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The revised Group Risk Assessment Model (GRAM 2): Assessing risk of reoffending among adults given non-custodial sanctions

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Aim: *To re-examine the Group Risk Assessment Model (GRAM) for predicting reoffending in adults given non-custodial sentences and to assess the accuracy of the model.*

Method: *Adult offenders given non-custodial sentences in 2011 were the cohort of interest. Reoffending within 24 months of the index appearance was measured using court data. Models predicting reoffending using personal, index offence and criminal history characteristics were undertaken using multivariate logistic regression and model fits were assessed. Model validity and reliability was also measured by applying the model estimates to sub-group data and to separate smaller cohorts.*

Results: *Of the 81,199 adult offenders, 26% reoffended within two years of the index appearance. The best model fit for GRAM 2 comprised age, gender, Indigenous status, number of concurrent offences, prior custodial sentence, prior proven offences and the index offence type. The internal and external validity of the model was strong, however application of the model to offenders from smaller geographical areas or to those with a prior history of prison or property offending should be undertaken with care. Application of the model for screening purposes should also be carefully considered.*

Conclusion: *The GRAM 2 has been shown to be a robust tool for predicting reoffending. Although reliable, model estimates and their applicability should be re-examined periodically.*

Keywords: *recidivism, Group Risk Assessment Model (GRAM), prediction, accuracy*

INTRODUCTION

Actuarial risk assessments use statistical algorithms to establish risk profiles associated with certain cohorts. In the context of recidivism, these models identify a combination of factors associated with reoffending in order to classify individuals into groups based on their likelihood of reoffending and tend to do so with a relatively high degree of predictive accuracy compared with clinical assessments (Andrews, Bonta, & Wormith, 2006). However the positive predictive validity of various models do range considerably and care must be taken to administer the appropriate model to the cohort under investigation (Fazel, Singh, Doll, & Grann, 2012; Singh, Grann, & Fazel, 2011). In order to allocate scarce resources more efficiently, second generation (static) risk assessment tools, due to their relative efficiency and ease of use (compared with clinical assessments and third generation [static plus dynamic] models), are becoming increasingly favoured by criminal justice agencies as a cost-effective method for identifying individuals at risk of reoffending.

The Group Risk Assessment Model (GRAM), developed by the NSW Bureau of Crime Statistics and Research (BOCSAR), is one such risk assessment tool (Smith & Jones, 2008a; 2008b). It predicts reoffending within 24 months of an index offence based on a variety of individual-level static risk factors including age, gender, Indigenous status, prior criminal history and current offences. Separate GRAM models have been estimated for juvenile and adult offenders given non-custodial

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sentences, as well as for adult offenders released from custody (Smith & Jones, 2008a; 2008b) each providing reasonable levels of predictive ability. The GRAM was originally developed to obtain more accurate estimates of trends in reoffending over time by comparing predicted reoffending rates (adjusting for the characteristics of offenders coming before the courts) with observed reoffending rates. This technique for monitoring trends in reoffending had previously been adopted by the UK Home Office, and the UK model (Offender Group Reconviction Scale) developed for this purpose has now undergone at least two major revisions with improved efficiency, validity and accuracy (Copas & Marshall, 1998; Howard, Francis, Soothill, & Humphreys, 2009; Taylor, 1999). While modellers have acknowledged that these types of risk assessment tools need to be periodically recalibrated to account for changing patterns of reoffending (Howard et al., 2009; Smith & Jones, 2008a), the frequency with which this process should be undertaken has not been clearly articulated.

However monitoring temporal trends in reoffending is just one of the potential uses of a risk assessment instrument like GRAM. Screening individuals who come in contact with the criminal justice system for further assessment or intervention is another important application. Previous work by BOCSAR has developed triage or screening tools based on the GRAM approach to assist correctional agencies in identifying higher-risk offenders who may need further, more rigorous, assessment (Fitzgerald & Graham, 2016; Lind, 2011; Ringland, 2011; Ringland, Weatherburn, & Poynton, 2015; Weatherburn, Cush, & Saunders, 2007) or who would benefit most from referral to specific treatment programs and/or to intensive case management (e.g. diversionary programs such Court Referral of Eligible Defendants Into Treatment, Life on Track, Youth on Track). A similar risk assessment screening tool has also been developed by Corrective Services NSW to predict risk of re-imprisonment amongst offenders serving time in custody in order to prioritise assessment of inmates (Corrective Services NSW, 2014). An important consideration in the application of these screening tools, however, is the extent to which the models can accurately discriminate recidivists from non-recidivists. Misclassification errors in the form of misses (not identified as high-risk but did reoffend) and false alarms (identified as high-risk but did not reoffend) incur costs, not only to the criminal justice system in terms of “money wasted” or “lost” savings, but also to the individual and their family who are subjected to unnecessary intervention by state agencies.

In the development of predictive models for screening purposes there is an inherent trade-off between the accuracy of risk classification and the efficiency of application. Comprehensive instruments which incorporate both static and dynamic risk factors may result in more accurate assessments of risk but if data collection for application of the model is labour intensive (e.g. special purpose surveys or expert opinion), then any benefits conferred by the superior model may be offset by the additional costs of measuring model inputs (Ringland, Weatherburn & Poynton, 2015). It is therefore imperative to consider both the purpose for which the instrument was intended and the way in which it will be applied in the field when considering the set of variables on which to base risk estimates. Fortunately, work to date indicates that the addition of dynamic risk factors to reoffending models provides only a small improvement in predictive ability when compared with standard models that rely only on static risk factors (McGrath & Thompson, 2012; Ringland, 2011; Ringland, Weatherburn & Poynton, 2015). This suggests that administrative data may, for the most part, be sufficient for screening purposes.

GRAM-based models have also been used in strategic analysis and policy development to forecast offender numbers who meet or exceed certain risk thresholds across different regions or local areas, or within specific subgroups (e.g. offenders receiving a supervised order). These estimates assist policy makers and treatment providers in selecting pilot intervention sites, budgeting for program expansion and developing targeted interventions. However, recent research assessing the viability of a similar risk assessment tool for violent Domestic Violence (DV) reoffending raised some concerns about the extent to which GRAM can validly be used for this purpose. Fitzgerald and Graham (2016) found that their actuarial risk model performed well when predicting recidivism amongst the broader population of DV offenders but poorly when trying to predict Indigenous DV recidivism; most likely because smaller proportions of Indigenous offenders were in the population of interest. The extent to which GRAM can validly be applied to smaller offender subgroups or localised areas has not yet been examined in any great detail.

THE CURRENT STUDY

The aims of the current study were threefold;

1. To update and recalibrate the GRAM model based on more recent data (GRAM 2)
2. To assess the predictive accuracy of GRAM 2 in different cohorts of offenders
3. To assess the viability of GRAM 2 as a screening tool

The current study aimed to develop risk models to estimate the probability of reoffending (at the population and individual level) within 24 months of an index event using court-based administrative data. This work built on the foundation already established by Smith and Jones (2008a) and where possible replicated their approach in order to maintain consistency over time. Model selection techniques were used to identify variables with a significant association with reoffending from potential predictors identified by previous research, and parameter

estimates were also compared with those obtained previously. The validity of the resultant model as a screening tool and/or as a means to (1) examine trends in reoffending across subsequent calendar years and (2) forecast high-risk offender numbers in local areas or amongst specific subgroups was also examined.

METHOD

DATA SOURCE

Data to conduct this study were obtained from the BOCSAR Reoffending Database (ROD; Hua & Fitzgerald, 2006). ROD contains records of all persons' offences (since 1994) and custodial episodes (since 2000), with offence data up to 30 June 2015 included for this study. Date of death as sourced from the NSW Registry of Births, Deaths and Marriages is also available on ROD. All appearances in a NSW court during 2011 were extracted from ROD for this study.

SAMPLE

Finalised court appearances with at least one proven offence in the Children's, Local, District or Supreme Courts or finalised Youth Justice Conferences (YJC) were included as the sample cohort. Cannabis cautions, police cautions or appearances at the Adult Drug Court were excluded (n=94,360 people). Appearances in which a custodial penalty was imposed (n=8,239), an offender was being held in remand for a previous offence (n=483) or in cases where the offender was still in custody for more than two days following the court appearance (n=725) were further excluded. People who died (n=795), and cases where there was missing gender or age information (n=561) were also excluded. Offenders who returned to custody for longer than 30 days during the follow-up period without having recorded a new proven offence were also excluded (n=401) because their exposure time during the follow-up period was significantly reduced. This included people who received a subsequent prison sentence for an offence committed prior to the index offence as well as those who were remanded for a new offence during the follow-up which was not finalised by the end of the observation period. For offenders with more than one finalised court appearance, an appearance was randomly selected as the index court finalisation date, giving a final sample of 85,559 offenders who received a non-custodial sentence in 2011.

DEPENDENT VARIABLE

The dependent variable used in this study was whether or not a person reoffended within two years of the index appearance. A reoffence was defined as an offence that was proven in court or resulted in a Youth Justice Conference (YJC) within 24 months of the index date and was finalised within 30 months (consistent with the approach taken by Smith and Jones; 2008a)[1].

EXPLANATORY VARIABLES

A range of potential explanatory variables were examined for inclusion in the regression model predicting reoffending. These included demographic variables, previous criminal history and characteristics of the index appearance.

Demographic variables

- Juvenile or adult: A juvenile was defined as anyone with an index appearance at the Children's Court or YJC. Conversely an adult was anyone with an index appearance at a Local, District or Supreme Court regardless of their age[2]
- Gender: male or female
- Age at index appearance
- Indigenous status: Indigenous status ever recorded in ROD. Recorded as Indigenous if the offender ever identified as an Aboriginal or Torres Strait Islander or else recorded as non-Indigenous
- Remoteness of area of residency: the Accessibility Remoteness Index of Australia was assigned to the residential postcode of the offender and was classified as major city, inner regional, outer regional, remote or very remote (Australian Bureau of Statistics, 2011b)
- Socio-economic disadvantage: the Socio-economic Index for Areas was used to assign the level of disadvantage based on the offenders' residential postcode (Australian Bureau of Statistics, 2011c).

Characteristics of index finalisation

- Number of proven concurrent offences at the index appearance
- Type of index offence: The principal offence category of the offender's index offence was categorised according to the Australian and New Zealand Standard Offence Classification [ANZSOC] (Australian Bureau of Statistics, 2011a) as:
  - Violent (01, 02, 03, 06)
  - Property / Theft (07, 08, 09)
  - Drug (10)
  - Driving (041, 14)
  - Against Justice Procedures (15)
  - Other (05, 11, 12, 16)
- Jurisdiction of the index contact: for adults this was whether the index appearance was in the Local, District or Supreme Court; for juveniles it was whether the index appearance was in the Children's Court or at a YJC.

Prior criminal history

- Number of appearances in court (or YJC) in which there was at least one proven offence in the five-year period prior to the index contact
- Number of custodial sentences received in the five-year period prior to the index contact
- Number of court appearances in the five-year period prior to the index contact in which at least one proven offence was property related
- Number of court appearances in the five-year period prior to the index contact in which at least one proven offence was violent
- Number of cautions received in the five-year period prior to the index contact.

MODELLING ADEQUACY & STRATEGY

Bivariate associations between each of the potential explanatory variables and reoffending were undertaken using Chi-Square analysis. Multivariate logistic regression models were then fitted to determine which combination of explanatory factors was most accurate in predicting recidivism. The model derived from Smith and Jones (2008a) was used as the first step in multivariate logistic regression models to predict two year reoffending. Variables that were significant at the bivariate level were then added to and removed from the model accordingly to derive the final model which provided the best fit. Three automated modelling strategies were compared to decide on the explanatory factors that should be included in the final models: stepwise regression, forward selection and backward elimination.

A number of different logistic regression models predicting reoffending were developed. Different classifications of important explanatory variables and the inclusion of offenders with a custodial sentence in the cohort were also considered. Goodness of fit of each model was assessed by the Hosmer-Lemeshow (H-L) statistic and the area under the ROC curve (AUC) or c-statistic (Hosmer & Lemeshow, 2004). The H-L statistic compares observed and predicted values for 10 equal-sized groups or reoffence predictor values derived from the model. Offenders with more characteristics positively associated with reoffending will have risk values in the higher decile range and those with fewer characteristics associated with reoffending will be in lower risk deciles. The H-L statistic follows a Chi-Square distribution and if significant indicates a poor model fit, but it is highly sensitive to small deviations between the two values when there is a large sample size. The AUC is a measure of concordance of the observed and predicted values, ranging between .5 (no better than chance prediction) and 1.00 (perfect prediction). In general, logistic regression models with an AUC (or c-statistic) of .70 or greater are considered to have an acceptable level of discrimination between groups. Models with AUC values of .60-.70 are considered to have a moderate level of discrimination, while .80 or greater indicates excellent discrimination (Hosmer & Lemeshow, 2004).

External validity of model performance was measured by splitting the data into a 50:50 random spilt to give a training and a test sample. A model was built on the training sample and its parameter estimates were applied to the test sample, providing predicted probabilities of reoffending in various variables of interest which could then be compared with actual recidivism rates.

Application of the model

Once the best fit of explanatory variables was determined and the associated coefficients estimated, the resultant model (GRAM 2) was compared and contrasted with the earlier GRAM model (Smith & Jones, 2008a), and then used to examine trends in reoffending across subsequent calendar years, adjusting for characteristics of the offender cohort. Here the parameter estimates derived from the final 2011 model (GRAM 2) were used to predict the proportion of offenders in 2012 and 2013 cohorts who reoffended within two years. The predicted reconviction rate was defined as the mean of the individual predicted probabilities across all offenders in the cohort. Ninety-five per cent confidence intervals (95% C.I.) around the predicted and observed recidivism proportions were calculated using the score method with continuity correction (Newcombe, 1998).

Two further potential applications of the model were also considered. Firstly, we examined the predictive accuracy of the model when applied to sub-populations of offenders, including GRAM 2's ability to predict recidivism rates amongst offenders appearing before specific Local Courts, residing in certain Local Government Areas (LGAs), offenders with any property or violent offences at the index appearance, or those sentenced to more severe penalties such as a supervised order. Secondly, we assessed the model's viability as a tool for screening offenders at risk of recidivism. Here the screening accuracy of reoffending predictions were examined using the following measures: sensitivity (or true positive; the model's ability to correctly identify someone who will reoffend), specificity (or true negative; the model's ability to correctly identify someone who will not reoffend), and positive predictive value (PPV, or precision; of those identified as being at risk of reoffending, the model's ability to correctly identify those who go on to reoffend).

If offenders are to be screened or triaged, the data available for assessing risk would vary at different stages within the criminal justice process. For this reason it was also useful to know whether or not police charge data could be used as the input source for GRAM 2. To undertake this comparison, data was extracted from the NSW Police Force's Computerised

Operational Policing System (COPS) for criminal incidents proceeded to court (or YJC for juveniles) against persons of interest in 2011 who were aged 15 years or older. People who received a caution, criminal infringement notice or warning were excluded. COPS charge data on persons of interest proceeded against were linked to ROD by unique offender identification number and charge date / index date, in order to ascertain whether a person of interest had a reoffence which was proven in court within two years of the initial charge. It should be noted that the penalty received (from the index charges) could not be ascertained from the police data, hence those who ultimately received a custodial sentence for the index charge could not be excluded. In addition, previous custodial sentences received also could not be obtained from the police data. Parameter estimates derived from the GRAM 2 (proven offence model) were applied to the police charge data and predicted probabilities of reoffending were compared with actual reoffence rates.

RESULTS

DESCRIPTIVE & BIVARIATE ANALYSES

The cohort consisted of 81,199 adults (of whom 26% reoffended within two years of the index appearance) and 4,360 juveniles (with a reoffending rate of 58%). Model analysis on the entire cohort indicated that separate models for juvenile and adults were required but for adult offenders, separate models for each gender were not required (see Appendix, Table A1 for these predicted reoffence rates compared with the actual reoffence rates). Hence results for the adult model are only presented from this point onwards. The juvenile model will be published in a later report.

Table 1 shows the bivariate associations between significant explanatory variables and reoffending in adults. Higher rates of reoffending were increasingly associated with offenders who were male, younger, Indigenous or the most socio-economically disadvantaged. Reoffending risk also increased with more concurrent offences at the index appearance and with a greater number of prior appearances with a proven offence or where a custodial sentence had been imposed within the previous five years. Higher rates of reoffending were also found for those with more prior appearances for a property or violent offence, and those who had received a caution in the previous five years. Reoffending also varied with the type of index offence and was slightly more common in offenders who appeared initially in the Local Court rather than the District or Supreme Court.

FINAL ADULT MODEL

Model development and Goodness-of-fit

Initially, the same variables as proposed by Smith and Jones (2008a) were included in the regression model. These included age, gender, Indigenous status, number of previous proven offences, number of concurrent offences, index offence and jurisdiction (Step 1, Table 2). The fit statistics for the resultant model were AUC=.764, and H-L statistic *p*=.001. As the age classification provided by Smith and Jones did not result in incremental parameter estimates for age, age groups were reclassified as 15-17 years, 18-24 years, 25-34 years, 35-44 years and 45 years and above. This did not alter the model fit and resulted in better incremental parameter estimates. Changing the Indigenous status from ever-recorded to status recorded at index contact however resulted in a lower AUC of .745, hence the original classification of Indigenous status (ever recorded) was kept. As jurisdiction had the least input[3] into the model we examined removing this and found that its removal slightly improved the model fit (Step 4, Table 2; AUC=.764, H-L *p*=.03). We then investigated whether adding any additional variables not included in the Smith and Jones model improved model fit.

Firstly, we added the number of prior appearances in which a custodial sentence was given (Step 5) and this provided us with an improved AUC=.765 and H-L *p*-statistic=.06. The removal of index offence type from the model resulted in worse fit (Step 6) and the addition of the number of prior appearances with a proven property offence or previous violent offence, or if a caution had previously been received (Steps 7-9) did not substantially improve the goodness-of-fit. Similarly, the addition of socio-economic disadvantage or remoteness of residency did not contribute to the model fit (Steps 10-11). Finally, altering the prior custodial sentence variable to binary (yes / no) did not substantially alter the model (AUC=.765, *p*-value=.07). Keeping in mind the relative ease with which a screening officer can obtain a response to this classification, it was decided that previous custodial history should be changed to a yes / no classification (Step 12). When previous appearances with a proven offence was also examined in the model as a yes / no classification, worse model fits resulted, hence the ordinal classification of this variable was kept.

The cohort was also extended to include offenders who were sentenced to a fulltime custodial sentence with a maximum of one year in prison, however the internal validity of the model based on this extended cohort was worse due to the significant H-L statistic (AUC=.763, *p*-value=.003).

Table 3 shows the odds ratios and parameter estimates of the final regression model. After adjusting for all covariates in the model, the relationships described in the bivariate associations were maintained. Male offenders, those who were Indigenous and younger offenders had a higher likelihood of reoffending. Increased risk of reoffending was seen with increasing number of concurrent offences, whether or not a custodial sentence had been given in the previous five years (OR=1.79, 95% C.I.

Table 1. Characteristics of distinct offenders convicted in NSW Local, District and Supreme Courts in 2011 (N=81,199) and the bivariate relationship between offender characteristics and reoffence within two years

Characteristic		N within category	% Reoffended
Sex	Male	63,980	27.3
	Female	17,219	20.8
Age	15-17	638	36.4
	18-24	22,090	30.5
	25-34	23,510	28.5
	35-44	18,180	26.1
	45 and above	16,781	15.6
Indigenous status	Non-Indigenous	56,454	27.2
	Indigenous	9,675	51.1
	Unknown	15,070	4.7
Socioeconomic disadvantage	Most disadvantaged	18,071	30.5
	Quarter 2	20,001	28.2
	Quarter 3	19,160	27.0
	Least disadvantaged	20,240	21.0
	Missing	3,727	12.0
Remoteness	Major City	54,015	26.0
	Inner regional	17,124	27.4
	Outer regional	5,547	28.3
	Remote	529	32.3
	Very remote	294	43.9
	Missing	3,690	12.0
Jurisdiction	Local Court	80,399	26.0
	District/Supreme Court	800	19.6
Index offence type	Driving	38,889	19.9
	Violent/sexual	10,825	25.5
	Theft / property	6,164	33.7
	Drug	6,861	30.6
	Justice	7,351	38.3
	Other	11,109	31.9
Number of concurrent offences	None	55,645	22.6
	One	14,406	30.2
	Two or more	11,148	37.0
Number of prior appearances with a proven offence in past 5 years	None	45,251	13.6
	One	16,179	29.0
	Two to three	12,912	44.3
	Four or more	6,857	65.2
Number of prior appearances where a custodial sentence was given in previous 5 years	None	76,180	23.3
	One	2,999	59.7
	Two or more	2,020	74.3
Number of prior property offences in previous 5 years	None	72,337	22.1
	One	5,766	51.3
	Two or more	3,096	68.2
Number of prior violent offences in previous 5 years	None	68,388	21.4
	One	9,360	45.4
	Two or more	3,451	62.5
A caution received in previous 5 years	No	75,819	24.5
	Yes	5,380	45.9

Note. All chi-square tests of association between reoffending and offender characteristics had *p*-values less than .01 indicating statistically significant bivariate relationships between reoffending and the offender characteristics.

Table 2. 2011 Model development process predicting reconviction within two years for offenders receiving non-custodial sentences in NSW adult courts

Step	Model	AUC	H-L *p-statistic*	Max r^2	Accept / Reject Step
1.	Using 2002 Model as base: Gender Indigenous status Age (13-21; 22-29; 30-39; 40 and above) Jurisdiction Index offence type Number of concurrent offences Number of court appearances with a proven offence in previous 5 years	.764	.001	.240	n/a
2.	Changing age classification of Step 1 to (15-17; 18-24; 25-34; 35-44; 45 and above)	.764	.002	.240	Accept
3.	Keeping new age classification and changing Indigenous status (ever) to Indigenous status at contact	.745	<.001	.209	Reject
4.	Removing jurisdiction from Step 2.	.764	.03	.240	Accept
5.	Add number of prior court appearances at which given a custodial sentence in previous 5 years to Step 4.	.765	.06	.244	Accept
6.	Removing index offence type from Step 5.	.764	<.001	.243	Reject
7.	Add number of previous appearances with a property offence to Step 5.	.766	.005	.246	Reject
8.	Add whether or not received a previous caution to Step 5.	.767	.002	.247	Reject
9.	Add number of previous appearances with a violence offence to Step 5.	.765	.06	.244	Reject
10.	Add SEIFA to step 5.	.765	.06	.244	Reject
11.	Add remoteness of residency to Step 5.	.762	.02	.240	Reject
12.	Change classification of court appearance with previous custodial sentence to y/n GRAM 2: Gender Indigenous status Age (15-17; 18-24; 25-34; 35-44; 45 and above) Index offence type Number of concurrent offences Number of court appearances with a proven offence in previous 5 years Whether or not have received a custodial sentence in previous 5 years	.765	.07	.244	Accept
13.	Change classification of previous appearances with proven offences to y/n	.757	.03	.228	Reject
14.	Adding offenders serving custodial sentence and using Model 2011	.763	.003	.243	Reject

Table 3. Final logistic regression model predicting reconviction within two years for offenders receiving non-custodial sentences in NSW adult courts in 2011 (N=81,199)

Characteristic		Parameter estimate (standard error)		Odds Ratio (95% C.I.)
Intercept		-2.216 (0.034)	***	
Sex	Male vs Female	0.230 (0.023)	***	1.26 (1.20, 1.32)
Indigenous status	Indigenous vs Non-Indigenous	0.571 (0.025)	***	1.77 (1.69, 1.86)
	Unknown vs Non-Indigenous	-1.435 (0.042)	***	0.24 (0.22, 0.26)
Age	35-44 vs 45 and above	0.343 (0.029)	***	1.41 (1.33, 1.49)
	25-34 vs 45 and above	0.426 (0.028)	***	1.53 (1.45, 1.62)
	18-24 vs 45 and above	0.590 (0.028)	***	1.81 (1.71, 1.91)
	15-17 vs 45 and above	1.410 (0.094)	***	4.10 (3.41, 4.92)
Index offence type	Violent/sexual vs Driving	-0.138 (0.028)	***	0.87 (0.82, 0.92)
	Property/theft vs Driving	0.129 (0.034)	**	1.14 (1.06, 1.22)
	Drug vs Driving	0.038 (0.032)		1.04 (0.98, 1.11)
	Justice vs Driving	0.083 (0.031)	*	1.09 (1.02, 1.16)
	Other vs Driving	0.108 (0.027)	***	1.11 (1.06,1.17)
Number of concurrent offences	One vs None	0.087 (0.023)	**	1.09 (1.04, 1.14)
	Two or more vs None	0.234 (0.025)	***	1.26 (1.20, 1.32)
Number of prior appearances with proven offence in past 5 years	One vs None	0.641 (0.023)	***	1.90 (1.81, 1.99)
	Two to three vs None	1.108 (0.024)	***	3.03 (2.89, 3.18)
	Four or more vs None	1.697 (0.033)	***	5.46 (5.11, 5.82)
Previous custodial sentence	Yes vs No	0.583 (0.036)	***	1.79 (1.67, 1.92)

Note. *p<.05; **p<.002; ***p<.001

1.67, 1.92) and with increasing number of appearances with a proven offence in the previous five years – with the odds for those with four or more prior appearances 5.5 times higher than those without any priors (95% C.I. 5.11, 5.82). The AUC of the final model was .765, indicating that the model provided an acceptable level of discrimination between true and false positives, and the H-L test statistic was not statistically significant (p=.07, χ^2=14.6, df=8). We therefore concluded that the model adequately fitted the data. Table 4 compares the odds ratios and the parameter estimates of GRAM 2 and the Smith and Jones model and found that GRAM 2 provided similar results to those of Smith and Jones (Table 4).

External validity of the final model

Using a 50:50 randomised split (two-fold cross-validation) we measured the external validity of the model. Here the model was "trained" on the first half (n=40,599) and then "tested" on the second half (n=40,600) where the estimates from the "trained" model were used to provide the predicted probabilities of the "tested". The AUC of the training sample was .766, very similar to that of the test sample of .768. Both are therefore similar to that of the final model of .765.

Table 5 shows observed and predicted rates of reoffending for the test sample by the variables of interest. Overall, there was excellent concordance between observed and predicted rates of reoffending in the test sample, with most estimates within 1-2 percentage points of the actual reoffence rate. Some variation from the observed rate was noted in remote areas of residency where a higher predicted rate (up to 4 percentage points) occurred; indicating that care should be taken when applying the model to small group classifications. Lower predicted rates occurred for offenders with a prior proven property/theft offence with a discrepancy of up to 6 percentage points found between predicted and observed reoffending rates. Similarly, careful consideration should be given to those with two or more previous custodial sentences, where the predicted rate was 6 percentage points lower than the actual rate.

APPLICATION OF THE MODEL

The parameter estimates from the final regression model based on the 2011 cohort were applied to similar cohorts of offenders with at least one proven offence finalised in 2012 or 2013. Estimated reoffending rates were then compared to observed rates of reoffending to examine estimates over time. The results from these analyses are summarised in Table 6. The predicted rates were 1.3 percentage points and 1.4 percentage points lower than the observed rates respectively, which suggest that reoffending rates are higher in 2012 and 2013 than predicted by the GRAM 2 model.

Table 4. Comparison between parameter estimates and odds ratios of the adult 2011 and 2002 models

Characteristic		2011 model		2002 model[a]	
		Parameter estimate	Odds Ratio (95% C.I.)	Parameter estimate	Odds Ratio (95% C.I.)
Intercept		-2.216		-1.745	
Gender	Female vs Male			-0.155	0.86 (0.82, 0.90)
	Male vs Female	0.230	1.26 (1.20, 1.32)		
Indigenous status	Indigenous vs Non-Indigenous	0.571	1.77 (1.69, 1.86)	0.539	1.71 (1.62, 1.81)
	Unknown vs Non-Indigenous	-1.435	0.24 (0.22, 0.26)	-2.036	0.13 (0.11, 0.15)
Age	13-21 vs 40 and above			0.741	2.10 (1.98, 2.22)
	22-29 vs 40 and above			0.259	1.30 (1.23, 1.37)
	30-39 vs 40 and above			0.305	1.36 (1.29, 1.43)
	15-17 vs 45 and above	1.410	4.10 (3.41, 4.92)		
	18-24 vs 45 and above	0.590	1.81 (1.71, 1.91)		
	25-34 vs 45 and above	0.426	1.53 (1.45, 1.62)		
	35-44 vs 45 and above	0.343	1.41 (1.33, 1.49)		
Index offence	Violent vs Driving	-0.138	0.87 (0.82, 0.92)	0.075	1.08 (1.02, 1.14)
	Theft vs Driving	0.129	1.14 (1.06, 1.22)	0.329	1.39 (1.31, 1.48)
	Drug vs Driving	0.038	1.04 (0.98, 1.11)	0.178	1.20 (1.11, 1.29)
	Other vs Driving	0.108	1.11 (1.06, 1.17)	0.248	1.28 (1.22, 1.34)
	Justice vs Driving	0.083	1.09 (1.02, 1.16)	[b]	[b]
Number of concurrent offences	One vs None	0.087	1.09 (1.04, 1.14)	0.126	1.13 (1.08, 1.19)
	Two or more vs None	0.234	1.26 (1.20, 1.32)	0.234	1.26 (1.21, 1.32)
Prior convictions (5 or 8) [c]	One vs None	0.641	1.90 (1.81, 1.99)	0.51	1.67 (1.58, 1.75)
	Two to three vs None	1.108	3.03 (2.89, 3.18)	0.908	2.48 (2.36, 2.61)
	Four or more vs None	1.697	5.46 (5.11, 5.82)	1.572	4.82 (4.57, 5.08)
District/Supreme court vs Local court		-		-0.507	0.60 (0.50, -0.72)
Prior custodial sentence	Yes vs No	0.583	1.79 (1.67, 1.92)	-	

[a] Smith and Jones, 2008a

[b] Justice was not included as a separate offence category in Smith and Jones (2008a)

[c] Smith and Jones (2008a) used convictions in the previous 8 years; the 2011 model used proven offences in the previous 5 years

Application of the model parameter estimates to specific sub-populations of offenders (Table 7) showed that the model was generally robust. Predicted two-year reoffence rates were similar (and not statistically significantly different) to observed rates at selected courts and in selected LGAs. Observed and predicted reoffence rates also did not vary significantly by type of offence at the index appearance (i.e. any proven property offence or any proven violent offence) or by type of penalty (i.e. a supervised order).

For the larger courts of Parramatta, Burwood, Bankstown and Newcastle, the predicted two-year reoffence rate was similar to that observed (within 1-2 percentage points of the observed rate). For the smaller courts, the predicted rates were within 2-3 percentage points of the observed rates, although due to the larger confidence intervals these differences were not statistically significant. For residency, most of the LGAs shown had a predicted reoffence rate within 2-3 percentage points of the actual rate, with the exception of Burwood LGA and Orange LGA. Again, however, due to the small sample size and hence the wider confidence intervals, the difference in the rates (of 3.5 percentage points each) were not statistically significant with estimates underestimated for each LGA. Hence caution is required when applying the model to predict reoffending in small areas or cohorts.

Predicted reoffence estimates were found for cohorts with specific offence types at the index appearance (i.e. this may have occurred at the index appearance but may not have been the principal offence), with a difference within 1 percentage point of actual and predicted rates for offenders having a proven violent or property/theft offence. Similar rates of predicted and actual reoffence rates were also seen for offenders given a supervised order at the index appearance (within a 3 percentage point difference).

Table 5. Observed and predicted rates of reoffending by variables of interest of the test cohort (50:50 split) using the estimates from the training sample

			Observed n=40,599	Predicted n=40,600
Characteristic	**Category**	**N**	**%**	**% (95% C.I.)**
Gender	Male	31,989	27.5	26.9 (26.4, 27.4)
	Female	8,611	20.5	20.6 (19.7, 21.5)
Age group	15-17	312	34.9	37.6 (32.2, 43.0)
	18-24	11,043	31.0	30.1 (29.2, 31.0)
	25-34	11,777	28.3	28.2 (27.4, 29.1)
	35-44	9,052	26.1	25.8 (24.9, 26.7)
	45 and above	8,413	16.0	15.3 (14.5, 16.0)
Indigenous status (ever recorded)	Non-Indigenous	28,189	27.3	27.0 (26.5, 27.5)
	Indigenous	4,811	51.1	51.2 (49.8, 52.6)
	Unknown	7,600	5.3	4.1 (3.6, 4.5)
Remoteness area of residency	Major city	27,060	26.0	25.1 (24.6, 25.6)
	Inner regional	8,569	28.2	27.3 (26.4, 28.3)
	Outer regional	2,727	27.7	28.5 (26.8, 30.2)
	Remote	263	29.7	33.7 (28.0, 39.5)
	Very remote	139	43.2	42.7 (34.5, 51.0)
	Missing	1,842	11.2	17.8 (16.1, 19.6)*
SEIFA	Most disadvantaged	8,900	30.7	29.1 (28.2, 30.1)
	Quartile 2	10,057	28.8	27.3 (26.4, 28.2)
	Quartile 3	9,563	27.2	26.2 (25.3, 27.1)
	Least disadvantaged	10,226	20.8	21.6 (20.8, 22.4)
	Missing	1,854	11.2	17.9 (16.1, 19.6)*
Prior appearances with proven offences in previous 5 years	None	22,740	13.7	13.4 (13.0, 13.8)
	One	8,031	28.8	29.0 (28.0, 30.0)
	Two, Three	6,420	44.9	43.7 (42.5, 44.9)
	Four or more	3,409	66.0	64.7 (63.1, 66.3)
Custodial sentence in previous 5 years	None	38,132	23.5	23.0 (22.6, 23.4)
	One	1,465	58.6	62.6 (60.2, 65.1)
	Two or more	1,003	76.3	70.4 (67.6, 73.2)[a]
Proven violent offence in previous 5 years	None	34,218	21.4	21.1 (20.7, 21.6)
	One	4,666	45.6	45.1 (43.7, 46.5)
	Two or more	1,716	64.5	61.5 (59.2, 63.8)
Proven property/theft offence in previous 5 years	None	36,198	22.2	22.2 (21.8, 22.7)
	One	2,844	51.9	47.8 (46.0, 49.7)*
	Two or more	1,558	68.4	62.8 (60.4, 65.2)*

Note. 50% training sample AUC=.766, r^2=.246; 50% test sample AUC=.768, r^2=.253

* Difference between the observed and predicted reoffence rate significant at $p<.05$

[a] Although not statistically significant, the difference between the predicted and observed reoffence rates are notable at greater than 5 percentage points.

Table 6. Predicted and observed rates of recidivism among the 2012 and 2013 adult samples, based on the estimates derived from the final logistic regression model of the 2011 adult sample

Year	N	Observed (95% C.I.)	Predicted (95% C.I.)
2011	81,587	26.9 (26.6, 27.3)	n/a
2012	76,062	29.2 (28.8, 29.5)	27.9 (27.6, 28.2)
2013	76,539	29.2 (28.9, 29.6)	27.8 (27.5, 28.2)

Table 7. Predicted and observed recidivism rates for smaller cohorts of offenders given non-custodial sentences in adult NSW courts in 2011

Variable	Category	N	Observed	Predicted (95% C.I.)
Court	Bankstown	2,408	27.0	25.8 (24.1, 27.6)
	Parramatta	3,079	25.1	25.1 (23.6, 26.7)
	Burwood	3,619	25.2	24.7 (23.3, 26.1)
	Newcastle	1,826	27.1	27.2 (25.3, 29.3)
	Lismore	788	26.7	30.2 (27.1,33.5)
	Orange	753	32.9	30.3 (27.1, 33.7)
	Dubbo	652	29.3	32.0 (28.5, 35.7)
LGA	Bankstown	2,134	28.4	26.6 (24.8, 28.5)
	Parramatta	1,966	26.4	26.1 (24.2, 28.1)
	Burwood	275	25.8	22.2 (17.7, 27.5)
	Newcastle	1,644	28.2	27.3 (25.1, 29.4)
	Lismore	519	28.5	30.9 (27.0, 35.0)
	Orange	572	34.4	30.9 (27.2, 34.8)
	Dubbo	578	28.7	31.7 (28.0, 35.6)
Any proven property offence at index appearance	Females	2,372	28.8	28.4 (26.6, 30.2)
	Males	4,734	38.6	38.1 (36.8, 39.5)
Any proven violent offence at index appearance	Females	2,901	22.3	23.3 (21.8, 24.9)
	Males	11,349	29.4	29.1 (28.3, 30.0)
Supervised sentence	Females	2,103	30.8	33.6 (31.6, 35.6)
	Males	9,707	37.7	39.0 (38.1, 40.0)

Note. Predicted estimates were not statistically significant from the actual reoffence rate for any variables.

Finally, when we examined sensitivity and precision (or PPV) of the final model at various thresholds of predicted probabilities, the results were not optimal (Table 8). As a reminder, sensitivity is the ability of the model to correctly identify someone who will go on to reoffend. The PPV is the proportion of those who reoffend out of those identified as being at-risk of reoffending. If this model is to be used for screening purposes by attending officers to predict reoffences amongst offenders receiving non-custodial sentences, then false positives and misclassifications of those at most risk would occur. For offenders given a non-custodial sentence and who were found to have predicted probabilities of recidivism of .3 or greater (i.e. classified at being at increased risk), it is estimated that only 61% of those who did go on to reoffend were classified at increased risk; and of those considered at-risk of reoffending (which was 33% of the cohort) approximately half (48%) would then go on to reoffend. As the classification of being at increased risk moved to a higher threshold of predicted reoffending probability, sensitivity became

Table 8. Sensitivity, specificity and positive predictive value (PPV) at various thresholds of reoffending from the 2011 final model

Threshold / Cut off	Number >= threshold	Sensitivity	Specificity	PPV
.3	27,049	61.2	76.4	47.6
.4	16,595	44.0	87.8	55.8
.5	10,041	30.0	93.8	62.8
.6	5,440	18.0	97.2	69.4
.7	2,540	9.1	99.0	75.3

Table 9. Predicted and observed rates of recidivism for the 2011 police charge adult sample, based on the estimates derived from a logistic regression model of the 2011 court adult sample (where previous custodial sentence was not included in the model)

Gender	N	Observed (95% C.I.)	Predicted (95% C.I.)
Female	17,685	27.5 (26.8, 28.1)	22.0 (21.4, 22.6)
Male	72,924	34.9 (34.6, 35.3)	29.0 (28.7, 29.3)

Note. Model fits where previous custodial sentence was not included were AUC=.764, H-L *p*-value=.03.

worse but precision and specificity improved. Hence, for a recidivism threshold of .7 or greater, of those considered at-risk of reoffending within two years (which was 3% of the cohort), 75% would proceed to reoffend, whilst only 9% of those who did go on to reoffend would have been classified as being at increased risk.

We also considered whether the model could be used on police charge data. To do this we linked persons of interest with matters proceeded against by police in 2011 from the COPS database to ROD to determine two-year reoffences. Parameter estimates from GRAM 2 were then applied to the charge data in order to compare actual and predicted reoffending rates. Estimates for age, gender and Indigenous status were applied directly but the parameter estimate of number of concurrent offences was applied to the number of current charges variable and the estimate for the number of prior court appearances with a proven offence was applied to the number of charges in the previous five years. However, as the police charge data did not contain information on prior custodial sentences, model estimates were obtained using the final model but with no custodial history included (i.e. effectively the model derived in Step 4, Table 2). In addition, where there were multiple charges at the index date, index charge type was assigned using the following hierarchy: violence, robbery/theft, driving, drug, offences against justice procedures.

Table 9 shows that applying the parameter estimates from GRAM 2 to a new cohort derived from police charge data resulted in less accurate predictions of a new proven court offence within 24 months; with up to 6 percentage point differences between the observed and predicted rates for both male and female offenders.

DISCUSSION

The primary aim of this study was to extend earlier BOCSAR work on risk assessment by updating and recalibrating GRAM (Smith & Jones, 2008). Informed by prior research, factors significantly associated with reoffending were identified and included in a multivariate model predicting reoffending within 24 months, and the validity of the resultant model (GRAM 2) was tested. Issues associated with the application of the new risk assessment tool were also explored in this study. Specifically, we examined the extent to which GRAM 2 could be validly used to screen offenders for further intervention/assessment, as well as the accuracy of the model in predicting recidivism amongst smaller subsamples of offenders. During the course of model development it became evident that separate analyses needed to be undertaken for adults and juveniles, and for adult custodial and adult non-custodial populations, which was similar to previous studies (Cunliffe & Shepherd, 2007; Smith & Jones, 2008a; 2008b; Whiting & Cuppleditch, 2006). The current report presented the results from the adult non-custodial model. Earlier risk assessment tools for juveniles and custodial populations have been dealt with elsewhere (Howard et al., 2009; Smith & Jones, 2008a; 2008b).

Consistent with Smith and Jones (2008a), the strongest predictor of adult reoffending within 24 months of appearing in court was criminal history. The odds of a new offence was over five times greater for offenders with four or more prior proven appearances compared with offenders who had none and 80% higher for offenders who had previously been sentenced to custody compared to those who had no prior custodial sentence. Reoffending likelihood was also higher amongst men, Indigenous offenders, younger offenders and those with a greater number of

concurrent offences at their index court appearance. There were also small but significant differences in reoffending likelihood across different offence types, with property offenders being identified as the most likely group to reoffend within two years. Model fit was maximised with the exclusion of court jurisdiction and the inclusion of prior custodial sentence as explanatory variables; the only two deviations from the original GRAM. Where they were able to be compared, parameter estimates from GRAM 2 were also very similar to the original GRAM, demonstrating that these risk factors are relatively stable predictors of reoffending.

Overall, GRAM 2 had a high degree of accuracy in predicting two-year recidivism rates. The AUC for the full model was .765, indicating an acceptable level of discrimination between groups and an improvement on the original GRAM (AUC .736; Smith & Jones 2008a). In addition, two-fold cross-validation showed that the model had good external validity for potential explanatory variables, however some discrepancies were seen where low numbers of classification resulted; such as in offenders residing in remote areas (where the model overestimated reoffending rates) and for offenders with a prior property/theft offence and for those with two or more prior custodial sentences (where the model underestimated reoffending rates).

The accuracy of the model in predicting reoffending among different cohorts of offenders was also generally good, with close concordance between observed and predicted proportions reoffending for most sub-populations of interest. However, there were some notable discrepancies. In particular, the model lost some fidelity when applied to small LGAs of residency. For example, there were up to 3.5 percentage point differences between actual and predicted reoffence rates for LGAs with relatively low volumes of offenders (e.g. Orange and Burwood). Together these results suggest that while GRAM 2 is a useful tool for predicting reoffending amongst the broader non-custodial population, its efficacy is reduced when applied to offender subgroups, particularly comparatively small cohorts.

Given that the discriminative ability of GRAM 2 was found to be acceptable, the model was used to examine trends in reoffending rates over time after adjusting for the characteristics of offenders coming before the courts. This analysis found significant differences between observed and predicted rates of reoffending for the 2012 and 2013 cohorts. In both years, the observed reoffending rate was 29.2%. However, the predicted rates adjusted for offender characteristics within these year cohorts were lower at 27.9% and 27.8% for 2012 and 2013, respectively. While this suggests that there may have been an upward trend in reoffending rates that cannot be accounted for by the type of offenders being charged, the difference between the observed and predicted reoffending rates is small (less than 1.5 percentage points) and therefore its clinical significance is questionable. Further work should be undertaken to determine whether this is a meaningful and ongoing change in reoffending rates or an artefact of the base year on which GRAM 2 was estimated.

The viability of GRAM 2 for use as a screening or triage tool was also considered in this study. Here, the purpose of GRAM 2 would be to classify offenders as “at-risk” of reoffending if they exceed a specific threshold or cut-off, thereby justifying their referral for further assessment or treatment/support. As with other similar screening tools (Lind, 2011; Ringland, 2011; Ringland et al., 2015), GRAM 2 did not provide high levels of accuracy in predicting, at the individual-level, who was at most risk of reoffending. A large proportion of misclassifications in the form of misses and false alarms were noted. For example, if a reoffending probability of .3 was selected as the cut-off for further intervention 27,049 offenders (33% of the cohort) would be identified as at-risk but only half of this group would actually go on to reoffend (PPV) and less than two-thirds of those who did reoffend would have been successfully identified (sensitivity). At the other extreme, using a threshold of .7 or greater would result in only 2,540 offenders being classified as at-risk of reoffending. While most of these 2,540 offenders will ultimately reoffend (75% PPV), just nine per cent of those who did reoffend would have been successfully identified and included in this group “targeted” for intervention. This illustrates that if GRAM 2 is to be used as a screening tool it is imperative that the benefits of correctly identifying an offender who goes on to reoffend are carefully weighed against the costs of falsely labelling an individual as a potential recidivist, or missing the opportunity to intervene with a higher number of high-risk offenders.

The stage within the criminal justice system at which individuals are to be screened or triaged for further intervention should also be taken into consideration. The analyses presented here suggest that GRAM 2 has a high degree of predictive accuracy when estimates are based on administrative court data but performs poorly when applied to police charge data. Using police charge data to predict the probability of a proven offence within two years resulted in discrepancies between actual and predicted reoffence rates of up to 6 percentage points. This is primarily because police charge data are unable to accurately measure current or prior incarceration history, prior offences or principal offence; factors demonstrated here as important predictors of reoffending risk. GRAM 2 would therefore be best placed to screen offenders at the point at which they appear before the court or after they have been sentenced. Were there a need to screen offenders at the point of charge then it would be necessary to develop and test a new purpose-built tool.

Despite the limitations outlined above, GRAM 2 provides a satisfactory basis for predicting reoffending which is superior to “guesswork” alone. It performs well when predicting reoffending

rates at the population level and is relatively accurate in predicting reoffence rates amongst most subgroups of offenders (although care is necessary when applying estimates to subgroups with small cohorts). Its usefulness at the individual level, however, is somewhat limited as misses and false alarms are common. Decisions based solely on an offender's predicted probability of reoffending from GRAM 2 estimates should therefore be avoided. There are numerous other factors known to be related to reoffending which are not captured in administrative data and therefore could not be considered for inclusion in GRAM 2. These include such things as history or current use of drugs and alcohol, employment status, marital status, motivation to change and support networks (Ringland, 2011; Smith & Jones, 2008a; 2008b). Clinical assessment of these factors should be combined with actuarial estimates in order to better judge who is at most risk of reoffending. In this way, GRAM 2 should be viewed as a first-step triage instrument which identifies "at-risk"' offenders who require further more comprehensive risk assessment (such as the Level of Service Inventory – Revised; see Andrews & Bonta, 1995).

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NOTES

1. Including cautions as a re-offence made little change to the re-offence rate (with an increase of 0.4%).
2. This approach was chosen to provide consistency with that taken by Smith and Jones (2008a), despite the potential for those aged 15-17 years to be those with more serious offences.
3. Jurisdiction was the last step in the model and the AUC did not improve from .764.

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APPENDIX

Table A1. Predicted and observed recidivism rates for juvenile and adult offenders given non-custodial sentences in adult NSW courts in 2011 using the model estimates derived from the entire cohort of juvenile and adults

Cohort		N	Observed	Predicted (95% C.I.)
Juvenile	Male	3,368	61.7	57.8 (56.1, 59.4)
	Female	992	44.0	49.9 (46.8, 53.0)
Adult	Male	63,980	27.3	27.5 (27.1, 27.8)
	Female	17,219	20.8	20.5 (19.9, 21.1)

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