REVISED ASSESSMENT PROTOCOLS AND SCORING METHODS FOR THE AUSTRALIAN CHILD RESTRAINT EVALUATION PROGRAM

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ABSTRACT

A consumer information based child restraint evaluation program was initiated in Australia in 1992. The assessment and evaluation procedures used in this program were recently reviewed and as a result, the assessment protocols and scoring methods have been significantly enhanced. This paper presents the revised assessment methods currently being used in the Australian Child Restraint Evaluation Program. The program includes both a dynamic performance assessment and an ease of use assessment.

Dynamic assessment includes frontal testing (56km/h and 34g) and two side impact tests (90 degree, 32 km/h and 16g; and 66 degree, 32 km/h and 16g). The side impact test set up includes a non-intruding side door structure. Rearward facing, forward facing and booster seats are subjected to all dynamic tests using dummies corresponding to their upper mass range design limits. An approach based on an objective, pre-defined rating matrix was developed to score and rate the relative dynamic performance.

The ease of use assessment method is based on the North American methods used by ICBC and NHTSA. Some enhancements to the individual items assessed and the ratings used were made to suit Australian conditions. Details of these enhancements are presented.

A scoring system that allows for a four step (A-D) rating system for both the dynamic and the ease of use performance was introduced and this is also presented and discussed in detail in this paper. Exemplar results from the first series of assessments are presented to demonstrate the benefits of the revised protocol and the scope for further improvements to the methods being used.

The process for the release of the test results and the response from media are also outlined.

BACKGROUND

The Australian Child Restraint Evaluation Program (CREP) has been operating in Australia since 1992. Like all consumer information programs, the underlying philosophy is to influence consumers and to provide motivation for manufacturers to market products that are at least equal to the best currently available, and that offer protection above the minimum requirements of the Australian Standard for child restraints (AS 1754). The first CREP was comprised of three assessment units; an assessment of dynamic crash performance; an evaluation of ease of installation and use; and an assessment of vehicle compatibility.

Original ease of installation and use trials were modelled on a draft International Standards Organization (ISO) child restraint system fitting trial standard that required recruitment of child and adult subjects [1]. This method proved to be a relatively expensive and time consuming exercise that did not reflect the observed problems with misuse. Following publication of results from the first CREP series, ease of use protocols were simplified and combined with the vehicle compatibility trial. This combination was then used for CREP Stages 2 (1996) and 3 (1999-2000).

More recently, Rona Kinetics developed comprehensive ease of use assessment protocols for the Insurance Corporation British Columbia (Canada) [2]. These were then adapted further by the National Highways Traffic Safety Administration (NHTSA) [3]. This development, together with concerns that the Australian CREP dynamic performance assessment was not keeping pace with test severities in New Car Assessment Program protocols, led to a review of the CREP assessment procedures in 2005. The outcomes from this review were more comprehensive ease-of-use assessment protocols, a revised dynamic test protocol and innovative scoring protocols [4].

This paper describes the new protocols being used in the Australian CREP and presents exemplar results achieved with these protocols.

EASE OF USE ASSESSMENTS

Misuse of child restraints is a significant problem, both in terms of frequency and consequence [5-12]. Reducing the propensity for misuse through improved restraint design is an important countermeasure to this problem. Review of results from earlier releases of the Australian CREP demonstrated that while substantial comparative information was collected about the ease of use of restraints on the Australian market (showing there were considerable differences between products), little information regarding the outcome of these assessments was actually communicated to the public. Furthermore, the methods used relied wholly upon expert opinion and were not documented in an objective way.

Following this review, significant changes were made to the ease of use evaluations and a methodology developed that allows for more objective rating of features weighted on their likely impact on reducing misuse, and the types of misuse that are influenced. This method is heavily based on the current North American ease of use rating schemes [3].

The ease of use criteria used are summarised in Appendix 1. Full details can be found at http://tinyurl.com/29me5k. The protocol is very similar to that used by NHTSA [3] with additional assessments of some features and a modified feature assessment ranking.

This method requires each feature listed within five 'categories' to be assessed individually. The 'categories' are: Packaging, Instructions, Labels, Securing/Releasing the Child, and, Securing/releasing the restraint within the vehicle (the latter was not used for booster ratings). Good, Acceptable, Marginal and Poor ratings were recorded for each feature according to the criteria set out for that feature (see Appendix 1), and where necessary additional comments were made. Results were stored within an electronic database. Digital photographs of each restraint and relevant components were taken.

As with earlier iterations of CREP, each device was evaluated by a single 'expert' assessor. However, to increase confidence in ratings, a second 'expert' independently did audit style assessments on a small sample of the restraints. A panel then compared the results and where appropriate, reviewed the assessment criteria and ratings for all restraints.

Initially, it was intended to use the same scoring protocol as NHTSA [3]. In this method each feature within each category is assigned a weighting factor of either 3, 2 or 1 according to risk of injury and severity of misuse. The features associated with the highest risk of severe injury if misuse occurs are given a 3 weighting. A numerical scale is also used to score the assessment outcome for each feature, with 3 points equating to good, 2 points to acceptable and 1 point to marginal and zero for poor. Under the NHTSA method, the two numbers are then multiplied together to provide a feature score (from 9 to zero). The scores within each category are then summed and divided by the sum of the applicable fixed weighting factors to provide a weighted average score. Similarly, an overall weighted average score is obtained by dividing the sum of all feature scores by the sum of all fixed weighting factors. The NHTSA weighted average will always be between 1 and 3 and within this range either 'C' 'B' or 'A' ratings are awarded for scores of < 1.7, 1.7 but < 2.4 and 2.4 – 3, respectively.

This approach to scoring had never been attempted in Australia. For this reason, results obtained using this ranking procedure, were carefully examined prior to finalization of the scoring protocol. Early analysis revealed that the "A, B, C" ratings did not usefully discriminate between products. This was contrary to the outcomes from direct observation of restraints during assessment, which identified significant differences. In particular most categories and overall ratings came out a "B" under the tripartite method. To overcome these problems, the weighted average method has been modified to allow A, B, C, and D ratings to be assigned for each category and for the overall performance to be based on a quartile ranking system.

In addition, a weighting factor of 4 was introduced to provide for design features that were innovative and effective in reducing the propensity for misuse. An example is "Audible and visual indication that harness is adjusted correctly" (See Appendix 1).

Under the NHTSA ranking method the range between the maximum and minimum value (with minimum value being 1/3 of the maximum value) is divided into 3 equal segments. Breakpoints are therefore 80% of the maximum score and above for A, 57% of the maximum score and above for B and below 57% for C. Our modification involves dividing this same range (i.e. range between maximum and 1/3 of the maximum) into four, so that breakpoints become 83% of maximum and above for A, 67% and above for B, 50% and above for C. Anything under 50% results in a D.

In the case of the overall rating, it was decided to assign equal weights to each category, since safety-related issues are inherent in the weights assigned to each feature within a category. Therefore an overall percentage was calculated from the average of the category percentages. The overall rating for a mode (forward or rear facing) was based on the same quartile breakpoints (83%, 67% and 50%). For convertibles, an overall rating was based on the worst mode rating.

The process for determining scores and ratings is graphically illustrated in Figure 1.

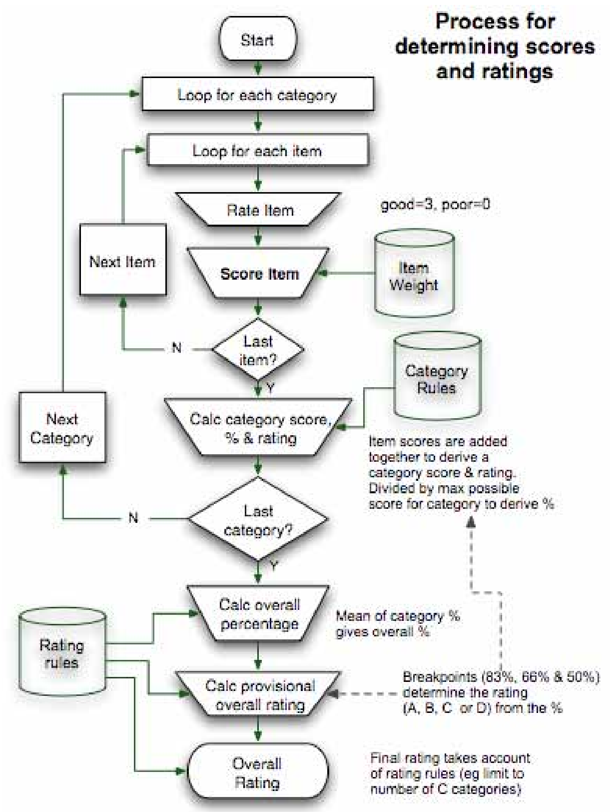

Figure 1. Ease of use rating process.

Exemplar overall ease of use results are shown below in Figures 2-4. As shown in these results all restraints assessed in this series scored an overall B or C rating. While the protocols allowed for discrimination across the spread of results, the spread was still relatively small. Rather than a reflection of the protocols, this is likely due to the fact that less than half of the currently available restraints have been tested and most of these were from a single manufacturer. Therefore instruction booklets and labels etc have the same format.

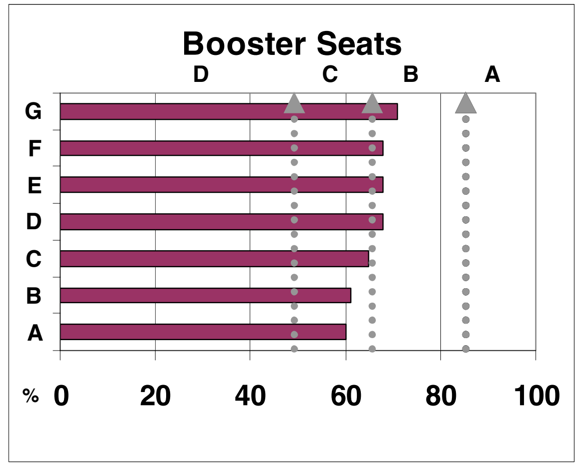

Figure 2. Ease of use overall results – Boosters.

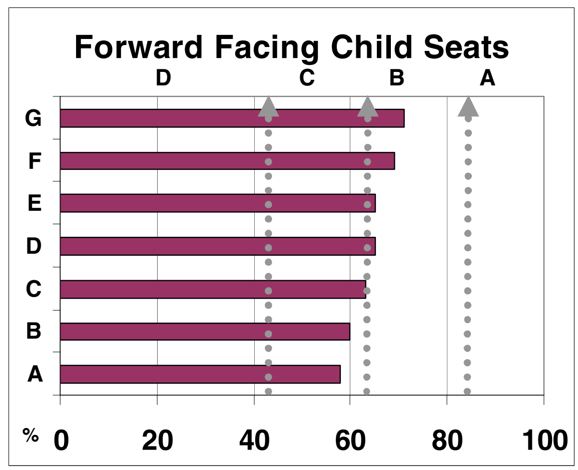

Figure 3. Ease of use overall results - Forward facing child seats.

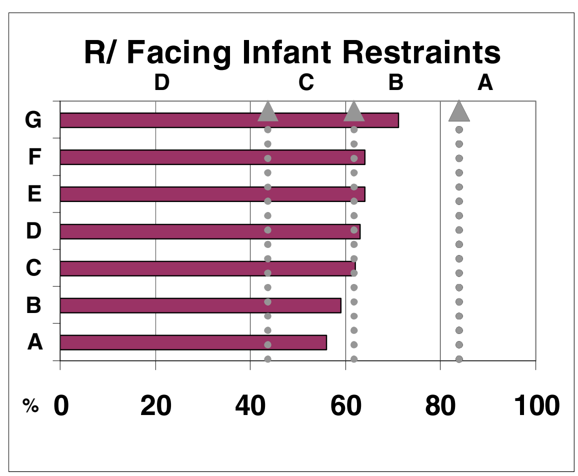

Figure 4. Ease of use overall results - Rearward facing infant restraints.

The fact that no restraint achieved an 'A' rating reflects the scope for improving features that would influence the propensity for misuse.

At this stage only the overall rating score is published in public documents, and available on stakeholder websites. However, scores from the individual categories (shown in Figures 5-7) provide more detailed information, both regarding the comparative performance and the scope for improvement.

Since there is little involved in installing a booster seat into a vehicle, this category was not assessed in this type of restraint. The results from the other categories assessed are shown in Figure 5 and illustrate distinct differences between restraints. While securing a child within a booster seat is relatively uncomplicated, the relatively low scores shown in Figure 5 related to this task (51%-62%) reflect the scope for improvement in this regard. The incorrect use of the seat belt in combination with booster seat use is a common observation in the field. Booster design features that minimise the likelihood of this form of misuse are to be encouraged. Therefore many boosters fell short in providing adequate ease of achieving and maintaining the correct belt path. Booster seats are also required to serve children over a wide range of seated heights. Many seats also failed to provide for children across the full spectrum of anthropometry.

Most of scores shown in Figure 5 related to features related to labelling were in the 78-79%, but 2 devices scored only 64%. There was a similar range in scores in the instruction booklet category. Both labelling and instructions are covered by the Australian Standard, and the major scope for improvement for the boosters seen to date, would be in the clarity and positioning of labels; and the clarity and provision of information in other languages in the instructions.

As shown in Figure 5, there were distinct differences in the quality of packaging, primarily in regard to the level and clarity of information supplied concerning which children should be using boosters. Premature graduation from booster seats to seat belts, and from forward facing child seats to booster seats are widespread problems in the field [11-12]. Providing this type of information clearly on packaging would greatly assist parents and carers in making good choices at the point of purchase.

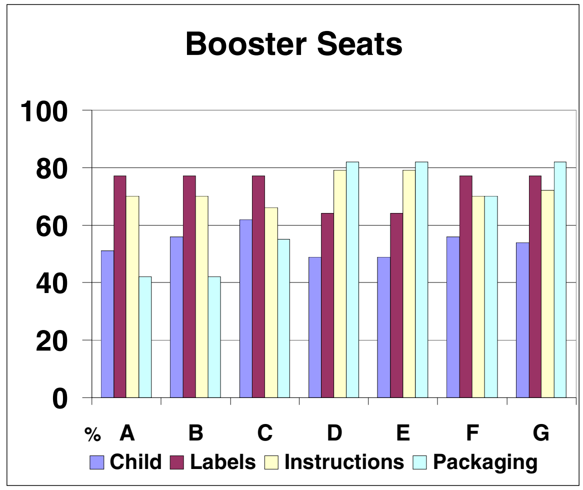

Figure 5. Ease of use category results- Boosters.

Exemplar results from the feature categories for forward facing seats are shown in Figure 6. Features related to ease of installation was assessed in these restraints. There was one restraint that clearly stood above the others in this regard, primarily due to the lack of complexity in achieving the correct belt path. However, there is room for improvement in all restraints, primarily in providing some form of feedback to users when the restraint is not installed correctly.

There were also substantial differences in features related to achieving proper use of the internal harness system, with a range of scores between 48% and 69%. The poorer scoring devices fell short in items related to the ease of removing the restraint cover and rethreading the harness. Again there is scope for improvement in the provision of some feedback mechanism, so that users know when the restraint is being used correctly. The range of scores in the label category was similar (48%-71%). Problems observed in this category included the positioning and clarity of labels. Ideally labels should include pictograms and be positioned near the task to which they refer.

Figure 7 illustrates exemplar results for rearward facing infant restraints. Most of the rearward facing restraints on the market in Australia are convertibles. The need for installation in two different ways results in potential for confusion around the correct seat belt path and is reflected in these reuslts. (This was also apparent in the convertibles among the forward facing restraints). The need for colour coding seat belt paths, labels and instructions for the different modes is high, and the lack of these features in Australian restraints affected the scores across a number of categories.

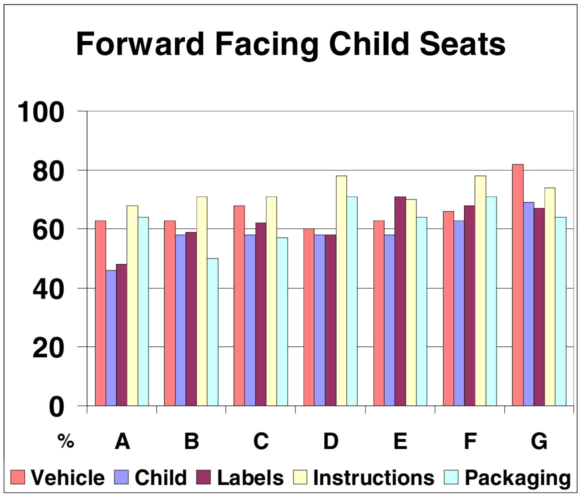

Figure 6. Ease of use category results- Forward facing child seats.

As was the case for forward facing restraints, there were significant differences in the ease of achieving and maintaining proper use of the restraint, with scores ranging from 42-70%. Again the poorer performers did not allow for the easy removal of covers and rethreading of the harness system, and all devices could be improved through the provision of feedback mechanisms to indicate correct use. Similar problems with labelling and instructions to that observed among the forward facing seats were also apparent in the rearward facing restraints.

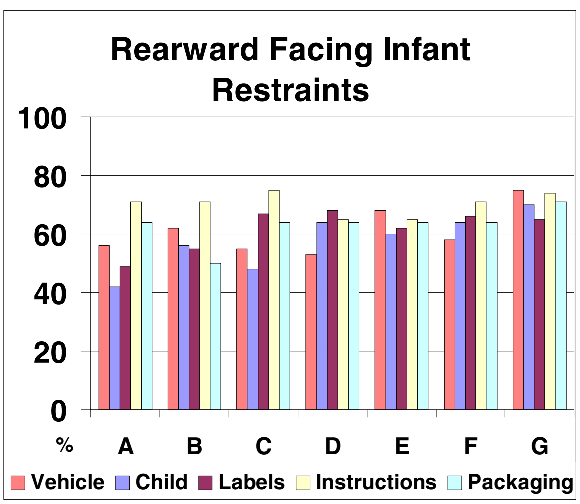

Figure 7. Ease of use category results - Rearward facing infant restraints.

Finally, it is important to note that not all restraints currently on the Australian market were assessed to the new protocols and that the exemplar results presented in the above Figures are a sample of the restraints that have been assessed thus far.

DYNAMIC PERFORMANCE ASSESSMENTS

Since its inception in 1992, the Australian CREP has included an assessment of dynamic performance in front, side, rear, and (for rearward facing restraints) inverted simulated impacts. The dynamic performance has been the focus of the rankings and information provided to consumers.

In the past, two frontal impacts were conducted, one at the same severity as the Australian Standard (49km/h, 20g), and one at a higher severity of 56km/h and 34g. The higher severity pulse originates from peak vehicle floor pan accelerations in the small number of vehicles tested in ANCAP in 1992, and also represents the upper acceleration envelope specified for the frontal tests in the Australian Standard.

In the first series of CREP, all restraints were subjected to both tests. However in all previous series since then, booster seats have been excluded from the higher severity test due to concerns regarding the robustness of the test dummy. Booster cushions (i.e. booster seats with no back) have not been included in the program since the first series of CREP.

Review of results obtained from these earlier evaluations found no worthwhile information was being gained from the lower severity frontal impact test. As a consequence the 48km/hr test has been dropped, and all restraints, including booster seats, are now subjected to the 56km/h test with a 34g pulse.

In frontal impacts in the revised protocols, dummy choice is based on the mass of the dummy being equal to or above the upper end of the mass limit for each type of restraint. The TNO P3/4 (9kg) is used for rearward facing restraints with upper mass limit of 9; the TNO P11/2 (11kg) for rearward facing restraints with upper mass limit of 12kg; the TNO P6 (22kg) for forward facing restraints (upper mass limit of 18kg); and the TNO P10 (32kg) for booster seats (upper mass 26kg).

Underscoring the development of the assessment protocols is a philosophy based on assessing the comparative performance of each type of restraint with respect to what the protective aims of that type of restraint are, rather than one based on biomechanical injury criteria.

For rearward and forward facing restraints in frontal impact, a high level of importance is placed on head displacement and measures that assess how well the restraint manages dummy deceleration.

No pre-defined limits of head excursion performance were set. Instead, the revised protocols allow for an objective comparison of restraint performance. Head excursion is recorded and scores assigned based on the range of excursions obtained. The best score (4) is given to that restraint with the least head excursion, the next best (3) to those within 50mm of that excursion, and so on. Similarly, head energy management is scored using the range of HIC36 scores obtained. The range is divided into 3 and the best score given to those devices in the lowest third and the worst score given to those in the highest third.

One of the primary design objectives of rearward facing restraints should be ensuring the distribution of crash forces is through the back of the child (or dummy). In earlier versions of CREP, head accelerations were used to assess how the crash forces were distributed in frontal impact, but review of the results from earlier programs demonstrated that chest accelerations are more reliable. If crash forces are distributed through the back of the dummy, the chest g's in the x axis should at least be equal to the those in the z axis, and a restraint that does this really well should have a higher deceleration through the x-axis than through the z-axis. Load distribution scores were assigned using a range reflecting this concept. An 'unacceptable' rating (i.e. a score of zero) was assigned if the chest X-axis peak g was less than 100% of the Z-axis peak g, but ≥ 90% of the Z-axis value. The next lowest score (1) was given when the acceleration in the x and z direction was approximately equal, and the higher scores awarded when more of the load was being distributed through the x direction. The highest possible score was awarded when the peak g in the x-axis was 130% or more of that in the z-axis. This ratio was chosen as it represents the best performing device currently on the market.

A complementary measure of restraint ride down was also made in the assessment of rearward facing restraints in frontal impact. This measure, called TEM (torso energy management) is calculated from the resultant chest acceleration over a specific time period (in a similar manner to HIC) and was scored in the same way as HIC. That is the range of TEM values obtained were divided into three and scores awarded accordingly.

Booster seats aim to improve the fit of the adult lap sash belt and their performance, particularly in frontal impact, should be assessed in these terms. In frontal impact tests, a high priority is therefore placed on the pre impact and during impact positioning of the sash and lap parts of the belt. High scores (4) were given when:

- the pre impact position of the sash was across and in contact with the dummy's shoulder and chest and essentially remained in place during impact, and
- the lap portion of the belt remained in place over the dummy's pelvic region, during the impact phase of the test.

Unacceptable (0) scores were given to those restraints that failed to meet these criteria and there was no criterion in between.

No attempt was made to compare head excursion or any measure of head energy management in booster seats in frontal impact. These types of measures were found to give misleading results since while they are heavily influenced by sash and lap strap positioning, low head excursion can be the result of submarining. This appeared to be the case in at least one of these tests.

Dummy retention in booster seats was assessed using three possible scores. A high score was awarded for complete retention and an unacceptable (0) score for complete ejection, of if the dummy's torso came free of the sash during the impact phase. A third low score (1) was available if the dummy's torso rotated so that it was only partially restrained by the sash.

To date, side impact performance in CREP has involved subjecting child restraints to two simulated side impacts; one test at 90 degrees and another at 45 degrees. The pulse used is the same as that required by the Australian Standard. To increase the severity of the test, a simulated side door structure was positioned adjacent to the test seat. The door which replicates a simplified rear door of a sedan, in shape and size, is a static structure.

Since the last CREP series and prior to the review of assessment procedures, the Australian Standard test methods and performance requirements in side impact were modified to also include the side door structure. This differs from the CREP door in that a poly carbonate inner door skin replaces the metal one used in CREP. Except for this detail, the 90 degree CREP side impact test now replicates the Standard test. In the Standard, booster cushions are exempt from this requirement.

The Standard also now requires all restraints to prevent head contact with the door. However for forward facing restraints and booster seats, the dummies specified by the Standard represent children at the lower end of the restraints size range, in terms of seated height. For this reason, the 90 degree test continues to be included in the CREP assessment, but the dummies used are modified to better represent the seated height of children at the upper end of the size range. For forward facing restraints, tests are conducted with a TNO P3 with a seated height modified to 605mm. Similarly, the booster seats were tested with the seated height of a TNO P6 increased by 40mm. Assessments were made on the absence or presence of head contact as well as the degree of head containment.

During the review of the original procedures, the 45 degree test was also found to be providing limited information useful in discriminating between the performances of the restraints. As a consequence, the 45 degree test has been replaced with one that more closely resembles a US NCAP side impact - that is at 66 degrees. The same dummies and performance aspects assessed in the 90 degree test are used in the 66 degree test.

The same door structure was used in these tests as that used earlier iterations of CREP. At this stage, the side impact test pulse remains at 32 km/h and 17g. Review of recent Australian NCAP side impact data suggests that this is an adequate severity.

All restraints are subjected to both these tests. Booster cushions (i.e. boosters without backs) remain excluded from CREP assessment.

To provide high levels of protection in side impact, child restraint systems need to minimise contact between occupants and the vehicle interior and, if contact occurs, minimise the severity of that contact. The greatest priority is head protection. In earlier versions of CREP, head displacement was assessed through noting any contact between the dummy's head and the test rig. The inclusion of a comparative HIC score was considered in this revision of the CREP protocols. However data from past (and this current) test series revealed the HIC values obtained depend more on the stiffness of the location of the contact between the door and the restraint than on the properties of the restraint. Even for restraints that completely contain the head, the variability in restraint/door contacts results in this measure being a poor indicator of any individual restraint's energy absorption features. Therefore no assessment of this type was included in this revision, but work continues on the development of an appropriate way to assess this important feature.

While the inclusion of head/door contact requirements in the Australian Standard has resulted in all devices providing some degree of head containment for the TNO P3 dummy, there is variability. For this reason the degree of head retention in side impact is also assessed. The highest score (4) is given if the head remains completely within the confines of the side wings, and a low score (1) is given if part of the dummy's head is exposed over the rim of the side wings during the impact phase of the test, but a head strike does not occur out side the device. Similarly, the Australian Standard requires the dummy to be retained in the device, however observations made in past and the present series revealed that in some cases one shoulder escaped from the harness in side impact. A high score for dummy retention was awarded when the dummy was fully retained and a low score (1) awarded if the dummy's torso was only partially restrained (one shoulder restrained) by the harness.

The rear impact and simulated inverted impact used in CREP in the past have been dropped from the new protocols because during the review, they were found to not be providing useful comparative data.

Summarised details of the revised dynamic test protocols are provided in Appendix 2, full details can be found at http://tinyurl.com/26qjqp.

In earlier versions of CREP, ranking and scoring of results consisted of, "preferred buy" ratings being given to a number of devices in each restraint type category. These were awarded to restraints that performed well in a number of areas, however the method was relatively subjective. The recent review of the program determined that there was significant scope for development of a more objective rating system that included formal documentation of objective protocols. A ratings system similar in methodology to the system being used in the ease of use assessment (and based on the method used by NHTSA) was therefore developed.

The features being assessed in the dynamic component are divided into a set of performance categories. Within each category, there are a set of items or individual performance aspects (PA). Each PA has been given a weight between 1 and 4 based on their importance in terms of offering crash protection in the real world. A numerical scale of 4 (good) to 0 (unacceptable) is used to rate the outcome for each PA. Scores for each PA are obtained by multiplying the outcome score by the weight for that PA. Category scores are arrived at by adding the scores obtained for that category and calculating what percentage this is of the maximum possible score for that category. Each category is then awarded an A, B, C or D ranking based on the breakpoints set out in Table 1.

These breakpoints have been set on the basis that any device scoring less than or equal to 50% of the maximum score is judged as 'unacceptable' and given a 'D' ranking. The range between 50% and 100% has then been divided into 3 equal ranks.

There is also one limiting rule applied to category and overall rankings. This rule is that if any device receives two or more '0' scores (i.e. an 'unacceptable') score that device can not be awarded an A or B ranking for that category or for an overall ranking**.**

'Performance Aspect' Set Score	**Overall Score**
The 'PA' set score ≥ 83% of maximum 'PA' scores that could be obtained for the set	The sum of the 'PA' scores ≥ 83% of the sum of the maximum scores that could be obtained for all the 'Performance Aspects'
The 'PA' set score < 83% but ≥ 67% maximum 'PA' scores that could be obtained for the set	The sum of the 'PA' scores ≥ 66% but < 83% of the sum of the maximum scores that could be obtained for all the 'Performance Aspects'
The 'PA' set score < 66% but ≥ 50% of maximum 'PA' scores that could be obtained for the set	The sum of the 'PA' scores ≥ 50% but < 66% of the sum of the maximum scores that could be obtained for all the 'Performance Aspects'
The 'PA' set score < 50% of maximum 'PA' scores that could be obtained for the set	The sum of the 'PA' scores < 50% of the sum of the maximum scores that could be obtained for all the 'Performance Aspects'

Table 1.
Ranking score calculations –Dynamic Testing

Exemplar overall dynamic performance results are shown in Figures 8-10. As shown in these figures there was a wide range in performance both between restraints of the same category and different restraint types. Booster seats achieved the lowest ratings, with most restraints achieving a C. There were no A level performances awarded, only one B and a D, the latter to a very poor performing seat.

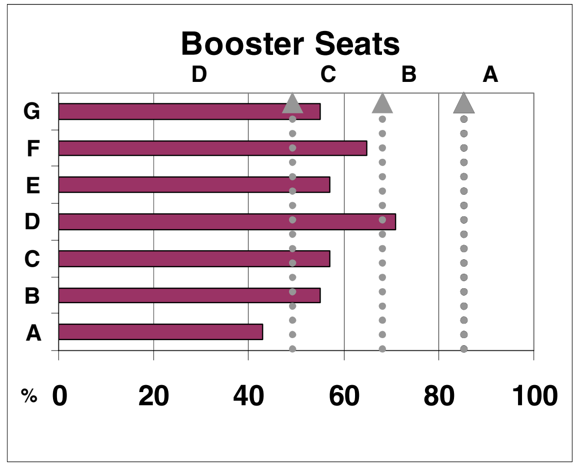

Figure 8. Dynamic overall results – Boosters.

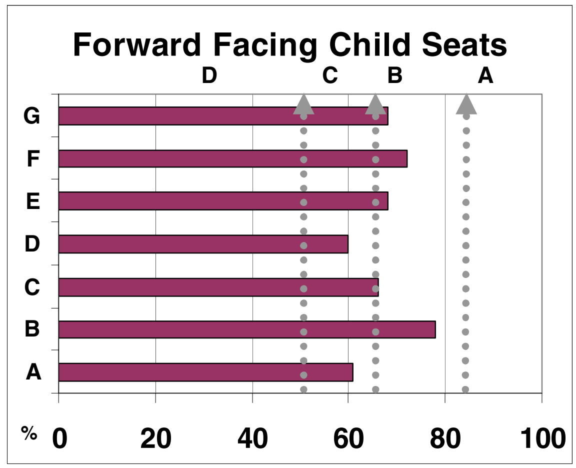

Figure 9. Dynamic overall results - Forward facing child seats

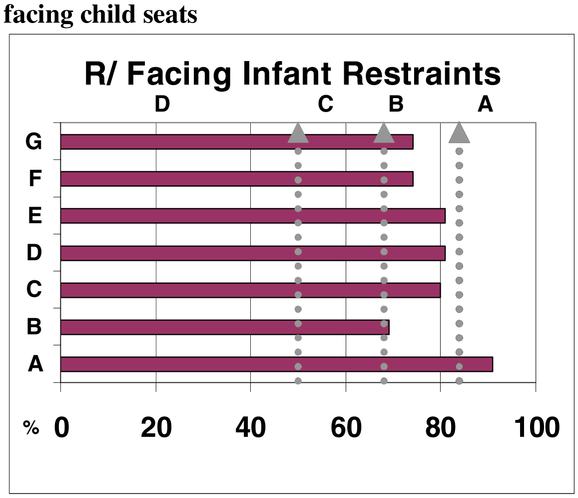

Figure 10. Dynamic overall results - Rearward facing infant restraints.

Similarly, there were no A levels among the forward facing seats. The majority achieved a B, with the two poorest performers achieving a C. Among the rearward facing restraints, one device scored an A, and the rest scored a B. Overall then, the rearward facing restraints appeared to be performing the best, and booster seats the worst.

These results illustrate the significant differences in performance that exists among restraints on the market in conditions beyond the minimum performance requirements of the Australian Standard, and the scope for further improvement in performance, particularly among booster seats and forward facing restraints (albeit it to a lesser degree).

As was the case for ease of use, only the overall scores are being published at this time, and these scores are not weighted by performance category. However review of the performance in different impact types provides some useful information.

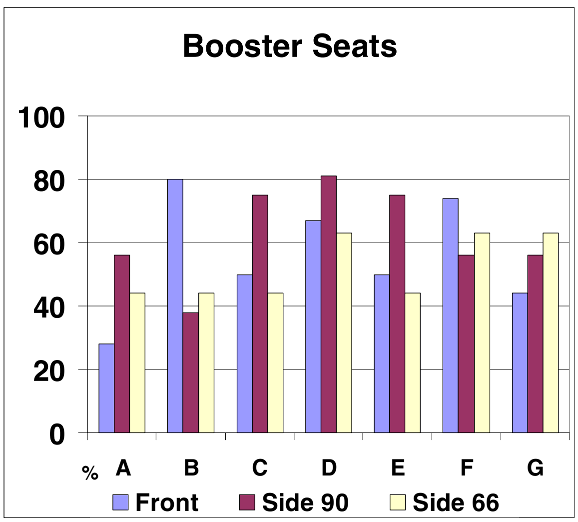

Figure 11. Dynamic category results – Boosters.

In boosters in frontal impact (see Figure 11), there was clear distinction between restraints with scores ranging from 28-70%. The best performing restraints had well positioned sash guides and crotch straps. Well placed sash guides correctly positioned and maintained the position of the sash part of the belt. This feature also controlled the dummy motion in a desirable way. Devices fitted with crotch straps (also called anti-submarine clips) maintained the position of the lap belt low down on the dummy pelvis throughout the impact. Those devices without these features performed poorly.

Among the boosters in the 90 degree side impact tests, there were 3 'groups' of devices - those that scored higher (75-80%); those that scored comparatively in the middle (50-60%; and one device that scored poorly (38%). Features affecting performance in side impact were:

- side wing height - higher side wings were better able to prevent contact between the dummy's head and the door,
- well positioned sash guides – these appeared to have a role in preventing the dummy's shoulder, and
- the use of a non-frangible material in their construction.

In the 66 degree tests, there was also a clear distinction in performance with scores grouped around 45% and 66%. The primary difference between the groups was that head contact with the side door occurred in the lower scoring devices.

Overall it appears that for booster seats in general, there are a number of areas where there is significant scope for improvement. These include:

- the provision of side structures that match the seated height of all children within the weight range of booster seats,
- improved torso restraint in side impact - this includes better structural integrity,
- better maintenance of the sash position during the impact phase in frontal and side impact, and
- improved lap belt geometry and maintenance during the impact phase.

Well positioned sash guides and crotch straps (or anti-submarine clips) appear to do address the latter two issues to some extent.

Results from the individual performance categories for forward facing child seats are shown in Figure 12. From this figure it appears the results obtained were more consistent across restraint types than they were among the booster seats. The biggest difference in performance was in frontal impact with 2 restraints scoring much better than the others. These restraints significantly outperformed the others in achieving reduced head excursion and HIC values.

There was much less difference between the overall category scores for forward facing seats in the 90 degree impacts. While all of the restraints are approved to the Australian Standard (and therefore must be able to prevent head contact between the TNO P3 and the door), only one prevented head contact using the dummy with a boosted seated height. However this restraint, as well as many of the others had difficulty in completely containing the head since the side wings allowed ½ to a 1/3 of the dummy's head (with boosted seated height) to be exposed.

The 66 degree impact tests provide better distinction between performance. Head contact with the window glass of the side door structure occurred in all cases. The primary difference in the poorer performing devices was that they allowed the left hand (nearside) shoulder strap to slip completely off the shoulder during rebound.

Overall points for improvement for forward facing restraints are:

- the provision of a better match between side wing height and the seated height of children in the upper mass range of the device,
- optimization of the belt path to assist in the reduction of head excursion and the stability of the device during rebound, and
- maintenance of good harness fit during the impact phase and rebound in side impact.

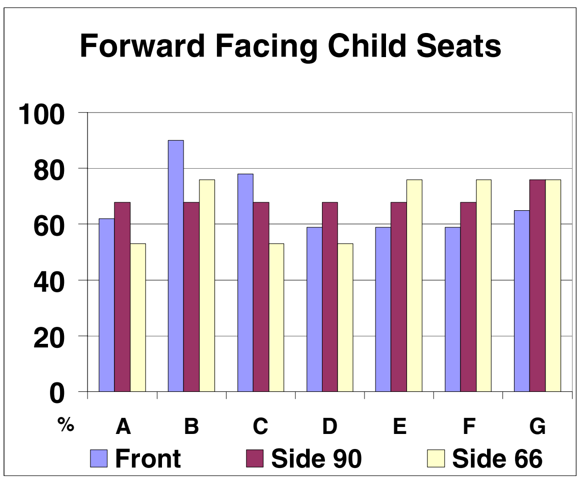

Figure 12. Dynamic category results - Forward facing child seats.

Among the rearward facing restraints there was one device with clearly superior performance in both the frontal and side impact categories (See figure 13). This device scored 96% in the frontal tests, performing the best in all aspects except the TEM (torso energy management) measurement (where it scored second best). The other restraints fell short primarily in their management of head and torso energy during the impact. The poorest performing restraints also failed to distribute the loads as well as the others, and retain the dummy's head.

There was no difference between the restraints in the 90 degree tests, all prevented head contact. This exemplifies the need for an adequate method for assessing the energy absorption ability of the restraints when the head is contained. Similarly, there was no head contact in the 66 degree tests. However there was one significant difference between the restraints. Some (scoring 100%) prevented head contact and contained the head fully within the confines of the restraint, while others allowed at least part of the head to move beyond the rim of the restraint.

The greatest scope for improvement observed in rearward facing restraints lies in the inability of some restraints (particularly convertible restraints) to completely contain the head in frontal and side impact. It is imperative that these features be addressed since exposure of the head of an infant over the rim of the restraint increases the risk of head contact with the vehicle interior and/or intruding structures. The other area of concern, also primarily observed in convertible restraints is the amount of vertical motion occurring during rebound.

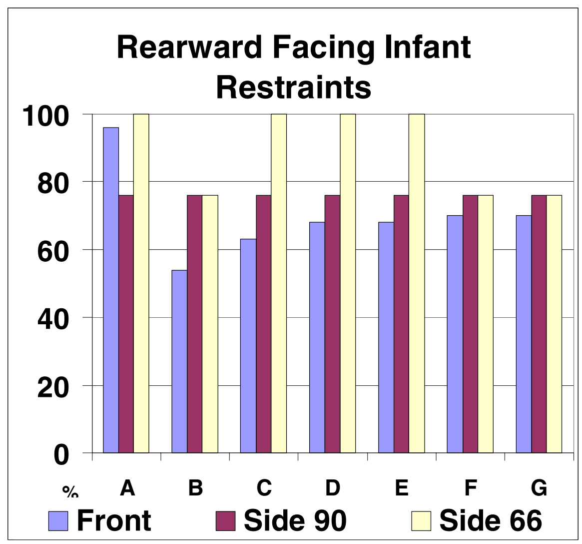

Figure 13. Dynamic category results - Rearward facing infant restraints

PUBLIC RELEASE OF RESTRAINT RATINGS

Experience from other vehicle safety advocacy programs, such as the Australian New Car Assessment Program, and the Used Car Safety Ratings shows that consumers want complex scoring information distilled into a simple form they can understand. In this case, it was felt that the dynamic and ease of use scores were quite different and should be presented separately. This would enable consumers to make their own judgement if they thought one factor was more important than the other.

The release of ratings is supported by a brochure and a media release. The brochure lists the restraints in categories in order of performance, best performing at the top of each table. This information is also published on stakeholder websites as close as possible to the time and date the media release is circulated.

Media releases are drafted by one stakeholder, circulated to other stakeholders for comment, then the final agreed version is legally reviewed.

The media release is embargoed and, on the day of the release, stakeholder representatives make themselves available for interviews. The response normally includes television interviews, as there is good video from the crash test facility, with high rating morning TV shows being particularly interested in the subject.

Newspaper coverage has also been widespread, as the information is appreciated in a range of areas, including maternity hospitals, child injury prevention groups and parent/consumer groups.

There is an ongoing significant level of enquiry to telephone information lines that confirms that the CREP stakeholders are strongly associated in the public's mind with the distribution of child restraint rating information.

DISCUSSION AND CONCLUSIONS

The overriding objective of a program such as CREP is to provide children with improved levels of crash protection - beyond the minimum required by the Standard. Firstly the program aims to influence consumers to buy restraints which rate well, and avoid the restraints which do not. This secondly provides an economic incentive for manufacturers to develop and market better performing products. Thirdly, to assist manufacturers, the program provides detail of where their products rate well and where they do not. Therefore it also provides useful step-by-step guidance on where and how the product needs to be improved.

Ensuring that useful, credible information is provided to consumers relies first and foremost on a reliable and appropriate assessment protocol. This was the driving force behind the recent review of the Australian CREP protocols.

It is important that assessment procedures meet three primary objectives. Firstly they must allow discrimination between restraints to allow for comparisons between the best and worst performers within a category; secondly they must encourage even the best performers to improve designs in necessary areas, and thirdly they must reflect issues relevant to the real world protection of children in cars.

The newly revised protocols, as presented here, clearly meet the first two objectives. Intuitive and anecdotal experience suggest they are also likely to meet the third, however scientifically robust validation methods are required to make sure. Two projects are currently underway to achieve this, and the results will be used to refine and enhance the CREP methodologies where necessary.

In addition to refinements following validation of the methodologies, it is intended that these protocols will undergo regular review. This is particularly important to allow the objectives of the protocols to continue to be met as changes occur in the design of restraints on the market and/or the requirements of the Standard. Feedback from those conducting the assessments is a useful source of potential refinements and enhancements.

Following the conduct of this most recent series using these newly revised protocols, a number of issues were raised for consideration in updated revisions.

For example the ability to discriminate adequately between the energy absorption features of restraints containing the head in side impact would be a significant enhancement.

While consumer information-based assessment programs focusing on child restraint design are likely to enhance the ease of use and dynamic performance of child restraints, the child restraint is only one piece of the protective system in the real world. There is also a need to encourage vehicle manufacturers to improve the ease of installing and using child restraint systems in specific models of vehicle and the development of effective strategies to achieve this is required. One possible measure raised in the past is the addition of some form of child restraint compatibility assessment to programs such as NCAP. An example of a possible scoring system is outlined by Brown et al [13].

Once there is an adequate assessment and scoring procedure, the critical part of the process is to ensure that the CREP results are readily available to consumers and that consumers use this information in making their purchasing decisions.

An important part of the consumer evaluation process is to provide guidance to manufacturers regarding where the highest priority areas for significant gains in performance lie. This recent series of ease of use assessments has indicated a number of features where specific attention is warranted. These include;

- provision of information regarding correct and appropriate use in languages other than English on packaging and within instruction booklets,
- one page pictorial set up and usage guides,
- better clarity in diagrams such that the information contained with diagrams on packaging, labels and in instructions books conveys all necessary information with no need to read any additional text,
- placement of labels on restraints in the vicinity of the task to which they refer, and
- colour coding of instructions, labels and seat belt routing (particularly for individual modes of use in convertible restraints).

The incorrect use of in-built harness systems (in forward facing and rearward facing restraints) and the sash of seat belts (in booster seats) are areas raising concern in the field. There is a need to encourage manufacturers to optimise their designs to reduce the propensity for this form of misuse. Bonus points were available in this series for restraints that provided some means of warning when the harness/belt was being used incorrectly (or conversely some feedback system denoting correct use). No restraints currently have any features like this and this would be one area where manufacturers could gain some edge for future programs.

In the dynamic assessments, the philosophy of assessing performance with respect to what the protective aims of that type of restraint are, rather than one based on biomechanical injury criteria is a relatively new approach, and resulted in some significant changes to the way restraint performance, (particularly in the case of booster seats) was assessed. Results indicate that this assessment approach allows for the useful discrimination between products based on observable differences in performance in the laboratory.

Of note, there was a substantial difference in the head excursion allowed between the best and the worst performing forward facing restraints. Overall, the results suggest there is specific scope for improving the performance of;

- convertible child restraints generally,
- booster seats, particularly those that do not incorporate adequate sash guides and crotch straps, and
- forward facing and booster seats in side impact, particularly in the head protection provided in side impact at the upper end of their mass limits.

Finally, it should be noted that due to differences in both the protocols and the scoring systems, it is not possible to compare the ease of use of Australian restraints and those in North America, or the dynamic performance results with those conducted elsewhere.

ACKNOWLEDGEMENTS

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APPENDIX 1: EASE OF USE ASSESSMENT PARAMETERS

CATEGORY		DESCRIPTION
CHILD		Buckle secured in reverse
CHILD		Indication buckle secured correctly
CHILD		Easy access to harness adjustment
CHILD		Ease of harness adjustment
CHILD		Indicator of correct harness adjustment
CHILD		Range of harness slots
CHILD		Visibility of slots
CHILD		Ease of changing slot position
CHILD		Threading straps when changing slot position
CHILD		Liner/harness interaction
CHILD		Consistency
CHILD		Removal of cover
CHILD		Removal of child when top tether attached
CHILD		Indication of correct harness us
CHILD		Seat belt path
CHILD		Indication of correct seat belt
CHILD		Height adjustable
CHILD		Ease of height adjustment
INSTRUCTIONS		Instructions generally
INSTRUCTIONS		Quick set up/reference guide
INSTRUCTIONS		Easy to read font
INSTRUCTIONS		Easy to understand diagrams
INSTRUCTIONS		Size range clearly indicated
INSTRUCTIONS		Modes of use clearly indicated
INSTRUCTIONS		Belt routing
INSTRUCTIONS		Using isofix
INSTRUCTIONS		Belt/harness use
INSTRUCTIONS		Correct use of top tether
INSTRUCTIONS		Using correct harness slot
INSTRUCTIONS		Warnings related to correct use of harness/belt
INSTRUCTIONS		For maintenance
INSTRUCTIONS		Location
INSTRUCTIONS		Accessibility
INSTRUCTIONS		In other languages
LABELS		Labels generally
LABELS		Easy to read font
LABELS		Easy to understand diagram
LABELS		Child size range indicated
LABELS		Modes of use indicated
LABELS		Instructions for belt path
LABELS		Instruction correct use of top tether
LABELS		Instructions for using correct harness slot or belt guide
LABELS		Warnings related to correct use of harness
LABELS		Labels Consistent with Instructions
LABELS		Durability of labels
LABELS		Location of labels
LABELS		Visibility of labels
LABELS		Identification of stabiliser Bar
LABELS		Colour coding for mode of use
PACKAGING		Easy to read font
PACKAGING		Child size range indicated for mode
PACKAGING		Modes of use clearly indicated
PACKAGING		Accommodation (vehicle)
PACKAGING		Appropriate use information provided in other language
INSTALLATION	*	Indication that seat belt is routed correctly
INSTALLATION	*	Correct belt routing evident
INSTALLATION	*	Ease of achieving belt path
INSTALLATION	*	interaction between harness and adult seat belt
INSTALLATION	*	Ease of using belt positioning feature
INSTALLATION	*	Ease of removing belt slack
INSTALLATION	*	Top Tether adjustment
INSTALLATION	*	Top Tether attachment to CRS
INSTALLATION	*	Seat back angle
INSTALLATION	*	Ease of changing recline angle
INSTALLATION	*	EASE OF USING STABILISER BAR
INSTALLATION	*	Accommodation in large family sedan
INSTALLATION	*	Ease of removing restraint

* Does not apply to Booster Seats

APPENDIX 2: DYNAMIC ASSESSMENT PARAMETERS

CATEGORY	Applies*	DESCRIPTION
FRONTAL	RF	Head retention
FRONTAL	FF	Forward head excursion
FRONTAL	RF, FF, BS	Dummy retention
FRONTAL		Upward and/or rotational displacement of the CRS in rebound
FRONTAL	RF, FF,BS	CRS security and integrity
FRONTAL	RF	Load distribution
FRONTAL	RF	Head energy management
FRONTAL	RF	Torso energy management
FRONTAL	RF, FF	Adjuster slip
FRONTAL	FF	Operation of quick release device
FRONTAL	BS	Seat belt sash strap location
FRONTAL	BS	Submarining
FRONTAL	BS	Seat belt strap location

*RF – Rearward Facing Infant Restraint, FF – Forward Facing Child Seat, BS – Booster Seat

CATEGORY	Applies*	DESCRIPTION
SIDE	RF, FF, BS	Head retention
SIDE	RF, FF, BS	Dummy retention
SIDE	RF, FF, BS	CRS security and integrity
SIDE	RF,FF	Adjuster slip
SIDE	BS	Seat belt sash strap location
SIDE		Labels generally
SIDE		Easy to read font
SIDE		Easy to understand diagram