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Miscellaneous

Relationship between penalties for road traffic infringements and crash risk in Queensland, Australia: a case-crossover study

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Abstract

Background: Most countries have detailed lists of traffic rules and elaborate legal regimes for penalizing drivers who break them. Previous research has suggested that drivers tend to drive more safely after receiving penalties for traffic infringements.

Methods: We linked driver-level data on infringements and crashes in Queensland, Australia (1995–2010) with information on the licence histories of all drivers in the state. We used a case-crossover design to examine drivers' risk of crashing in the month following an infringement penalty. We also examined whether changes in crash risk following infringement penalties varied according to driver age and gender, type of infringement and whether the offender was at fault in a subsequent crash.

Results: Drivers had higher risks of crashes following infringement penalties [odds ratio (OR) 1.32; 95% confidence interval (CI) 1.29–1.36], especially crashes in which the offender was at fault (1.41; 1.36–1.46). Crash risk relative to a comparable period was particularly high for teenage drivers (1.55; 1.34–1.78) and among drivers penalized for dangerous driving (3.19; 2.52–4.03) or driving under the influence of alcohol (1.99; 1.67–2.37). The risk remained relatively high for more than 6 months after the penalty, but declined steadily over this period.

Conclusions: Crash risk among drivers in Queensland was higher, not lower, following receipt of penalties for traffic infringements. Penalties themselves are unlikely to increase crash risk. A more likely explanation is that penalties (or the corresponding infringements) mark episodes of risky driving. Our findings suggest that such episodes trounce any deterrent effect penalties may produce.

Key words: Injuries, accidents, traffic, law, public health

Key Messages

- The theory of specific deterrence suggests that drivers should drive more safely after being penalized for traffic infringements, and some prior research supports this theory.
- This study found that drivers in Queensland had 32% higher odds of crashing following receipt of a penalty for a road traffic infringement.
- The odds of a crash in which the driver was at fault were 41% higher. Crash odds were two to three times higher after infringements for dangerous driving and driving under the influence of alcohol.
- Penalties are unlikely to increase crash risk; a more likely explanation is that penalties mark episodes of risky driving.

Introduction

Despite impressive gains in road safety in many countries over the past 50 years, injuries from traffic accidents continue to wreak a devastating toll on human life and well-being. In 2010, road injury accounted for 3% of deaths[1] and 3% of disability-adjusted life years[2] globally; it ranks as the eighth leading cause of years of life lost.[1] The gains from seatbelts and from safer vehicle and roadway redesign have been examined extensively, and evidence mounts regarding the benefits of reductions in the incidence of speeding and driving under the influence of alcohol.[3–6] What is the safety impact of the ubiquitous legal regimes for promulgating and enforcing road rules?

According to classic deterrence theory, sanctioning dangerous behaviour discourages it, thereby improving safety.[7] Deterrence theorists have described two distinct mechanisms of action.[8,9] 'General deterrence' refers to the threat of punishment prevailing in society at large. In the road traffic context, this is the diffuse signal that emanates from the very existence of the regime: drivers seek to obey road rules because they realize they risk fines and penalties if they break them. 'Specific deterrence', on the other hand, arises from direct personal experience. Drivers who infringe road rules and are penalized learn their lesson; they become less likely to reoffend, which indirectly leads them to drive more safely.

Over the past 40 years, dozens of studies have sought to measure deterrent effects of traffic laws. The vast majority address the impact of drunk driving laws on recidivism or crash risk. Certain drunk driving laws have exhibited strong general deterrent effects,[10–12] but the evidence for specific deterrence is mixed.[13–16] Relatively few studies have ventured beyond drunk driving to consider other offences (e.g. speeding, red-light running, failure to wear seatbelt) and the effects of the predominantly civil penalties (e.g. fines, demerit points) used to sanction them. Although these types of offences and penalties may be more mundane than drunk driving, they are far more prevalent.

Outside the drunk driving realm, previous research has found general deterrent effects, in the form of lower recidivism and/or crash rates, from increases in fines,[17,18] introduction of a penalty points system[19] and new bans on dangerous driving.[20] Two studies of specific deterrence have both detected effects. Li *et al.*[21] examined a cohort of nearly 30 000 Maryland drivers who were ticketed for speeding; they found lower risks of subsequent speeding citations but higher risks of crashes among drivers who elected to appear in traffic court, compared with drivers who chose to mail in payment of their fines. Redelmeier *et al.*[22] followed a sample of drivers in Ontario, Canada, who were convicted of a wide range of traffic offences. Offenders' risks of having fatal crashes in the month after a conviction were about 35% lower than in a comparable period; 2 months after the conviction this 'benefit' had reduced, and by 3–4 months it was no longer significantly different from baseline risk. Limitations in the design of Li *et al.*'s study allowed only weak claims to be made about the effect of penalties on safety. By contrast, Redelmeier *et al.*'s case-crossover design permitted stronger claims, and the researchers concluded that the penalties caused a sharp—albeit transient—reduction in Ontario drivers' risks of fatal crashes.

We investigated specific deterrence from traffic law enforcement in the state of Queensland, Australia. We employed a similar study design to the one used by Redelmeier *et al.*, but analysed a much larger sample of drivers, infringements and crashes over a longer period of time. Our goal was to quantify the effect of infringement penalties on crash risk in this population.

Methods

Setting

With 4.8 million residents, Queensland is the third most populous state in Australia.[23] Its regime for driver licensing and regulation[24] is broadly similar to those in Australia's other states and territories, and to regimes in many other countries. In Queensland's infringement scheme, each road traffic offence triggers a fine and carries a specified number

of demerit points. Drivers who accumulate 12 or more demerit points in a 3-year period face licence suspension.[24] Penalties are typically issued by police on the spot (i.e. at the roadside, immediately after the infringement occurs) or, in the case of infringements detected by fixed or mobile traffic enforcement cameras, within several weeks.[25,26]

Data and variables

The Queensland government routinely collects details of both traffic infringements and crashes. Accurate tracking of infringements is essential for the operation of the state's demerit point system. All crashes that cause death, injury or substantial property damage are recorded, provided they are reported to the Queensland Police Service. The 'substantial' property damage threshold is met if at least one vehicle is towed away, the cost of damage to all property exceeds $AU2500 (before December 1999), or the cost of damage to property other than vehicles exceeds $AU2500 (from December 1999).[27]

The Queensland Department of Transport and Main Roads (DTMR) provided us with de-identified data on all infringements ($n = 11\,639\,604$) and crashes ($n = 331\,102$) that occurred in the state between 1 January 1995 and 31 December 2010. DTMR also provided de-identified licence histories for all drivers in Queensland over the same period; for each driver, this included dates when the driver was licensed and, if applicable, dates when the licence was suspended or disqualified. Using de-identified numbers unique to each licensee, we linked the infringement, crash and licence history data to create the study dataset.

The study dataset included variables describing drivers (age, sex), crashes (severity, fault) and infringements (type, number of demerit points). The infringements typology we used was based on several broad categories set forth in the Australian and New Zealand Offence Classification.[28] Crash severity was described by mutually exclusive categories pertaining to the most serious outcome in the crash (fatality, injury requiring hospitalization, injury requiring medical treatment, injury not requiring medical treatment or property damage only). Determinations of fault for each crash, including single vehicle collisions, are made by DTMR on the basis of the police report. The label is applied to the person judged to be most at fault, and to any persons issued with traffic infringement notices in connection with the crash.

Study design

Following other leading studies of predictors of traffic crashes,[22,29–33] we used a case-crossover design coupled with conditional logistic regression. The case-crossover design compares an individual's risk in a period immediately before or after an event of interest (the case period) with the same individual's risk in a period substantially removed in time from the event of interest (the control period). The chief advantage of this approach is that by having individuals serve as their own controls, unobserved characteristics that are relatively fixed in time (e.g. kilometres driven, driving competence) should not confound the results.[34] The threat of confounding from such unobserved between-driver differences is believed to be very substantial, which is why the case-crossover design has emerged as an attractive analytical approach for quantifying risk factors for automobile crashes. (Further detail on the case-crossover design is provided in the Supplementary Appendix, available as Supplementary data at *IJE* online).

Crashes were the event of interest in our analysis. We calculated the odds of drivers having incurred an infringement penalty in the 1-month period leading up to a crash, relative to their odds of having incurred a penalty in the corresponding 1-month period of the previous calendar year. Thus, if the incidence of infringement penalties is lower in the period immediately before a crash, it suggests a deterrent effect from traffic law enforcement.[34] This particular construction of the case-crossover design is a desirable way to examine the penalty-crash relationship for several reasons, which are described in the Supplementary Appendix; it also follows the construction used by other studies that have employed this design.

Separation of the beginning of the case and control period by 12 months accounts for seasonal variation in driving behaviour and reduces the possibility that effects of experiencing a penalty in the control period carry into the case period. For infringements where the penalty is usually issued on the spot, the date of awareness of the penalty was set at the date of infringement. For infringements usually detected by cameras (speeding, red-light), the penalty date was set 3 weeks after the infringement date to allow time for the driver to become aware of the penalty.

Study sample

Our sample frame consisted of 311 102 crashes–all reported crashes that resulted in fatalities or hospitalization (1 January 1995–31 December 2010) or in other injury or property damage alone (1 January 1995–31 December 2009). The crashes involved 439 926 drivers who were licensed and identifiable. Our analytical sample consisted of the subset of those drivers who met all of the following four eligibility criteria. (Further details of how we derived the analytical sample are provided in Figure A1 in the Supplementary Appendix, available as Supplementary data at *IJE* online.)

First, the drivers were involved in a crash between 1 February 1996 and 31 December 2010. (Drivers with crashes occurring only between 1 January 1995 and 1 February 1996 were excluded because the absence of data about infringements prior to 1 January 1995 meant it was not possible to observe them in a control period.)

Second, the drivers received an infringement penalty either in the case period (month preceding the crash) or control period (same 30-day period 12 months earlier), but not both. Any penalties associated with the crash were excluded from consideration. The crash-centred design meant that drivers without the crash and penalty profile described in these first two eligibility criteria contributed no information to the analysis.

Third, the drivers held a licence unencumbered by a suspension or disqualification throughout the case and control periods.

Finally, the drivers had been licensed for at least 2 years at the commencement of the control period. (The purpose of excluding drivers licensed for less than 2 years was to remove drivers who had restricted driving rights under Queensland's graduated licensing scheme.)

Analysis

We calculated the ratio of the odds of a penalty in the case period relative to the odds of a penalty in the control period using conditional logistic regression. This was done for the sample as a whole and for various subsamples. Formally, our design estimates the odds of penalty prior to a crash. However, if crashes are less often preceded by penalties then penalties are necessarily associated with a reduction in crash risk commensurate with the odds ratio estimated. In other words, the estimates are essentially interchangeable. We report odds ratios for the effect of penalties on crash risk, both because this format is easier to interpret and because other studies that have paired the case-crossover design with conditional logistic regression to estimate crash risk have presented estimates in this way.

We tested the statistical significance of each odds ratio using a Wald test. Only a small fraction of the data were missing (<0.25% for all variables analysed). All analyses were conducted in R (version 3.0.1).[35]

Sensitivity analysis

To test and correct for confounding due to within-individual variation, we conducted a sensitivity analysis using an alternative design: case-time-control.[36] Specifically, we matched each driver in the case-crossover analysis to a driver who was not involved in a crash. The matching criteria were age, sex, postcode and date of birth. We then calculated the relative odds of these other drivers experiencing infringement penalties in case and control periods that aligned with those of their matches in the case-crossover sample, and used the resultant measures to adjust the odds ratio of interest. (Additional details of the case-time-control method and its rationale are provided in the Supplementary Appendix, available as Supplementary data at *IJE* online.)

Ethics

The Human Research Ethics Committee at the University of Melbourne approved the study.

Results

Table 1 reports characteristics of the drivers ($n = 22\,378$), crashes ($n = 21\,905$) and penalties ($n = 26\,118$) in the analytical sample; 31% of drivers were 25 years or younger at the time of their involvement in a crash and 73% were male. This reflects the greater propensity of younger drivers and male drivers to have crashes. In all, 63% of drivers involved in crashes were judged to be at fault; 1% of crashes were fatal; 46% resulted in the need for hospitalization or medical treatment of at least one person; 38% caused property damage only; 57% of infringement penalties occurred in the case period. Speeding offences were the most common type of infringement, accounting for 60% of all infringements.

Overall, drivers had higher risk of crashes following infringement penalties [odds ratio (OR) 1.32; 95% confidence interval (CI) 1.29–1.36]. Every subgroup analysed showed elevated crash risk, although there was considerable variation in risk levels across subgroups. Drivers under 20 years of age had substantially higher odds of crashes following penalties than older drivers did (OR 1.55; 95% CI 1.34–1.78), but there were no differences by driver sex or crash severity (Figure 1). Infringements had a stronger association with crashes in which the driver was at fault (OR 1.41; 95% CI 1.36–1.46) than those in which the driver was not at fault (OR 1.19; 95% CI 1.14–1.24).

Crash risk varied substantially by type of infringement (Figure 2). Risks were highest following infringements for dangerous driving (OR 3.19; 95% CI 2.52–4.03) and driving under the influence of alcohol (OR 1.99; 95% CI 1.67–2.37). Infringements of an administrative nature—such as offences linked to registration, insurance and vehicle standards—were also associated with elevated crash risk, although the effects were relatively modest (OR 1.36; 95% CI 1.22–1.53).

Figure 3 indicates the duration of the period of heightened crash risk following infringement penalties. Crash risk

Table 1. Description of the sample used in the main analysis

	n	%
Drivers (22 378)		
Age at crash		
≤ 19 years	828	4
20–25 years	6001	27
26–30 years	3361	15
31–60 years	11 002	49
≥ 61 years	1182	5
Unknown	4	0
Sex		
Male	16 254	73
Female	6120	27
Unknown	4	0
At fault		
Yes	14 052	63
No	8326	37
Crashes (21 905)		
Severity		
Fatal	269	1
Hospitalization	4652	21
Medical treatment	5487	25
Minor injury	3228	15
Property damage only	8269	38
Infringements (26 118)		
Interval[a]		
Case	14919	57
Control	11228	43
Type		
Speeding	15573	60
Uninsured/unregistered/defective	1669	6
Red light	1164	4
Failure to stop/give way	800	3
Seat belt	771	3
Alcohol offence	602	2
Heavy vehicle offence	601	2
Mobile phone	469	2
Dangerous driving	387	1
Other	4082	16
Demerit points		
0	5141	20
1	6192	24
2	598	2
3	11 999	46
4+	2188	8

[a]The Case and Control totals do not sum to the total number of infringements (n= 26 118) because a small number of infringements occurred in the intervals of interest for more than one crash.

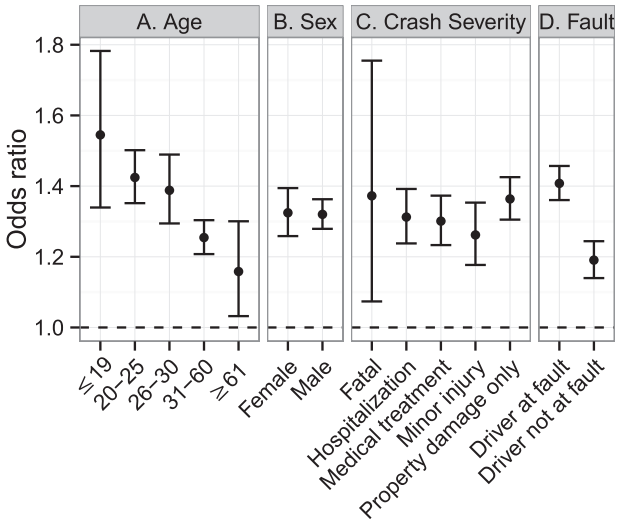

Figure 1. Odds of crash after an infringement, by characteristics of drivers and crashes.

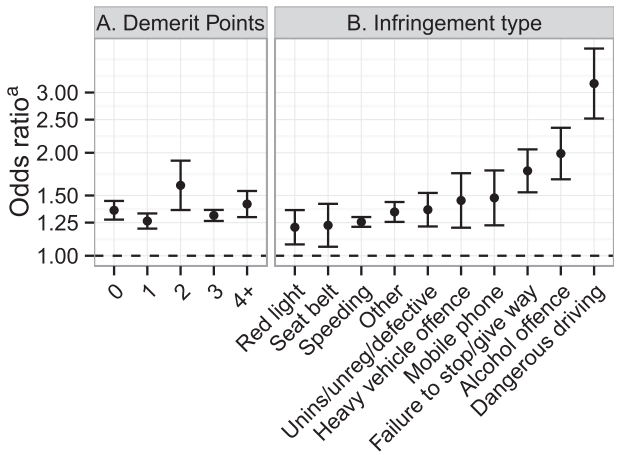

Figure 2. Odds of crash after an infringement, by demerit points associated with the infringement and infringement type.
[a]The Y-axis is plotted on a log scale.

was highest in the month following an infringement penalty. It then declined steadily over the ensuing 5 months approaching—although not quite reaching—baseline levels.

The sensitivity analysis, which examined the robustness of our findings by employing a case-time-control design, produced estimates with identical directions, and similar levels of size and significance. In general, however, the magnitude of the heightened crash risk observed in the case period was slightly attenuated. A complete set of results is shown in the Supplementary Appendix Tables A1 and A2 (available as Supplementary data at *IJE* online).

Discussion

This study found that drivers in Queensland had 32% higher odds of crashing following receipt of a penalty for a road traffic infringement than they did in another comparable period; the odds of a crash in which the driver was at fault were 41% higher. Crash odds were two to three times as high after infringements for dangerous driving and driving under the influence of alcohol, but only marginally higher after infringements related to registration, insurance

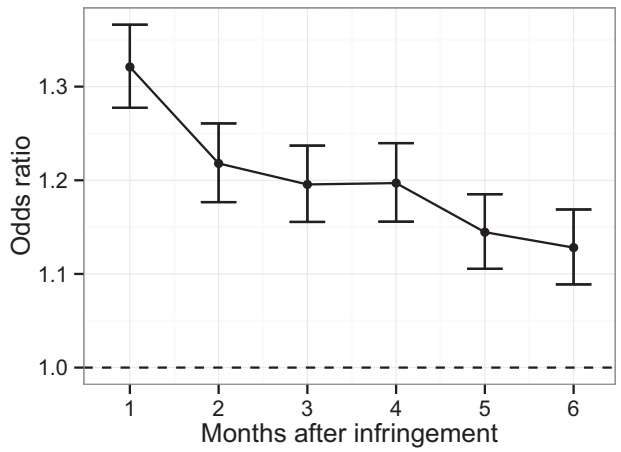

Figure 3. Odds of crash 1 to 6 months after an infringement penalty.

and vehicle standards. The risk appeared to decay over time, peaking in the month following receipt of the penalty and declining thereafter.

Studies of drunk driving laws dominate the literature on specific deterrence from traffic laws. The standard approach is to compare the effects of different forms and levels of punishment on recidivism among drunk-driving offenders. The evidence is somewhat mixed. A few studies have detected significant specific deterrent effects,[14,37] but most have found no effects, very small effects or effects only in discrete subpopulations such as first-time offenders.[13,15,16,38,39] There are good reasons, however, to be cautious about generalizing from these findings to other types of offences. Drink driving constitutes a small proportion of all offences (in our sample, 2%) and sits at the egregious end of the traffic offence spectrum, and alcohol addiction among drunk drivers may mute their susceptibility to deterrent effects.[40]

Outside drink driving, Redelmeier *et al.*'s[22] innovative use of the case-crossover design to study the behaviour of Ontario offenders is the leading attempt to date to quantify specific deterrent effects from traffic penalties. Using essentially the same study design in Queensland, we found higher risk in the wake of penalties, not lower risk as Redelmeier *et al.* had.

What explains this fundamental discrepancy? Redelmeier *et al.*'s sample was substantially smaller (about 2% of the size of ours) and restricted to fatal crashes. However, this is not a convincing explanation for the discrepancy because sub-analyses of our sample showed that penalized drivers were also at heightened risk of fatal crashes. Nor are there obvious differences between Queensland and Ontario: both are large states or provinces with similar histories and cultures and ostensibly similar infringement regimes. One possible difference relates to intensity of enforcement. If offenders were more likely to be penalized in Ontario than Queensland, it may explain detection of a deterrent effect there. In fact, the opposite seems more plausible: Redelmeier *et al.* reported 'no special enforcement technologies' in use in Ontario during their study period, whereas speed and red-light cameras were widely used in Queensland during ours. In short, we cannot explain the discrepancy.

Why was the crash risk of Queensland drivers higher following penalties? Could the experience of being penalized plausibly increase drivers' risk of crashing? If fear of attracting further penalties prompted drivers to drive with extreme caution, this may have increased their crash risk. Alternatively, penalized drivers may have been seduced by the 'gambler's fallacy', a cognitive bias in which offenders' behaviour is shaped by a belief that being caught and penalized again is exceedingly unlikely.[41]

Although it is possible that such 'anti-deterrent' phenomena may account for the pervasive effects we observed, we believe this is unlikely. A more compelling explanation is that infringements mark episodes of dangerous driving, and crash risks are highest during such episodes. Several of our sub-analyses support this theory: penalized drivers were at higher risk of crashes in which they were at fault than crashes in which they were not; risks were higher following infringements that were indicative of dangerous driving than they were following infringements of a more administrative nature; and the decline in risk observed in the months following an infringement is consistent with the type of decay one would expect to observe toward the end of an episode of risk.

The latter point warrants further explanation. If risky driving episodes exist, and are associated with higher risks of both penalties and crashes, then crash risk should, on average, peak close to the moment of infringement and decline thereafter; this would produce the type of downward-sloping curve we observed. Research into the nature and causes of risky driving episodes appears to be limited, although several studies[42–44] have detected higher risks of crashing and offending shortly after stressful life events, such divorce or job loss.

It was possible to conduct an additional test of the theory that infringements mark risky driving episodes. For two of the infringement types included in our study—speeding and red-light violations—use of cameras meant that there was a delay between when some of the offences occurred and when drivers learned they had been penalized. (Because our analysis was focused on deterrence, we handled this delay by lagging the effective date of these penalties by 3 weeks to ensure drivers were aware a penalty had been imposed.) If infringements mark episodes of risky driving, then crash risks should be at least as high at the time of the offence as they are at the time penalty

notices are received. Indeed, if there is any deterrent effect at all, risks should be lower in the latter period. We removed the 3-week lag and re-estimated crash risk following red-light and speeding offences. Crash risk was higher than the comparable period for both red-light offences (OR 1.35; 95% CI 1.20–1.51) and speeding offences (OR 1.29; 95% CI 1.25–1.34). More importantly, estimates of the increase in odds were, respectively, 66% and 12% higher than the corresponding odds ratio from the lagged analyses. This result bolsters the inference that drivers experience episodes of dangerous driving, during which both infringements and crashes are more likely to occur.

The chief advantage of the case-crossover design we used is that it adjusts for unmeasured confounders that are fixed in time. The most important confounders are likely to be individuals' driving patterns, including time spent on the road and routes travelled. Because these confounders are not entirely fixed in time, some of the heightened risk observed is likely to be attributable to residual differences in the drivers' exposure to penalty risk in the case and control periods. For example, since the crash occurs at the conclusion of the case period, it is guaranteed the driver is actively driving at least at the conclusion of the case period, but there is no such guarantee for the control period. Such 'confounding by indication' is a limitation of the case-crossover design. It cannot be dismissed as an alternative explanation for our main finding of higher crash risk after a penalty, because that period is closer in time than the control period to the only moment in the study timeline (i.e. the crash) when it is certain drivers in our sample were at the wheel. Additionally, it may help to explain certain results in the sub-analyses, such as why the odds ratio for not-at-fault crashes is greater than 1 and why the crash risk shown in Figure 3 still had not reached baseline levels 6 months after the infringement penalty.

Another limitation of the case-crossover design is the odds ratio estimates are derived from only a subsample of the crashes and infringements observed. Specifically, our estimates are derived from 7% of the recorded crashes with identifiable drivers during the study period and 0.24% of all infringement penalties issued. It is reasonable to expect that our estimates of heightened crash risk are generalizable to penalized drivers excluded from the analysis for design reasons, although we cannot be certain of this.

The extent to which our findings are generalizable outside Queensland is unknown. Since the only other study like ours reached an opposite result among a sample of Canadian drivers, replication of the analysis in other settings would be valuable. The availability in many countries of high-quality population-level data on both traffic law offenders and crashes should make replication elsewhere feasible.

An important implication raised by findings from this study is that, whatever specific deterrent effect traffic infringement penalties may have on driver safety, this effect is overwhelmed by the risks associated with episodes of dangerous driving. This insight has quite profound implications for traffic law enforcement policy and practice. Infringement penalties may serve social justice ends and respond to community expectations. But to the extent their objective is to rein in risky driving, the reality is that their value as a specific deterrent appears limited. From an accident prevention standpoint, interpreting infringements as markers of dangerous driving, and using their incidence to target other interventions that reduce drivers' risk, may have far greater potential to improve road safety than meting out fines and demerit points.

Some targeting already occurs. In Queensland, and in other places, certain infringements lead to heavy sanctions, such as immediate licence suspension or custodial sentences. However, these tend to be heavy-handed interventions triggered by egregious offences or recidivism; thus, they are located at the extreme end of the infringement spectrum. There may be considerable scope for exploiting the predictive power of infringements on individual driver risk in the lower reaches of this spectrum, and using that information to guide the application of less punitive interventions, such as mandatory driver education and targeted surcharges on fines and demerit points. Further, given the potential for the prediction to mark an episode of risky driving, experimentation with a licence suspension version of 'flash incarceration'[45] may yield safety benefits.

Supplementary Data

Supplementary data area available at *IJE* online.

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