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Stowable Head Restraint Non-Use Position Study

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16. Abstract

A study was conducted to determine the minimum torso angle change of the J826 manikin that will give an occupant a clearly recognizable, physical cue that the stowed head restraint is not in position and needs to be raised. A successful physical cue was considered to be one that resulted in the rear seat occupant raising the stowed head restraint to its properly deployed position. The study also compared the effect of protruding head restraints to the use of a warning label that told the occupant to adjust the head restraint.

The test involved 68 participants who experienced four treatment conditions (three torso angles and one label). The baseline condition of 5 degrees of torso angle change was implemented using a 2005 Chrysler Town and Country minivan with Stow n' Go rear seats. To achieve the other two conditions of 10 degrees (based on another manufacturer's head restraint design) and 15 degrees, additional head restraints were modified. The label that comprised the fourth treatment condition was created based on the label from a 2005 Volvo SC90 center, rear seat head restraint. Testing was conducted in a static setting but using a ruse that led participants to believe that they would be driving a vehicle as part of the test. Participants were asked to sit in the subject seat and fasten the safety belt in preparation for watching a brief instructional video and then being driven to another location. Data collected included the participant's response to the stowed head restraint (i.e., whether or not the person adjusted the head restraint).

Results of this study suggest that a head restraint design that produces a 5-degree change in occupant torso angle is unlikely to be sufficiently uncomfortable to achieve a success rate in communicating to occupants that the head restraint should be raised from the stowed position. The head restraint design that produced a 10-degree torso angle change was found to be successful in influencing a majority of participants, 79 percent, to adjust the head restraint. While the 15-degree torso angle condition saw 100 percent compliance, this invasive design is likely to draw consumer complaints due to annoyance. Thus, the 10-degree head restraint condition should be considered for use in encouraging safe head restraint adjustment for seats with stowable head restraints.

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1.0 INTRODUCTION

1.1. Background

To improve rear visibility and allow rear seats to be folded into a compact form providing more cargo space, some vehicles (e.g., vans and SUVs) are now being designed with rear seat head restraints that can be moved into a "non-use" position that does not require removal of the head restraint. A head restraint in a non-use position does not provide the occupant safety benefits that a properly deployed head restraint would. NHTSA has stated that the non-use position of a rear seat head restraint should be "clearly recognizable." To date, manufacturers have employed two methods of indicating to a seat occupant that the head restraint should be raised: 1) a forward-protruding head restraint that gives a physical cue that it should be raised, and 2) a head restraint label that uses symbology to communicate the message that the head restraint must be raised when an occupant is seated in that position. The protruding head restraint has been used in a 5-degree design (Chrysler minivans) and 10-degree design, while the label method has been used in Volvo vehicles and possibly other makes.

To support development of a Global Technical Regulation (GTR) as well as a petition response, Rulemaking requested human factors testing to provide an objective basis for determining how much head restraint protrusion would lead occupants to recognize the non-use position and move it into the proper position. Thus, a study was conducted to determine the minimum torso angle change of the J826 manikin that will give an occupant a clearly recognizable, physical cue that the stowed head restraint is not in position and needs to be raised. A successful physical cue was considered to be one that resulted in the rear seat occupant raising the stowed head restraint to its properly deployed position. The study also compared the effect of protruding head restraints to the use of a label.

1.2. Objectives

This study determined the torso angle of an occupant of a rear seat with head restraint in a non-use position that could be considered the minimum angle that results in the non-use position condition of the head restraint being clearly recognizable to that occupant. The effectiveness of the protruding head restraint was compared to a label.

2.0 METHOD

2.1. Approach

A human factors study was conducted to determine the minimum torso angle change of the J826 manikin that would give an occupant a physical cue that the head restraint is not in position. The torso angle change is caused by a fore-protruding, stowed head restraint (i.e., head restraint in a non-use position) whose purpose is to cause the occupant to lean forward thereby indicating to the occupant that the head restraint should be raised into a properly deployed position. Since at least one other manufacturer uses an alternative method (a label to indicate to the occupant that the head restraint should be raised), this option was also examined to assess its effectiveness.

The test vehicle noted in Appendix C of the Daimler Chrysler FMVSS No. 202 Petition for Reconsideration shows a drawing of a 2005 Dodge Grand Caravan Stow 'n' Go seat back. This is the same seat used in the 2005 Chrysler Town and Country minivan. To conduct the testing we needed a test vehicle complete with head restraint, plus two additional head restraints that could be modified and put in place of the OEM head restraint for other treatment conditions. Since we were able to acquire the second row seating (consisting of two separate seats) from a Chrysler Town and Country minivan purchased for unrelated testing, a Town and Country minivan was acquired for use in data collection to minimize cost (i.e., eliminated need to buy two additional head restraints). Note that the Chrysler Town and Country minivan test vehicle has second row seats that recline.

Testing involved four treatments, three torso angles and one label, as pictured in Figure 1. The baseline condition of 5 degrees of torso angle change was implemented using a 2005 Chrysler Town and Country minivan with Stow n' Go rear seats. To achieve the other two conditions of 10 degrees (based on another manufacturer's head restraint design) and 15 degrees, additional head restraints were modified. The label that comprised the fourth treatment condition was created based on the label from a 2005 Volvo SC90 center, rear seat head restraint. Additional details on these treatment conditions are provided in Section 2.2.

5 degrees 10 degrees 15 degrees Label

Figure 1. Treatment conditions

Testing was conducted in a static setting but using a ruse that led participants to believe that they would be driving a vehicle as part of the test. Participants were asked to sit in the subject seat and fasten the seatbelt in preparation for watching a brief instructional video and then being driven to another location. Data collected included the participant's response to the stowed head restraint (i.e., whether or not the person adjusted the head restraint), as well as participant standing height, sitting shoulder height (measured inside and outside of the vehicle), and questionnaire responses.

2.2. Test Preparation

2.2.1. Torso Angle Measurement

Measurements were taken using an H-point machine to determine the backset distances needed to obtain 10- and 15-degree changes in torso angle. These backset distances were then used to create modified head restraints, which served as treatment conditions in addition to the OEM stowed head restraint position of 5 degrees torso angle change. Here, the backset distance refers to the distance between the head restraint and headroom probe of the H-point machine (since initially, the manikin head form was not available for measuring).

First, the seatback angle was set to a normal driving or riding seatback angle of approximately 25 degrees as recommended in SAE J826. The seat was moved back to its rearmost setting to allow for positioning of the H-point machine. The H-point machine was installed in the vehicle and adjusted per SAE J826. The backset distance was measured for the condition with the head restraint stowed and for the condition with the head restraint fully extended. This was done using a standard tape measure. Measurements were taken from the top front of the head restraint (approximately 1 inch down, where the surface was flat) to the front of the headroom probe. In addition to the backset distance, the torso angle was recorded for each condition using an inclinometer placed on the vertical structural component of the H-point machine. Once these two conditions were confirmed, the H-point machine was angled forward manually, using the inclinometer to add 5 and 10 degrees, with backset measurements taken at each position. The vertical height measurement consisted of the distance between the height probe of the H-Point machine and the top of the head restraint.

Using these measurements, preliminary head restraint modifications were created by modifying the posts that secure the head restraint to the seat (see Section 1.4.2). The modified head restraints were then installed in the vehicle and measurements were again taken to ensure that they created the desired change in torso angle, except that measurements were taken from the actual point of contact of the head restraint to the H-point machine (this time using the manikin head form). Taking the measurements in this manner allowed for a more accurate determination of the backset distance to get the torso angles as close to the desired values as possible. Following confirmation of the measured values, the two modified head restraint fixtures were finalized in preparation for data collection. Table 1 contains these final measured values for the backset distance and torso angle metrics. For each condition, the height of the fully raised head restraint from the H-point was confirmed to be approximately 760 mm.

Table 1. Head Restraint Measured Values

Condition	Torso Angle (deg)	Torso Angle Difference (between conditions, in deg)	Backset Distance (horizontal offset in mm when HR is up)	Vertical Height (amount head form is above HR in mm when HR is up)
OE head restraint up	25.5	N/A	75	98
OE head restraint stowed (5 degree torso angle change)	19.1	6.4 (manufacturer states 5)	above	above
10 degree torso angle change (stowed)	14.2	4.9	37.5	90
15 degree torso angle change (stowed)	9.1	5.1	5	78

2.2.2. Head Restraint Modification

Modifications of the OEM head restraints to create the 10- and 15-degree conditions only involved changes to the posts of the head restraint. The posts were cut near the top. For each head restraint, a piece of metal was cut to a length according to the measured distance required for that treatment condition as determined by the method described in Section 2.2.1. The piece of metal was positioned between the cut ends of the posts to produce a horizontal, forward offset in the head restraint. The metal extension piece was fastened to the cut ends of the posts at the head restraint using set screws and fastened to the other cut ends by welding. Since this method of modification retained the OEM function of the head restraint posts for vertical positioning and head restraint removal, the head restraints could be easily removed from the seat and re-installed to permit quickly changing the treatment conditions between participants. The three head restraint conditions used in this study are pictured in Figures 2 through 5. Note that these fixtures were created to produce the desired torso angles and that production head restraints may not resemble this design.

Figure 2. Side-view photos of the three head restraint conditions, stowed.

Figure 3. Top-view photos of the three head restraint conditions.

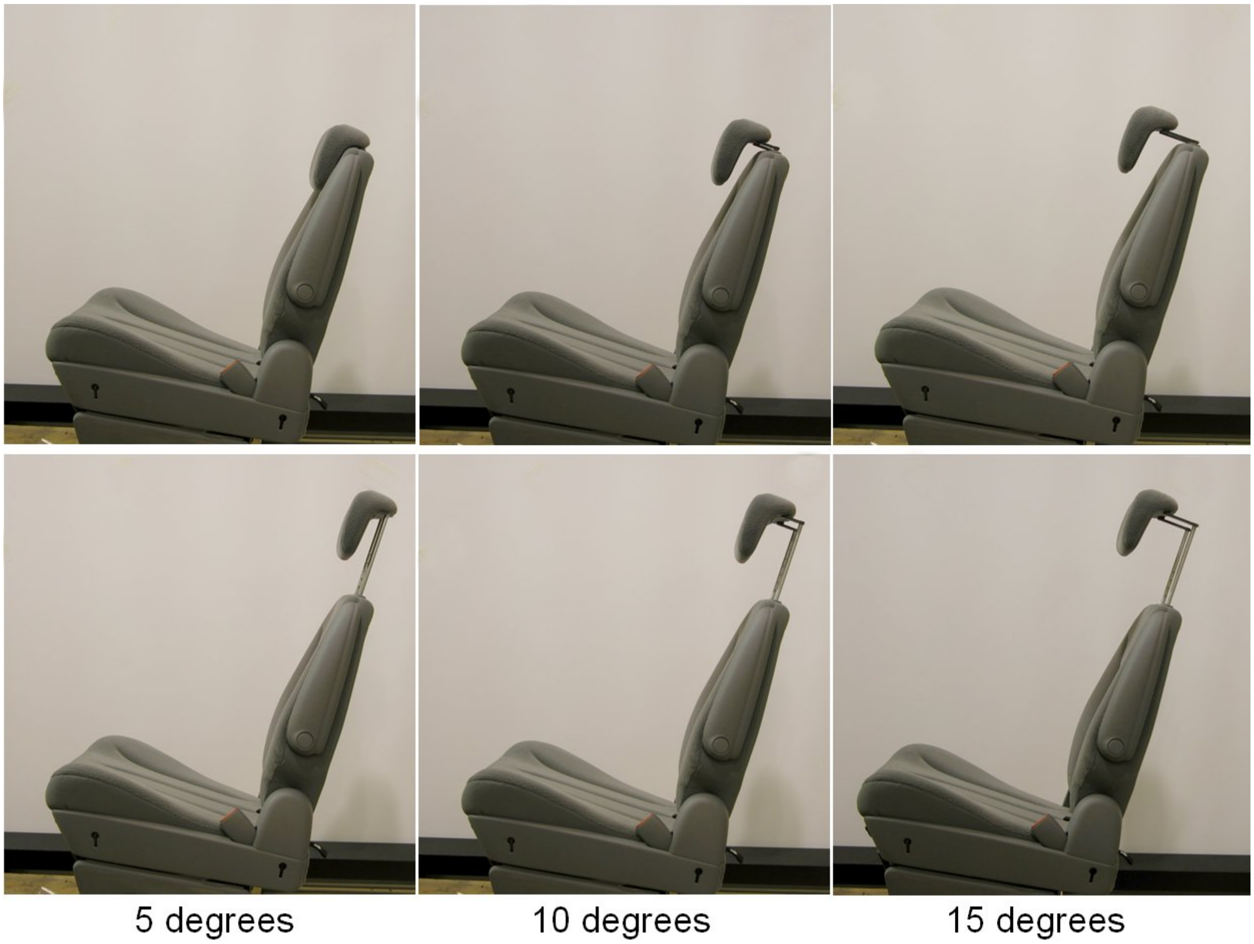

Figure 4. Side-view photos of the subject seat with three head restraint conditions, stowed and deployed, no occupant.

5 degrees 10 degrees 15 degrees

Figure 5. Side-view photos of the subject seat with three head restraint conditions, stowed and deployed, with occupant.

2.2.3. Label Condition Design

An alternative cue condition consisting of a warning label was developed based on a Volvo label. Figure 6 shows the Volvo label as installed by the manufacturer. Figure 7 shows the detail of the Volvo label (a) and the modified label used for this study (b). Modifications were made to improve the clarity of the symbol including, changing the "x" to a "no" (circle with diagonal slash) symbol, rotating the image of the person to show him bending forward due to the stowed head restraint, and adding an arrow to indicate that the head restraint as pictured on the right side of the image had been raised to a proper position. For testing, this label was paired with the 5-degree torso angle condition.

Figure 6. Volvo head restraint label (center of photograph).

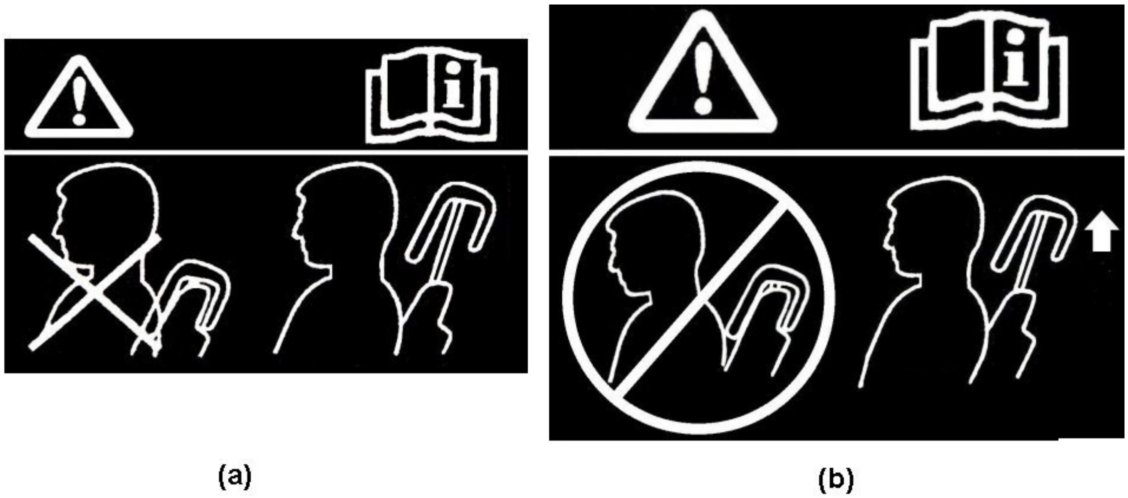

Figure 7. Illustrations showing detail of the Volvo label (a) and the modified label (b)

The modified label was printed to be similar in size to the OEM Volvo label. The dimensions of the printed portion of the Volvo label were approximately 0.88 inch high by 1.38 inches wide. The dimensions of the printed portion of the modified label used in this test were approximately 1.25 inches high by 1.5 inches wide. A photograph of the installed label as used for testing is shown in Figure 8.

Figure 8. Modified head restraint label as mounted for testing.

2.3. Experimental Design

The study design involved a single independent variable consisting of the cue used to indicate that the head restraint was in a stowed position. The cue levels included three torso angles (5, 10, and 15 degrees) and one label.

2.4. Participants

Participants were 68 employees of the Transportation Research Center Inc. (TRC). Approximately half of the participants were technical and administrative support staff, while the other half were composed of entry-level test drivers. Gender was not considered to be a relevant factor in this study.

In selecting the range of participant heights to be included, the following were considered: 1) the height of typical rear seat passengers, 2) the age of rear seat occupants most frequently injured, and 3) the dimensions of the subject seat. The typical height of rear seat passengers and the dimensions of the subject seat were considered to establish the range of occupant heights that would be most likely to experience discomfort due to a stowed head restraint. Participant age was considered since it is plausible that younger occupants might be less likely to experience discomfort due to poor posture and might be less likely to voice their discomfort due to immaturity.

To determine the typical height and age of rear seat passengers, the weighted frequency of occupants in the rear seat were examined using NASS data from 1993-2003 (outboard rear seats only). The mean height of rear seat occupants was 4 foot 7.5 inches (s.d. 14.2 inches). These data showed that most rear seat passengers were younger than 23 years old. The average age of rear seat occupants was 15.4 years (s.d. 14.8). Complete distributions for age and height are shown in Figures 9 and 10.

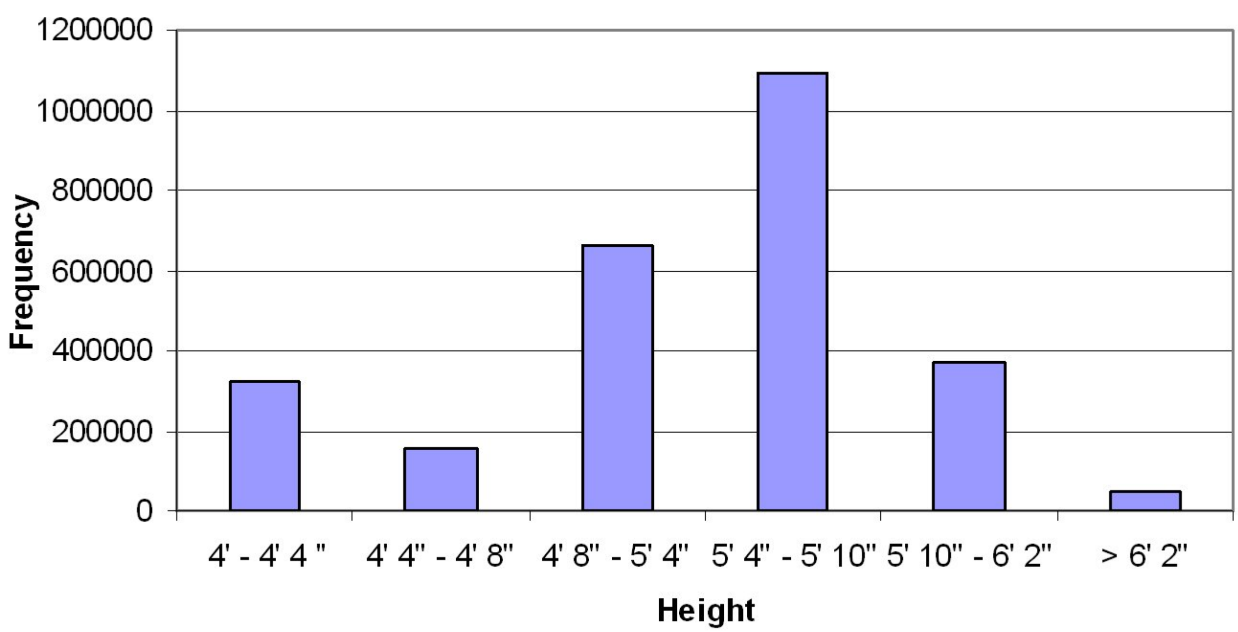

Figure 9. Distribution of the heights of rear seat occupants (NASS 1993-2003)

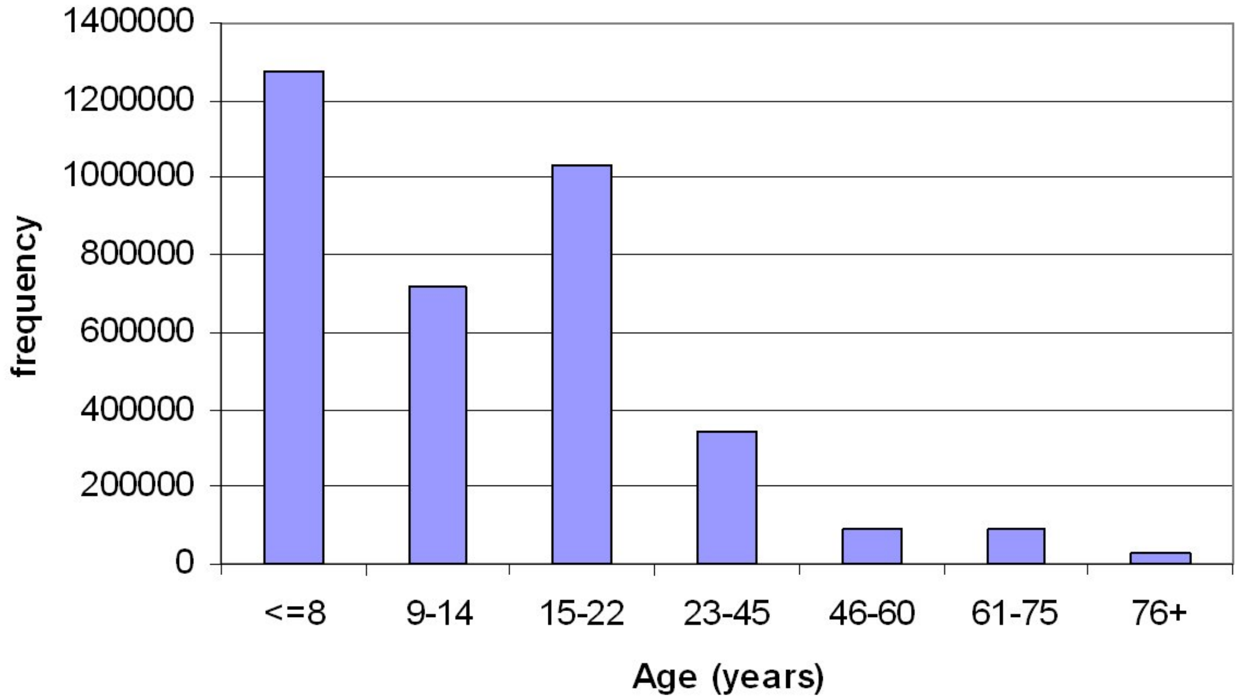

Figure 10. Distribution of the ages of rear seat occupants (NASS 1993-2003)

Table 2 shows mean height by age values for the 1993-2003 NASS data examined.

Table 2. Mean Height by Age (1993-2003 NASS)

	Occupant Height (in)		
Age	Mean	Standard Deviation	% of Rear Seat Population
<=8	13.8	9.3	35.6%
9-14	59.9	5.8	20.1%
15-22	67.1	3.6	28.9%
23-45	66.8	4.5	9.5%
46-60	65.1	3.0	2.6%
61-75	64.2	5.2	2.5%
76+	65.0	3.5	0.8%

The primary participant recruitment criterion was standing height, since most people know what this number is as opposed to their sitting shoulder height. Thus, participants were recruited according to their standing height. Care was taken to ensure that the ruse chosen was not defeated by this screening question. The rationale for choosing the range of standing heights used in this testing follows.

2.4.1. Participant Height Criteria Selection

The height of rear seat passengers directly impacts where the stowed head restraint would contact them. To determine how the subject seat might interact with occupants of different heights, the dimensions of the subject seat were measured. The seat dimensions were considered along with standard sitting shoulder height values for adult males and females to establish the range of occupant heights that would be most likely to experience discomfort due to a stowed head restraint. The standing height values used for recruitment were established through extrapolation from the sitting shoulder height values.

The height of the lower edge of the stowed head restraint in the test vehicle is approximately 18.5 inches with respect to the seat pan, as indicated in Figure 11. It appeared that an occupant whose sitting shoulder height is approximately this value would not be uncomfortable with the head restraint fully stowed. It was unclear how much greater than 18.5 inches the threshold lies at which an occupant's sitting shoulder height would be sufficiently large for the person to experience discomfort.

Figure 11. Approximate dimensions of second-row seat from a 2005 Chrysler Town and Country minivan (Note: photo was edited to show both stowed and fully extended positions of the head restraint).

The height at which children are no longer required to be seated in a child safety seat is 57 inches. A 57-inch tall child (10 to12 years old) would have a sitting shoulder height of about 19.3 inches (based on extrapolation from NIST data found on the Internet). Since in its stowed position, the bottom of the head restraint is at 18.5 inches, a 57-inch-tall child may not be tall enough to experience discomfort created by a stowed head restraint. Furthermore, children of this age may not be mature enough to conclude that something is wrong with the seat configuration if they experience only minor discomfort. For this reason, as well as the difficulty in recruiting minor subjects, participants younger than 18 were not pursued. One 10-year-old boy was examined in the subject seat to get an idea of the level of discomfort that might be experienced by a youngster (see Figure 12).

5 degrees 10 degrees 15 degrees

Figure 12. Child occupant (10 years old, 52 inches tall) shown with the three head restraint conditions.

For this testing the lower limit of height range was 60 inches, which corresponds to a 5th percentile female, as indicated in Table 3. The standing height value of a 75th percentile male, 71 inches, was used as the upper limit of participant height. We attempted to balance participant height by condition by recruiting an equal number of participants per 2-inch range of height.

Table 3. Approximate Anthropometric Values (Salvendy, 2nd ed.)(Shaded cells represent missing data.)

		Standing		Sitting		Sitting Shoulder	
		Male	Female	Male	Female	Male	Female
	5	1640	1520	855	800	548.5	509.1
	40	1730	1600				
mm	**50**	1755	1625	915	860	597.8	555.5
	60	1780	1650				
	95	1870	1730	975	920	646.3	603.6
	5	64.6	59.9	33.7	31.5	21.6	20.1
	40	68.2	63.0				
in	**50**	69.1	64.0	36.1	33.9	23.6	21.9
	60	70.1	65.0				
	75	71.0 (per Woodson)					
	95	73.7	68.2	38.4	36.2	25.5	23.8

2.5. Procedure

Testing was conducted during August, September, and October 2005 at the NHTSA Vehicle Research and Test Center in East Liberty, Ohio. To expedite data collection, testing was conducted without the vehicle being driven.

The protocol involved the following steps that were performed by the experimenter:

1. Read introduction sheet containing ruse and sign.
    a. Participants were given a sheet containing the following statement: “NHTSA is gathering drivers’ opinions on a state-of-the-art lane departure warning system that is available for the first time as original equipment in the 2005 Infiniti FX35. Today you will experience a demonstration of this system and then you will be asked for your opinions about it. This should only take about 30 minutes. If you’re prepared to participate, please sign and date below.”
    b. After signing, the experimenter said, “If you’re ready, we’ll walk out to the transport vehicle that will take us to the test vehicle. “
2. Seat participant in vehicle.
    a. The seat was positioned at its rearmost longitudinal setting to decrease the chance of participants getting a good look at the rear of the head restraint. The initial condition of the vehicle involved both second row seats being reclined to 25 degrees as recommended in SAE J826.

b. The participants were instructed to sit in the appropriate seat and secure the seat belt.

    i. Script: "This van will be our transport to get to the test vehicle. Before driving over to where the test vehicle is located, I'm going to show you a short video describing the Infiniti lane departure warning system. After the video I'll ask you to complete a short survey about your opinions of the system and then we'll ride over and let you see the vehicle first-hand. Now, please get into the van and secure your seat belt and I'll start the video player. "

c. If participant asked if there was a problem with the head restraint or asked if they could adjust it, the experimenter stated that they could "…adjust it however you need to for your own comfort."

d. Video length was 5 minutes, the maximum observation time.

3. Exposure and observation (static) with video recording.

    a. During the seating procedure (step 2) and the video presentation (if necessary), the participant was monitored to assess whether they made any attempt to deploy the stowed head restraint. The maximum duration of exposure time (to provide an end to the test in the event that a participant does not attempt to remedy the head restraint position) was equal to the duration of the video clip shown.

4. After observation is complete (5 minutes or before), ask participant to complete the questionnaire.

    a. The first page of the questionnaire inquired about the participant's degree of comfort with the seat and head restraint, as well as label conspicuity (for those who experienced the label condition) and comprehension (for all participants).

    b. The second page of the questionnaire began with the following statement:

    "Thank you for completing the survey. There will actually be no driving involved in your participation. Our true interest is in assessing seat and head restraint comfort. Please do not talk to anyone about this test, as we will have other on-site employees participating in the coming weeks. Participants cannot know in advance that this test is focused on seat comfort. Thanks in advance for your cooperation."

    Following this statement, the questionnaire proceeded to probe the participant for reactions to the other two head restraint torso angle conditions. The experimenter exchanged the initial head restraint for the two other head restraint conditions and the participant's reactions to those conditions were collected.

5. Following completion of the questionnaire, measurements were taken for sitting shoulder height in vehicle, standing height without shoes, sitting shoulder height outside of the vehicle, and photograph were taken of the seated participant.

3.0 RESULTS

3.1. Participant Demographic Information

Sixty-eight participants were tested including 47 males and 21 females. Participants' ages ranged from 20 to 74 years old, with an average age of 45.6 and median age of 47.5. Figure 13 shows the distribution of participant heights by treatment condition.

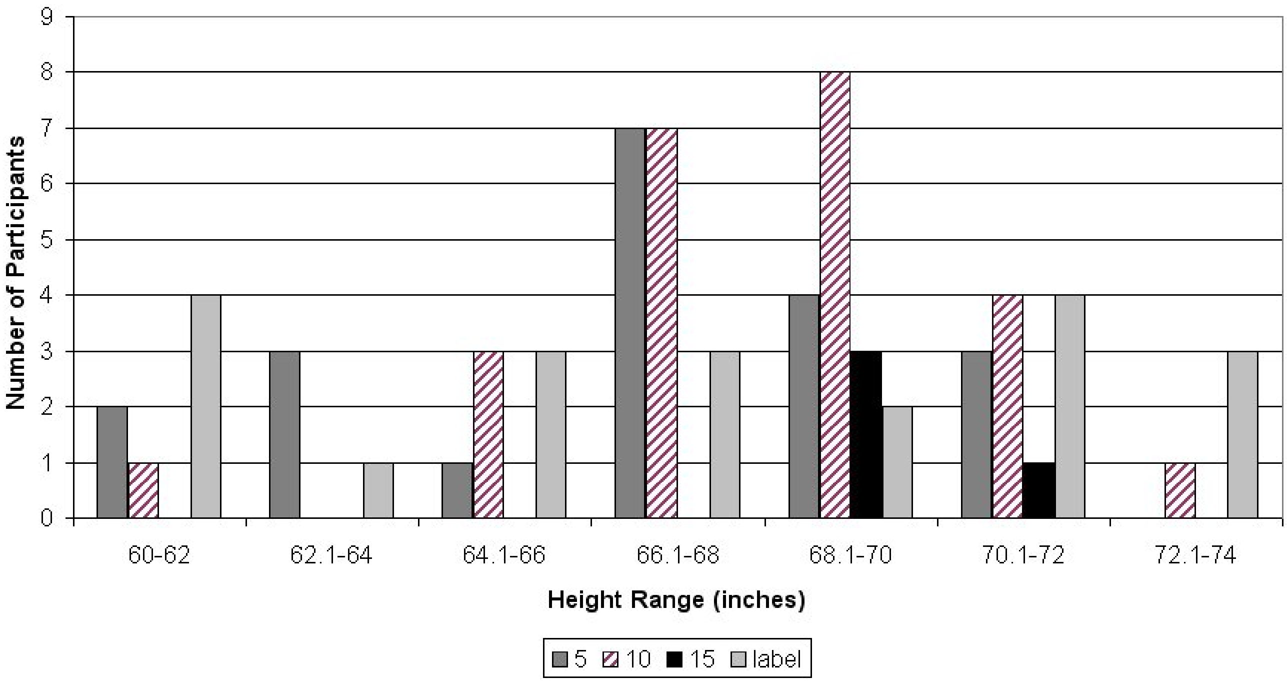

Figure 13. Distribution of participant heights by treatment condition.

3.2. Initial Treatment Responses

Participants' responses to the initial treatment condition presented to them are summarized in Table 4. Table 5 shows the number and percent of participants per condition who adjusted the head restraint and breaks these figures down by treatment condition and age. Of the participants who adjusted the head restraint, 88 percent adjusted it immediately after sitting down.

In the early stages of data collection, 100 percent of four people run in the 15-degree condition adjusted the head restraint. The percent of participants who adjusted the head restraint in the 10-degree condition was also quite high. Based on these early trends, it was assumed that further testing of the 15-degree condition would continue to show 100 percent compliance (i.e., head restraint adjustment). As a result, testing of the 15-degree condition was discontinued with only four participants having been run.

Table 4. Number of Participants Who Adjusted the Head Restraint by Condition.

Condition	Number of Participants Who Adjusted	Number of Participants (n)	Percent Who Adjusted
5 degree torso angle change (Chrysler OEM)	3	20	15%
10 degree torso angle change	19	24	79%
15 degree torso angle change	4	4	100%
Label	0	20	0%
Total	26	68	38%

Table 5. Ratio (Adjusted/Participated) and Percent of Participants Who Adjusted the Head Restraint by Condition and Age.

	18-29 years		30-44 years		45 years and older		Total	
Condition	Ratio	Percent	Ratio	Percent	Ratio	Percent	Ratio	Percent
5 degree torso angle change (Chrysler OEM)	1/4	25%	1/3	33%	1/13	8%	3/20	15%
10 degree torso angle change	3/6	50%	7/7	100%	9/11	82%	19/24	79%
15 degree torso angle change	1/1	100%	0/0	0%	3/3	100%	4/4	100%
Label	0/2	0%	0/6	0%	0/12	0%	0/20	0%
Total	5/13	38%	8/16	50%	13/39	33%	26/68	38%

It should be noted that three participants receiving the 5-degree or label condition adjusted the seat back angle in an effort to increase their comfort. Of these three, only one adjusted the head restraint in addition to the seat back angle. Given the low incidence of seat back adjustment, it is believed that the adjustability of the second-row rear seats used in this study did not confound the results.

3.3. Non-Naive Responses to Additional Head Restraint Conditions

After participants experienced their assigned treatment condition and their response was observed both visually and via the questionnaire, they were shown the remaining two torso angle conditions and were asked whether those conditions might be effective in indicating to them that the head restraint should be raised. Out of 68 participants, 63 stated that they would adjust the subsequent conditions in addition to the first condition they experienced. Four who experienced the 10-degree condition as their primary treatment condition (3 of the 4 raised the head restraint) and then experienced the 5-degree condition stated that the 5-degree condition would not cause them to raise the head restraint. One participant who experienced the label condition as the primary treatment and did not raise the head restraint subsequently reported that he would also not raise the 10-degree head restraint condition if presented with it. The remaining 63 participants all stated that the other torso angle conditions that they were shown would, in fact, cause them to raise the head restraint. However, these responses, which were given after the participant was aware of the purpose of the test, do not match the "unalerted" responses given by participants who received the 5-degree torso angle condition as their primary treatment.

Only 10 percent of participants stated that they always adjust the head restraint when in a vehicle. Some participants stated that they do not typically adjust the head restraint when riding in another person's vehicle. A few participants stated that they might have adjusted the head restraint if they had thought they would be seated in the vehicle for a longer period of time. While these qualitative comments regarding head restraint adjustment imply low adjustment rates, the rates of compliance seen in response to two of the three torso angle change head restraint conditions were not low. The label condition affected no response reportedly due to people not noticing it. However, it should be noted that vehicle owners might be more likely to notice a label present in their own vehicle than to notice such a label in someone else's vehicle, particularly one in which they believe they will only be riding in briefly.

3.4. Label Content Comprehension

Tables 4 and 5 showed that no participants who received the label condition treatment adjusted the head restraint. In response to the questionnaire item that inquired about the perceived meaning of the label, 33 of the 68 participants (49 percent) correctly interpreted the label to indicate that the seat occupant should raise the head restraint to its proper position to support the occupant's head in the event of a crash. Sixteen participants thought the label informed the occupant that the head restraint was adjustable (i.e., they read it as providing information, rather than as instructing them to take action). The remaining 19 participants stated that they did not understand the meaning of the label.

3.5. Additional Comments

An alternative to either the protruding head restraint or label methods might be to use an instrument panel telltale to indicate to the driver when a rear seat passenger has not raised the head restraint. This places the responsibility of ensuring compliance with the driver rather than the seat occupant.

4.0 CONCLUSIONS

Results of this study suggest that a head restraint design that produces a 5-degree change in occupant torso angle is unlikely to be sufficiently uncomfortable to achieve a success rate in communicating to occupants that the head restraint should be raised from the stowed position. The head restraint design that produced a 10-degree torso angle change was found to be successful in influencing a majority of participants, 79 percent, to adjust the head restraint. While the 15-degree torso angle condition saw 100 percent compliance, this invasive design is likely to draw consumer complaints due to annoyance.

Considering that a number of participants expressed reluctance in regards to adjusting the head restraint in another person's vehicle, it is possible that each of the head restraint conditions would see larger degrees of compliance (i.e., head restraint adjustment) if present in a person's own vehicle. Given this assumption that actual compliance percentages might be higher in the real-world, or at least in peoples' own vehicles, the 10-degree head restraint condition may approach 100-percent compliance in peoples' own vehicles. Thus, based on this assumption and the results of the research, the 10-degree head restraint condition should be considered for use in encouraging safe head restraint adjustment for seats with stowable head restraints.

5.0 REFERENCES

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