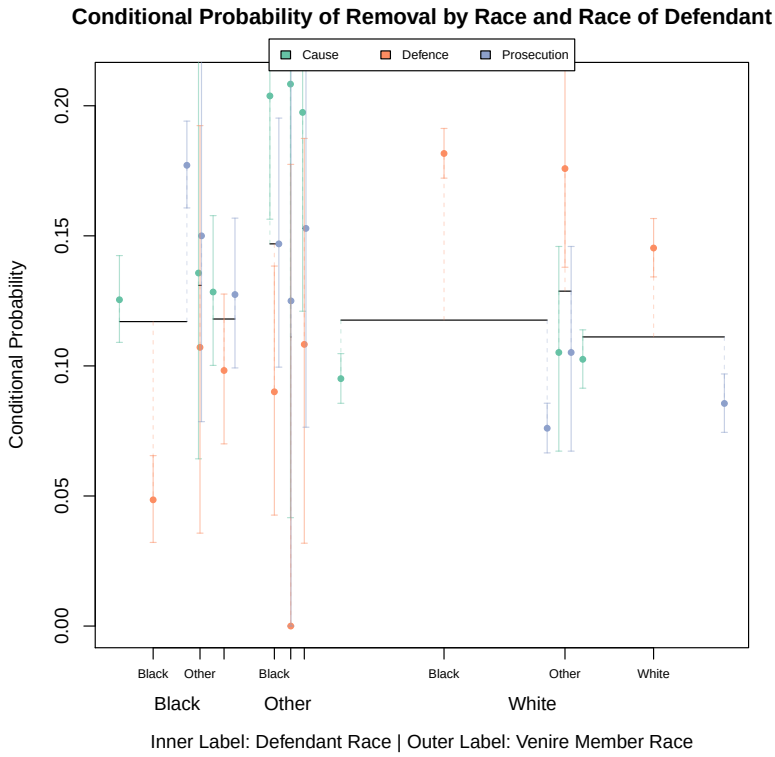
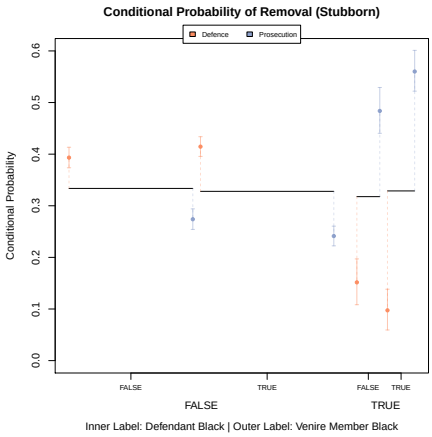


Figure 4.3: The plot of conditional strike probability by racial combination from above with confidence intervals added. Note that many of the seemingly striking departures seen are insignificant when these confidence intervals are applied.

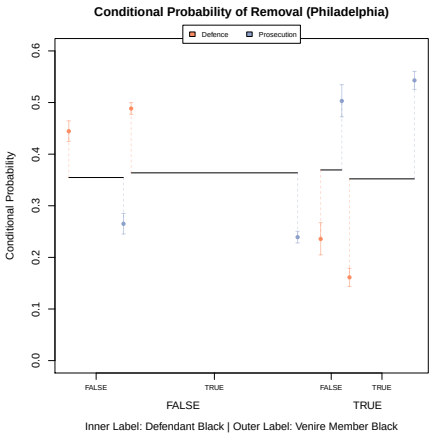
time and in different regions is important to motivate its generality. To that end, Figure 4.2 was reproduced for the Sunshine capital cases, the Stubborn data, and the Philadelphia data. These plots can be see in Figure 4.4.

Three important differences between Figure 4.4 and Figure 4.3 must be noted when interpreting these visualizations. The first of these is that data differences have limited the scope of the comparison to simply the prosecution and defence strike rates, as the Stubborn data does not include any information on strikes with cause. Second, the Sunshine data used to generate the mobile plot in Figure 4.4 is filtered to only the first degree murder trials, as the other two data sets only addressed capital trials (i.e. those with the death penalty), while the Sunshine data had a broader scope. Finally, the race and defendant race were further simplified to logical indicators of whether the race variable was black or not.

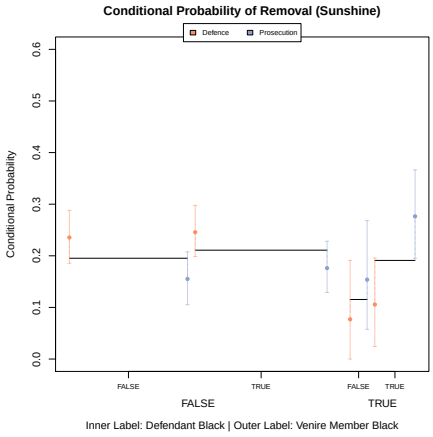
Despite the very different study sample universes of these three data sets, all display identical patterns, with only the magnitudes of the different strike rates differing. The mobile plot format makes several interesting patterns immediately clear. The similar level of all black lines within each plot shows that in each data set, the aggregate probability of removal is similar across racial minority combinations. However, these aggregate similarities hide the vastly different strategies of the defence and prosecution which are consistent across the data. The defence has a tendency to retain visible minority venire members, striking them at a lower rate than the white venire members, while the prosecution shows a pattern which mirrors that of the defence, removing more visible minorities and fewer



(a) Pattern in the Stubborn Data



(b) Pattern in the Philadelphia Data



(c) Pattern in the Sunshine Data

Figure 4.4: The conditional probability of defence and prosecution peremptory challenge by racial minority status across all capital trials in all data sets. The pattern, though sometimes different in magnitude, is quite consistent across the three examined data sets, despite the significant differences in the respective study sample universes.

white venire members. In all data sets the gap between these probabilities and the implied removal rates is greatest for the black venire members in cases with black defendants.

It should be noted that the Sunshine data set looks most unique of the three, and this may be a result of the sample size. While the Philadelphia data and Stubborn data both collected data which included multiple years, the Sunshine data was restricted to trials which occurred in 2012. This small sample is the reason for the large confidence intervals present in Figure 4.4c. This small sample size does not explain the overall lower strike rate observed in the capital trials in this data, which is also visible in Table 4.2. This departure may be of interest for further investigation.

4.3 Other Factors

Of course, it would be incorrect to conclude immediately that the cause of the racial patterns observed across these data sets is race itself. There may be a plethora of attitudes

associated with race that could serve as legitimate cause for a peremptory challenge. As noted by Justice Byron R. White in the majority opinion in Supreme Court of the United States (1965)

> [The peremptory challenge] is no less frequently exercised on grounds normally thought irrelevant to legal proceedings or official action, namely, the race, religion, nationality, occupation or affiliations of people summoned for jury duty. For the question a prosecutor or defense counsel must decide is not whether a juror of a particular race or nationality is in fact partial, but whether one from a different group is less likely to be.

This quote leads directly to the heart of the problem. Without detailed transcripts indicating how the venire members were questioned, it cannot be known if the aggregate pattern of removal is the result of racially based strikes, or whether the lawyers determined valid reasons for a peremptory challenge during the voir dire process which are simply related to race. For example, if defence attorneys reasonably assumed that trust in and deference to authority and law enforcement would make a venire member predisposed to reject arguments provided about possible mishandling of evidence without proper consideration, this would be reasonable grounds for peremptory challenges of individuals with that opinion. If such opinions were distributed heterogeneously by race, the aggregate pattern may appear to reflect racially-based decision making by the defence attorneys[6].

4.3.1 Political Affiliation in the Sunshine Data

Revesz (2016) provides, inadvertently, data which might support the above defence of peremptory challenges on the basis of confounding variables in the United States. He notes that the distribution of political affiliation in the United States is not consistent across races, with black voters far more likely to vote for the Democratic Party and far less likely to vote for the Republican Party, while white voters are more uniformly distributed and likely to vote independently. If political affiliation is used as a surrogate for ideology and point of view, this suggests that the observed pattern in the Sunshine data could be the result of defence lawyers removing conservative venire members and prosecution lawyers attempting to remove liberal ones. As the Sunshine data has political affiliation, the results of Revesz can be compared to this data. The resulting figure, Figure 4.5, displays the conditional probability of political affiliation across races and genders.

What is immediately apparent viewing this plot and the data in Revesz (2016) is how closely the two data sets agree. Black voters vote Democratic a vast majority of the time, while the political leanings of white voters are less cohesive. Note additionally that the horizontal lines in this plot are all very close to 0.33, as almost all voters are Democrat, Republican, or independent. The "ideological imbalance" of racial voting tendencies, as Revesz aptly calls it, is a clear confounding factor and a possible source of a legitimate cause for an initially suspect overall trend. As such, it was investigated using the mobile plot.

To control for the defendant race as well, which already appears to be important, the venire members were split into the simplified racial groups black, white, and other. Then

[6] Grosso and O'Brien (2012) and Baldus et al. (2001) both provide such detailed attitudinal survey data, but how this data interacted with the questions asked during voire dire is unclear. Additionally, it is missing in the Wright et al. (2018) data.

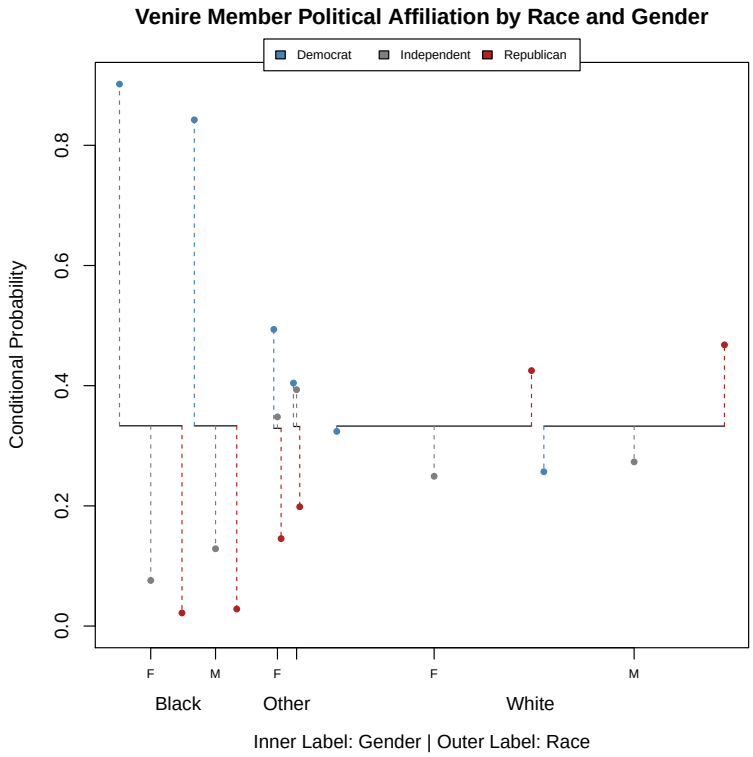


Figure 4.5: Conditional probabilities of political affiliation by race and gender. In this plot, it is clear the black venire members are far more homogeneous than the white venire members for both genders, with the vast majority voting Democrat.

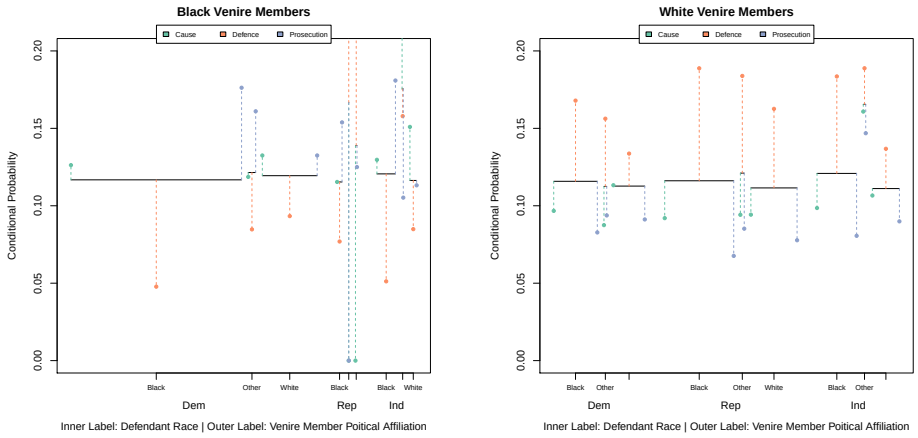
mobile plots of the conditional strike probabilities for the different venire member races given the defendant race and political affiliation were generated. Figures 4.6a, 4.6c, and 4.6b display these mobile plots.

This sequence of three plots immediately suggests that a political argument is insufficient for this data. For each venire member race and defendant race, the political affiliation of the venire member does not radically change the pattern of strikes for any party in the court. Rather, the court tendencies for each political affiliation, venire member race, and defendant race seem to follow the pattern seen in 4.2 for all political affiliations with the exception of some very small subgroups of black venire members[7]. It should be noted that many of the other, less noticeable subgroups represented by this particular set of plots will be too small to provide statistically significantly results. Regardless of these difficulties with sample size, the consistency of the pattern of strikes across political affiliations provides rather stark evidence against a hypothesis of political affiliation as a primary cause of the strikes in the data.

4.3.2 Gender in the Sunshine Data

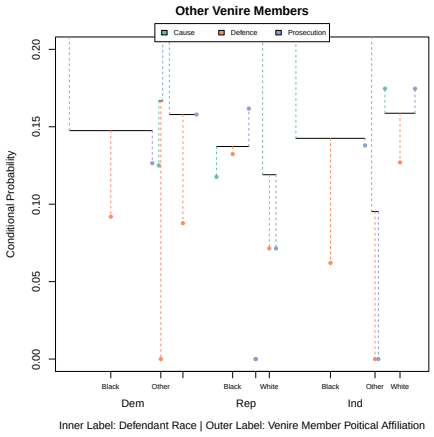
Another factor which may have an impact is that of gender. While *J.E.B. v. Alabama* (Supreme Court of the United States (1993)) has also ruled peremptory challenges for this

[7]The subgroups, black republican venire members for white or other race defendants, have sizes 1 and 10, respectively. The study examines a total of 29636 venire members.



(a) Black Venire Members

(b) White Venire Members



(c) Other Venire Members

Figure 4.6: Conditional probability of venire member strike by defendant race and political affiliation, split by race. Note how the pattern of conditional probabilities is the same across political affiliations for the same defendant race within a particular venire member race, and this pattern is the aggregate pattern seen in Figure 4.2

reason alone unconstitutional in the United States, it is noted in Van Dyke (1977) on page 152-153 that prosecutor's guidelines have, in the past, recommended using peremptory challenges to remove female venire members[8], and so perhaps it is a relevant factor. Additionally, there is a relationship between gender and race in the data, as noted in Wright et al. (2018): black males are highly under-represented relative to black females. Luckily,

[8] Van Dyke provides specific guidelines for sex written by Jon Sparling, an assistant district attorney in Dallas, which read:

i.) I don't like women jurors because I don't trust them.

ii.) They do, however, make the best jurors in cases involving crimes against children.

iii.) It is possible that their "women's intuition"[sic] can help you if you can't win your case with the facts.

iv.) Young women too often sympathize with the Defendant; old women wearing too much make-up are usually unstable, and therefore are bad State's jurors.

If data on make-up use and jury outcome is ever collected perhaps Mr. Sparling's bold claim can be tested, but until then it is better treated as prejudice.

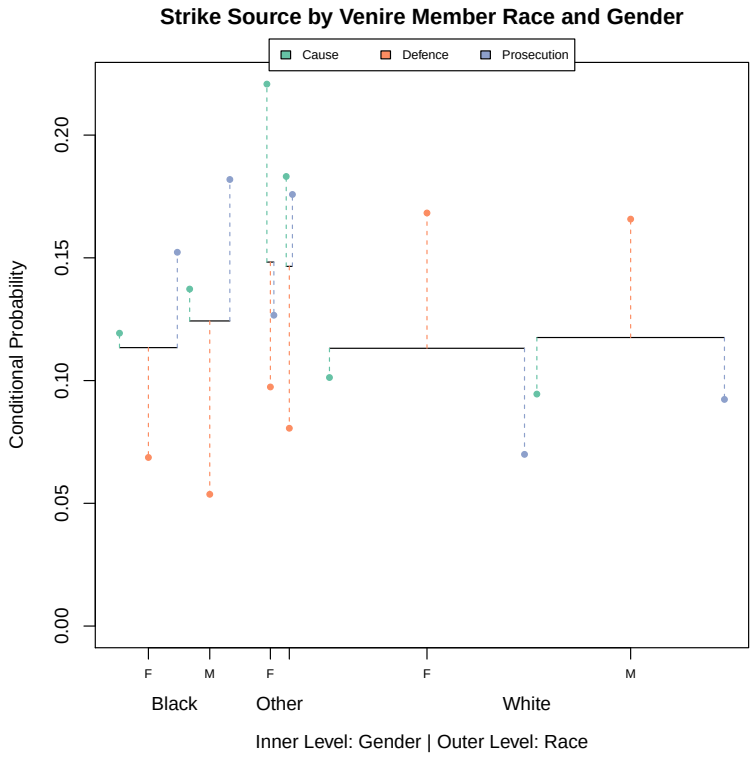


Figure 4.7: Conditional probabilities of strike source by race and gender. Note that the pattern is nearly identical for the genders within each racial group.

the relationship between race, gender, and peremptory challenges can be visualized quite neatly without the need to split the plots as was done in Figure 4.6. Figure 4.7 displays the mobile plot for race, gender, and strike source.

The same pattern is seen here for the most part, that of a dearth of defence strikes against visible minorities and a surplus against white venire members, with a mirrored tendency for both the prosecution and challenges with cause. One may be motivated next to ask whether such oppositional patterns are just a quirk of the data or display method. Perhaps conditioning on gender alone, for example, would create a similar pattern of tendencies of the court. Figure 4.8 shows a plot of the court's strike tendencies given the gender of venire member to defendant gender to investigate this possibility.

The characteristic pattern seen throughout the other plots is not present. At this point the message from these additional mobile plots should be clear. That is, the dominant determinant of the strike probability for a venire member is their race. The race of the defendant does impact this somewhat, but plots across gender and political affiliation for both venire members and defendants in numerous combinations suggest that race is the dominant factor in determining the probability a venire member will be struck by the prosecution, defense, or removed by cause. This hypothesis, motivated by these plots, is examined more rigorously through the construction and testing of specific models in 4.4.

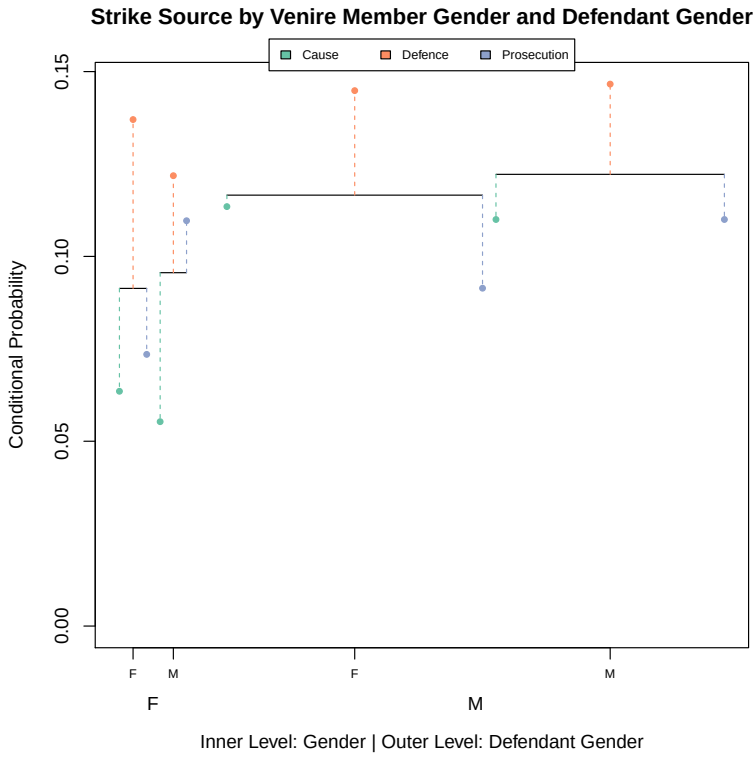


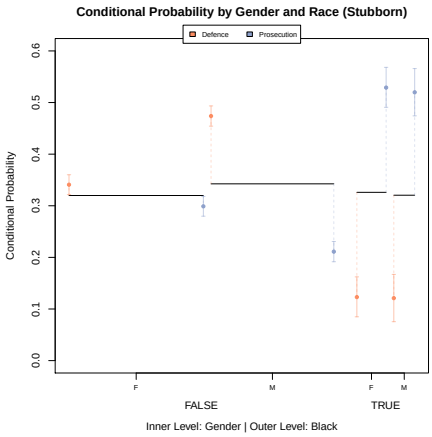
Figure 4.8: Conditional probabilities of strike source by venire member gender and defendant gender. The characteristic swap between racial minorities and white venire members and the oppositional preferences of the prosecution and defence cannot be seen here.

4.3.3 The Stubborn and Philadelphia Data Sets

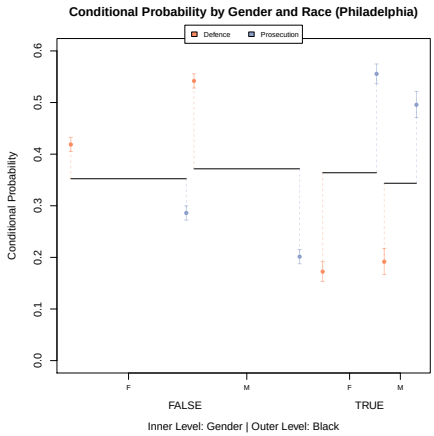
Grosso and O'Brien (2012) and Baldus et al. (2001) did not collect data on the political affiliation of the venire members[9], and Grosso and O'Brien (2012) did not record the gender of the defendant. Consequently, of the above plots, only Figure 4.7 can be compared to these two data sets. Figure 4.9 displays the plots. Note that as before, the data has been restricted to ensure analogous study universes across the data sets.

This, again, shows a pattern very similar to the overall Sunshine data, and the differences in pattern between these data sets are minor. The race of the venire member seems to be analogously important across all data sets as it was in Figure 4.4. Such similarity is somewhat surprising, as these data sets have considerably different sample universes both spatially and temporally as discussed in 3. When displayed visually as above, the similarities are nothing short of striking.

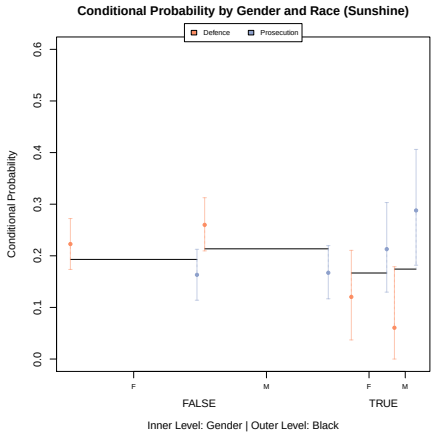
[9]While it is perhaps possible that the different combinations of the attitudinal data collected by these groups could be used with data on the voter profiles most typically associated with the political affiliations of different groups in the United States, such an investigation is beyond the scope of this text. Lacking such a predictor, it is also unclear which attitudinal variables would be most comparable to the political affiliation, and so attempting to compare this pattern would be futile.



(a) Pattern in the Stubborn Data



(b) Pattern in the Philadelphia Data



(c) Pattern in the Sunshine Data

Figure 4.9: The conditional probability of defence and prosecution peremptory challenge by venire member race and gender for all capital trials in all data sets. The pattern, though sometimes different in magnitude, is quite consistent across the three examined data sets, despite the significant differences in the respective study sample universes.

4.4 Modelling

4.4.1 Multinomial Logistic Regression

Despite how suggestive these above results are for the Sunshine data set, refining the estimates for the impact of race on the probability of rejection and controlling for the myriad of possible confounding factors motivated the fitting of multiple models. This is helped by the deliberately suggestive nature of the mobile plots used in Figure 4.2 and elsewhere. The plot displays the conditional distribution of a categorical variable with multiple levels, which evokes ideas of a conditional multinomial distribution to the statistically-minded. Consequently, fitting multinomial log-linear regression seemed a natural choice.

It should be noted that early modelling instead used Poisson regression due to the difference in implementations of multinomial regression (based on neural networks in `nnet`) and Poisson regression (based on iteratively-reweighted least squares in `glm`). The implementation difference, however, is not due to a difference in theory. As the conditional

distribution of a particular outcome given some marginal count is multinomial (as shown in C), these two models are essentially equivalent. There are known transforms (Baker (1994)) to move between the models and their equivalencies are well documented (Lang (1996)). Multinomial regression was chosen for greater interpretability, as in a Poisson model the parameters of interest were all interactions as opposed to main effects. The specific implementation of multinomial regression utilized is the `multinom` function in the `nnet` package in R , which implements a method of fitting multinomial models discussed in Venables and Ripley (2002).

In multinomial regresson, the coefficients for each possible outcome generated for each factor of interest are log odds ratios of that outcome relative to some reference level, called a pivot. Mathematically, the coefficients give how a change in the independent variables changes $\frac{\pi_i}{\pi_{pivot}}$. For all models, the pivot outcome chosen was the probability of a venire member sitting on the final jury, in other words the probability their disposition was coded as "Kept." Coefficients were then estimated using treatment contrasts with a black female venire member with Democrat voting tendencies in a case with a black female defendant used as the reference treatment (using the notation from 0.2: the reference venire member combination is $\mathbf{x} = (1, 1, 1, 1, 1, 1)^T$).

While the choice of race, gender, and political affiliation for the reference level was not deliberate, the choice of pivot outcome, that of a venire member being kept, was made in order to make the visualizations constructed using the coefficients clearer and easier to compare to previous visualizations. Previous visualizations, including the mobile plots, have displayed the conditional probabilities of removal with cause and strikes by defence and prosecution, and if any were used as the pivot their coefficient estimates would be hidden as the intercept.

The mobile plots created in 4.3 and 4.2 suggest, primarily, that an interaction between race and defendant race is relevant in modelling the conditional probability of venire member rejection. These plots do not suggest that any other interactions are likely to be significant. This led to a model:

$$\begin{aligned} \log \frac{\pi_d^{(i)}}{\pi_1^{(i)}} &= a_d + \mathbf{x}_i^T \beta + (re)_i \beta_{re} \\ &= a_i + r_i \beta_r + e_i \beta_e + p_i \beta_p + g_i \beta_g + s_i \beta_s + (re)_i \beta_{re} \end{aligned} \tag{4.4.1.1}$$

The fundamental purpose of fitting this model is to test two effects. The first is whether the interaction between defendant race and venire member race is significant, as has been suggested by the controversial trials named in 2, and the second is whether the venire member race is a significant factor in the presence of the other controlled factors. These two assumptions can be testing by fitting models nested in 4.4.1.1:

$$\log \frac{\pi_d^{(i)}}{\pi_1^{(i)}} = a_d + \mathbf{x}_i^T \beta \tag{4.4.1.2}$$

$$\log \frac{\pi_d^{(i)}}{\pi_1^{(i)}} = a_d + \mathbf{x}_i^T \beta' \tag{4.4.1.3}$$

Where $\beta'_r = 0$. Comparing 4.4.1.2 and 4.4.1.3 to 4.4.1.1 gives striking results. These can be see in Table 4.3, which compares the deviances of the different models sequentially.

Table 4.3: Comparison of models 4.4.1.3 and 4.4.1.2 to 4.4.1.1, displaying the residual deviance, residual degrees of freedom, differences, and p-value of these differences for adjacent models.

Model	Residual df	Residual Deviance	Difference	$P(\chi^2)$
4.4.1.3	55527	39496		
4.4.1.2	55521	39087	405	0
4.4.1.1	55509	39023	67	1.4e-9

Even when controlling for defendant characteristics and the venire member's political affiliation and sex, the race of the venire member and its interaction with the defendant race are both highly significant at the $\alpha = 0.05$ level. This suggests that the rejection of venire members is, at least in part, based on their racial characteristics. Whether this is due to opinions associated with race or not is impossible to say from this data, but the control of political affiliation provides a suggestion that commonly held opinions within racial groups are not the cause. Note that the residual deviance values suggest that this model is underdispersed, suggesting that the significant test results gained are conservative.

Due to its significance compared to the other models, 4.4.1.1 was taken as the final model to estimate the race effects with precision. The estimated coefficients for the different effects and their approximate 95% confidence intervals, calculated using the standard errors of the coefficients and using a normal assumption[10], are displayed in Table 4.4.

Table 4.4: The coefficients of 4.4.1.1 and approximate 95% confidence intervals. The features of venire members are given no indication, those of the defendant are clearly indicated as such.

Coefficient	Cause	Defence	Prosecution
(Intercept)	-2.18 (-2.4,-1.96)	-2.66 (-2.88,-2.44)	-1.45 (-1.64,-1.26)
Other	0.59 (0.3,0.89)	0.63 (0.22,1.04)	-0.19 (-0.52,0.14)
White	-0.25 (-0.4,-0.1)	1.21 (1.02,1.4)	-0.8 (-0.95,-0.66)
Defendant Other	0.02 (-0.5,0.55)	0.69 (0.08,1.29)	-0.21 (-0.71,0.3)
Defendant White	0.03 (-0.19,0.26)	0.67 (0.39,0.95)	-0.33 (-0.55,-0.11)
Independent	0 (-0.13,0.13)	0.06 (-0.05,0.18)	-0.03 (-0.17,0.1)
Libertarian	-0.5 (-1.74,0.74)	-0.7 (-1.93,0.54)	-0.28 (-1.51,0.96)
Republican	-0.14 (-0.27,-0.02)	0.14 (0.04,0.25)	-0.22 (-0.35,-0.08)
Male	0.03 (-0.07,0.12)	-0.01 (-0.09,0.08)	0.26 (0.16,0.36)
Defedant Male	0.74 (0.55,0.94)	0.25 (0.1,0.39)	0.21 (0.04,0.38)
Other & Def. Other	-0.08 (-1.29,1.13)	-10.68 (-10.68,-10.68)	0.12 (-1.29,1.53)
White & Def. Other	0.18 (-0.42,0.78)	-0.65 (-1.3,0)	0.62 (0.03,1.21)
Other & Def. White	0.02 (-0.55,0.6)	-0.46 (-1.21,0.29)	0.61 (-0.02,1.23)
White & Def. White	0.03 (-0.23,0.28)	-0.91 (-1.2,-0.61)	0.42 (0.16,0.67)

[10]This assumption is only valid asymptotically, but for the large demographic groups the estimates are still a useful guide.

4.4.2 Examining the Coefficients

This table is somewhat daunting and difficult to interpret. No sense for the relative magnitudes of the coefficients or their significance is offered by the precise recording of all values. This motivated further visualization of these parameter estimates in an intuitive and simple way. Motivated by Solt and Hu (2018), a custom dot and whisker plot was generated. This plot displays the coefficient estimates as points in the centre of a line, the endpoints of which give the associated confidence intervals. A vertical line is placed at zero to provide a reference for the sign and significance of different parameters. Modifying this concept to suit the multinomial regression data was simple, as it only required grouping the different possible outcomes for each parameter spatially. Figure **??** displays these parameter estimates in the dot-whisker format.

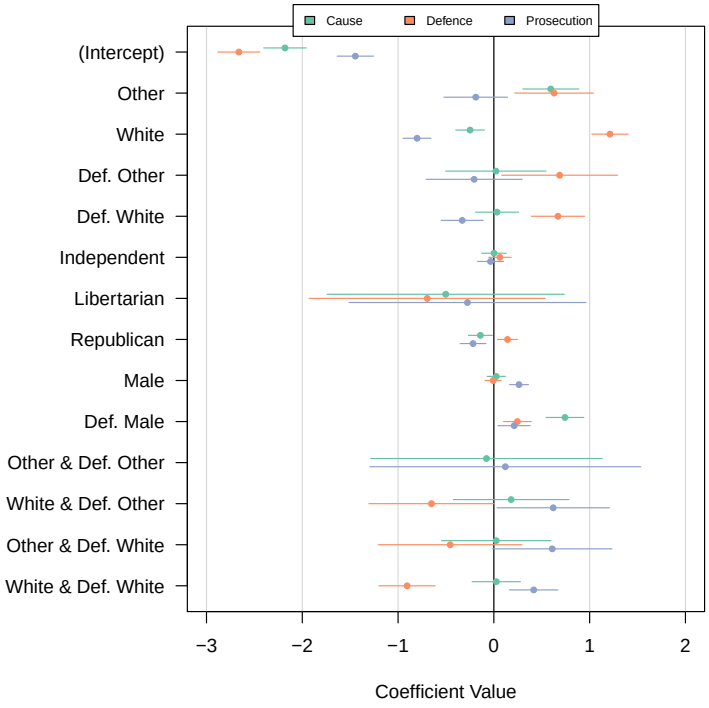


Figure 4.10: Model coefficients from the full model, 4.4.1.1, displayed using a dot-whisker plot. The lines indicate the confidence intervals while the central points indicate the point estimates of coefficients.

This plot is considerably less daunting than the table, and provides a much clearer picture of the magnitudes, signs, and significances of the variables. However, there is still considerable visual clutter. As was noted as early as Figure 4.3, the sample sizes in the Sunshine data set corresponding to racial groups other than white or black are too small to make statements of significance. This same pattern is observed here, were all coefficients estimating the effects of other racial groups have wider confidence intervals and are rarely significant. Additionally, the lack of libertarian voters creates large uncertainty about the estimates of this parameter as well. To provide a clearer picture of the racial coefficient estimates and the effect of the other controls, a second dot-whisker plot was generated excluding these parameter estimates in Figure 4.11.

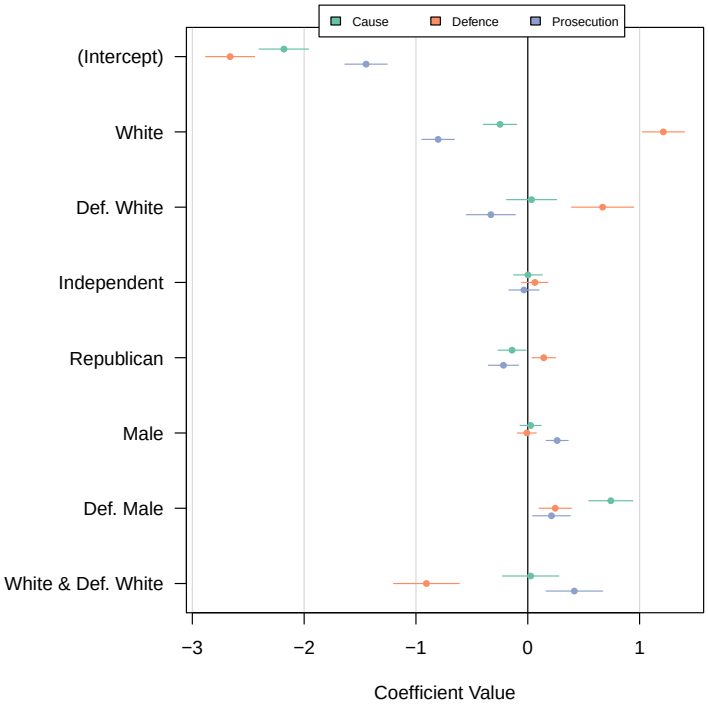


Figure 4.11: Select model coefficients from the full model displayed using a dot-whisker plot. The lines indicate the confidence intervals while the central points indicate the point estimates of coefficients.

The first feature of this plot to notice is the position of the coefficient estimates relative to the black line at zero. This indicates the sign of the coefficient, where a positive sign indicates that a coefficient increases the probability of a venire member being struck by a particular source in the presence of the factor corresponding to the coefficient and a negative sign indicates that the presence of said factor decreases the probability of a venire member being struck. The pattern of positive and negative values suggests the uncontrolled patterns noticed in the mobile plots were not completely wrong.

First, take a broad overview of the patterns. The variables which show the greatest significance and the characteristic oppositional tendencies of the prosecution and defence are all race variables. The effect of a white venire member, white defendant, and their interaction all display significant, and opposite, tendencies for the prosecution and defence. Moreover, the magnitude of the defence coefficients is always greater than the prosecution for the race variables. This suggests that the defence probability to strike is affected far more by race variables than the prosecution probability to strike. To put this more simply, the defence is more sensitive to the racial aspects of the trial in general.

A quick survey of the prosecution and cause coefficients shows far less agreement than seemed apparent in the mobile plots. Scanning from the top to the bottom, the cause coefficients match the prosecution for a few groups, but are generally quite different and are often more similar to the defence than the prosecution. The suggestive pattern of matching prosecution strikes and causal strikes viewed in 4.2 vanishes when controls are placed on possible confounders[11]. In general, the cause strike coefficients are lower in

[11] This serves as an excellent demonstration of how complex multiple confounders can create spurious

magnitude than both the prosecution and defence, with the notable exception of the effect for male venire members, where it is significantly greater than both.

In order to look more specifically some important differentiation is necessary between the intercept values and the other coefficients. As with all linear models, the intercept values provide a locational measure. That is to say, the intercepts provide the base level upon which the coefficients act. Consequentially, the negative values of the intercept for all strike sources is to be expected. In the Sunshine data more venire members were kept than rejected, as can be seen in Tables 4.2 and 4.1, and so the intercept, which gives the log odds ratio of each strike outcome to the venire member being kept, would naturally be negative for all strike sources.

The more important feature to note for this intercept is the large difference between the different strike sources, without overlapping confidence intervals. These suggest that all three strike sources behave differently in the reference group, which consists of a female, black, Democrat venire member in a case with a female, black defendant. Crucially, the defence intercept is far lower than the prosecution, matching what was observed in Figure 4.2, where the lowest defence strike probability occurred for black venire members in cases with black defendants. Also visible in this figure is an increase in defence strike probability and decrease in prosecution strike probability for a white defendant with a black venire member. This pattern is reflected perfectly in the positive defence coefficient and negative prosecution coefficient for white defendants.

The coefficients for white venire members also match the expectations of Figure **??**. The defence attains its largest positive coefficient for this group and the prosecution is largest negative value. The dominant effect of venire member race visible throughout the mobile plots in 4.3 and 4.2 is reflected by the dominance of the magnitudes of the coefficients for white venire members relative to the reference black venire members. The defence is much more likely to reject a white venire member and the prosecution much less likely.

Slightly attenuating this pattern is the interaction effect between a white defendant and a white venire member. For this specific combination, the defence is less likely to reject than for a white venire member with a black defendant, while the prosecution is more likely to reject. Both of these trends seem to be significant based on the plotted confidence intervals. Combine this observation with the almost mirrored pattern for a white defendant with a black venire member (given by the white defendant coefficient), and a more nuanced strategy becomes clear. While the prosecution dominantly rejects black venire members and the defence dominantly rejects white venire members, they are also sensitive to possible racial matches. The defence pattern is consistent with a strategy which aims to partially select for venire members which have the same race as the defendant, while the prosecution has the opposite pattern.

This pattern is precisely the problematic behaviour which was implied by the individuals that viewed the Gerald Stanley murder trial as a travesty. While the data here *cannot* reveal anything about that *specific* trial, or indeed about the exercise of peremptory challenges in Canada generally. That such a pattern is clearly present in the data will no doubt feel vindicating for those still musing on its perceived injustice.

Such racial patterns in the prosecution and the defence dominate all other effects. The political effect is minor, though consistent with the hypothesis put forward by Revesz (2016),

patterns.

with a preference for Republicans by the prosecution and a preference for Democrats by the defence. Interestingly, all strike sources seem to have an increased probability for male venire members, suggesting a universal preference for female venire members on the jury. One would hope that this pattern is for some other reason than anything listed on pages 152-153 of Van Dyke (1977) and reproduced here in 4.3.1. While no detailed explanation is forthcoming for this pattern in the presence of racial and political affiliation controls, it would certainly be an interesting avenue for further research, as the exercise of peremptory challenges based purely on gender is also protected since *J.E.B. v. Alabama* (Supreme Court of the United States (1993)).

A lack of consistent information between data sets and of time made fitting additional models using the other data sets more difficult. Regardless of the lack of specific coefficient comparisons due to these difficulties, the above findings are consistent with the modelling results in Grosso and O'Brien (2012) and Baldus et al. (2001). Both of these studies performed logistic regression analysis of the prosecution strike patterns, controlling for attitudinal variables. In both cases, the venire member race remained a significant predictor of the venire member removal. Additionally, Baldus et al. fit analogous models for the defence strike use and found the race remained significant even when the attitudinal variables were controlled. The resuls of the modelling performed here add evidence to this mounting case of racial importance in the execution of peremptory challenges.

4.5 Trial Level Summary

While Wright et al. (2018) reported a great deal of aggregate statistics about the venire members themselves, one piece of investigation which was lacking was an analysis which aggregated and viewed the trends for the cases, rather than simply for individual venire members. As we cannot know why a potential venire member is struck individually, and viewing their aggregate statistics tells us nothing about how different strikes relate to each other, it is possible we are viewing some effect which is not a result of persistent bias across trials, but is rather the result of some other effect.

By aggregating the venire members by trial and viewing the demographic trends in strikes and behaviour at this level, we gain a more detailed insight into the impact of challenges at a more relevant scale. Additionally, such aggregation allows for the synthesis of certain measures, such as a disitributional difference via the Kullback-Leibler divergence (Kullback and Leibler (1951)), which would otherwise not be well defined. This particular perspective of the data has also not been explored by any other studies known to the author.

4.5.1 Estimating Struck Juror Counts

One gap which was present in the Sunshine data was the total count of defence and prosecution removals for each trial. While this variable is of minor importance for modelling the individual venire members, it is of major interest when viewing the trials themselves. While counts of these strikes were provided in the data, there were many missing values, or values inconsistent with the number of associated venire members in the data. For example, many of the recorded values in these columns were zero even when venire members associated with that trial were marked as struck.

To remedy this, for each trial a number of variables were generated. Primarily, these variables were counts of the number of venire members with particular characteristics which were struck by both the prosecution and defence in the trial. For example the variable `DefRem.Race.Black` provided the count of black venire members struck by the defence. To provide an estimate of the number of venire members removed by each strike source, these counts were summed for one particular variable, typically gender. The sum was then compared to the recorded value for that party's removed count. The greater of the two values was kept as an estimated count to be used in analysis. For both the prosecution and the defence, about 80% of the sum and recorded values matched exactly and about 18% of the recorded values were less than the sum. This suggests some incompleteness for the remaining 2–4% of the data.

4.5.2 Visualizing the Racial Trends

The Positional Boxplot

Motivated by the plots in the `extracat` package in R (Pilhöfer and Unwin (2013)), in particular the `rmb` plot, a positional proportion plot, called here the "positional boxplot," was developed to display the strike tendencies across trials. The data for each trial consists of categorical variables and two integer counts corresponding to the estimated defence and prosecution strike counts described in 4.5.1. The positional boxplot was developed to investigate the relationship between the strike patterns of both parties and the defendant race.

Therefore, the positional boxplot is designed to visualize the conditional distribution of a categorical variable given two integer count variables. Each observation consists of a level of a categorical variable and two counts. Across the whole data, there may be occurrences of identical values for the two counts. At each unique combination of integer counts observed, a box is placed with an area proportional to the number of observations with that specific combination. Each box is then subdivided horizontally such that the width of each subdivision is proportional to the corresponding count of each level of the categorical variable that occurs with that specific integer combination.

Figure 4.12 displays a positional boxplot of defendant race to prosecution and defence estimated strike counts. While the internal box patterns look rather similar everywhere, split somewhat evenly between black and white defendants, their areas are quite revealing. In the aggregate examination of the data, it was clear that the defence had an overal higher strike rate than the prosecution, this effect can be viewed clearly in Figure 4.8 where the defence has a higher strike rate across all gender combinations. What was not clear was whether this pattern reflected the typical pattern at the individual trial level or was rather due outlier cases with abundant defence strikes. The areas of the boxes in Figure 4.12 indicate clearly that the defence typically uses more peremptory challenges than the prosecution in each trial.

Of course, the most striking result of the modelling from 4.4 seen clearly in Figure 4.11 was the dominance of the venire member race in determining their strike probabilities. Viewing the defendant race may simply be the wrong plot. Breaking this apart to display the racial tendencies across trials for both the defence and prosecution could reveal interesting patterns. Such a plot is shown in 4.13.

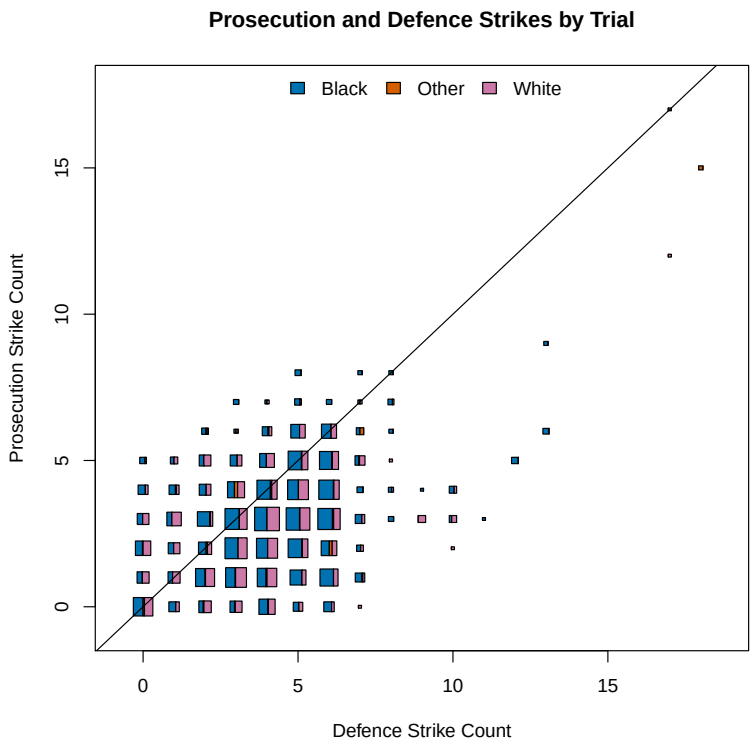


Figure 4.12: The positional boxplot of strikes by race of defendant for the Sunshine data. There does not seem to be a dependence of strike counts on the defendant race, the boxes look similar across the entire plot.

Figure 4.13a shows the strong preference of the defence to strike white jurors regardless of the defendant race. The tendency of the defence to strike jurors different than the defendant noted in 4.4.2 is also visible in this plot. Note how the black defendants generally make a greater proportion of the points for higher white venire strike counts. In contrast, the opposite trend is shown in Figure 4.13b, where the boxes further to the left have a greater proportion of black defendants and those moving up have a greater proportion of white defendants.

Interestingly, the prosecution also seems less biased than the defence at the trial level. The distribution of strikes seems similar between both black and white venire members. Such an appearance, however, is misleading, because it fails to account for the number of black and white venire members presented to the court. These numbers are very different, as can be seen by the lengths of the horizontal black lines in Figure 4.2. A sizeable majority of the venire members are white. Luckily, with trial aggregated data, the raw strike counts can be normalized into proportions. The resulting scatterplots of these proportions by trial are displayed in Figure 4.14.

Here, the prosecution and defence biases are much more clear. The prosecution never strikes more than 40% of white venire members presented, and on average strikes a greater proportion of the black venire than the white venire. The defence, in contrast, regularly strikes more than 40% of the white venire, and on average strikes a greater proportion of the white venire members than the black venire members. This reinforces the aggregate observations made in 4.4, indicating that these mechanics operate on the individual trial

level, and not just over all trials. Additionally, the high variation visible in Figure 4.14 suggests that the aggregate patterns described in 4.4 are not followed by all defence of prosecution lawyers, merely on average.

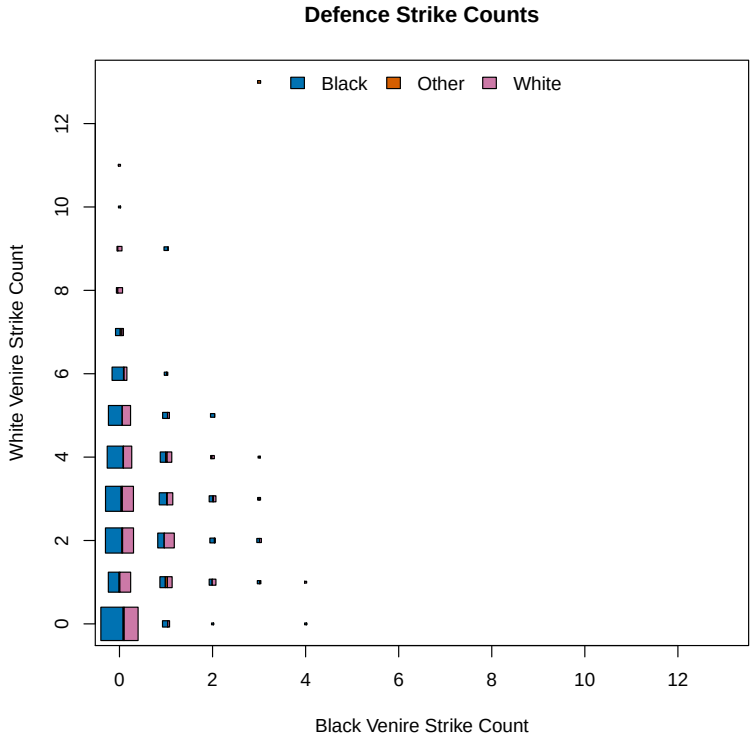
While these differences are perhaps interesting, the far more interesting observation that can be gleaned from these plots is the fundamental difference in inclusion of minority and majority groups in jury formation. The aggregate statistics indicate that the black venire members are a minority, and Figure 4.14 suggests that as a consequence, it is common that a majority or all of the potential black jurors will be removed by peremptory challenge while such an occurrence is incredibly rare for the majority white jurors, if not impossible. While in many trials all black venire members were struck, in not a single trial was every white venire member struck. This suggests that if one had a strategy of keeping minorities off of juries, the peremptory challenge system would make this task easier. Such an observation is obvious in theory, but it is no less striking to see it emerge from the data.

4.6 On Jury Selection

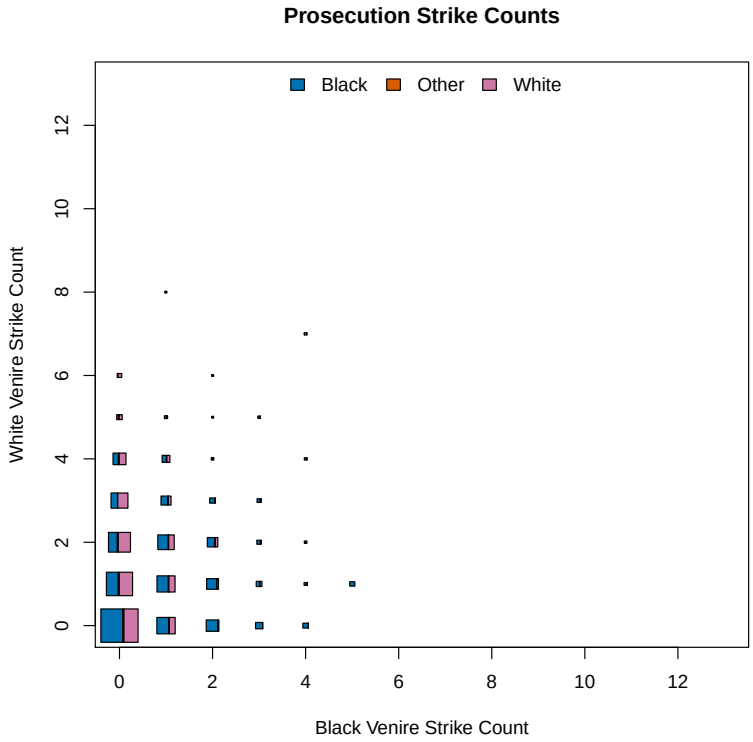
Van Dyke (1977) spends much of chapters four and five exploring the causes for the underrepresentation of certain groups in jury venires, and his analysis suggests that underrepresentation starts at the jury selection stage due to fewer non-white individuals registering to vote generally (page 89), and the process of applying to be excused from jury duty, in which economic hardship, which impacts disadvantaged economic groups to a greater extent (pages 113-120), is a common reason for excusal from jury duty.

Such explanations provide a plausible reason why black males would be most underrepresented in venires, and why the majority of the venire is white in this data despite the majority of defendants being black. Such issues with the jury selection process will not, and cannot, be solved by simply removed the peremptory challenge. They have much more to do with the relationship between certain groups and wider society, and so require more comprehensive and complex solutions.

The Gerald Stanley case serves as an excellent demonstration of this problem. As Quenneville and Warick (2018a) report, 750 individuals on the jury roll were sent court summons, but only 204 of these individuals appeared on the day of the trial. This large non-response population introduces the potential for incredible bias in the venire that is to be used for selection. If there is some relationship between demographics and an inability to serve on a jury or a lack of will to respond to a court summons, as Van Dyke (1977) suggests with ample evidence, then problems with minority representaton may be due in larger part to the method of jury summons than the exercise of challenges in the courtroom. Removing the peremptory challenge may serve as a useful step in the right direction, but it cannot be expected to “fix” minority representation alone.

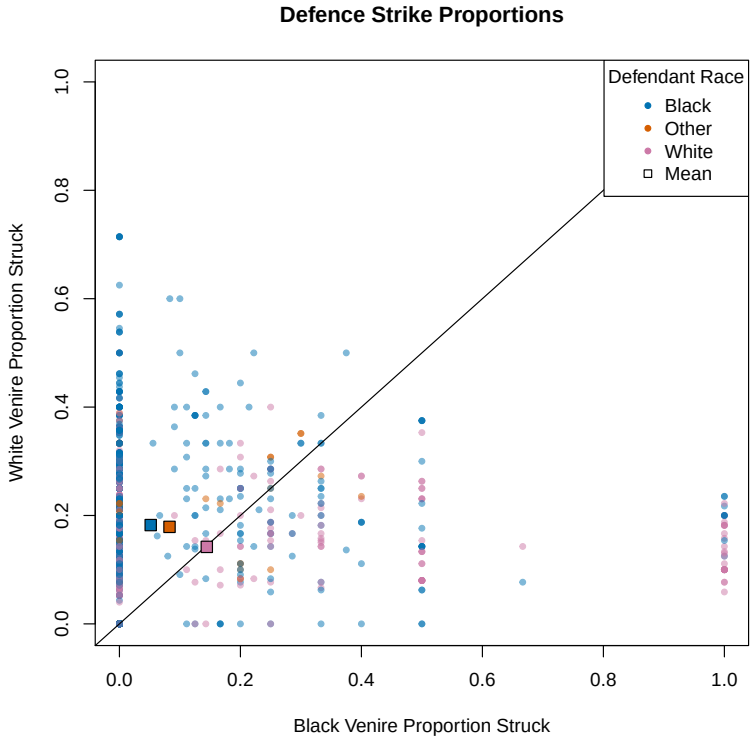


(a) Defence racial strike pattern

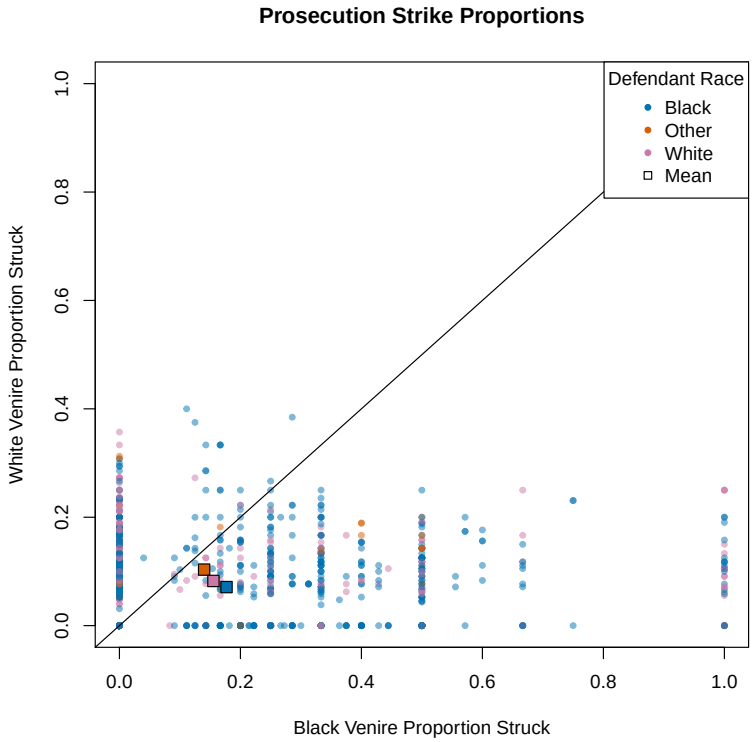


(b) Prosecution racial strike pattern

Figure 4.13: Positional boxplot of racial strikes by defence and prosecution.



(a) Defence racial strike pattern



(b) Prosecution racial strike pattern

Figure 4.14: Positional boxplot of racial strikes by defence and prosecution.

Chapter 5

Summary

Summarize the presented work. Why is it useful to the research field or institute?

5.1 Future Work

One obvious way to extend the work done here is through more thorough modelling. While the multinomial regression model fit in 4.4 served its purpose, much more precise models could be fit using casual graphs. Such causal modelling has the possibility to extend the observations of the model from the simple pattern identification of the multinomial model and visualizations presented here to precise statements about the magnitude of causal effects between factors. Representing the factors in a causal graph would also be a useful exercise in making the assumptions of the model abundantly clear. Logistic regression models and multinomial models, which have been the norm for peremptory challenge data so far, are less clear about their assumptions, especially to those not trained to fit and analyze these models.

Other possible models of interest are mixed models. In this work the attempts to fit mixed models were not discussed, but at several points models with random effects for each trial were attempted. Unfortunately, these models failed to converge. Not a great deal of time was spent trying to transform the data to facilitate convergence to a reasonable value, and so no mixed models were fit. Such models are attractive because they have the potential to flexibly control for a host of factors which will vary over the course of each trial, and do so in a manner which involves minimal parameters. Controlling a random effect for lawyer, for instance, could shed light on how variable lawyers are in their behaviour. This dimension of individual variability is essentially unadressed by the aggregate examinations of this work.

Another extension would be further investigation of the Sunshine data. It is an incredibly rich data set and this work only examined one small facet of it. The crime classification outlined in 3.1, for example, was never utilized in the analysis of this data, despite the investment of time and effort in performing this clean up. Perhaps this method could also be applied to other irregular data in court cases or elsewhere to efficiently categorize irregular strings.

Finally, as Wright et al. (2018) notes, more data is needed on this topic generally. Further

efforts to collect data and reinforce or refute the findings of this work and previous ones should be undertaken, and efforts to centralize and regularize the data would assist in the ease of analysis. Increased transparency and centralized data collection have the potential to allow for a greater understanding of which elements of the jury trial system work and which are inappropriate. As Wright et al. puts it:

> The transformative power of data, in our view, is not limited to traffic stops or jury selection. We place our proposal in the larger context of using transparency to change criminal justice practices for the better. As Andrew Crespo has pointed out, the criminal courts already collect useful facts that remain hidden because they are scattered in single files or inaccessible formats. An effort to assemble these facts in aggregate form could improve the courts' efforts to regulate the work of other criminal justice players, such as police and prosecutors.

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Appendix A

Developing an Effective Visualization of Conditional Probability

One deficiency of the results of the previous investigations was a failure to generate compelling and effective visualizations of the trends of peremptory challenges for different racial groups. While such visualizations are not necessarily critical to analysis, they can often be incredibly useful to not only communicate data, but to motivate further investigations and models in a way which is clearer and more intuitive than a simple table of values.

The first attempt at such a visualization was the mosaic plot (as discussed by Friendly (1994)) using the `mosaicplot` function in the `graphics` package in R (R Core Team (2018)). Figure A.1 displays this first approach with disposition related to the simplified races of both the defendant and the venire member.

This visualization suffers from a number of limitations, some of which are obvious, and others of which are best explained by the hierarchy of accuracy of visual perception provided in Cleveland and McGill (1987). The obvious limitations are the lack of ability to perceive the differences for the smallest groups, which are compressed enough that their error is nearly imperceptible. Additionally, the ordering of the axes is incredibly important in how the different areas appear visually, and comparing the different areas is unclear if any specific comparisons are to be made.

This may be somewhat unsurprising. Cleveland and McGill (1987), in their ranking of visual displays by accuracy of perception place area low in the hierarchy, below angles, lengths, and positions along common scales. In *The Visual Display of Quantitative Information*, Tufte gives two more sources of possible criticism of the mosaic plot as displayed in Figure A.1: the concept of data-ink and the dimensionality of visualization.

Of the mosaic plot, one may ask how much of the "ink", or structure, on the page is necessary to communicate the information present. If one has a desire to "above all else show the data" as Tufte does, then these large shaded rectangles, which are likely not perceived accurately according to Cleveland and McGill, seem unnecessary compared to a simpler visualization. This is the concept of "data-ink," to reduce the complexity of the structures and chart used to display the data.

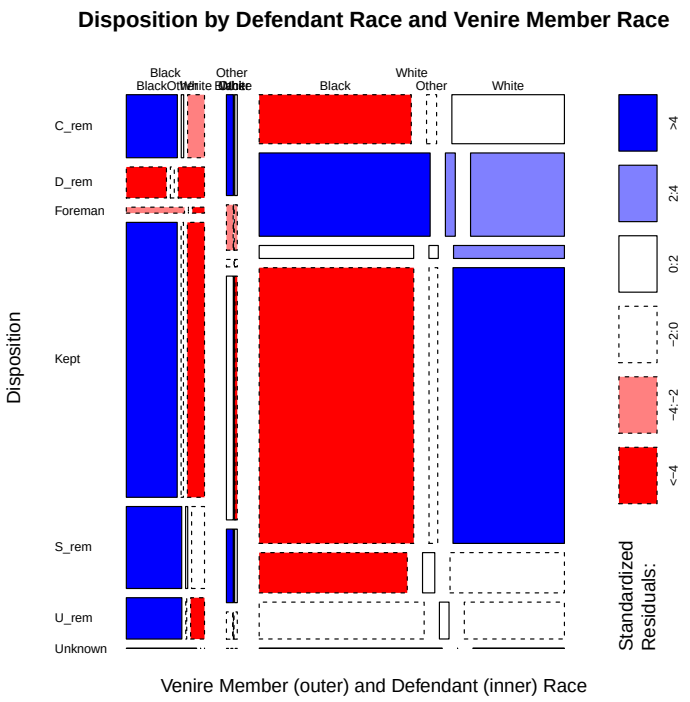

Figure A.1: A mosaic plot of the simplified defendant and venire member race and their relation to the disposition of the venire member.

Hand-in-hand with this concept for this plot is Tufte's rule that the dimensionality of the visualization should not be larger than the data. In the case of the mosaic plot this is not strictly violated, as the marginal lengths used to create the areas reflect a measurement of the data. Nonetheless, the areas of each rectangle correspond to a simple count in a contingency table, and perhaps an area is not the best way to represent such a singular value.

Motivated by these concepts, parallel coordinates (as in Wegman (1990)) were used to visualize the data next, as can be seen in Figure A.2. This attempted visualization is arguably more difficult to interpret than the mosaic plot. It is cluttered by the parallel coordinate lines, the bars emanating from each point obscure the fact that the end point of the bar is the only feature of interest, and the meaning of the black reference line is entirely unclear without extensive explanation. Finally, by viewing the distribution of each disposition, the wrong conditional density is being examined, $P(Race, RaceDefendant|Disposition)$. Multiple edits and re-conceptualizations of the concept eventually resulted in Figure **??**, which will be called the "mobile plot" due to its passing resemblance to the mobiles hung above babies' cribs.

An example of this plot can be seen in 4.2. Note that this plot is less cluttered than either the mosaic plot or the first parallel coordinate plot, despite displaying more information. It is also more efficient with data-ink, avoids displaying data with higher dimensions that the data itself, and uses redundant encoding of information in visual cues which are high in the hierarchy presented by Cleveland and McGill (1987).

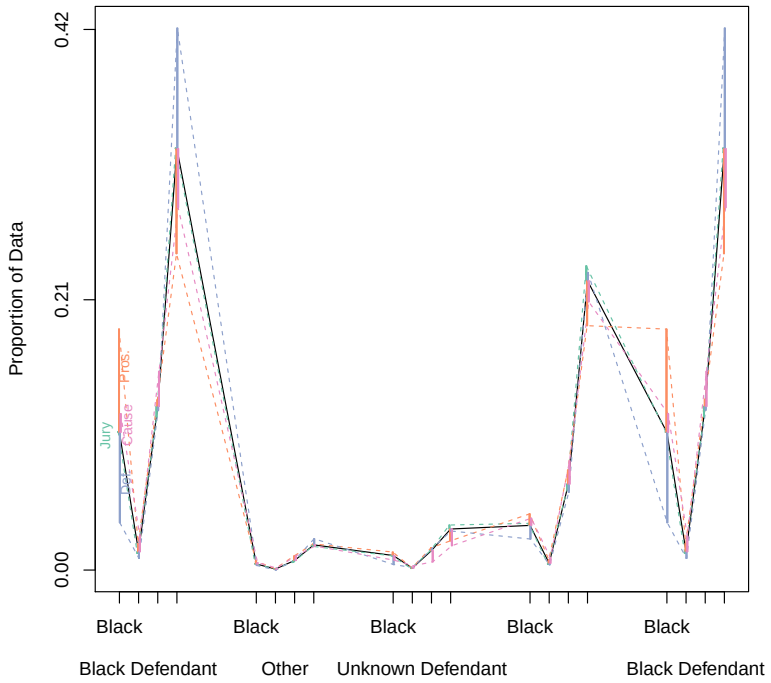

Figure A.2: The first attempt at a parallel coordinate plot attempted. Note that the cramped display and unclear definition of the axis make interpretation even less intuitive than the mosaic plot, suggesting that this first attempt was a decided failure.

An explanation of the features and encoding used in the mobile plot is presented in A.1.

A.1 The Mobile Plot

The mobile plot consists of multiple grouped vertical lines anchored at one end to horizontal black lines, and at the other to points. Information is encoded using length, colour, and position relative to a common scale. The vertical axis is meant to show the value of a continuous variable, while the horizontal axis shows the value of a, possibly hierarchical, categorical variable. It can be used to display the relationship between three categorical variables and a continuous variable in a meaningful two-dimensional plot.

To show the grouping of categories on the horizontal axis, position is used. Those categorical levels which are grouped by some separate categorical variable are placed closer to each other than those which are not in the same group. Each categorical variable combination corresponds to a single horizontal black line, the length of which is proportional to the count of the associated combination in the data being plotted. The vertical position of this line corresponds to the value of the continuous variable expected for that particular combination.

Each of the vertical lines which extend from this horizontal line corresponds to a particular value of a third categorical variable, coloured to show the specific level across the

different horizontal lines. The end points of these lines represent the observed value of the continuous variable for the three way combination of categorical variables represented by the vertical and horizontal line combination. The lengths of these lines correspond to the deviation of the observation from the expectation. If a different expectation is expected for the different values of the third categorical variable, the horizontal lines can be split evenly and placed vertically at this expectation, to the detriment of grouping clarity.

In the case that such a split is not used an the continuous variable is the probability of a particular value of the third categorical variable given the first two, the plot serves as a visual test of a very specific hypothesis: that of a uniform distribution of the third categorical variable with respect to the two variables represented horizontally. Such a plot is powerful because it allows for the simple detection of main effects and interaction effects over the three categorical variables against this hypothesis.

Appendix B

Complementary information

B.1 Jury Sunshine Irregularities

Table B.1: Jury sunshine data irregularities noted in data flattening

Charges without trial (ACISID)	08CRS50940, 08CRS52888, 09CRS000305, 09CRS1106, 09CRS50752, 10CR52031, 10CRS051975, 10CRS1215, 10CRS397, 10CRS51388, 10CRS51610, 10CRS52410, 11CRS051642, 11CRS051795, 11CRS1577, 11CRS1745, 11CRS1783, 11CRS51204, 11CRS51895, 11CRS52470, 08CRS54836, 08CRS50113
Prosecutors without trials (IDs)	1-000, 11B-000, 12-000, 14-000, 15B-000, 16A-000, 16B-000, 17A-000, 17B-000, 19A-000, 19B-000, 20A-000, 20B-000, 21-000, 22A-000, 22B-000, 24-000, 25-000, 27A-000, 27B-000, 28-000, 29A-000, 29B-000, 30-000, 6-000, 9-000
Trial missing charge (ID)	710-01

B.2 Jury Sunshine Charge Classification

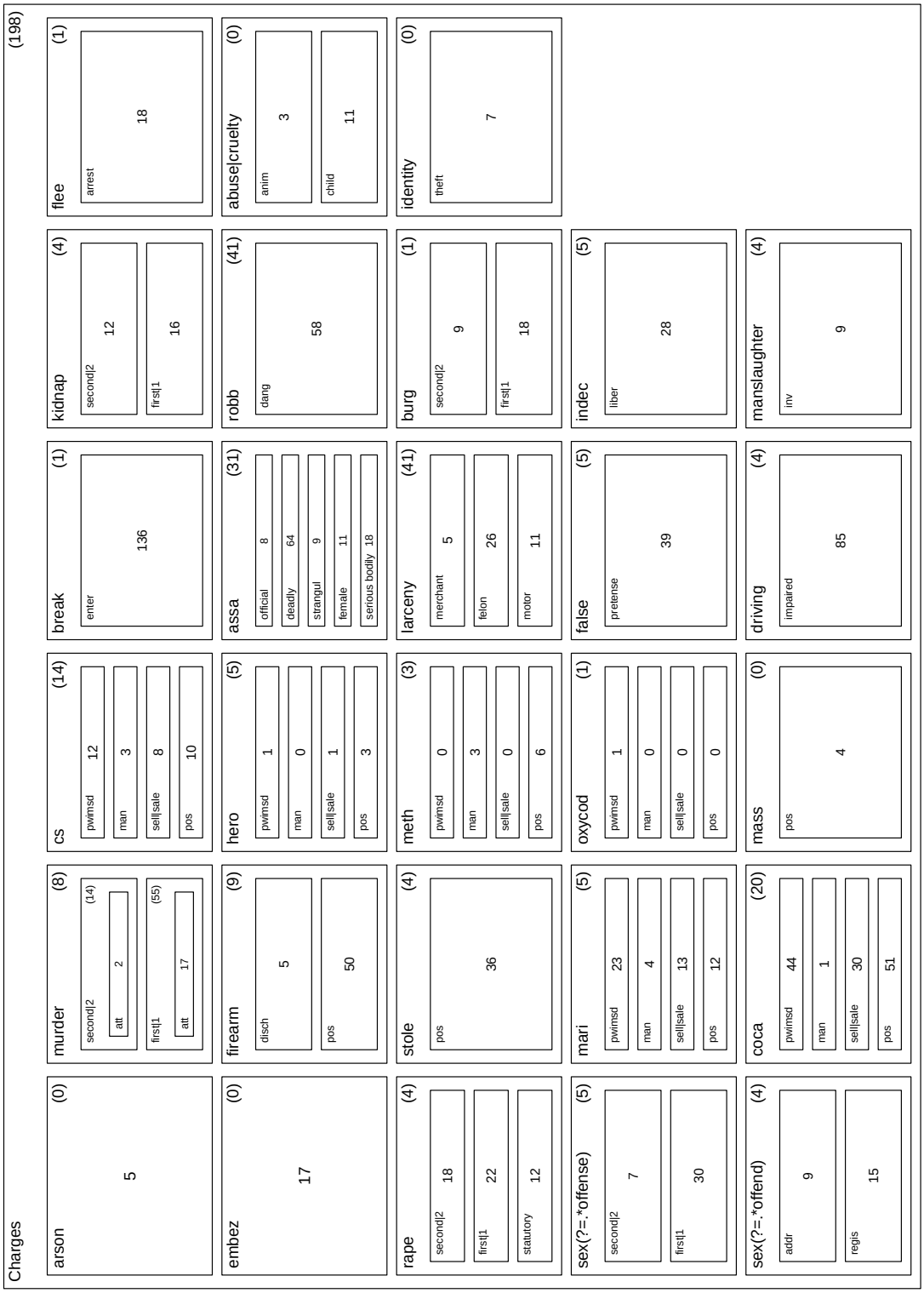

Figure B.1: The regular expression charge tree arranged by hierarchy with counts provided. The counts in brackets indicate the counts of charges which could not be classified to a lower level of the hierarchy

Appendix C

Mathematical Results

C.1 Conditional Distribution of a Poisson Expectation Given Marginal Counts

For simplicity, consider a Poisson random variable Y with a rate dependent only on one discrete random variable: $X \in \{1, \ldots, m\}$. Let the count of values observed for $X = i$ be Y_i and denote $E[Y_i|X = i] = \lambda_i$. Additionally denote the sum of all counts as $N = \sum_{i=1}^{m} Y_i$. The feature of interest is then the distribution of $Y_1, \ldots, Y_m|N = n$. Or by the definition of the conditional distribution:

$$P(Y_1 = y_1, \ldots, Y_m = y_m|N = n) = \frac{P(Y_1 = y_1, \ldots, Y_m = y_m, \sum_{i=1}^{m} Y_i = n)}{P(\sum_{i=1}^{m} Y_i = n)} \tag{C.1.0.1}$$

Clearly this density is zero if $\sum_{i=1}^{m} y_i \neq n$, but consider its value with for $\sum_{i=1}^{m} y_i = n$. Start with the distribution of $N = \sum_{i=1}^{m} Y_i$. Note that for $A \sim Pois(\lambda_A)$ and $B \sim Pois(\lambda_B)$, where A and B are independent, the distribution of $A + B$ can be derived quite easily using the characteristic function $\varphi_{A+B}(t)$:

$$\varphi_{A+B}(t) = E[e^{it(A+B)}] = E[e^{itA}]E[e^{itB}] = e^{(\lambda_A+\lambda_B)(e^{it}-1)}$$

This is the characteristic function of a $Pois(\lambda_A + \lambda_B)$ variable, and so the sum of two Poisson random variables is a Poisson random variable with a rate corresponding to the sum of the two variables. Iterating this, then, one obtains $N \sim Pois(\sum_{i=1}^{m} \mu_i)$, and so the denominator of C.1.0.1 is:

$$P\left(\sum_{i=1}^{m} Y_i = n\right) = \frac{e^{\sum_{i=1}^{m} \mu_i}(\sum_{i=1}^{m} \mu_i)^n}{n!}$$

Additionally, recognizing that the Y_{ij} are independent, and considering only the case where $\sum_{i=1}^{m} y_i = n$, as the density is zero otherwise, this can be further simplified, as this joint density can be split into a product of marginal densities:

$$P\left(Y_1 = y_1, \ldots, Y_m = y_m, \sum_{i=1}^{m} y_i = n\right) = P(Y_1 = y_1)P(Y_2 = y_2)\ldots P(Y_m = y_m)$$

Now each independent marginal is Poisson distributed, so the product of all of these marginals is:

$$P(Y_1 = y_1)P(Y_2 = y_2)\ldots P(Y_m = y_m) = \frac{e^{\sum_{i=1}^{m}\mu_i}\mu_1^{y_1}\mu_2^{y_2}\ldots\mu_m^{y_m}}{y_i!y_2!\ldots y_m!}$$

And so C.1.0.1 simplifies to

$$\begin{aligned} &\frac{e^{\sum_{i=1}^{m}\mu_i}\mu_1^{y_1}\mu_2^{y_2}\ldots\mu_m^{y_m}}{y_i!y_2!\ldots y_m!} \cdot \frac{n!}{e^{\sum_{i=1}^{m}\mu_i}(\sum_{i=1}^{m}\mu_i)^n} \\ &= \frac{m!}{y_1!y_2!\ldots y_m!}\left(\frac{\mu_1}{\sum_{i=1}^{m}\mu_i}\right)^{y_1}\left(\frac{\mu_2}{\sum_{i=1}^{m}\mu_i}\right)^{y_2}\ldots\left(\frac{\mu_m}{\sum_{i=1}^{m}\mu_i}\right)^{y_m} \end{aligned} \tag{C.1.0.2}$$

C.1.0.2 is recognizably the multinomial distribution, where the probability of a particular class i is given by the ratio of μ_i to the sum over all μ_j. ■

Appendix D

Code

D.1 Data Processing Code

The data processing functions and code are available through the author's GitHub (https://github.com/Salahub/
where the processed data is also provided.

D.2 Analysis Code

As for the data processing code, this code is posted on the author's GitHub (https://github.com/Salahub/perem

Epilogue

A few final words.

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