The overrepresentation of youths in crashes involving casualties is a significant public health issue in most high-income countries. As a result, prevention of crashes by novice drivers is a key focus for many jurisdictions, policymakers, and researchers. The introduction of graduated driver licensing, which gradually introduces full driving privileges for novice drivers, has brought about significant reductions in crashes, particularly in settings where more stringent conditions such as restrictions on passenger numbers and night driving have been introduced. Research on novice drivers’ risky behaviors and risk perceptions is crucial to understanding how this initiative can be improved or how complementary interventions can be developed.

There is much to be learned about the impact of novice drivers’ risky driving and how it is associated with their increased risk of crash. Recent research confirms that certain risky driving behaviors are more prevalent among younger drivers than older drivers, especially among men. These include high-level speeding and speeding for the thrill of it, following too closely to the vehicle ahead, violating traffic rules, not using seatbelts, using mobile phones while driving (including text messaging), driving during high-risk nighttime hours, and driving older vehicles.

In addition, certain driving behaviors have been demonstrated to be of higher risk for young novice drivers than for experienced adult drivers; these include carrying peer passengers or multiple passengers and driving under the influence of alcohol, even at low concentrations.

Paradoxically, given higher levels of risk taking, young drivers are often found to be more aware of driving risks than drivers of other age groups, particularly regarding alcohol, although young males tend to have poorer perceptions of risk than females. Nonetheless, young people who undertake or are exposed to risky driving behaviors tend also to perceive driving risks as low.

In a prevalence study conducted recently in Australia, McEvoy et al. reported that those who reported mobile phone use while driving regarded a range of risky driving practices as significantly less dangerous than those who did not report phone use.

Young people’s risk perceptions, however, can be dependent on context. For example, although speeding per se or under usual conditions is typically viewed as risky, speeding on a clear, dry day is not. Driving fast because one is in a hurry is considered not as risky as driving fast to test a car’s speed, whereas racing other cars ranks among the highest perceived risks. Likewise, studies have found that the general public considers only small excess rates of speed (64 km/h in a 60-km/h zone and 105 km/h in a 100-km/h zone) to be acceptable but that high school students of driving age accept higher speeds: in one study, one quarter of students accepted 70 km/h or more in a 70-km/h zone as safe and one quarter accepted 120 km/h or more in a 100-km/h zone as safe if conditions were good. In another study, when asked how much over a 60 km/h speed limit a driver would have to be going to be considered “stupid,” young drivers reported a significantly higher speed threshold than older drivers, but there were no differences in reported thresholds for a driver to be considered “irresponsible” or “criminal.”

Differences in young drivers’ perceptions of other risks have also been found. For example, ratings of perceived risk have increased from very low when peer passengers are in the car to higher ratings when passengers have been drinking alcohol, smoking marijuana, or are not wearing seatbelts to highest ratings when passengers are trying to get the driver to speed or are acting wild. Regarding driving while using a mobile phone, hands-free use has been considered less risky than manual use and answering a call, dialing, or text messaging as more risky than talking on a phone.

Such findings raise questions about whether risk perception and risky driving behaviors are...
strongly related and whether either is directly associated with crashes. Few recent studies of novice drivers have explored these issues, particularly the utility of either risk perception or risky driving behaviors for predicting the risk of a crash. An earlier study conducted in Australia found that self-reported risky driving behaviors were linked to increased risk of crashes in the first year of driving, but this study did not examine the impact of risk perception on crash risk.46 Our aim was to explore the risky driving behaviors and risk perceptions of a cohort of young, newly licensed drivers and to determine the associations between these factors and crash risk.

METHODS

The DRIVE Study is a prospective, Web-based cohort study of young drivers in the state of New South Wales, Australia, for which detailed methods have been previously reported.47 Briefly, all drivers resident in New South Wales aged 17 to 24 holding a first-stage provisional motor vehicle license between June 2003 and December 2004 were invited to participate in the study. This provisional license is the first license allowing unsupervised driving. At the time of the study, drivers holding this license could have no alcohol in the bloodstream and could drive no faster than 90 km/h, and all New South Wales drivers were restricted from manual use of mobile phones. All respondents gave consent for their survey data to be linked prospectively to data held by the state jurisdictional authority, the Roads and Traffic Authority of New South Wales, including information about licensing test attempts and police-reported crashes.

Crash records were obtained for the 10-year period from January 1, 1996 to December 31, 2005. In New South Wales, according to the Road Transport Act 1999, a crash must be reported to police when any person is killed or injured, when there is damage of over Aust $500 to property other than the vehicles concerned, when drivers involved in the crash do not exchange insurance and contact information, when one or more of the drivers is reported to be driving under the influence of alcohol, or if a vehicle involved in the crash is towed away.

The DRIVE Study questionnaire contained questions on demographic information, driving experience and training on the provisional license, self-ratings of driving ability, and average weekly driving hours (the main measure of driving exposure).47 The questionnaire also included 14 items regarding risky driving behaviors (Table 1) and 10 items regarding risk perceptions (Table 2) that were adapted from previous research.48,49 For risk behavior items, participants were asked, “How often do you [engage in a particular behavior]?”, possible responses and corresponding scores were: very often = 4, often = 3, sometimes = 2, hardly ever = 1, and never = 0; the total score range was 0 to 56. For risk perception items, participants were asked, “When you are driving, how safe do you think the following are?”, with response options and scores as follows: always safe = 3, mostly safe = 2, sometimes safe = 1, and rarely safe = 0; the total score range was 0 to 30. Higher scores on the scales thus represent more risky driving behavior and more risky perception (poorer perceptions of safety). The summative scores for risky driving behaviors and risk perception were categorized into tertiles (low, medium, and high).

Participants were assured that all information was confidential and that identifying information would not be stored or used in conjunction with the questionnaire responses.

Statistical Analyses

The primary outcome variable, a driver’s number of police-reported crashes, was categorized as 0 or as 1 or more crashes during follow-up. Exposure variables were risky driving behaviors and risk perceptions. The number and proportion of participants who reported that they “very often” or “often” undertook each risky driving behavior were calculated. A similar approach was used to determine number and proportion of responses to each risk perception as “always safe” or “mostly safe.” Differences by gender for each factor in risky driving behavior and risk perception scales were examined with the χ² test.

We analyzed data by using summative scores for risky driving behaviors and risk perception categorized into tertiles (low, medium, and high) and applying a Poisson regression model to determine relative risks (RRs) and 95% confidence intervals (CIs), including stratification by gender. Relative risks were preferred because of

RESULTS

In total, 20,822 young drivers completed the baseline survey (with 95% completed online) and gave consent for data linkage. The majority (74.6%) of the study population was aged 17 to 18 years: 54.6% were female. During an average follow-up of 2 years, 92.8% had no police-recorded crashes as a driver, 6.8% had 1 such crash, 0.3% had 2 crashes, and 0.01% had 3 crashes. Of the 20,822 participants, 2.7% had crashes recorded prior to joining the study.

Table 1 presents the number and proportion of participants (total sample and by
gender) who reported "very often" or "often" partaking in risky driving behaviors; the most commonly reported were driving with multiple passengers (almost half of respondents), driving while listening to loud music (two fifths), and driving at 70 km/h in a 60-km/h zone (one fifth). Least common was driving without a seatbelt (<1%). With the exception of driving 10 km/h over the posted limit, the greatest discrepancies for driving 70 km/h in a 60-km/h zone and late-night driving. 

Composite scores were calculated and correlated for those who responded to all risky driving behavior and risk perception items (n=19,569). There was a positive but weak association between risky driving behaviors and risk perception (r=0.05; P<.001). Table 3 presents the results of the regression analyses exploring the associations between summative scores of risky driving and of risk perception and the likelihood of a crash, stratified by gender. Univariate analyses showed that drivers with both medium and high scores on the risky driving measure were significantly more likely to have a crash than those with low scores. This relationship remained after adjustment for multiple confounders. Further controlling for risk perception did not significantly alter the results. The key finding, therefore, was that high scores for risky driving were associated with a 50% increased crash risk (adjusted RR=1.51; 95% CI=1.25, 1.81). Further exploration confirmed that each risky driving item was significantly independently associated with increased crash risk at P<.05, with the exception of nonuse of seatbelts (P=.24).

A high score compared with a low score on the risk perception measure (poorer perception of safety) was also associated with increased crash risk in univariate and multivariate models; however, this significant association was not sustained after adjustment for risky driving behavior. There were no significant differences in risk estimates by gender. Although the effect size for risky driving behaviors was higher for women than men (for women, RR=1.68; 95% CI=1.30, 2.17; for men, RR=1.41; 95% CI=1.08, 1.84), the difference was not significant. There was, similarly, no difference by gender in the effect of risk perception on crashes (Table 3). Likewise, there was no effect modification by age for either risky driving behaviors or risk perception.

**DISCUSSION**

We found that self-reported risky driving behaviors among novice drivers were linked to a 50% increased risk of a crash after control for...
studies have also shown that young people who perceive driving risks as high can still report engaging in these behaviors.\textsuperscript{18,37} The need for interventions targeting risky driving behavior, independent of risk perception, is clear and offers some explanation as to why drivers’ education programs that focus on increasing awareness and knowledge of driving risks without seeking behavior change have generally not succeeded in reducing crashes.\textsuperscript{52,53} Research suggests that licensing reform has an important role in effecting behavior change among novice drivers.\textsuperscript{3,4,54–56} Enforcement regimes can effectively deter risky driving behavior without requiring improvements in risk perceptions, both through issuance of sanctions (specific deterrence) and through highly visible programs that appear ubiquitous (general deterrence).\textsuperscript{57}

As highlighted in this research, novice drivers ranked 2 known risk behaviors—driving with multiple passengers and driving late at night—lowest on the risk perception scale. Driving with multiple passengers was also the most commonly reported risky driving behavior for both genders (almost half of the sample). Research has shown that implementing graduated driver licensing restrictions to limit passengers and restrict late-night driving among new drivers has reduced crashes.\textsuperscript{54–56} These findings suggest that such licensing reforms are warranted.

Most risky driving behaviors reported by study participants were not common—generally, they were reported to be undertaken very often or often by fewer than 5% of participants. However, in addition to the high level of driving with multiple passengers, over 40% of participants reported driving while listening to loud music and one quarter of men and one fifth of women reported very often or often driving at about 10 km/h over the speed limit in a 60-km/h zone. Risks associated with driving with loud music are not well understood and have not been a specific focus of safety campaigns; however, loud music can act as a distraction, and research suggests that listening attentively to the radio can worsen driving performance, particularly lane keeping, as much as a mobile phone conversation.\textsuperscript{58} In comparison, the risks of speeding have been well documented and widely targeted in statewide campaigns in the study location.\textsuperscript{59} Although this level of speeding can be viewed as commonplace among other driver groups and acceptable within the driving community,\textsuperscript{60} it remains a dangerous practice: the risk of a crash when driving at 70 km/h is 4 times the risk at 60 km/h.\textsuperscript{61}

Current licensing countermeasures to address speeding behavior among young novice drivers include reduced demerit point thresholds and more severe penalties for

### TABLE 2—Number and Proportion of Participants Aged 17–24 Years Rating Risk Perception Items as Always Safe or Mostly Safe, by Gender: The DRIVE Study, New South Wales, Australia, June 2003–December 2004

<table>
<thead>
<tr>
<th>Rates the Following as Always Safe or Mostly Safe</th>
<th>Total Sample</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>% (95% CI)</td>
<td>No.</td>
</tr>
<tr>
<td>Driving with 2 or more passengers</td>
<td>18694</td>
<td>89.8 (89.4, 90.2)</td>
<td>8559</td>
</tr>
<tr>
<td>Driving between midnight and 6 am</td>
<td>11018</td>
<td>52.9 (52.2, 53.6)</td>
<td>5747</td>
</tr>
<tr>
<td>Driving at 110 km/h in a 100-km/h zone</td>
<td>7552</td>
<td>36.3 (35.6, 36.9)</td>
<td>4262</td>
</tr>
<tr>
<td>Driving at 70 km/h in a 60-km/h zone</td>
<td>6412</td>
<td>30.8 (30.2, 31.4)</td>
<td>3432</td>
</tr>
<tr>
<td>Driving while talking on a mobile phone</td>
<td>2017</td>
<td>9.7 (9.3, 10.1)</td>
<td>1172</td>
</tr>
<tr>
<td>Driving a poorly maintained car</td>
<td>1368</td>
<td>6.6 (6.2, 6.9)</td>
<td>871</td>
</tr>
<tr>
<td>Driving with a blood alcohol level just over the legal limit</td>
<td>1180</td>
<td>5.7 (5.4, 6.0)</td>
<td>749</td>
</tr>
<tr>
<td>Driving while using SMS on a mobile phone</td>
<td>1048</td>
<td>5.0 (4.7, 5.3)</td>
<td>555</td>
</tr>
<tr>
<td>Driving after smoking marijuana</td>
<td>922</td>
<td>4.4 (4.1, 4.7)</td>
<td>537</td>
</tr>
<tr>
<td>Going through a red light</td>
<td>593</td>
<td>2.8 (2.6, 3.1)</td>
<td>313</td>
</tr>
</tbody>
</table>

Note. SMS = short message service; CI = confidence interval.
TABLE 3—Crude and Adjusted Relative Risks (RR) for Associations Between Risky Driving Behavior, Risk Perception, and Likelihood of Crash Among Young Drivers Aged 17–24 Years, by Gender: The DRIVE Study, New South Wales, Australia, June 2003–December 2004

<table>
<thead>
<tr>
<th>Measure and Value</th>
<th>Crude RR (95% CI)</th>
<th>Risky Driving Behavior, Adjusted RRa (95% CI)</th>
<th>Risk Perception, Adjusted RRa (95% CI)</th>
<th>Risky Driving Behavior and Risk Perception, Adjusted RRa (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>All participants</td>
<td>Male participants</td>
<td>Female participants</td>
</tr>
<tr>
<td>Risky driving behavior</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.70 (1.50, 1.94)</td>
<td>1.58 (1.34, 1.85)</td>
<td>...</td>
<td>1.51 (1.25, 1.81)</td>
</tr>
<tr>
<td>Medium</td>
<td>1.25 (1.09, 1.44)</td>
<td>1.32 (1.12, 1.55)</td>
<td>...</td>
<td>1.30 (1.10, 1.54)</td>
</tr>
<tr>
<td>Low (Ref)</td>
<td>1.00</td>
<td>1.00</td>
<td>...</td>
<td>1.00</td>
</tr>
<tr>
<td>Risk perception</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.39 (1.22, 1.57)</td>
<td>...</td>
<td>1.31 (1.13, 1.53)</td>
<td>1.09 (0.92, 1.29)</td>
</tr>
<tr>
<td>Medium</td>
<td>1.04 (0.90, 1.20)</td>
<td>...</td>
<td>1.11 (0.94, 1.30)</td>
<td>1.00 (0.84, 1.18)</td>
</tr>
<tr>
<td>Low (Ref)</td>
<td>1.00</td>
<td>...</td>
<td>...</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risky driving behavior</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.56 (1.29, 1.89)</td>
<td>1.48 (1.17, 1.88)</td>
<td>...</td>
<td>1.41 (1.08, 1.84)</td>
</tr>
<tr>
<td>Medium</td>
<td>1.27 (1.03, 1.56)</td>
<td>1.40 (1.10, 1.79)</td>
<td>...</td>
<td>1.39 (1.08, 1.79)</td>
</tr>
<tr>
<td>Low (Ref)</td>
<td>1.00</td>
<td>1.00</td>
<td>...</td>
<td>1.00</td>
</tr>
<tr>
<td>Risk perception</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.25 (1.04, 1.51)</td>
<td>...</td>
<td>1.24 (0.99, 1.55)</td>
<td>1.08 (0.84, 1.38)</td>
</tr>
<tr>
<td>Medium</td>
<td>0.90 (0.73, 1.12)</td>
<td>...</td>
<td>0.99 (0.77, 1.27)</td>
<td>0.91 (0.70, 1.17)</td>
</tr>
<tr>
<td>Low (Ref)</td>
<td>1.00</td>
<td>...</td>
<td>...</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risky driving behavior</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.74 (1.45, 2.08)</td>
<td>1.75 (1.40, 2.18)</td>
<td>...</td>
<td>1.68 (1.30, 2.17)</td>
</tr>
<tr>
<td>Medium</td>
<td>1.20 (1.00, 1.45)</td>
<td>1.26 (1.01, 1.57)</td>
<td>...</td>
<td>1.23 (0.98, 1.55)</td>
</tr>
<tr>
<td>Low (Ref)</td>
<td>1.00</td>
<td>1.00</td>
<td>...</td>
<td>1.00</td>
</tr>
<tr>
<td>Risk perception</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>1.36 (1.13, 1.63)</td>
<td>...</td>
<td>1.38 (1.12, 1.71)</td>
<td>1.08 (0.85, 1.38)</td>
</tr>
<tr>
<td>Medium</td>
<td>1.11 (0.92, 1.34)</td>
<td>...</td>
<td>1.20 (0.97, 1.48)</td>
<td>1.06 (0.85, 1.33)</td>
</tr>
<tr>
<td>Low (Ref)</td>
<td>1.00</td>
<td>...</td>
<td>...</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Note. CI = confidence interval. Crude RRs were from univariate analysis; adjusted RRs were from multivariate analysis.

aAdjusted for age, gender (for total sample analysis), country of birth, socioeconomic status, remoteness of residential postcode, months on learner license, professional supervised driving hours on learner license, private supervised driving hours on learner license, number of attempts at driving tests, self-rated driving ability, average weekly driving hours, months between provisional license and study entry, and previous crash.

The finding that men reported more frequently engaging in several risky driving behaviors and had poorer risk perceptions than women supports findings of previous studies.5–12 Although young men have been identified as a particular target for interventions to reduce risky driving, the association between risky driving and the risk of crash did not differ by gender in the current study; that is, whether male or female, those who reported undertaking a high level of risky driving behaviors had an increased risk of crash. This reinforces the need to include the entire young driver population in targeted interventions.

Limitations
As the young drivers included in this research were volunteers and not a representative sample of the general population, estimates of the population prevalence of exposures or outcomes were not calculated. However, the study population represented a broad cross-section of the young driver population and substantial heterogeneity in the distribution of potential risk factors for crashes was achieved, making it possible to explore the associations of interest.47

The measures of risky driving behaviors and risk perception were obtained via self-report, and the possibility of socially desirable responses cannot be excluded. Therefore, the magnitude of association between risk perception, risky behaviors, and crashes may be underestimated. However, questionnaire items were based on previous studies and a wide distribution in responses was found. Moreover, several risky driving and crash-based studies have confirmed the accuracy and reliability of self-reports in this field.68 Nonetheless, the use of response scales applied in this research has been questioned, particularly regarding risk perceptions and in rating several items as a measure of overall risk perception.69 Questionnaire-based measures of risk perception have also not compared directly with other measures, such as identifying risks in videos of driving scenarios.70 In addition, given that young people have reported context-dependent perceptions of risk,63,65 the findings relating to risk perception need further investigation. It is possible that the current measure was not sensitive enough to determine stronger associations between risk perception and crash risk.

offenses.62,63 However, research in Europe has found mixed results regarding the impact of such initiatives on crashes.1 Alternatively, in some jurisdictions, novice drivers must pass a “good behavior” period—free of any offenses such as speeding—before they can progress to the next stage of licensing.63,64 Some research also suggests that these initiatives have an important role in motivating behavior change and reducing crashes65,66; however, this is not a well-researched countermeasure. Further, speeding remains a significant contributing factor to crashes by novice drivers61,64,66; this is true in our study location, where 40% of fatal crashes involving 17- to 25-year-old drivers involve speeding.67 At the time of recruitment, the state already had a reduced demerit point threshold for newly licensed drivers, but it has since introduced more severe penalties for speeding as part of a “zero tolerance” campaign on speeding.67 Any serious speeding offense now leads to suspension of license. The present findings suggest that targeted initiatives such as these are warranted.
The driving exposure measure was also a self-report measure and was based on average weekly driving hours at the time of the survey. This may not be sensitive enough to detect differences in actual mileage driven or variations in driving exposure over time, both of which alter the level of crash exposure. The possible influence of this limitation on the results is unknown, but this measure is widely used in this field when it is the best available option.38,71

Given the large sample size needed to generate sufficient power to produce reliable estimates of factors associated with the risk of crash, a relatively rare outcome, there have been few studies that have examined associations between risky driving and crash risk. Further, there have been few large-scale observational studies of novice drivers worldwide that have had the capacity to link detailed questionnaire data to routinely collected data sources. This study therefore has some significant strengths, including 100% consent from participants to access data on crashes from police reports. The breadth of the questionnaire data allows adjustment for multiple confounding variables, crucial in an observational study but rare in large-scale studies of novice drivers that use routinely collected data from jurisdictional licensing and crash data sources.

Conclusions

This study has highlighted that self-reported risky driving is associated with a 50% increased risk of crashes but that the effect of risk perception, although an independent predictor of crashes, is attenuated once risky driving is accounted for. A detailed understanding of the associations between risky driving behaviors and the risk of crash is useful in determining enhancements to current interventions and further developments, including the types of novice driver policies that need strengthening. The findings suggest that the introduction of restrictions on the number and age of passengers and on nighttime driving, as well as additional measures to address speeding, are warranted, and that both male and female novice drivers must be targeted in such intervention. However, a system-wide approach that more broadly targets risky driving as an unacceptable behavior can improve effectiveness and provide additional benefits by engaging the wider driving community.36,60,72

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Contributors

R. Ivers, M. Stevenson, M. Woodward, and R. Norton conceptualized the study and R. Ivers supervised all aspects of its implementation. R. Ivers and T. Senserrick led the writing. S. Boufous, H.-Y. Chen, and M. Woodward conducted the analyses. All authors contributed to the interpretation of the findings and the writing.

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Human Participant Protection

This study was approved by the University of Sydney Human Research Ethics Committee and the New South Wales Department of Health Ethics Committee. Participants provided consent online or in writing.

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