U.S. Department
of Transportation
National Highway
Traffic Safety
Administration

www.nhtsa.gov

DOT HS 811 514

September 2011

Effectiveness of Rear Seat Head Restraint Non-Use Position Discomfort Indicators

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS 811 514		

4. Title and Subtitle	5. Report Date
Effectiveness of Rear Seat Head Restraint Non-Use Position Discomfort Indicators	September 2011
	6. Performing Organization Code NHTSA/NVS-312
7. Author(s) G. H. Scott Baldwin, Adam T. Andrella, and Thomas A. Ranney, Transportation Research Center Inc.; Elizabeth N. Mazzae, National Highway Traffic Safety Administration	8. Performing Organization Report No.
9. Performing Organization Name and Address National Highway Traffic Safety Administration Vehicle Research and Test Center P.O. Box 37 East Liberty, OH 43319	10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Highway Traffic Safety Administration 1200 New Jersey Ave, SE Washington, D.C. 20590	13. Type of Report and Period Covered 14. Sponsoring Agency Code

15. Supplementary Notes

The authors wish to thank Jodi Clark and Ed Parmer for their support of this project.

16. Abstract

An experiment was conducted to compare the effectiveness of head restraints modified to increase the likelihood of eliciting uninstructed adjustments from a non-use to a deployed position among naïve users. Fifty-nine participants aged 18-46 years experienced one of three head restraint conditions. The first condition consisted of an unmodified, original equipment (OE) second-row head restraint from a 2009 Ford Flex, which was compliant to specifications in the United Nations' Global Technical Regulation (GTR) No. 7 intended to provide distinct physical cues to alert occupants to the need to adjust the head restraint. The second condition consisted of an OE head restraint modified to be longer vertically, which also met the GTR specifications. Lastly, a thicker head restraint producing a torso angle change of 10 degrees from the seat back (10 degrees), one of multiple compliance options allowed in FMVSS No. 202, was examined.

Participants were asked to enter the driver's side rear seat of a vehicle for the stated purpose of being driven to another site to participate in a different experimental protocol. During the brief ride between the two locations, the participants' responses to the stowed head restraint were recorded by a hidden video camera. Video records were analyzed to identify observable evidence of discomfort and participants' attempts to reposition the head restraint from a non-use to a deployed position. Effectiveness of the physical cue was defined as the percentage of occupants that showed discomfort and/or moved the stowed head restraint to a deployed position without specific instruction.

Fourteen of 22 passengers (64%) in the 10-degree condition made some attempt at adjustment, compared to 3 of 19 (16%) in the Lengthened OE and 0 of 18 (0%) in the baseline (OE) condition. Differences in the adjustment rates between the 10-degree and other two conditions were statistically significant. 79% of participants in the 10-degree condition adjusted the restraint immediately after securing the seat belt. The results of the study indicate clearly that the 10-degree head restraint was significantly more effective than the OE or lengthened OE restraints in motivating adjustment attempts by participants. The results of the present study were consistent with those of the previous study.

17. Key Words	18. Distribution Statement Document is available to the public from the National Technical Information Service www.ntis.go		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 40	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized.

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EXECUTIVE SUMMARY

Many vehicles are designed with rear-seat head restraints that can be moved into a stowed or non-use position when an occupant is not present. This adjustment may improve rear visibility and/or allow rear seats to be folded to increase available cargo space. However, when rear seats remain upright, a head restraint in a non-use position does not provide an occupant with the same safety benefits as a properly deployed head restraint.

In 2005, NHTSA VRTC conducted a study to determine the minimum torso angle change that would give an occupant a clearly recognizable physical cue that a stowed head restraint needed to be raised to a properly deployed position. The head restraint design producing a 10-degree torso angle change led 19 of 24 (79%) participants to adjust the head restraint.

More recently, Global Technical Regulation (GTR) No. 7 provided design specifications for stowed head restraints. GTR No. 7 allows manufacturers to select one of five options, two of which were examined in the current study.

A single experiment was conducted in which naïve participants were exposed to one of three head-restraint conditions in a non-use position in a single vehicle, a 2009 Ford Flex Limited. The first head restraint condition consisted of an unmodified, original equipment (OE) second-row head restraint from a 2009 Ford Flex, which was compliant to specifications in the United Nations' Global Technical Regulation (GTR) No. 7 intended to provide distinct physical cues to alert occupants to the need to adjust the head restraint. This "OE" condition was referred to as the baseline. The second condition consisted of an OE head restraint modified to be longer vertically, which also met the GTR specifications. Lastly, a thicker head restraint producing a torso angle change of 10 degrees from the seat back (10 degrees), one of multiple compliance options allowed in FMVSS No. 202, was examined.

Fifty-nine participants (ages 18 – 46) took part in this study, including 36 females and 23 males. Participants were asked to enter the driver's side rear door and sit in the rear seat on which one of the head restraints was positioned in the stowed condition. Participants were told that they were to be driven to another site to participate in a different experimental protocol. During the 5-minute ride between the two locations, the participants' responses to the stowed head restraint were recorded by an unobtrusive video recorder in the test vehicle. Video records were analyzed to identify observable evidence of discomfort and participants' attempts to reposition the head restraint from a stowed to a deployed position.

Fourteen of 22 passengers (64%) in the 10-degree condition made some attempt at adjustment compared to 3 of 19 (16%) in the Lengthened OE and 0 of 18 (0%) in the baseline (OE) condition. Differences between the 10-degree and other two conditions were statistically significant, supporting the conclusion that the 10-degree head restraint was significantly more effective in eliciting adjustment attempts.

In the 10-degree condition, 11 of 14 participants initiated their adjustments in the first 30 seconds following door opening. Two participants endured the drive, exit and re-entry before adjusting the restraint on the return trip, while one participant waited almost 4 minutes before adjusting the head restraint. Most commonly, participants adjusted the restraint immediately after securing the seat belt.

Data from the 10-degree condition were combined with comparable data from a 2005 NHTSA study to estimate real-world adjustment probability. Based on combined results from 46 participants, the expected adjustment rate was estimated to be between 61 and 83 percent with 90 percent confidence.

1.0 INTRODUCTION

1.1. Background

Many vehicles are designed with rear-seat head restraints that can be moved into a stowed or non-use position when an occupant is not present. This adjustment may improve rear visibility and/or allow rear seats to be folded into a compact form to increase available cargo space. However, when rear seats remain upright, a head restraint in a non-use position does not provide an occupant with the same safety benefits as a properly deployed head restraint. In 2005, NHTSA VRTC conducted a study to determine the minimum torso angle change of the J826 manikin (SAE, 1995) that would give an occupant a clearly recognizable, physical cue that the stowed head restraint was not in a properly deployed position (Mazzae & Baldwin, 2006). Head restraints causing a change in the occupant's torso angle due to contact with the head, neck, or upper spine were examined in a static vehicle setting. The head restraint design producing a 10-degree torso angle change was found to be successful in influencing a majority of the participants (19 of 24 = 79 percent) to adjust the head restraint. While a 15-degree torso angle change was more successful on a considerably smaller sample (4 of 4 = 100 percent), the thickness of this design was deemed by NHTSA staff to be overly invasive and thus likely to draw consumer complaints due to annoyance. Thus, the 10-degree requirement was adopted into the FMVSS 202a final rule of 2007. The non-use configuration of the adopted head restraint requirement was aimed at producing a 10-degree torso angle change only. Conformance with the discomfort metric was not considered. Note that a shingle design conforming to the discomfort metric does not generally conform to the 10-degree requirement, or vice versa.

More recently, Global Technical Regulation (GTR) No. 7 (United Nations, 2008) has provided specifications for giving an occupant a clearly recognizable physical cue that the stowed head restraint is not in an occupant-ready position and needs to be raised. This specification is known as the "discomfort metric." Since it has come about fairly recently, the discomfort metric was not considered during the development of FMVSS 202a and was not assessed in the 2005 NHTSA study. Therefore, it is not an option under FMVSS 202a. Also, a head restraint that is designed to meet the discomfort metric (such as the original equipment (OE) design evaluated herein) does not generally conform to the 10-degree requirement, or vice versa.

GTR No. 7 allows manufacturers to select one of five options. The options include:

- The head restraint must automatically return to an in-use position when a 5th percentile female Hybrid III dummy is positioned in the seat;
- The head restraint must be capable of "manually rotating either forward or rearward by not less than 60 degrees from any position of adjustment intended for occupant use";

- The head restraint must be clearly marked with a durably affixed label in the form of a pictogram which may include explanatory text. The label shall provide either an indication when the head restraint is in a non-use position or provide information to enable an occupant to determine whether the head restraint is in a non-use position.
- The head restraint must cause the torso line angle of the J826 manikin to be at least 10 degrees closer to vertical than when the head restraint is in any position of adjustment in which its height is not less than that specified in paragraph 5.1.1 of the regulation.
    - For outboard designated seating position, the specified height is 750 mm in any position of adjustment; or
- Discomfort metric; described below.

The first three options are permitted by FMVSS No. 202a. The last two options were examined in the current study.

Section 5.4.4.3 of the GTR No. 7, specifies an acceptable range of HLE, which represents the distance between lower edge of the head restraint and the R-point, which simulates the position of the center pivot of the human torso and thigh (see Figure 1). Specifically, HLE shall be not more than 460 mm, but not less than 250 mm. Additionally, the head restraint thickness (S) shall not be less than 40 mm. This option provides for the use of a longer head restraint, a larger portion of which would be in contact with the seated occupant's back when the restraint is in the non-use position. Alternately, as put forth in Section 5.4.4.4 of the GTR No. 7, the head restraint shall cause the torso line angle to be at least 10 degrees closer to vertical relative to the deployed position of the restraint. This specification is intended to provide discomfort when the occupant is forced to sit more forward in the seat. Both options are intended to provide the physical cues that will effectively motivate occupants to adjust the head restraint to a deployed position. In the deployed position, the source of discomfort is eliminated.

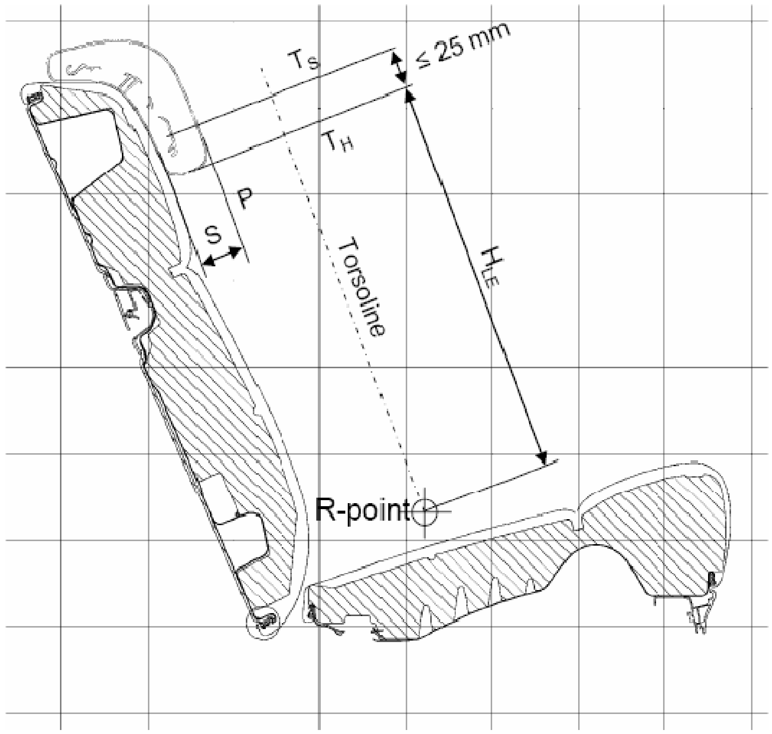

Figure 1. Discomfort metric measurement definitions (from GTR No. 7)

1.2. Objectives

The primary objective of this research was to evaluate the effectiveness of the discomfort metric in eliciting adjustments from a stowed to a deployed position among seated occupant passengers in a moving vehicle[1]. Two GTR-compliant head restraint designs conforming to the discomfort metric (but that are not FMVSS No. 202a compliant) were evaluated: one that barely meets the dimensional requirements, and another, longer version that safely meets the requirements.

As a secondary objective, a third head restraint design was also assessed. This was a shingle design that was not compliant with the discomfort metric but created a 10-degree offset (i.e., it was 202a compliant). Its effectiveness was compared to the other two designs, and to the design used in the Study 1 evaluation in a static vehicle of the 10-degree design. It was a thicker restraint that causes a 10-degree torso angle change between the non-use and deployed positions.

In evaluating all designs, effectiveness was defined as the percentage of naïve participants who express obvious discomfort and/or attempt to adjust the restraint from

[1] The first study (Mazzae, E. N. & Baldwin, G. H. Scott, 2005) involved evaluation of the effectiveness of head restraint designs in a static, non-moving vehicle.

a non-use to a deployed position. Note that this differs somewhat from the previous NHTSA study, which counted a "successful adjustment" when a rear seat occupant recognized the non-use position and re-adjusted the head restraint spontaneously (within the first 5 minutes of static observation). In that study, the design that produced the 10-degree torso angle change resulted in an 80% adjustment rate.

2.0 METHOD

2.1. Approach

A single experiment was conducted in which naïve participants were exposed to one of three head restraint conditions in a non-use position. To ensure that participants were naïve concerning the true purpose of the experiment, the test protocol involved the use of a ruse that led participants to believe that they were recruited to participate in an automotive visibility assessment study, which required transport to a secondary location. Accordingly, participants were told that they would be driven to the test location and were asked to sit in the rear-passenger seat of the transport vehicle and fasten the seatbelt. Standard test protocol at NHTSA's Vehicle Research and Test Center is to instruct test participants to fasten the safety belt when driving or being driven in a test vehicle.

They were subsequently driven to the secondary location and participated in a (10-15 minute) visibility assessment protocol. The drive provided 5 to 6 minutes of exposure to one of three head restraint conditions in a non-use position. During the ride between locations, the participants' responses to the head restraint stimulus were recorded by a hidden video camera and recorder in the test vehicle. Video records were subsequently analyzed to identify observable evidence of discomfort and participants' attempts to reposition the head restraint from a non-use to a deployed position. On trials involving adjustment attempts, the amount of exposure time before responding was determined. Exposure was measured from the time the participant first opened the rear passenger door. The protocol was similar to that used in the earlier study (Mazzae & Baldwin, 2006), except for the driving component, which was not previously used.

All testing was done with a single 2009 Ford Flex Limited with leather seats. This vehicle's original equipment rear outboard seat head restraint served as the baseline condition for the study. As can be seen in Figure 2, this shingled head restraint was fairly low profile and was layered forward of the flat seat back without any apparent contours in the head restraint or seat that would cause the lower portion of the head restraint to blend into the seat back. Figure 3 shows the H-point machine as installed and adjusted per SAE J826 [SAE, 1995] in the driver-side outboard 2nd row seat with the OE head restraint in a non-use position.

Figure 2. 2nd row outboard OE head restraint of a 2009 Ford Flex Limited

Figure 3. H-point machine as installed in the vehicle (and adjusted per SAE J826) in driver-side outboard 2nd row seat with OE head restraint in non-use position

The other two shingled head restraint conditions consisted of a longer head restraint that was stowed lower on the seat back (Lengthened OE) and a thicker head restraint producing a torso angle change of 10 degrees from the seat back (Thickened-OE). Additional details of these three treatment conditions are provided in Section 2.2.

2.2. Test Preparation

OE head restraints were modified to create the Lengthened-OE and Thickened-OE head restraints. Modifications involved making changes to the metal posts and frames, adding foam and creating new upholstery covers for both head restraints. The modified head restraints were designed such that raising them did not require an abnormally large amount of force. Care was also taken to create the modified head restraints such that they appeared visually to be original equipment components of the test vehicle used. Covers for the modified head restraints were made at a professional upholstery shop using leather covering material from OE head restraints. Figure 4 and Figure 5 present basic mechanical drawings of the two modified head restraint (HR) designs, along with the original OE head restraint.

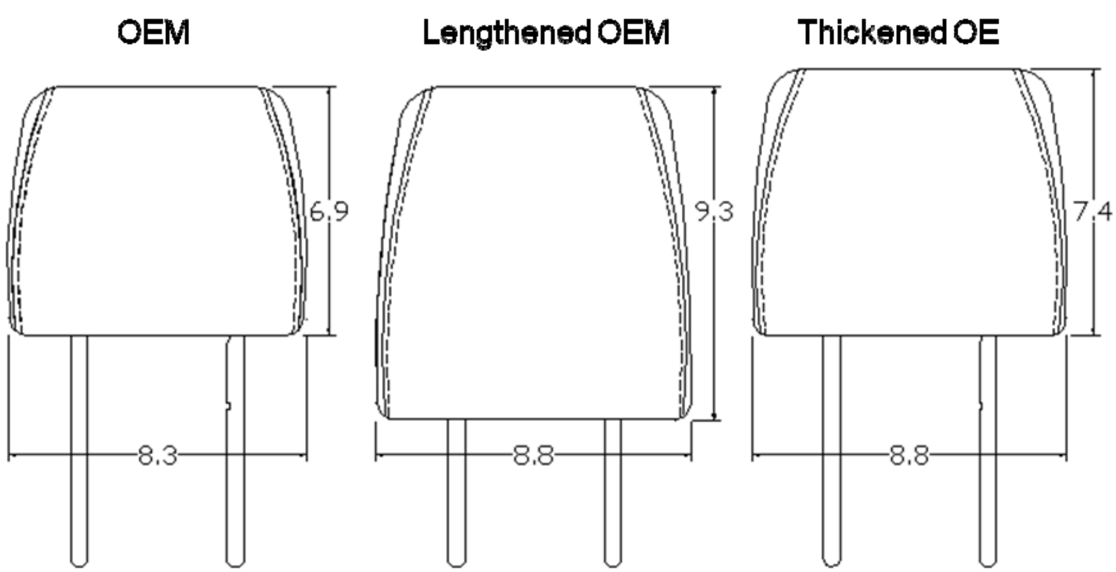

Figure 4. Front view drawing of three head restraint conditions (units: inches).

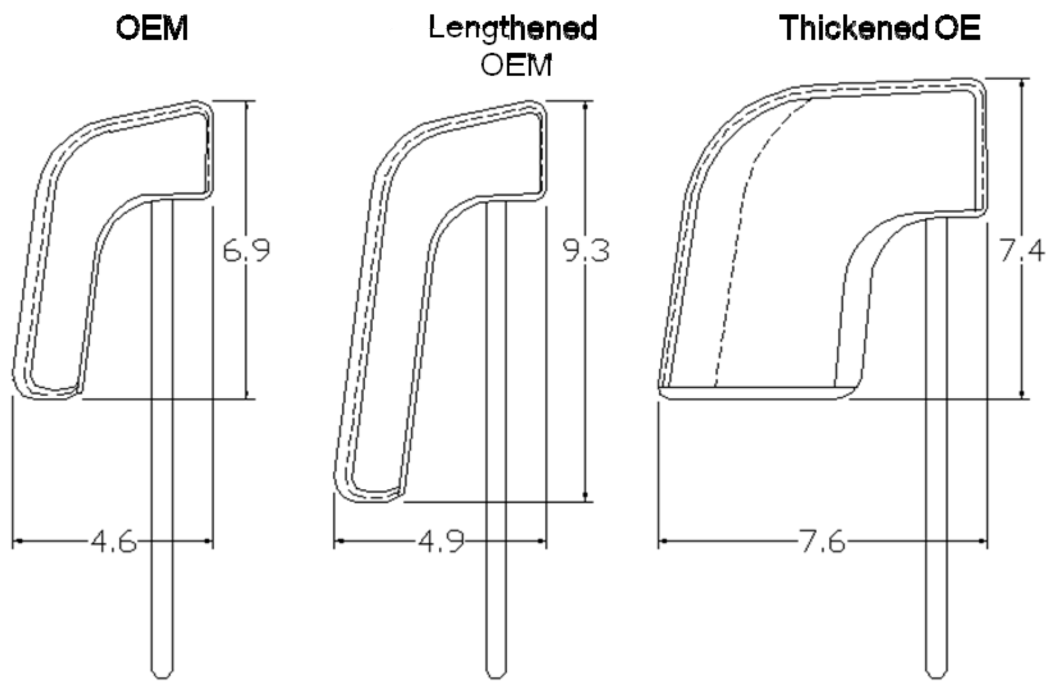

Figure 5. Side view drawing of three head restraint conditions (units: inches).

2.2.1. Lengthened Head Restraint Modification

For the Lengthened-OE head restraint condition, the modification required the head restraint be extended downward by approximately 60 mm. To create the additional length, an additional OE head restraint was purchased and cut such that the bottom half (frame and foam) could be added to the bottom of the head restraint being lengthened. Using this method, the matching framework could be welded together to create the longer head restraint.

2.2.1. Thickened Head Restraint Modification

The Thickened-OE design was created by adding foam to the face of an OE head restraint, thereby increasing the S-dimension to produce a torso angle change in the occupant. While the HLE for this head restraint condition could have been constrained to be less than 460 mm to conform with the GTR discomfort metric (the actual 471 mm dimension does not conform), this was not done. If the shingle had been a little longer and not as thick, a head restraint that conforms to both the discomfort metric and the 10-degree requirement may have been achieved. Also, such a head restraint may have taken on a more “normal” looking appearance.

The 10-degree design (Thickened OE) was developed through an iterative process of measuring torso angle and then adding additional foam as needed. Torso angle was measured using an H-point machine (SAE, 1995). First, the seatback angle was set to a default riding seatback angle of approximately 25 degrees, as recommended in SAE

J826.[2] The seat was moved backward to its rearmost longitudinal setting to allow for positioning of the H-point machine. The H-point machine was installed in the vehicle and adjusted per SAE J826. Torso angle was measured by placing an inclinometer on the vertical structural component of the H-point machine as it rested against the head restraint in its non-use position. This process was repeated until a 10-degree torso angle change was achieved.

Creating the head restraint that produced a 10-degree (V torso angle change required cutting the head restraint support posts near the top, such that a piece of metal could be positioned between the cut ends of each post to produce a horizontal, forward offset in the head restraint. The piece of metal was cut to a length according to the measured distance required to support the 10-degree condition (Thickened OE), as determined by the method described above. The metal piece was welded to each of the cut ends of the posts to create the new head restraint frame with the desired forward offset. Foam was added to the back of the head restraint to fill in the gap created by the forward offset.

Since this method of modification retained the OE 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 quick changing of the treatment conditions between participants. The three head restraint conditions used in this study are pictured in Figure 6 through Figure 11.

Figure 6. Angled-view of subject seat with stowed head restraints

[2] The manufacturer's specified setting for the Flex seat is 21 degrees as reported by Ford to NHTSA's Office of Vehicle Safety Compliance.

Figure 7. Angled-view of subject seat with raised (deployed) head restraints

Figure 8. Side-view of subject seat with stowed head restraints

OEM   Lengthened OEM   10 degrees

Figure 9. Side-view of subject seat with raised (deployed) head restraints

OEM   Lengthened OEM   10 degrees

Figure 10. Front-view of subject seat with stowed head restraints

OEM   Lengthened OEM   10 degrees

Figure 11. Front-view of subject seat with raised (deployed) head restraints

2.2.2. Torso Angle Measurement

The H-point machine was used to document the torso angle change generated by the OE and the lengthened head restraint conditions. Torso angle change values, based on the average of five measurement trials rounded to the nearest tenth of a degree, are presented in Table 1. A photo of one of these measurements is shown in the figure below. While the measurements were taken with the head restraint fully stowed, a subsequent measurement was taken to determine the torso angle change with the head restraint in the lowest in-use position. The torso angle change difference between the stowed and lowest in-use positions for the OE head restraint was 0.9 degrees.

Figure 12. H-point Machine Installed for Measurement of Torso Angle Change.

Table 1. Head Restraint Measured Values

Condition	Torso Angle (Degrees)	Torso Angle Difference* Degrees)	HLE Value (mm)	S-dimension (mm)
No Head Restraint	24.3	NA	NA	NA
OE Head Restraint (Stowed)	22.0	2.3	462	43
Lengthened Head Restraint (Stowed)	19.5	4.9	406	51
10-Degree Torso Angle Change (Stowed)	14.3	10.1	471	128

*Torso angle difference is with respect to "normal riding seatback angle" of approximately 25 degrees, as recommended in SAE J826.

HLE values were also measured. As shown in Figure 1, HLE defines the distance from the R-point to the bottom of each head restraint, when stowed. Thus, the HLE value is the distance along the seatback from the bottom of the stowed head restraint to a location in space that is approximately where a typical passenger's hips might be located. HLE values are presented in Table 1.

2.3. Experimental Design

The experiment evaluated the effects of three head restraint designs on occupants' responses to physical cues in the stowed condition. The levels of the single independent variable, head restraint design, included: (1) an OE head restraint (OE); (2) an OE head restraint modified to stow lower on the seat (Lengthened-OE); and (3) a head restraint modified to provide a 10-degree torso angle change with respect to the seat back (Thickened-OE). In an attempt to match sample characteristics across conditions, the original experimental design defined 6 standing height groups (60.0-61.9, 62.0-63.9, 64.0-65.9, 66.0-67.9, 68.0-69.9, 70.0-71.9 inches) that would be balanced within head restraint conditions. The design called for two participants per standing height group per head restraint condition, for a total of 36 participants. While it was hypothesized that seated height was potentially more relevant for influencing participants' responses to the head-restraint cues, it was considered more difficult to recruit participants on the basis of seated height, because prospective participants would be unlikely to know this dimensional information. Therefore, as the experiment began, participants were recruited and classified based on standing height. Gender was balanced by standing height and head restraint condition to the extent possible. Toward the end of the experiment, NHTSA staff decided to expand the design in an attempt to balance the treatment conditions by seated height. The number of participants was increased to accommodate this design change. This change, together with the difficulty of recruiting based on seated height, resulted in a slightly unbalanced design. However as demonstrated in Section 3.0, differences in seated and standing height among participants in the three head-restraint conditions were not statistically significant. This result indicated that differences in participants' responses between the head restraint conditions were not due to differences in seated and/or standing height. As a result, the head restraint condition was the only factor in the between-subjects' design.

The data obtained from each participant included standing height, seated height, the participant's response to the stowed head restraint (whether or not an adjustment was attempted), and time to adjust the head restraint (when applicable).

2.4. Participants

Fifty-nine participants completed the study. Participants ranged in age from 18 to 46 years old (M = 31.7, SD = 8.6). Participants ranged in height from 60 to 72 inches (M = 66.0, SD = 3.3). Seated height ranged between 31.75 and 39.25 inches (M = 35.62, SD = 1.71). There were 36 females and 23 males in the sample.

2.5. Participant Pay

Participants received $58 for their participation in the study. If a participant had voluntarily withdrawn or was terminated from the study before completion, the participant would have been paid a prorated rate for the time spent at the facility. However, all participants completed their participation in this study.

2.6. Ruse

To ensure that participants' responses were as natural as possible, a ruse was used to conceal the true purpose of the study. The ruse was a rear-visibility test protocol that was highly familiar to the experimenters. Accordingly, participants were told that their participation in the rear-visibility protocol required them to be transported to a secondary location on the proving ground.

This familiarity of the rear visibility protocol made it easy for the experimenters to provide realistic answers to questions posed by participants before or after the protocol. Rear visibility testing has been regularly performed at NHTSA's Vehicle Research and Test Center by the same experimenters. Therefore, this ruse was successfully executed without suspicion among the participants. Since participant height was relevant to both the head-restraint and the rear-visibility (ruse) protocols, questions about height, posed during the screening interview, did not raise suspicion among prospective participants.

2.7. Procedure

Testing was conducted during March and April of 2010 at the Transportation Research Center proving ground in East Liberty, Ohio. The following sections describe the processes of recruitment and testing.

2.7.1. Recruitment

Participants were recruited from both on-site and general public sources, using flyers and newspaper advertisements. Respondents were subjected to a phone screening process, in which personal and health-related questions were asked (including standing height). The rear-visibility test protocol was described at that time. Interested participants meeting the height and age criteria were scheduled and given directions to TRC, if necessary.

2.7.2. Testing

Upon arrival at the proving ground gatehouse, the participant was met by a VRTC research assistant in a separate vehicle. The research assistant led the participant to the NHTSA Vehicle Research and Test Center (VRTC) building and escorted him or her into a briefing room. The research assistant introduced the participant to the experimenter, who gave the participant a Participant Informed Consent Form (Appendix A). As part of the ruse, the Participant Informed Consent Form described a rear visibility test protocol. Permission was obtained for video recording of the participant.

After agreeing to participate, the participant was led to the test vehicle, where the driver (research assistant) was waiting to take the experimenter and participant to the secondary location for the rear visibility test. The experimenter led the participant to the rear door on the driver's side and instructed him/her to open the door, get in, get comfortable, and buckle the seat belt in preparation for the drive to the other building. The head restraint for that seating location had been positioned in the non-use position. If participant asked if there was a problem with the head restraint or asked if it could be adjusted, the experimenter was instructed to reply: "…adjust it however you need to for your own comfort."

It should be noted that for this study, the head restraint for the 2nd row center seating location was removed and the passenger-side 2nd row seat was folded to a horizontal orientation with some test equipment (e.g., traffic cones) resting on it. These steps were taken to remove other 2nd row head restraints from sight of the test participant so that additional modified head restraints were not needed for the test. This is not believed to have had any effect on the participants' behaviors.

Once the participant was seated and belted, the experimenter walked around to get in the front passenger seat for the trip to the other building. The driver then drove to the secondary location (i.e., from point A to B in Figure 12), which was approximately 2.75 miles and required 5.5 minutes of travel time. For participants who did not adjust the restraint upon entry, the drive was intended to provide additional exposure to the physical cue provided by the stowed head restraint.

Upon arrival at the secondary location, the participant was taken inside a building, in which the rear visibility test protocol was completed. This test took approximately 5-15 minutes and included measuring the participant's standing and seated height. During this time, the head restraint was repositioned, if necessary, in the non-use position. The participant was then led to the same (rear driver-side) seat for the ride back to the main building. The driver and experimenter were in the front seats as on the first drive. For participants who had not adjusted the head restraint during the first drive, the drive back to VRTC provided additional exposure to the stowed head restraint.

Upon returning to VRTC, the participant was told that he or she had participated in a natural assessment of rear seat and head restraint comfort. The participant was asked if an adjustment had been attempted during one of the drives and if discomfort due to the stowed head restraint had been perceived. After all questions had been answered, the participant was paid and asked not to mention the head-restraint component of the testing to any people who might participate in the study.

The experimenter then led the participant to his/her vehicle. The research assistant led the participant in their vehicle back to the proving ground gatehouse to exit the facility.

Figure 13. Test Path (Yellow Line from A to B).

3.0 RESULTS

3.1. Demographic Information by Head Restraint Condition

Table 2 presents the means and standard deviations of participant age, standing height and seated height by treatment condition.

Table 2. Mean and Standard Deviation Values for Age, Standing and Seated Height by Head Restraint Condition

Condition	N	Age	Standing Height	Seated Height
OE	18	32.8 (8.2)	65.7 (3.5)	35.6 (1.6)
Lengthened OE	19	31.0 (9.8)	66.4 (3.5)	35.9 (1.8)
10 degrees	22	31.5 (8.3)	66.0 (3.2)	35.4 (1.8)

Analyses of Variance (ANOVA) were computed to determine whether differences between test conditions were statistically significant. Test results were all not significant ($p > .05$), which implies that there were no meaningful differences between test conditions groups with respect to age, standing height, or seated height. It is highly unlikely therefore, that any differences in responses between test conditions were due to any of these factors.

3.2. Initial Treatment Responses

Participants' responses to the stowed head restraint are summarized in Table 3.

Table 3. Number of Participants Who Adjusted the Head Restraint by Condition

Condition	Number of Participants Who Adjusted	Number of Participants (n)	Percent Who Adjusted	90% Confidence Interval
OE	0	18	0%	NA
Lengthened OE	3	19	16%	[2.0 – 29.6]
Thickened OE (10 degree)	14	22	64%	[46.8 – 80.5]
Total	17	59	29%	[19.1 – 38.5]

Passengers in the 10-degree condition were significantly more likely to attempt to adjust the head restraint than in other conditions (χ^2 (1) = 23.48, $p < .0001$). There was no difference between OE and Lengthened-OE conditions (χ^2 (1) = 3.09, $p = .08$).

Adjustments to the stowed head restraint differed considerably in the amount and type of effort and in their effect. For each of the 17 trials on which participants were judged to have attempted a head-restraint adjustment, the effectiveness of the adjustment was coded from the video. The following criteria were defined:

- Full adjustment: Movement to, or near to, full deployment
- Partial adjustment: Partial movement, final position not near full deployment
- Minimal Adjustment: No discernible movement (despite effort)

Table 4. Effectiveness of Adjustment Attempt

Condition	N Success	Full Adjustment	Partial Adjustment	Minimal Adjustment
Lengthened OE	3	1	0	2
Thickened OE (10 degree)	14	10	4	0

Ten of 14 attempted adjustments to the 10-degree restraint were effective. Effective adjustments were generally more direct than partial movements. Two of the three attempted adjustments to the Lengthened-OE restraint were ineffective because the restraint did not move easily from the non-use position. It is possible that modification of the head restraints affected the ease with which they could be raised and lowered, however this was not confirmed.

3.3. Effect of Age and Seated Height on Adjustment probability

Using data from the 10-degree restraint condition, two categories of seated height were created, using the midpoint of the overall seated height distribution. Specifically, participants were separated into the following groups: Shorter: < 35.75 inches, N = 10; Taller: ≥ 35.75 inches, N = 12. The Taller participants were slightly more likely (8/10 = 80%) to attempt to adjust the restraint than the shorter participants (7/12 = 58%), but this difference was not statistically significant (χ^2 (1) = 1.18, p = .28)

Similarly, participant age was separated into two categories (Young < 31 years; Old ≥ 31 years). The older participants were slightly more likely to attempt adjustments (7/10 = 80%) than the younger participants (7/11 = 63%), however this difference was not statistically significant (χ^2 (1) = 1.0, p = .76).

3.4. Time of Adjustment

The response time of participants in adjusting the head restraint was measured for all participants. Response time was measured from the time the door was initially opened until the point at which an adjustment was initiated. The authors believed that quicker responses may indicate a more successful adjustment cue. Figure 14 summarizes these data for the 14 participants who attempted adjustments in the 10-degree condition. No participants in the OE condition adjusted the head restraint so no response time data exist. Since only 3 of 19 participants in the lengthened OE condition adjusted the head restraint these data are not reported here.

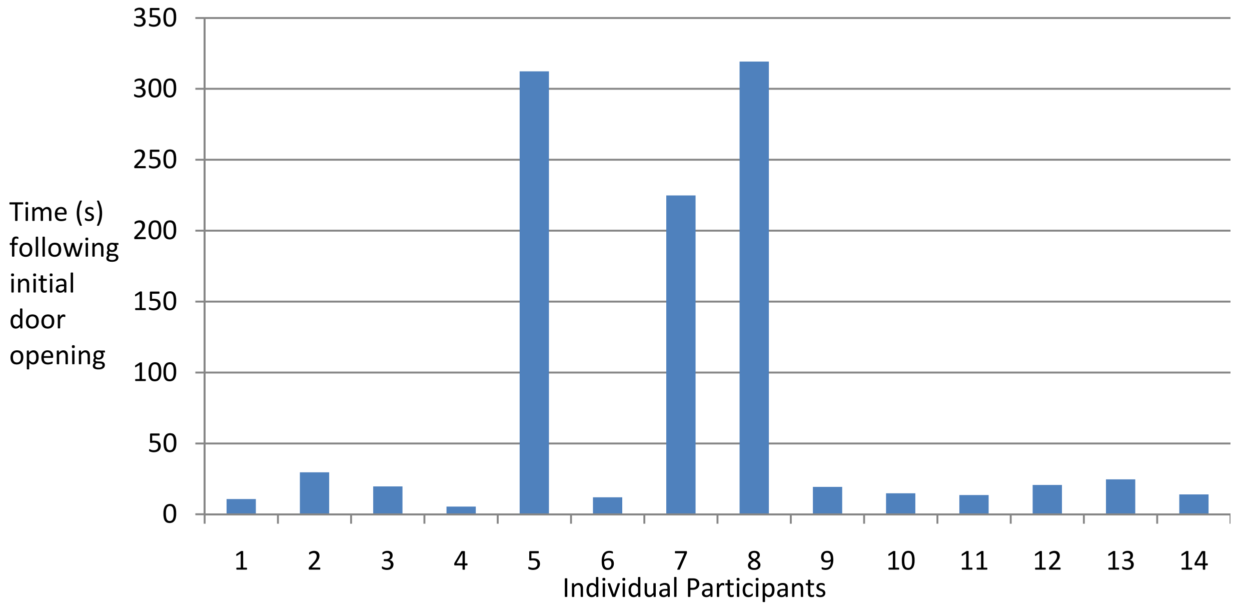

Figure 14. Time of Restraint Adjustment: 10-Degree Condition

Eleven of 14 participants initiated their adjustment in the first 30 seconds after the initial door opening (M = 16.8 s; SD = 6.8 s) upon entering the vehicle for the first time. Two participants (Subjects 5 and 8, Figure 12) adjusted the restraint for the first time at the beginning of the return trip. One participant (Subject 7, Figure 12) initiated the adjustment toward the end of the first trip. Of the 11 participants who adjusted the head restraint within the first 30 seconds, 6 did so immediately after fastening the seat belt, 2 did so before fastening the seat belt, and 3 did so after a brief wait. For the two participants who adjusted the restraint on the second trip, the adjustment was made immediately after fastening the seat belt.

3.5. Post-Test Interview

For subjects who did not adjust the head restraint, a post-test interview provided information to aid in explanation of the lack of response. Table 5 summarizes post-test interview data.

Table 5. Effectiveness of Adjustment Attempt

Condition	Negative comments	Positive comments	No comments	Total Subjects who did not adjust HR
OE	2	1	15	18
Lengthened OE	6	0	10	16
10 degrees	6	1	1	8

4.0 DISCUSSION

Results of this study show that head restraints complying with the GTR discomfort metric, but not with FMVSS 202a – the OE design and the lengthened OE design were not as effective in inducing head restraint adjustment as was the Thickened-OE (10-degree) head restraint condition. Only 3 of 19 (16%) in the Lengthened-OE head restraint condition and 0 of 18 (0%) in the baseline (OE) condition made some attempt to adjust the head restraint. Conversely, 14 of 22 passengers (64%) in the Thickened-OE head restraint condition made some attempt at adjustment. Both modified head restraint conditions were more effective in eliciting adjustments than the OE condition. Differences in adjustment rates between the 10-degree and other two conditions were statistically significant, supporting the conclusion that the 10-degree head restraint was significantly more effective in eliciting adjustment attempts than either GTR-compliant head restraint.

In the Thickened-OE (10-degree) head restraint condition, 11 of 14 participants initiated their adjustments within the first 30 seconds following the opening of the vehicle door through which they then entered. Two participants endured the drive, vehicle exit, and re-entry before adjusting the restraint on the return trip, while one participant waited almost 4 minutes before adjusting the head restraint. Most commonly, participants adjusted the restraint immediately after securing the seat belt.

79% of participants in the Thickened-OE (10-degree) head restraint condition initiated their adjustment in the first 30 seconds after the initial door opening. This indicates that a majority of participants felt minimal reluctance to adjust the head restraint. Zero and 16% of participants adjusted the head restraint in the OE and Lengthened OE conditions, respectively, indicating little or no motivation for adjustment. Post-test interviews showed that most of the non-adjusting users of the Lengthened-OE head restraint complained about comfort, while very few of the OE users did the same.

The results indicate that the 10-degree (thickened) head restraint was significantly more effective than the other two restraints in motivating adjustment attempts within the time constraints of the experimental protocol.

4.1. Comparison with Prior NHTSA Study

The results of the present study were generally consistent with those of the previous study that used a similar protocol (Mazzae & Baldwin, 2006) but lacked any driving of the test vehicle, instead observing occupant behavior in response to the 10-degree head restraint condition in a stationary vehicle. The consistency of results for frequency of adjustment for the two studies is highlighted in Table 6.

Table 6. Comparison of Adjustment Probabilities for Current and Previous Studies (Thickened OE/10-degree head restraint condition)

Condition: 10 degrees	Number of Participants Who Adjusted	Number of Participants (n)	Percent Who Adjusted	90% Confidence Interval
Study 1	19	24	79%	[65.5 – 92.8]
Current Study	14	22	64%	[46.8 – 80.5]

The percentage observed in the current study (64%) is slightly below the lower bound of the confidence interval derived from the results of the previous study (65.5%), which suggests there may have been differences between the study protocols. This hypothesis was tested formally; a statistical comparison of the results from the two studies indicated that these differences (i.e. 64 versus 79 percent adjustment rate) are not statistically significant, χ^2 (1) = 1.37, p = .24). This result indicates that the differences between the two studies were not due to differences in the protocol and that the samples represent the same population of individuals. Specifically, the inclusion of a drive instead of an extended static component of the protocol did not have a substantive effect on the adjustment compliance for the 10-degree head restraint condition.

4.2. Limitations of the Current Study

Only one test vehicle was involved in the current study: a 2009 Ford Flex. This was done to minimize the complexity and magnitude of the effort required to complete the study.

The seat back was more reclined than the manufacturer's design configuration (25 deg vs. 21 deg). The effect of this seat back angle difference on participants' behavior is unknown.

As noted in the procedural description, the seat adjacent to that the participant was seated in was folded down. This way, the subjects did not see the unoccupied head restraint requiring only one head restraint to be built for each for the lengthened and thickened design conditions. This is not believed to have had any effect on the participants' behaviors or propensity to move a particular head restraint design. However, data are not available to support this position. The possibility may exist that if participants could have looked over and observed the adjacent head restraint, the observation may have given them some information that could have affected their decision to make an adjustment or not.

While the HLE for this head restraint condition could have been constrained to be less than 460 mm to conform with the GTR discomfort metric (the actual 471 mm dimension does not conform), this was not done. If the shingle had been a little longer and not as thick, a head restraint that conforms to both the discomfort metric and the 10-degree requirement may have been achieved. Also, such a head restraint may have taken on a more "normal" looking appearance.

5.0 SUMMARY

A single experiment was conducted in which naïve participants were exposed to one of three head-restraint conditions in a non-use position in a single vehicle, a 2009 Ford Flex Limited. The first head restraint condition consisted of an unmodified, original equipment (OE) second-row head restraint from a 2009 Ford Flex, which was compliant to specifications in the United Nations' Global Technical Regulation (GTR) No. 7 intended to provide distinct physical cues to alert occupants to the need to adjust the head restraint. This "OE" condition was referred to as the baseline. The second condition consisted of an OE head restraint modified to be longer vertically, which also met the GTR specifications. Lastly, a thicker head restraint producing a torso angle change of 10 degrees from the seat back (Thickened-OE), one of multiple compliance options allowed in FMVSS No. 202, was examined.

Fifty-nine participants were exposed to a ruse involving being driven to another site to participate in a different experimental protocol. During the 5-minute ride between the two locations, the participants' responses to the stowed head restraint were recorded by an unobtrusive video recorder in the test vehicle.

Fourteen of 22 passengers (64%) in the Thickened-OE hear restraint condition made some attempt at adjustment compared to 3 of 19 (16%) in the Lengthened OE and 0 of 18 (0%) in the baseline (OE) condition. Differences between the 10-degree and other two conditions were statistically significant, supporting the conclusion that the 10-degree head restraint was significantly more effective in eliciting adjustment attempts than either GTR-compliant head restraint. Furthermore, adjustments made by participants in the Thickened-OE (10-degree) head restraint condition were initiated quickly, most within the first 30 seconds following the opening of the vehicle door through which they then entered.

As a final analysis, data from the Thickened-OE (10-degree) head restraint condition were combined with comparable data from a 2005 NHTSA study to estimate real-world adjustment probability. Based on combined results from 46 participants, the expected adjustment rate was estimated to be between 61 and 83 percent with 90 percent confidence.

The results of the study indicate clearly that the discomfort metric does not provide a sufficient cue to consistently elicit head restraint adjustment. The results of the study indicate clearly that the 10-degree head restraint was significantly more effective than the OE or lengthened OE restraints in motivating adjustment attempts by participants. The results of the present study were consistent with those of the previous study.

6.0 REFERENCES

Mazzae, E. N. & Baldwin, G. H. Scott (2005). Stowable Head Restraint Non-Use Position Study. Report No. DOT HS 809 957. Washington DC: U.S. Department of Transportation, National Highway Traffic Safety Administration.

SAE (1995). Devices for use in defining and measuring vehicle seating accommodation. SAE Surface Vehicle Standard J826, SAE International: The Engineering Society for Advancing Mobility Land Sea Air and Space. Warrendale, PA.

United Nations (2008). Global Technical Regulation No. 7: Head Restraints; Established in the Global Registry on 13 March 2008.

7.0 APPENDIX A: PARTICIPANT INFORMED CONSENT FORM

STUDY: Rear Visibility Assessment Study
STERLING IRB ID: 3417
DATE OF IRB REVIEW: 01/21/10

PARTICIPANT INFORMED CONSENT AND CONFIDENTIAL INFORMATION FORM

STUDY TITLE: Rear Visibility Assessment Study

STUDY INVESTIGATOR: G. H. Scott Baldwin

STUDY SITE: Transportation Research Center Inc.
10820 State Route 347
East Liberty, OH 43319

TELEPHONE: 800-262-8309

SPONSOR: US Department of Transportation's,
National Highway Traffic Safety Administration

You are being asked to participate in a research study. Your participation in this research is strictly voluntary, meaning that you may or may not choose to take part. To decide whether or not you want to be part of this research, the risks and possible benefits of this study are described in this form so that you can make an informed decision. This process is known as informed consent. This consent form describes the purpose, procedures, possible benefits and risks of the study. This form also explains how your information will be used and who may see it. You are being asked to take part in this study because the study investigator feels that you meet the qualifications of the study.

The study investigator or study staff will answer any questions you may have about this form or about the study. Please read this document carefully and do not hesitate to ask anything about this information. This form may contain words that you do not understand. Please ask the study investigator or study staff to explain the words or information that you do not understand. After reading the consent form, if you would like to participate, you will be asked to sign this form. You will be given a copy of your consent form to take home and keep for your records.

PURPOSE

This research study is being conducted by the National Highway Traffic Safety Administration (NHTSA). The purpose of this study is to collect information from the user's point of view when seated in a vehicle. During this study, participants will be asked to perform a rear visibility assessment test in which participants are asked if they can see objects placed around the vehicle. This type of assessment helps researchers identify the potential blind spots of vehicles for people of a wide variety of standing heights.

Participant's Initials ____________

STUDY REQUIREMENTS

You are being asked to participate in this research study because:

- You are 18 – 45 years of age,
- You have a valid, unrestricted U. S. driver's license (except for restrictions concerning corrective eyeglasses and contact lenses),
- You have a minimum of two years driving experience,
- You drive at least 7,000 miles per year, and
- You are in good general health.

NUMBER OF STUDY SITES AND STUDY PARTICIPANTS

This study will take place at one research site (Transportation Research Center Inc.) and will include at least 36 participants.

STUDY PROCEDURES

Before participating in this research study, you will be asked to read this Participant Informed Consent and Confidential Information Form in its entirety. After all of your questions have been answered, you will be asked to sign this form to show that you voluntarily consent to participate in this research study.

Your participation in this research study will consist of one session lasting approximately 1 hour. During this session you will be asked to complete specific test objectives. A member of the study staff will give you detailed instructions and will accompany you at all times during your participation in this research study. Some of your actions may be videotaped while you are taking part in this study.

Rear Visibility Assessment:

During this study, you will be transported to another building near the front entrance of the proving ground. Then you will get into the driver's seat of a stationary vehicle located inside a large bay of that building to perform the rear visibility assessment test. During this test, you will be asked if you can see objects placed around the vehicle. First you will sit in the driver's seat and adjust the seat and center rearview mirror and you will be given instructions. Then, the test will begin and you will respond to whether or not a reflector can be seen at various locations behind the vehicle by using the center rearview mirror. This test identifies the mirror's blind spot behind the vehicle based upon how you are seated.

Summary of Study Procedures:

You will be accompanied by a study investigator at all times. The following procedures will take place at your session:

Participant's Initials ____________

- After signing this consent form, you will be transported to the other building.
- You will then enter the building and proceed to the test vehicle.
- You will enter the test vehicle and adjust the driver's seat and center rearview mirror to your comfort level.
- You will receive training on the rear visibility assessment task and proceed with testing by responding to whether or not you can see the test object behind the vehicle by looking in the center rearview mirror.
- When the test is complete, you will step out of the vehicle for a measurement of your standing height.
- You will then be transported back to this building for a final discussion and payment for participation.
- Once payment is made, your participation in this research study is complete and you will be escorted back to your personal vehicle and to the proving ground entrance gate.

NEW INFORMATION

We do not anticipate that any changes to procedures will take place during this study. However, any new information developed during the course of the research that may affect your willingness to participate will be provided to you.

RISKS

Participants will be asked to ride in a vehicle on the proving ground to get back and forth between buildings, and asked to sit in a vehicle to perform the rear visibility assessment test. During the drives between buildings, participants will be subject to all risks and uncertainties normally associated with riding in a vehicle on the Transportation Research Center (TRC) access roads (two-lane rural roads), and in parking lots. A number of controls exist to reduce the risk of crashing. Specifically, proving ground traffic is generally light and access to the proving ground is controlled.

In addition, the rear visibility assessment test will be conducted in a stationary test vehicle located inside a controlled laboratory environment. For these reasons, the risks are considered to be less than might be expected when engaging in comparable tasks in an uncontrolled outdoor test environment or while riding on public roads under light to moderate traffic conditions.

You will not be asked to perform any unsafe acts. There are no known physical or psychological risks associated with participation in this study beyond those described above. If you ask to stop as a result of discomfort, you will be allowed to stop at once.

BENEFITS

This research study will provide data that will be used by researchers to provide a scientific basis for developing recommendations or standards. Your participation in this study will provide data that may help develop these recommendations or standards.

You are not expected to receive direct benefit from your participation in this research study.

Participant's Initials ______________

ALTERNATIVES

This study is for research purposes only. Your alternative is to not participate.

CONDITIONS OF PARTICIPATION, WITHDRAWAL, AND TERMINATION

Participation in this research is voluntary. By agreeing to participate, you agree to cooperate in accordance with all instructions provided by the study staff. If you fail to follow instructions, or if you behave in a dangerous manner, you may be terminated from the study. You may withdraw your consent and discontinue participation in the study at any time without penalty.

COSTS TO YOU

Other that the time you contribute, there will be no costs to you.

COMPENSATION

You may receive up to $58.00 if you complete the study. If you voluntarily withdraw or are removed from this study before the test is complete, you will receive a pro-rated portion of that amount for the time that you spend at our facility.

COMPENSATION FOR RESEARCH RELATED INJURY

TRC, Inc. will maintain insurance that will cover you in the event of a crash occurring on TRC facilities while riding in a government-owned vehicle. This insurance will provide coverage if you are injured up to a limit of $10,000.00. You should contact your insurance company to check on additional coverage.

If you are injured in a crash while on TRC facilities, emergency personnel will be dispatched to treat you. The nearest hospital is about 15 miles away.

USE OF INFORMATION COLLECTED

In the course of this study, the following data will be collected:

- Engineering data (such as the information recorded by the research staff)
- Video data (such as the information recorded by in-vehicle video cameras)

Information NHTSA may release:

The **engineering data** collected and recorded in this study will include data sheets of the rear visibility assessment. This data will be analyzed along with data gathered from other participants. NHTSA may publicly release this data in final reports or other publication or media for scientific, education, research or outreach purposes.

The **video data** recorded in this study includes your video-recorded likeness. The video data may include information regarding your performance. Video will be used to examine your

Participant's Initials ____________

experiences while participating in this research. NHTSA may publicly release video image data (in continuous video or still formats) either separately or in association with the appropriate engineering data for scientific, educational, research or outreach purposes.

Information NHTSA may not release:

Any release of **engineering data** or **video data** shall not include release of your name. However, in the event of a court action, NHTSA may not be able to prevent release of your name or other personal identifying information. NHTSA will not release any information collected regarding your health and driving record.

QUESTIONS

Any questions you have about the study can be answered by G. H. Scott Baldwin or the study staff by calling 1-800-262-8309.

If you have questions regarding your rights as a research participant, or if you have questions, concerns, complaints about the research, would like information, or would like to offer input, you may contact: Rev. Paul E. Gamber, J.D., Chairman of Sterling Institutional Review Board, 6300 Powers Ferry Road, Suite 600-351, Atlanta, Georgia 30339 (mailing address) at telephone number 1-888-636-1062 (toll free).

INFORMED CONSENT

By signing the informed consent statement contained in this document, you agree that your participation is voluntary and that the terms of this agreement have been explained to you. Also, by signing the informed consent statement, you agree to participate in accordance with all instructions provided by the study staff. You may withdraw your consent and discontinue participation in the study at any time without penalty.

NHTSA will retain a signed copy of this Participant Informed Consent and Confidential Information Form. A copy of this form will also be provided to you.

Participant's Initials ____________

Informed Consent Statement

I certify that:

- I have a valid, U. S. driver's license.
- All personal and vehicle information as well as information regarding my normal daily driving habits provided by me to NHTSA, and/or Transportation Research Center Inc. (TRC) employees associated with this study during the pre-participation phone interview and the introductory briefing was true and accurate to the best of my knowledge.
- I have been informed about the study in which I am about to participate.
- I have been told how much time and compensation are involved.
- I have been told that the purpose of this study is to collect information from the user's point of view when seated in a vehicle.
- I agree to cooperate in accordance with all instructions provided to me by the study staff.

I have been told that:

- The study will be conducted on the Transportation Research Center proving ground and the risks are minimal.
- For scientific, educational, research or outreach purposes, video images of my participation may be used or disclosed by NHTSA, but my name and any health data or driving record information will not be used or disclosed by NHTSA.
- My participation is voluntary and I may refuse to participate or withdraw my consent and stop taking part at any time without penalty or loss of benefits to which I may be entitled.
- I have the right to ask questions at any time and that I may contact the study investigator, Scott Baldwin, or the study staff at (937) 666-4511 or 1-800-262-8309 for information about the study and my rights.

I have been given adequate time to read this informed consent form. I hereby consent to take part in this research study.

I, ____, voluntarily consent to participate.
(*Printed Name of Participant*)

____

Signature of Participant Date

____

Printed Name of Person Obtaining Consent

____

Signature of Person Obtaining Consent Date

Participant's Initials ____________

INFORMATION DISCLOSURE

By signing this document, you agree that the National Highway Traffic Safety Administration (NHTSA) and its authorized contractors and agents will have the right to use the NHTSA engineering data and the NHTSA video data for scientific, educational, research or outreach purposes, including dissemination or publication of your likeness in video or still photo format, but that neither NHTSA nor its authorized contractors or agents shall release your name; and you have been told that, in the event of court action, NHTSA may not be able to prevent release of your name or other personal identifying information. NHTSA will not release any information collected regarding your health and driving record, either by questionnaire or medical examination. Your permission to disclose this information will not expire on a specific date.

Information Disclosure Statement

I, ____, (Printed Name of Participant) grant permission to the National Highway Traffic Safety Administration (NHTSA) to use, publish or otherwise disseminate NHTSA engineering data and NHTSA video image data, as defined in the Participant Informed Consent and Confidential Information Form (including continuous video and still photo formats derived from the video recording), and associated with the appropriate engineering data for scientific, educational, research or outreach purposes. I have been told that such use may involve widespread distribution to the public and may involve dissemination of my likeness in video or still photo formats, but will not result in release of my name or other identifying personal information by NHTSA or its authorized contractors or agents. I have been told that my permission to disclose this information will not expire on a specific date.

____

Signature of Participant   Date

Participant's Initials ____________

DOT HS 811 514
September 2011

U.S. Department
of Transportation

**National Highway
Traffic Safety
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