Sun Visors and Head Injury Protection in Australia and the United States

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ABSTRACT

An estimated 3,000 fatalities and 8,000 serious head injuries result from head impacts with vehicle upper interior surfaces during crashes each year in the United States. Sun visors occupy a strategic location in motor vehicles for potentially reducing head injuries. Current U.S. regulations require only that sun visors use energy-absorbing padding, allowing manufacturers to specify the characteristics of the padding. In contrast, Australia has a design rule for sun visors with specified performance criteria. Sun visors from 26 different vehicles were tested to compare the relative head injury protection offered by Australian market cars and comparable American market cars. The average head injury criterion (HIC) scores reflect a wide disparity in the energy managing capabilities of the tested visors, ranging from 568 to 2765. Five of the Australian sun visors that produced HIC scores of less than 1000 had U.S. counterparts that produced HIC scores double to quadruple those of the Australian sun visors. The findings of the study clearly indicate that the technology and manufacturing ability exists to produce sun visors than can reduce head impact severity.

INTRODUCTION

An estimated 3,000 fatalities and 8,000 serious head injuries result from head impacts with vehicle upper interior surfaces during crashes each year in the United States (Monk et al., 1988). In a review of 96 National Accident Sampling System and National Crash Severity Study cases from 1981-84, Monk et al. found that the sun visor/front header is second only to the A-pillar as the contact surface for serious (AIS $\geq$ 3) head injuries (1988). One method of reducing these types of injuries is to limit head contact with vehicle upper interior surfaces by increasing the use of seat belts and air bags. Although restraint systems are very effective at reducing serious head injuries, they alone may not be enough. The National Highway Traffic Safety Administration (NHTSA) has estimated that belted occupants accounted for one-third of the serious head injuries incurred from contact with vehicle upper interior structures in 1989 (Partyka, 1991). In addition, belted occupants may impact vehicle upper interior surfaces even when there is an air bag deployment (NHTSA, 1992).

Sun visors occupy a strategic location in motor vehicles for potentially reducing head injuries. They cover significant portions of the frequently impacted front headers, and they can be simply redesigned using readily available padding material to reduce the severity of head injuries. For example, in tests of head impacts into A-pillars, NHTSA found that the addition of just one inch of padding substantially reduced the potential for head injuries (Monk et al., 1986). With this minimal amount of padding, sun visors could provide an immediate means for increasing front header protection without degrading their primary function.

Although NHTSA has proposed a regulation that would require all manufacturers to reduce the head injury potential associated with head strikes of the upper interiors of vehicles (58 *Federal Register* 7506-7525), the current United States standards require only that sun visors use energy-absorbing padding, allowing manufacturers to specify the characteristics of the padding (49 *CFR 571*.201 S3.4). In a 1992 report, Digges et al. described a method for comparing the head protection offered by sun visors and showed that there is wide variability in the performance of sun visors available on 20 different 1991 model year cars. These results suggest that without more specific guidelines, many manufacturers will be unlikely to utilize the full potential of sun visors to mitigate head injury in crashes.

In contrast to the United States, Australia does currently have a design rule for sun visors with specified performance criteria [Australian Design Rule (ADR) 11/00 Internal Sun Visors]. The ADR is intended to assure a minimum measure of protection from head contacts with the sun visor/front header.

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ADR 11/00 includes a minimum radius requirement for any rigid material on the sun visor as well as an energy absorption requirement. This requirement specifies, under prescribed test conditions, an allowable maximum acceleration level of 80 times the acceleration of gravity on a headform, except for instances of less than 3 milliseconds, where the maximum is 200 times the acceleration of gravity. The ADR test procedure requires an impact to the sun visor with a spherical headform with a mass of 6.8 kilograms and a diameter of 165 millimeters at an impact velocity of 3.5 meters per second (just under 8 mph). During this test, the sun visor is placed flat on a 300 kilogram anvil and the surface of the sun visor is perpendicular to the direction of travel of the head (ADR, 1992).

Not all Australian sun visors have to meet these requirements, because the regulations permit manufacturers, if they so choose, to certify their sun visors to the Economic Commission for Europe (ECE) Standard 21/01, Annex 4. In this standard, as with the ADR, a sun visor is impacted with a 6.8 kilogram, 165 millimeter diameter headform in a direction normal to the surface of the sun visor. The resultant acceleration incurred during the impact can not exceed 80 times the acceleration of gravity for a period greater than 3 milliseconds. The ECE standard differs from the ADR in that it requires that the sunvisor be tested while mounted on the supporting member on which it is to be installed on the vehicle. The impact velocity for these tests is 24.1 km/h (15 mph), but it can be lower in cases where the prescribed impact angle is not perpendicular to the impact surface. Although the ECE standard tests at a higher speed, it would permit less protective sun visors than those meeting the ADR because of the much more rigid impact fixture in the latter test.

In the current report, the method developed by Digges et al. (1992) is used to compare the relative head injury protection offered by Australian cars with sun visors certified to the ADR 11/00, by Australian cars certified to the alternative ECE standard, and by comparable American market cars that must meet only the vague requirement that sun visors contain energy absorbing material.

METHOD

Sun Visor Selection

Driver-side sun visors from a total of 26 different vehicles were tested; 18 were from passenger vehicles sold in Australia and 8 were from vehicles sold in the United States. The Australian sun visors, which were supplied by the Royal Automobile Club of Victoria, Australia, were from 1993 model year vehicles (except where noted) and were made by a total of 10 American, Asian, and European car manufacturers. In addition to supplying the sun visors, the Automobile Club also asked the manufacturers for information regarding which design rule (ADR or ECE) the sun visors met.

Twelve of the 18 Australian models had direct counterparts sold in the United States. For four of these 12 models, the sun visors available in both the United States and Australia were identical, but the driver-side sun visors from the eight remaining models sold in the United States were different. Table 1 lists the Australian models, their United States counterparts, and their associated part numbers and retail (excluding taxes) costs.

Table 1
Australian and United States Sun Visors

Australian Model	Sun Visor Part Number	Cost[1]	United States Counterpart	Sun Visor Part Number	Cost[2]	United States Part Different
BMW 318i	51 16 1 977 524	$45	BMW 318i	51 16 1 977 523	$77	No
Ford Capri	FOJY-7604104 CVP	19	Mercury Capri	FOJY-7604105 CVP	53	No
Ford Falcon	ED F04100 A1	16	None			
Ford Bronco	RE 1504104AA1FA	36	Ford Bronco	E9TZ 1504104B1A	54	Yes
Ford Laser-KH	BS79-69-270 06	32	None			
GM Holden Commodore	92028143TZ	16	None			
Honda Accord	83230-SM4-E23ZB	52	Honda Accord	83280 SM4 A23ZG	44	Yes
Honda Civic	HO-832-30SR3E00ZB	28	Honda Civic	83280 SR3 A002B	34	Yes
Mercedes-Benz 190E	A201B10 410 B320	34	Mercedes-Benz 190E	12481007 10	149	Yes
Mitsubishi TR Magna	11410 DA1	19	None			
Mitsubishi NH Pajero	MB 879379	17	Mitsubishi Montero	MR 114891	71	Yes
Mitsubishi CC Lancer	MB 793998	24	None			
Nissan U12 Pintara[3]	NI-96400-J8023	24	Nissan Stanza[3]	96401 65E70	46	Yes
Nissan N14 Pulsar	NI-96400-J9003	28	None			
Saab 900	9849845	90	Saab 900	9849837	77	No
Toyota Camry	74310 YB010-16	15	Toyota Camry	74320 33010-K0	29	Yes
Toyota Corolla	74310 YA010-19	10	Toyota Corolla	74320 1A160-B0	30	Yes
Volvo 940	6812765-3	50	Volvo 940	6812770-3	54	No

[1] Cost in U.S. dollars at 1 $A= $0.74 U.S. All Austrialian costs are retail (excluding taxes) replacement prices as of May 1993.
[2] All U.S. costs are retail (excluding taxes) replacement prices as of July 1993.
[3] 1992 models

Test Device and Equipment

Using the method of Digges et al. (1992), the tests were conducted by impacting the sun visors with a Hybrid III head form and measuring the accelerations incurred by the head form during impact. The calculated resultant acceleration was then used to determine the Head Injury Criterion (HIC) score for each impact. A drop tower was used to accelerate the head form such that its impact velocity was 11 miles per hour. The drop tower operates by raising a cable-guided carriage vertically, with the head form attached, to a height which, when allowed to free-fall, will produce the desired impact velocity.

The sun visors were placed flat on a steel platform in the path of the normal direction of travel of the head form. The head form impacted the sun visors in an orientation such that there was one-half inch between the head form's nose and the sun visor just as the forehead began impact with the sun visor. A breakaway hook allowed the head form to detach from the guiding carriage during impact with the sun visor.

The Hybrid III head form was fitted with three accelerometers, and the output data were recorded with a three-channel data acquisition system. A computer program then calculated the HIC score.

Velocity was measured just prior to impact using an infrared emitter and detector, whose beam is broken by two wands that are a measured distance apart. A timer recorded the delay between the breakage of the beam, and the elapsed time and measured distance were then used to calculate impact velocity.

Test Method

Three sets of 26 different vehicle sun visors were tested, resulting in triplicate tests for each sun visor. The tests were run in three series, with one of each of the 26 sun visors included in each series. One test was conducted on each of the three identical sun visors for each model, except for 10 repeat tests in the first series, which were necessary because of a fault in the data acquisition system that altered the sensitivity of the accelerometers. An integration of the acceleration curves from these 10 tests corresponded to impact velocity of about 8 miles per hour, clearly underestimating the actual impact velocity of 11 mph. Consequently, the first 10 tests of the first series were repeated at a location on the sun visor not previously impacted. It was decided that repeating the tests in a secondary location on the sun visor would not introduce a bias since the 10 sun visors are both consistent in cross section and homogeneous in construction. With the exception of the 10 repeat tests, the sun visors were impacted at a center location.

The Hybrid III head form was calibrated prior to beginning the first test series. The tests of the Australian sun visors and the United States sun visors were conducted in random order. There was a delay of 5-10 minutes between tests.

The Hybrid III head form was outfitted with a new head skin and calibrated prior to beginning the second series. The second test series was conducted in reverse order of the first test series. Again there was a delay of 5-10 minutes between tests.

The third series of tests was conducted with a typical delay of three hours between tests, and the Hybrid III head form was calibrated prior to the beginning of testing each day.

RESULTS

Table 2 gives the test results for the sun visors in cars sold in Australia and Table 3 gives the results for sun visors in cars sold in the United States. The average HIC score for each sun visor is given, as well as the impact numbers corresponding to the order in which the sun visors were tested, the HICs calculated in each of the three test series, and the coefficient of variation for the three tests. Table 4 lists the results for the Australian sun visors, arranged from the lowest to highest average HIC score, and the corresponding average HIC score for the United States counterparts.

Twenty-five of the 26 sun visors tested had coefficients of variation of 14 percent or less between the three repeated tests. The U. S. model Honda Accord, however, had a variation of 29 percent. One possible cause of this variation is the built-in vanity mirror on the sun visor.

The average HICs reflect a wide disparity in the energy managing capabilities of the 26 sun visors tested. The resulting HIC scores ranged from 568 to 2765. Five of the Australian sun visors that produced HIC scores of less than 1000 had United States counterparts that produced HIC scores double to quadruple those of the Australian sun visors.

Thirteen of the 18 Australian sun visors produced average HIC scores of about 1000 or less. Only one of the sun visors certified to the ADR had a average HIC score above 1000. In contrast, many of the Australian sun visors certified to the ECE standard performed little better than their U.S. counterparts. These sun visors with a HIC score of about 1000 or less are installed on vehicles sold by seven different vehicle manufacturers. Cost seems not to be a factor, as the better performing sun visors were among the cheapest. It is particularly interesting that the Toyota Corolla, for example, has a sun visor that sells for three times as much in the United States as in Australia but allows HIC scores nearly three times as high.

Table 2
Results of Australian Sun Visor Tests

Australian Sun Visors	Certified Standard[4]	Average HIC	Series 1		Series 2		Series 3		Coefficient of Variation
			Impact No.	HIC	Impact No.	HIC	Impact No.	HIC	
Ford Bronco	ADR	837	1 [1]	787	26	907	1	816	7.5
Mitsubishi Pajero	ECE	568	2 [1]	568	25	570	2	566	0.0
Nissan Pintara (1992)	ADR	861	3 [1]	887	24	838	1	859	2.9
Mercedes-Benz 190E	ECE	1819	4 [1]	1758	23	1829	2	1869	3.1
GM Holden Commodore	ADR	891	5 [1]	907	22	874	1	893	1.9
Toyota Camry	ADR	793	6 [1]	768	20	794	2	816	3.0
Honda Accord	ECE	1606	7 [1]	1599	19	1598	1	1620	0.8
Ford Falcon	ADR	1069	8 [1]	1107	18	1027	2	1072	3.8
SAAB 900	ECE	791	9 [1]	864	17	734	1	776	8.4
Ford Laser	ADR	645	10 [1]	633	16	655	2	648	1.7
Honda Civic	ECE	2544	11	2507	15	2767	3	2357	8.2
Volvo 940	ECE	662	12	630	14	654	1	701	5.5
Toyota Corolla	ADR	841	13	853	13	813	2	858	2.9
Mitsubishi Magna	ADR	958	14	946	12	889	1	1038	7.8
Mitsubishi Lancer	ECE	2606	15	2930	11	2618	2	2270	12.7
BMW 318i (M)	ECE	1991	16	2119	10	N/A [2]	1	1863	9.1
Ford Capri	ADR	884	17	927	9	849	2	877	4.5
Nissan Pulsar	ADR	909	18	909	N/A [3]		N/A [3]		N/A

1. Repeat test on an untested portion of the sun visor. The first test is invalid due to a fault in the data acquisition system.
2. Missed Data Collection.
3. Only one sun visor was available for testing.
4. Based on a manufacturers inquiry.
(M) denotes mirror.

Table 3
Results of United States Sun Visor Tests

United States Sun Visors	Average HIC	Series 1		Series 2		Series 3		Coefficient Of Variation
		Impact No.	HIC	Impact No.	HIC	Impact No.	HIC	
Mercedes-Benz 190E (M)	1236	19	1387	8	1083	1	1237	12.3
Honda Civic	2765	20	2842	7	2910	2	2542	7.1
Honda Accord (M)	1646	21	1709	6	1141	1	2088	29.0
Toyota Camry	2608	22	2706	5	2612	2	2507	3.8
Toyota Corolla	2603	23	2799	4	2826	1	2183	14.0
Mitsubishi Montero (M)	2612	24	2798	3	2521	2	2518	6.2
Nissan Stanza (1992)(M)	1821	25	1921	2	1721	N/A[1]		7.8
Ford Bronco	2577	26	2619	1	2460	1	2652	4.0

(M) Denotes mirror.
1 Only two sun visors were available for testing.

Table 4
Comparison of Australian and United States Sun Visor Tests

Australian Sun Visor	Certified[1] Standard	Average HIC	United States Counterpart	Average HIC
Mitsubishi Pajero	ECE	568	Mitsubishi Montero (M)	2612
Toyota Camry	ADR	793	Toyota Camry	2608
Ford Bronco	ADR	837	Ford Bronco	2577
Toyota Corolla	ADR	841	Toyota Corolla	2603
Nissan Pintara (1992)	ADR	861	Nissan Stanza (1992) (M)	1821
Honda Accord	ECE	1606	Honda Accord (M)	1646
Mercedes-Benz 190E	ECE	1819	Mercedes-Benz 190E (M)	1236
Honda Civic	ECE	2544	Honda Civic	2765

[1] Based on a manufacturers inquiry.
(M) Denotes mirror.

DISCUSSION

The findings of the study clearly indicate that the technology and manufacturing ability exists throughout the industry to produce sun visors that can reduce head impact severity. However, without an effective government standard, manufacturers are not producing sun visors that could help reduce the severity of head injuries sustained by impacts to the sun visor in crashes. The availability of better energy managing sun visors on some models in Australia compared with the equivalent models in the United States indicates that automobile manufacturers are unwilling to produce better sun visors without effective government regulation.

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