HEAD RESTRAINT POSITIONING AND OCCUPANT SAFETY IN REAR IMPACTS: THE CASE FOR SMART RESTRAINTS.

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ABSTRACT

Head restraint positioning was examined for drivers in the United States and front seat passengers in both the United Kingdom and the U.S.. Video footage of real world driving situations was analyzed to provide data on the position of head restraints, together with details of occupant and vehicle characteristics. At least 88% of occupants had the restraint positioned too low, and in at least 24% of cases the restraint was too far from the head horizontally. These findings have serious implications for safety, particularly in rear impacts. There is, therefore, a need to improve head restraint design and the arguments for smart restraints are examined.

ALTHOUGH NECK INJURIES DO OCCUR IN FRONTAL AND SIDE IMPACTS, they are more likely to be sustained by occupants involved in rear end collisions, despite the fact that a majority of rear impacts occur at speeds of less than 40 km/hr (Parkin et al., 1995). The difference in neck injury risk as a function of collision type is illustrated by Larder et al. (1985) who report that a neck injury was sustained by 17% of occupants involved in frontal collisions, compared with 31% of occupants in rear impacts. In most cases, the neck injuries sustained in rear-end impacts are described as 'whiplash' related, although the mechanisms behind whiplash injuries are not fully understood. It is believed, however, that neck injuries in rear-end collisions are usually related to shear and then extension-flexion motion of the neck and this results from the rearward motion of the head relative to the torso (Svensson et al., 1993). According to the Abbreviated Injury Scale (AIS) (Association for the Advancement of Automotive Medicine, 1990), which rates injuries according to their threat to life, whiplash injuries are coded as minor. Although the majority of neck injuries are soft tissue only and not life threatening, however, about 10% of cases will result in some permanent disability (Nygren et al., 1985). In addition, soft tissue neck injuries have a high economic cost; it is reported by the Insurance Institute for Highway Safety (1995) that neck sprains account for 66% of insurance claims for bodily injuries in the U.S..

HEAD RESTRAINTS - In an attempt to reduce the severity and incidence of neck injuries, head restraints were introduced into vehicles to restrict the rearwards motion of the head relative to the chest. In the U.S. they became mandatory for the front seats of vehicles in 1969 (see Federal Motor Vehicle Safety Standard 202), and whilst head restraints are not legally required in British vehicles, requirements relating to their structure and fitting are specified in European safety standards 78/932/EEC and E.C.E. regulation No.25. As a result of the introduction of head restraints in the U.S., O'Neill et al. (1972) report that insurance claims relating to neck injuries were reduced by 18%. The effectiveness of these restraints, however, was found to vary a great deal between different car models. Conversely, Morris & Thomas (1996) report that, in British vehicles, 'head restraints have not been found to mitigate neck injuries in either front or rear impacts at a statistically significant level'. As Olsson et al. (1990) point out, 'neck injuries are still common in rear-end collisions'. Consequently, it appears that in most cases head restraints are not providing adequate protection against neck injury, and this can usually be explained, in part, by inadequate head restraint design. For optimal efficacy, a head restraint should be designed such that it is able to be positioned correctly in relation to the head of the occupant. Ideally, the centre of the front of the restraint should be level with the centre of gravity of the head, and at minimal horizontal distance from it. If the restraint is too low, rearward motion of the head is not prevented and as a result the risk of neck injury cannot be reduced (Nygren et al., 1985). In addition, a low head restraint can increase the severity of hyperextension by acting as a fulcrum (Severy et al., 1968). Similarly, a large horizontal distance between the head and the restraint means that rearward head movements cannot be adequately curtailed, and it is concluded by Olsson et al. (1990) that, relative to occupants with head to head restraint separations of less than 10cm, occupants having a separation of more than 10cm had an increased risk of neck injury in rear end collisions.

Clearly it is accepted that, for optimal protection, a head restraint should be positioned such that its centre is level with the centre of gravity of the head, and at minimal horizontal distance from it. It is frequently reported, however, that head restraints are incorrectly positioned for a large number of car occupants. Viano & Gargan (1995) report from an observational study that only 10% of drivers had the head restraint placed in the most favourable position. Similarly, the Insurance Institute for Highway Safety (1995) report observational data which shows that the head restraint was incorrectly positioned, either vertically or horizontally (or both), in 65% of vehicles with adjustable restraints, and in nearly half of those having fixed restraints. A second study showed that only 5 of 164 car models assessed were rated as having 'good' head restraint geometry, where 'good' referred to a maximum vertical distance of 6cm between the top of the head and the top of the restraint, accompanied by a maximum horizontal distance between the head and the restraint of 7cm. In contrast, the head restraints in 117 of the models, equating to 71%, were rated 'poor' since they produced a vertical separation of at least 10cm, with a minimum horizontal distance between head and restraint of 11cm. Further, in a study of the sitting positions of U.K. drivers (Parkin et al., 1993), it was found that 50% of drivers had the head restraint positioned more than 15cm away from the head horizontally, and in only 5% of cases was the restraint in the correct vertical position. Clearly then, a significant reduction in the risk of neck injury could potentially be achieved by educating car occupants to position adjustable restraints correctly. More specifically, Viano & Gargan (1995) suggest that if all adjustable restraints were placed in the up position, the whiplash injury risk could be lowered by 28%. An alternative solution, however, is to increase the number of fixed restraints provided in vehicles since these do not rely on adjustments made by vehicle occupants. Of the 164 car models assessed by the Insurance Institute for Highway Safety (1995), only 27 had fixed head restraints, and although half of these were rated 'poor', all 5 of the restraints rated as 'good' were fixed. This suggests that adjustable head restraints, whose effectiveness depends on adjustments made by the occupant, are less likely than fixed restraints to improve occupant safety in rear impacts. It is important to note, however, that the geometry of fixed restraints is also an important issue since they must offer adequate protection for the range of occupants for whom the vehicle is designed to accommodate. Consequently, there is a need for real world data on occupant sitting positions so that design can offer maximal protection to more car occupants.

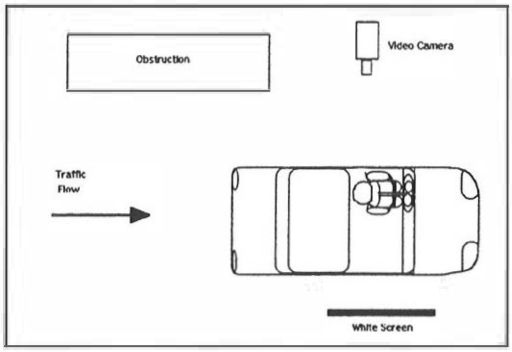
AIMS AND OBJECTIVES - This study aims to investigate the positioning of head restraints for front seat car occupants in order to supplement the results of Parkin et al. (1993) in providing real world data for both drivers and front seat passengers in the U.K. and the U.S.. In addition, factors affecting the position of the head restraint are also investigated in order to identify the parameters that need to be addressed in future design. Finally, the results are discussed in terms of smart restraint systems.

METHODOLOGY

The method used in this study was based upon that employed in the previous study of Parkin et al. (1993), which investigated the sitting positions of drivers in the U.K.. The field work took the form of three studies. The first, based in the U.K., looked at head restraint positioning for front seat passengers, and the second and third studies observed drivers and front seat passengers in the U.S. The field experimental procedures remained essentially the same, but were adapted to accommodate left-hand drive cars in the U.S..

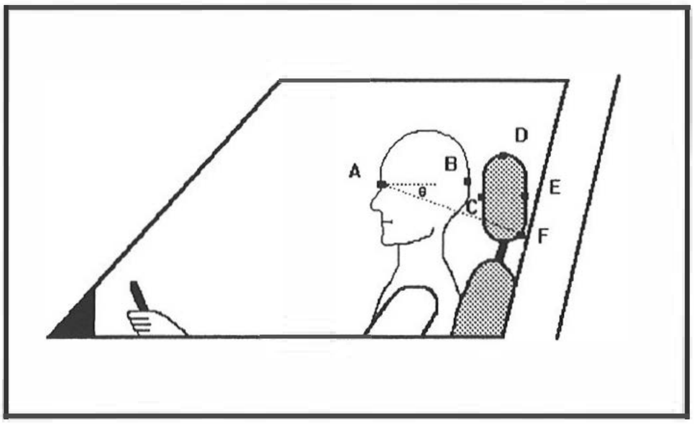
FIELD SET-UP - A video camera equipped with a high speed shutter (1/2000 sec) was used to film occupants in cars which passed in front of a white screen. The camera was placed at right angles to the traffic flow at a height level with the mid point of the side window for an average vehicle, and this is shown, using U.S. drivers as an example, in Figure 1.

Figure 1: Experimental Set-Up



VIDEO ANALYSIS & CALIBRATION - Video footage was played back, and measurements were taken from a stilled image on a television monitor. The dimensions recorded were the distance between either the nasion (bridge of the nose) (A) or the back of the head (B), to the most clearly visible of four points on the head restraint (C, D, E, F). The angle (θ) subtended by the line connecting these two relevant points (e.g. A and F), and the horizontal, was also recorded. These measures are detailed, using the U.S. driver as an example, in Figure 2.

Figure 2 - Details of Measurements Recorded



The measurements recorded were then converted to more useful dimensions by the following procedures. Initially a scaling factor was applied to all measures, and this was derived by comparing the known dimension of the B-pillar for individual car models with that recorded on-screen. The -6% correction factor used by Parkin et al. (1993) was also applied to the data since the equipment and procedure were the same in both studies. Consequently, since on-screen measurements were found to be between 1% and 11% greater than actual values, the level of accuracy of the results was brought to within +/- 5%. Once scaled and corrected, these measures were then converted geometrically into the final measures using known head restraint dimensions and anthropometric data on head widths (Pheasant, 1988). The final measures used in the analysis are listed below.

- Horizontal distance between the centre of the back of the head and the central front point of the head restraint.
- Vertical distance between the centre of the back of the head and the central front point of the head restraint.

VEHICLE SAMPLE - The sample of cars analyzed in the U.S. comprised 39 make/models which were selected on the basis of popularity. This was derived from sales figures relating to the preceding 2 years, and all vehicles were under 9 years old at the time of filming. The U.K. car sample was the same as that used by Parkin et al. (1993) and comprised 19 make/models also selected on the basis of popularity. For each study, the vehicle populations were broken down, according to wheelbase, into size categories such that the vehicle range was representative of the car population. In total, 2935 cars were analyzed (see Appendix A).

OCCUPANT CHARACTERISTICS - Since the occupant population was self generating, occupant characteristics could not be controlled but were simply recorded in the video analysis. Only adults were used in the study, and age was classified as 'young' if the passenger looked to be aged between 16 and 34 years, 'middle-aged' if between 35 and 55, and 'elderly' if aged over 55 years. Tables 1 and 2, below show how the vehicle occupant population was comprised across both gender and age.

Table 1 - Vehicle Occupant Population by Gender

Gender	U.K. Front Seat Passengers	U.S. Front Seat Passengers	U.S. Drivers	Total
Male	367 (36.7%)	325 (35.0%)	576 (57.2%)	1268 (43.2%)
Female	633 (63.3%)	603 (65.0%)	431 (42.8%)	1667 (56.8%)
Total	**1000**	**928**	**1007**	**2935**

Table 2 - Vehicle Occupant Population by Age

Age	U.K. Front Seat Passengers	U.S. Front Seat Passengers	U.S. Drivers	Total
Young	482 (48.2%)	531 (57.2%)	524 (52.0%)	1537 (52.4%)
Middle Aged	379 (37.9%)	311 (35.5%)	387 (38.4%)	1077 (36.7%)
Elderly	139 (13.9%)	86 (9.3%)	96 (9.5%)	321 (10.9%)
Total	**1000**	**928**	**1007**	**2935**

RESULTS

VERTICAL SEPARATION - Although it is recognized that the optimal position of the restraint is such that its centre is level with the centre of gravity of the head, the difficulty in locating this point of the head in the videotape analysis means that in this study the optimal position is redefined. Consequently, the ideal position of the restraint is taken to be such that its centre is level with the centre point of the back of the occupant's head. The results relating to the vertical distance between the central points of the back of the head and the front of the head restraint are shown in Table 3. In all cases the value represents a position of the restraint below the optimal position described previously. In addition to mean distances, 99th percentile male values are listed since these give an indication of the extremes that should be accounted for in the design process.

Table 3 - Height of Centre of Head Above Centre of Head Restraint

Population Group	99th %ile Male	Mean	Std. Dev.
U.K. Passengers	191mm	58mm	47mm
U.S. Drivers	210mm	85mm	47mm
U.S. Passengers	199mm	65mm	51mm

In addition, it was found that 88% of U.K. passengers, 97% of U.S. drivers, and 91% of U.S. passengers had the restraint positioned below the optimum level (see Figure 3).

An Analysis of Variance (ANOVA) was used to examine the effect of population characteristics on vertical head restraint position, and this technique was also used to investigate vehicle characteristics.

Occupant gender was found to significantly affect vertical position for U.K. passengers ($F(1,865) = 88.33$, $p<0.01$), U.S. drivers ($F(1,889) = 22.44$, $p<0.01$), and U.S. passengers ($F(1,743) = 22.14$, $p<0.01$). In each case, male occupants had a greater separation between the head and the restraint than female occupants (see Figure 3). Conversely, occupant age was significant in affecting vertical head restraint position for only passengers in the U.K. ($F(2,865 = 3.23$, $p<0.05$), such that younger and middle aged passengers had a greater separation than older ones (see Figure 4). In both Figures 3 and 4, a positive value represents a position of the restraint below the centre of the head, whereas a negative value represents a position of the restraint above the head.

Figure 3: Vertical Distance to Head Restraint by Sample and Gender

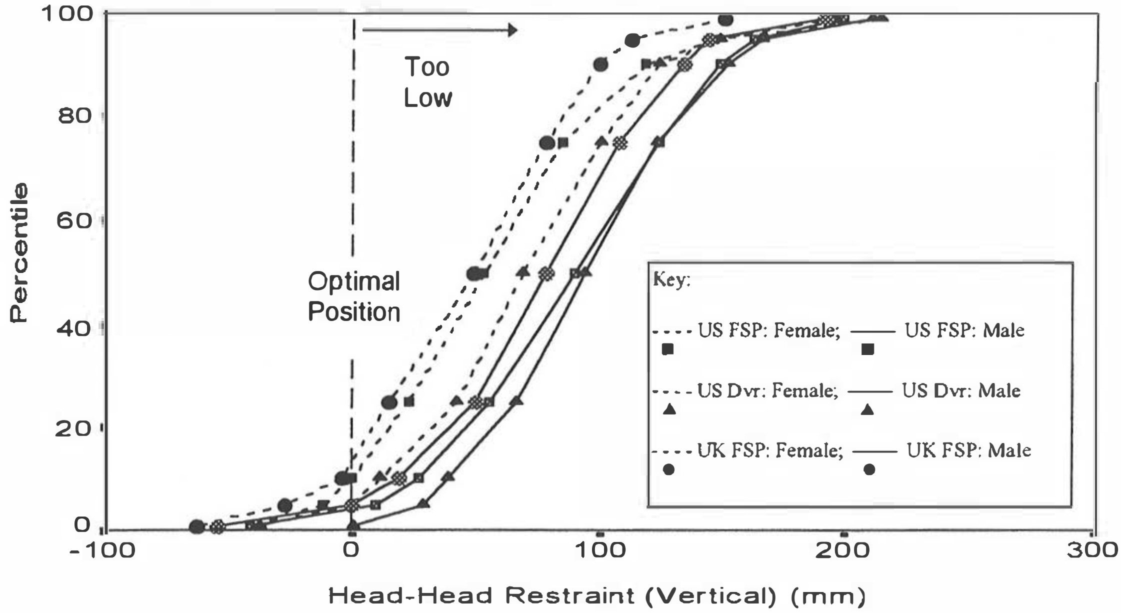
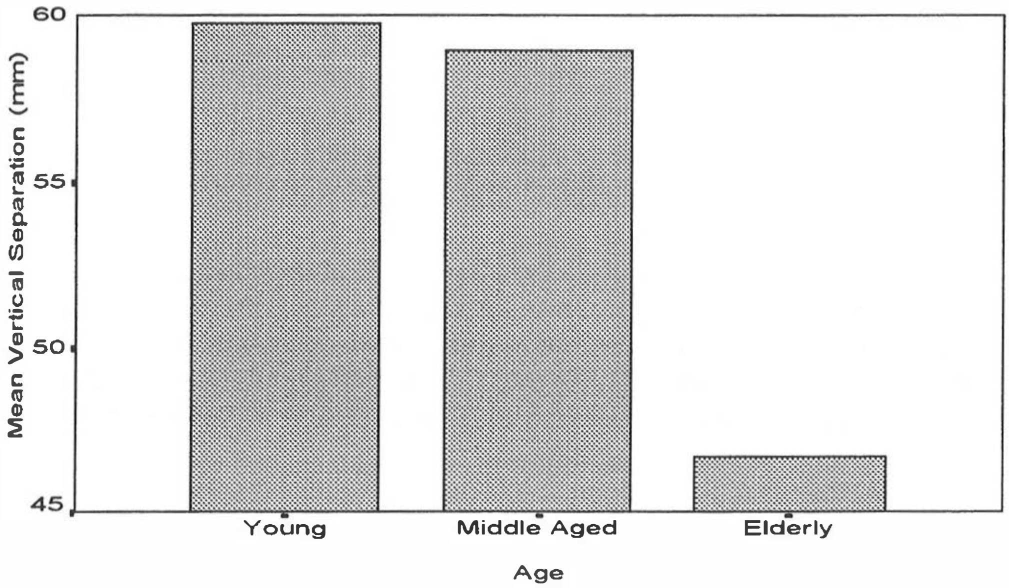


Figure 4: Vertical Distance to Head Restraint by Age: U.K. Passengers.



Characteristics of the vehicle were only significant in affecting restraint position for U.S. occupants. In the case of drivers, the important variables were vehicle size ($F(3,889) = 4.09$, $p<0.01$) and door number ($F(1,889) = 21.79$, $p<0.01$), such that the mean separation was greater by 11mm in large as opposed to small cars, and by 17mm in 5 door as opposed to 3 door vehicles. For passengers, only door number was significant ($F(1,743) = 11.17$, $p<0.01$), and again the mean separation was 17mm greater in 5 as opposed to 3 door cars.

HORIZONTAL SEPARATION - The results relating to the horizontal distance between the back of the head and the front of the head restraint are shown in Table 4. In addition to mean distances, 99th percentile values within each sample are listed since these give an indication of the extremes that should be accounted for in the design process.

Table 4 - Horizontal Distance Between Head and Head Restraint

Population Group	99th %ile	Mean	Std. Dev.
U.K. Passengers	281mm	66mm	60mm
U.S. Drivers	284mm	91mm	59mm
U.S. Passengers	287mm	73mm	62mm

In addition, it was found that 24% of U.K. passengers, 40% of U.S. drivers, and 31% of U.S. passengers had the restraint positioned more than 10cm away from the back of the head horizontally (see Figure 5). In addition, some occupants were observed with the restraint resting in the nape of the neck, and this is represented in Figure 5 by negative values.

An Analysis of Variance (ANOVA) was used to examine the effect of population characteristics on horizontal head restraint position, and this technique was also used to investigate vehicle characteristics.

Occupant gender did not significantly affect horizontal head to head restraint separation for any sample (see Figure 5). In fact, the only population factor having a significant effect on the distance was occupant age in the case of drivers in the U.S. ($F(2,889) = 3.50$, $p<0.05$). In this population group, the horizontal separation between the head and the restraint was greater in elderly as opposed to young drivers (see Figure 6).

Conversely, characteristics of the vehicle were relatively important in affecting horizontal head restraint positioning, but only for occupants in the U.S. Vehicle size had a significant effect in the case of both drivers ($F(3,889) = 10.78$, $p<0.01$) and passengers ($F(3,743) = 4.68$, $p<0.01$). In the case of drivers, the separation was greater in large cars than in small ones by 30mm. Similarly, for passengers, the separation was greater by 39mm in extra large as opposed to small cars. Door number also had a significant effect on the distance for drivers ($F(1,889) = 42.71$, $p<0.01$) such that the separation was greater by 29mm in 5 as opposed to 3 door vehicles.

Figure 5: Horizontal Distance to Head Restraint by Sample and Gender

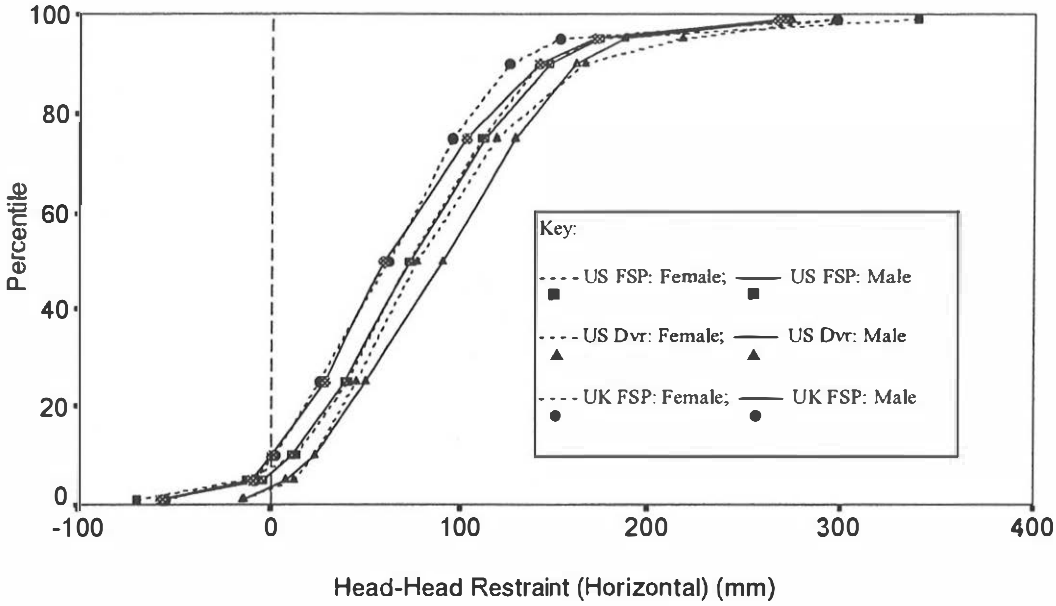
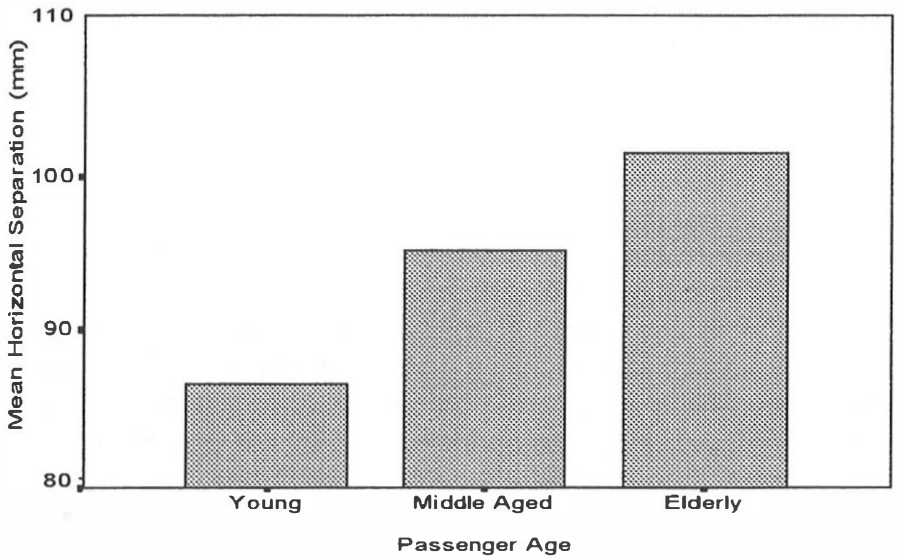


Figure 6: Horizontal Distance to Head Restraint by Age: U.S. Drivers



DISCUSSION

VERTICAL SEPARATION - The optimum vertical position of the head restraint, as defined in this study, is such that the centre of the restraint is level with the centre of the back of the head. The results show, however, that within each sample analyzed, the average vertical position of the restraint is at least 6cm below the centre of the head. Further, the separation increases to approximately 20cm at the 99th percentile male value. The results also show that in the majority of cases the head restraint is positioned below its optimum level, and this is the case for 88% of passengers in the U.K., 91% of passengers in the U.S. and 97% of U.S. drivers.

Clearly, a large proportion of front seat occupants are not adequately protected by the head restraint. Generally, however, occupants in the U.S. are at greater risk of neck injury than those in the U.K., and it is suggested that this reflects the fact that the stature of U.S. adults is on average approximately 15mm greater than the stature of adults in the U.K. (Pheasant, 1988). In addition, within the U.S. population, head to head restraint separation is generally greater for drivers than for passengers. This could relate to the possibility that passengers may be more likely than drivers to adopt a relaxed posture which would result in the head being closer vertically to the restraint.

The factors affecting the vertical distance between the head and the restraint include both occupant and vehicle characteristics. In all cases, occupant gender has a significant effect on the vertical separation between head and restraint, and the distance is generally greater for males than for females. It is likely that this is because men are typically taller than women, and this is illustrated by Pheasant (1988) who, at the 50th percentile level, reports a difference in stature of 130mm, and a difference in sitting height of 60mm. In addition, the vertical position of the head restraint for passengers in the U.K. is also significantly affected by occupant age such that older passengers were seen to have the head closer vertically to the head restraint. This is also likely to be a result of differences in stature, particularly apparent in persons over the age of 65, and, although the age categories are different to those used in this study, these differences are illustrated by Pheasant (1988); At the 50th percentile level, the stature of persons aged 65-80 years is less than that of 19-45 year olds by 60mm for men, and 45mm for women. For sitting height, the corresponding value for both males and females is 40mm.

Characteristics of the vehicle are also important in determining vertical head to head restraint separation, but this applies only to U.S. occupants and is probably due to the greater variation in the size of vehicle found on U.S. roads. For passengers in the U.S., the separation was seen to be greater in large as opposed to small vehicles, and a possible explanation could relate to differences in the seats provided in different size vehicles. In addition, for U.S. occupants, vertical head to head restraint separations were greater in five as opposed to three door cars.

HORIZONTAL SEPARATION - The ideal horizontal position of the head restraint is such that it is in contact with the back of the occupant's head. In this position the restraint can most effectively reduce the rearward motion of the head and thus reduce injury risk. More specifically, Olsson et al. (1990) report that a distance between the head and the head restraint of more, as opposed to less, than 10cm, correlates with increased injury risk in rear end collisions. The results show that the mean separation ranges from 7 to 9cm, and at the 99th percentile value this rises to approximately 28cm. It was also found that approximately one in four passengers in the U.K. have the restraint positioned more than 10cm away from the head, and the corresponding figures for U.S. passengers and drivers are around 31% and 40% respectively.

Clearly, a significant proportion of front seat car occupants are at increased risk of neck injury due to a large horizontal distance between the head and the head restraint. Generally, however, there are differences between the population groups analyzed. These were found to be consistent with the differences seen in the vertical positioning of restraints such that occupants in the U.S. were more likely than occupants in the U.K. to have a greater horizontal separation between head and head restraint, and within the U.S. population, drivers had a greater risk of injury than front seat passengers.

The factors affecting the horizontal position of the head restraint include both occupant and vehicle characteristics, and although these differ between samples, vehicle characteristics were generally the more important. Gender was not seen to significantly affect horizontal position of the restraint for any sample, and for both sets of front seat passengers, age was also non-significant in affecting horizontal positioning of the restraint. Occupant age was important, however, in affecting horizontal head restraint position for U.S. drivers, in that older as opposed to younger drivers were seen to have the head positioned on average further away from the restraint.

As stated previously, characteristics of the vehicle are more important than occupant characteristics in determining horizontal head to head restraint separation. As is the case with vertical positioning, however, this applies only to occupants in the U.S. and again is probably due to the greater variation in the size of vehicles found on U.S. roads. For both drivers and passengers in the U.S., the characteristics of size and door number were found to affect significantly the horizontal positioning of the head restraint. The separation was seen to be greater in large as opposed to small vehicles, and a possible explanation could again relate to the differences in seats provided. Finally, a greater separation was seen between the head and the restraint in five as opposed to three door cars.

SUMMARY OF RESULTS - The position of the head restraint was found to be too low and too far from the head horizontally in a significant proportion of cases. The great majority of occupants (88% of U.K. passengers and a greater number of occupants in the U.S.) have the head restraint too low to provide optimum protection against injury to the neck. In addition, 24% of U.K. passengers, and a greater proportion of U.S. occupants, had a distance of at least 10cm between the head and the restraint horizontally, and this means that, according Olsson et al. (1990), a significant proportion of the car occupant population is at increased risk of neck injury in an impact, relative to occupants having the restraint more suitably positioned.

Head restraint positioning was found to be worse in the U.S. as compared to the U.K., in that in the U.S. there was a greater distance between the head and the head restraint, both horizontally and vertically. It is suggested that the greater vertical separation may relate to the increased stature within the U.S. population, whereas the difference in horizontal separation may relate to differences in vehicles found in the U.K. and the U.S.. The mispositioning of the head restraint was also seen to be greater for drivers than for passengers, and it is proposed that this is likely to reflect an altered physical attitude taken by drivers to access vehicle controls.

With respect to the factors affecting head restraint positioning, population variables were mainly important in determining vertical separation, and this probably reflects differences in stature as a function of gender and age. Conversely, variables relating to the vehicle were seen to be important in determining both the vertical and horizontal position of the restraint, but only in the U.S. where there is generally more variation in vehicles.

REDUCING THE RISK OF NECK INJURY - This study shows that current head restraints are not providing optimum safety for most vehicle occupants. Head restraints were introduced into vehicles in an attempt to reduce the severity and incidence of neck injuries, but to be most effective, these restraints must be positioned high and close enough to the head in order to curtail it's rearward motion relative to the torso. In a majority of cases, however, the restraints were observed to be too low, and too far horizontally from the head, and this, for the most part, was the result of inadequate positioning of adjustable restraints on the part of vehicle occupants. Many restraints were left in the 'down' position, and it is suggested that the reasons behind this are a combination of laziness or ignorance on the part of the occupant as to correct adjustment, and also a preference for lower positions on the grounds of comfort and visibility. In some cases, however, the inappropriate position of the restraint appeared to be the result of design inadequacies which meant that the optimum position could not be obtained, and this applied to fixed restraints as well as to those that were adjustable. There is, therefore, much potential for reducing neck injury risk through design.

Head Restraint Design - The results of this study indicate that the risk of neck injury can be reduced by improving the design of head restraints, and already advanced head restraints have been developed. As reported by the Insurance Institute for Highway Safety (1995), engineers at General Motors have patented a design for a head restraint that pivots forward when sufficient force is applied to a seat back by a rearward moving occupant. In addition, the Insurance Institute for Highway Safety (1995) report that Swiss engineers are currently developing a system which uses an electronic sensing device to automatically position the restraint correctly according to occupant head position. In essence, designers are moving towards the concept of smart head restraints.

Smart Head Restraints - The concept of restraints that are able to account for variations in impact and vehicle type, along with occupant characteristics, has recently received much attention within the field of vehicle safety. Current restraints, which have been effective in reducing the number of deaths and serious injuries occurring in accidents, are unable to provide optimum safety for all vehicle occupants. Devices such as airbags, pretensioners and weblocks are activated only when specified decelerations are reached, and as such they can, to some extent, address impact characteristics. Typically, however, restraints are *optimized* around a single crash condition with a single occupant in a single sitting position. They are unable, therefore, to adequately address variations in impact and vehicle characteristics. In addition, they do not take account of variations in biomechanical tolerance or injury risk, which result from differences in occupant characteristics (e.g. gender, age, height, weight) or from the wide variation seen in occupant sitting positions (Parkin et al., 1993; Cullen et al., 1996). Consequently, smart restraint systems have been proposed (Mackay et al., 1994). Within a smart approach, variability can be introduced into a restraint system through the use of discretionary force limiters and weblocks, variable force pretensioners, airbags with variable volumes and inflation rates, and automatically adjusting head restraints. Consequently, it is argued that smart restraints, in addressing vehicle, impact and occupant characteristics, can improve occupant safety by reducing injury risk.

In particular, since the results of this study suggest that a single head restraint is unlikely to be capable of providing maximum safety levels for all vehicle occupants, the risk of neck injury is likely to be reduced by the provision of smart head restraints. Such head restraints could be automatically positioned correctly in relation to the head of an occupant through the use of an electronic sensor system. In the most advanced systems the position of the head could be monitored continuously. Smart head restraints could, therefore, improve occupant safety and they have an additional advantage over current head restraints because they are less dependent upon action taken by the occupant.

Seat Back Properties - In addition to the properties of the head restraint, the properties of the seat back are important in determining the risk of neck injury for occupants involved in vehicle impacts. As stated by Svensson et al. (1993), 'the elastic rebound of the backrest can aggravate the violence of the whiplash motion and delay contact between the head and the head restraint'. Further, Parkin et al. (1995) found that neck injuries were twice as frequent in vehicles with unyielding seats than in those with seat that yielded under force, and it is suggested that 'increasing seat back strength may well lead to an increase in minor AIS1 neck sprains'. In contrast, however, it should be noted that increasing seat back strength can in some cases improve occupant protection. Indeed, seat strength requirements are currently under discussion and the current trend is towards stronger seat backs which are more able to protect occupants in frontal collisions by acting as a luggage retention barrier.

CONCLUSIONS

- The majority of front seat vehicle occupants are at increased risk of neck injury as a result of a poorly positioned head restraint;
- Occupants in the U.S. have a greater horizontal and vertical separation between the head and the restraint than occupants in the U.K.;
- Within the U.S. population, the head restraints of drivers are mispositioned more frequently than those of front seat passengers;
- The vertical distance to the restraint is related to occupant gender and age
- The horizontal position of head restraints is largely affected by vehicle size and door number, but only for occupants in the U.S., and;
- The results of this study support the case for automatically adjusting head restraints within a smart approach.

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APPENDIX A - Vehicle Populations

Table 1: U.K. Passengers

Make/Model	Size	Freq.
Citroen BX	3	31
Ford Escort Mk3	1	62
Ford Escort Mk4	1	86
Ford Fiesta	1	78
Ford Sierra	3	160
Ford Granada	3	36
Peugeot 205	1	54
Peugeot 405	3	40
Rover 200/400	2	108
Rover 800	3	18
Rover Metro	1	70
Rover Montego	2	78
Vauxhall Astra	2	30
Vauxhall Carlton	3	18
Vauxhall Cavalier	3	78
Vauxhall Nova	1	29
Volvo 7 Series	3	8
VW Golf	2	9
VW Polo	1	7
Total		**1000**

Size:
1=Small
2=Medium
3=Large
4=Extra Large

Table 2: U.S. Drivers & Passengers

Make/Model	Size	Freq. (Drivers)	Freq. (Pass.)
Acura Integra	2	18	16
Acura Legend	4	22	8
Buick Century	3	15	9
Buick Le Sabre	3	11	10
Cadillac De Ville	4	5	18
Cadillac El Dorado	3	0	5
Cadillac Seville	3	0	5
Chevrolet Cavalier	2	35	30
Chevrolet Corsica	2	6	9
Chevrolet Lumina	3	4	6
Chrysler Le Baron	2	7	4
Dodge Intrepid	4	1	2
Dodge Neon	3	13	9
Ford Escort	2	55	37
Ford Mustang	2	7	9
Ford Taurus	3	93	64
Ford Thunderbird	4	9	6
Geo Prizm	1	8	9
Honda Accord	3	158	152
Honda Civic	2	11	87
Lexus ES	2	2	3
Lincoln Town Car	4	8	12
Mazda 626	2	18	13
Mazda Protege	2	17	12
Nissan Altima	2	14	14
Nissan Maxima	3	16	18
Nissan Sentra	2	45	38
Oldsmobile Achieva	2	5	5
Oldsmobile Ciera	3	27	16
Pontiac Grand Am	2	23	23
Pontiac Grand Prix	3	7	6
Toyota Camry	2	89	112
Toyota Corolla	1	95	98
Toyota Paseo	1	2	4
Toyota Turcell	1	32	25
VW Golf	1	11	13
Volvo 7 Series	3	7	10
Volvo 8 Series	3	7	5
Volvo 9 Series	3	4	6
Total		**1007**	**928**