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FACTORS AFFECTING TETHER USE AND MISUSE

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16. Abstract

This project investigated factors relating to tether use and misuse. Volunteer testing was performed with 37 subjects on 16 different vehicles using 2 forward-facing child restraints (Britax Marathon 70 or the Evenflo Triumph), with each subject performing 8 child restraint installations on a set of four vehicles. Vehicles were selected to provide a variety of general tether locations (filler panel, upper seatback, lower seatback, floor, or roof), as well as a variety of recommended tether routings with respect to the head restraint: under, over, around. Simple instruction regarding the LATCH system was provided after the fourth trial.

Subjects used the tether in 89% of the 294 forward-facing trials and attached the tether correctly in 57% of installations. Subjects were more likely to use the tether if they were less than age 40, had previous tether experience, if the tether was located on a filler panel, and if the vehicle did not have any potentially confusing hardware. In addition, tether use was 83% in the first four trials and increased to 95% in the last four trials after instruction was provided.

Subjects had the greatest difficulty in the pickup truck, which use loops of webbing as a router for the installed position and the tether anchor for the adjacent position; the tether was attached correctly in only 11 percent of installations. Tethers were more likely to be used when the tether anchor was located on the filler panel of sedans, which had a use rate of 95 percent, compared to when the anchor was located on the floor, roof, or seatback, which had use rates ranging from 79 to 89 percent. Tethers were less likely to be attached correctly when there was potentially confusing hardware present, 47 percent, compared to 70 percent. In addition, tether anchors located on the filler panel or mid seatback had higher rates of correct attachment, 60 and 69 percent , respectively, than those on the floor, roof, or lower seatback, which all had correct attachment rates lower than 50 percent . No vehicle tether hardware characteristics or vehicle manual directions were associated specifically with correct tether routing and head restraint position.

Installations involving the single tether strap were 10 times as likely to have the tether attached correctly and 1.7 times as likely to be routed correctly and have the head restraint positioned correctly, compared with installations with the v-shaped tether. Lack of instruction in most vehicle owner's manuals regarding the routing of a V-style tether more challenging to use. With the single strap-style tether, it was more straightforward to have the tether strap flat and pull it tight, as well as to route it as directed. With the V-style tether, the adjustment hardware was often located underneath or close to the head restraint when installed in the vehicle, making it difficult to tighten.

Recommendations to reduce tether misuse include labeling tether anchors, eliminating confusing hardware, allowing any head restraint position (including removal), providing instruction for routing V-style tethers, allowing options in tether routing, and redesigning tether anchors/routers found in pickup trucks.

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Introduction

Background

LATCH Implementation

In an effort to make child restraint installation easier, the LATCH (Lower Anchors and Tethers for Children) system was required in vehicles and child restraints manufactured after September 2003. The vehicle part of the system consists of two lower anchors located near the seat bight and a top tether anchor generally located rearward of the seatback, mounted to the filler panel, floor, roof, or seatback. On the child restraint, the LATCH system consists of lower connectors linked to the child restraint either with webbing or rigid connections. Federal Motor Vehicle Safety Standard (FMVSS) 225 defines the hardware requirements for the vehicle, while FMVSS 213 defines the hardware requirements for the child restraints. The LATCH system is based on a similar effort by the International Standards Organization (ISO), which defines the ISOFix system as using rigid lower anchors and a means to reduce forward rotation such as a top tether or floor support leg.

LATCH was intended to simplify child restraint installation by using the LATCH connectors as the main attachment to the vehicle, thus eliminating the need to lock the vehicle seatbelt. For forward-facing installations, using the top tether can improve the quality of the installation and provides safety benefits by reducing head excursion. However, most studies of child restraint installation errors with LATCH indicate that instead of eliminating misuse, new forms of misuse have been introduced (Decina and Lococo 2007, Jermakian and Wells 2010, SafeRideNews 2011). One of the key new misuses is failure to use the tether, with several studies documenting that fewer than half of caregivers with tether hardware available use it with forward-facing child restraints. In the most recent study, tethers were used in 56 percent of forward-facing child restraint installations (Eichelberger et al. 2013). When those who had not used the tether were asked the main reason for not using it, the most common response was lack of awareness of tethers or how to use them (Eichelberger 2013). Other misuses include loose tethers and loose LATCH straps. In addition, some caregivers installed their child restraints using both the seatbelt and LATCH system, which is not usually permitted by manufacturers' instructions.

LATCH Usability

While some vehicles do allow easy installation with LATCH, in other vehicles lower anchors are difficult to access and use, and seatbelt hardware can interfere with use of lower anchors. Identification of tether anchors can also be a problem in some vehicles. Several efforts have been undertaken to improve the usability of LATCH and reduce incompatibilities between child restraints and vehicles. The SAE Child Restraint Systems (CRS) Subcommittee and ISO TC22/SC12/WG1/TF2 have drafted procedures and tools for assessing LATCH usability and the compatibility between vehicle and CRS when using LATCH (SAE 2009, ISO 2010a, 2010b). The SAE procedures generally have tools and procedures for quantifying hardware, while the ISO procedures focus on instructions and labeling and more qualitative assessments of hardware usability. NHTSA has also proposed a consumer information program (NHTSA, March 2011) whereby vehicle manufacturers would provide a list of child restraints that fit in each vehicle model, but has not yet issued details of the final program.

Klinich et al. (2010a, 2010b, 2013c) performed tests with volunteer subjects to identify factors that contribute to child restraint installation errors. Testing was conducted in three phases. The first phase examined different child restraint features, the second phase looked at alternate labels and child restraint manuals, and the third phase looked at different types of vehicle hardware. For the results associated with child restraint features, LATCH connector type, LATCH belt adjustor type, and the presence of belt lockoffs were associated with the tightness of the child restraint installation. Correct tether use was associated with the tether storage method. Compared to the effects of different child restraint designs, variations in labels and manuals have a small effect on installation error.

In the study phase examining vehicle differences, vehicles requiring higher forces to attach connectors to lower anchors were more likely to be attached incorrectly. Vehicle seats with a bightline waterfall (which places the lower anchor above the seating surface) increased rates of tight child restraint installation for both seatbelt and LATCH installations. Subjects used the tether correctly in 30% of installations. Subjects used the tether more frequently during LATCH installations compared to seatbelt installations, and in sedans (with anchor locations on the filler panel behind the head restraint) than in vehicles with the tether anchor located on the seatback. However, when the tether was used, it was routed correctly more often in vehicles with the tether anchor on the seatback.

A study sponsored by the Insurance Institute for Highway Safety focused more specifically on vehicle factors affecting LATCH usability (Klinich et al. 2012, 2013a, 2013b). The project involved three phases. First, LATCH implementations in 98 2011 or 2010 model-year vehicles were measured. Second, ISO and SAE LATCH usability rating systems were used to assess all vehicles using data from the second row left position, and child restraint/vehicle interaction was assessed using both ISO and NHTSA proposed procedures. Third, volunteer testing was performed with 36 subjects on 12 different vehicles using 3 different child restraints, with each subject performing 8 child restraint installations, to identify what features and ratings were associated with reduced installation errors using LATCH.

The results from the vehicle survey indicate that most vehicle manufacturers provide LATCH hardware at only the minimum number of seating locations required by FMVSS 225, which are two positions equipped with lower anchor bars and a top tether anchorage and one additional top tether anchorage. Only 7 vehicles had three sets of LATCH hardware in the second row, while most of the remaining 91 vehicles were only equipped with LATCH in each outboard position and a tether anchor in the center position. In the 21 vehicles with a third row, four had no tether anchors and 11 had no lower anchors in the third row. Fifty-nine vehicles met the SAE recommended lower attachment force of 75 N (16.9 lb) or less, while 15 vehicles required forces from 2 to 8 times this value. Only 2 vehicles met SAE recommendations for clearance angle of at least 75 degrees around the lower anchors. The depth of the lower anchors relative to the bight is less than 2 cm in 28 vehicles, 2-4 cm in 34 vehicles, and greater than 4 cm in 36 vehicles. The most common location for the tether anchor is the seatback (42) and package shelf (35). The lower anchors are marked in 77 vehicles, while the tether anchors are marked in 68 vehicles.

ISO ratings of vehicle LATCH usability ranged from 41% to 78%, while vehicles assessed using the SAE draft recommended practice met between 2 and all 10 of the recommendations. There was a slight correlation between vehicles meeting SAE recommended practices and ISO usability ratings. Twenty vehicles with a range of vehicle features were assessed using the ISO vehicle/child restraint form and 7 child restraints; ISO vehicle/child restraint interaction scores ranged from 14% to 86%, where 100% is the best score. Based on these interaction scores, the Cosco Alpha Omega, the Chicco KeyFit, and Evenflo Maestro were used with a subset of 12 vehicles to perform volunteer testing and assess the quality of subject installations. However, the correct use of lower anchors was associated with a lower anchor clearance angle greater than 54°, an attachment force of 40 lb or less, and lower anchor depth within the bight of less than 2 cm. Correct lower anchor use also had 3.3 times higher odds of tight installation compared to incorrect use.

Tethers were used in 48 percent of forward-facing installations, with subjects using the tether more frequently during LATCH installations (54 percent) compared to seatbelt installations (33 percent). For installations using tethers, the tether was used correctly in 46 percent of trials. The most common errors were incorrect routing with respect to the head restraint (44 percent), loose tethers (26 percent), attachment to incorrect hardware (22 percent), and incorrect orientation of the tether hook (22 percent). Tether anchor characteristics including location, wrap distance, marking, and visibility were all examined but no specific vehicle factors predicted the use or correct use of tethers.

Objective

The recent UMTRI project conducted for the IIHS identified three key vehicle LATCH lower anchor characteristics that are associated with improved rates of correct lower anchor use by volunteers. However, no factors associated with correct top tether use were identified. Vehicles in the previous volunteer study of LATCH (Klinich 2013a) were selected based on various vehicle seat and LATCH characteristics but had limited variability in tether anchor characteristics that may affect tether use. The limited variability in tether anchor characteristics, combined with low tether use rates, limited the ability to identify tether anchor characteristics associated with tether use. The current study focused on identifying characteristics of vehicle tether anchors that increase the use and correct use of tethers. The protocol was designed to provide a larger number of trials with tether use than in the previous study, and vehicles were selected primarily based on their tether anchor characteristics.

Methods

Experimental Design

Thirty-six subjects were recruited and divided into four groups of nine subjects each. Each subject was asked to perform eight forward-facing child restraint installations. Each test session lasted approximately two hours, with subjects compensated $40 for their time. Appendix A contains the text used to screen subjects, while Appendix B contains the consent form.

Four groups of four vehicles (a total of 16 configurations) were evaluated in this study, with each volunteer experiencing one set of vehicles. Each set of four vehicles was selected to provide a variety of general tether locations (filler panel, roof, floor, lower seatback, mid seatback), as well as differences in recommended routing with respect to the head restraints. Each group of nine subjects was tested using four vehicles, with the order of vehicles changed with each subject.

For the vehicle setup, head restraints were initially positioned in the highest position. Adjustable seatbacks were placed near the design seatback angle, unless otherwise directed in the vehicle owner's manual. The front seats were adjusted to the mid-track position with the seatback two notches rearward of full upright.

Testing was performed with two child restraints set up for forward-facing harness mode. Figure 1 shows comparative views of the two child restraints. The Evenflo Triumph was equipped with a single tether strap, while the Britax Marathon 70 has a V-shaped tether strap. These two restraints were chosen because while they were both convertibles, they had different shell shapes, and the attachment point of the tether on the back of the child restraint differed by approximately 50 mm in height. Installations alternated between the two models of child restraint, such that two installations in each vehicle were performed with different child restraints (each child restraint was installed once in each vehicle). The child restraints were configured for the forward-facing orientation before testing began. No child dummies were used in testing.

Figure 1. Child restraints used during volunteer testing; Evenflo Triumph (C2) and Britax Marathon 70 (C1).

The detailed test protocol is found in Appendix C. In the first four trials, the subject was directed to install the first child restraint using LATCH. If the subject asked what LATCH is, the experimenter directed them to consult the vehicle and child restraint manuals. The last four trials were repeated in the same four vehicles using the child restraint in each vehicle that was not used in the first four trials. The experimenter provided each subject with basic instruction regarding LATCH before the fifth trial began, as follows:

"The LATCH system lets you install the child restraint with two connectors on the child restraint that attach to bars located in the vehicle seat, plus a top tether on the child restraint (show it to them) that connects to a tether anchor in the vehicle. You can find out information about the vehicle anchors in the owner's manual. "

The test matrix for subject group ABCD is shown in Table 1. The trial matrix used a split-plot experimental design, with all possible combinations of vehicles and child restraints tested across subjects. The design allows estimation of key main effects within subjects, and some interactions are assessed between subjects. Letters designate the vehicles and 1 and 2 designate the two child restraints. The order of the study vehicles and the vehicle and child restraint combinations was varied for each volunteer to minimize learning effects. In the first four and last four tests, each subject tests each vehicle once and each child restraint twice. If child restraint 1 was paired with a particular vehicle in the first four trials, child restraint 2 was paired with that particular vehicle in the last four trials. The same matrix was used for subject groups EFGH, IJKL, and MNOP.

Table 1. Example test matrix for vehicle group ABCD.

	Trial Number (instruction provided between trial 4 and 5)							
Subject	1	2	3	4	5	6	7	8
1	A1	B2	C1	D2	C2	D1	B1	A2
2	B2	C1	D2	A1	D1	A2	C2	B1
3	C1	D2	A2	B1	A1	B2	D1	C2
4	D2	A2	B1	C1	B2	C2	A1	D1
5	A2	B1	D1	C2	D2	B2	C1	A1
6	B1	C2	A2	D1	A1	C1	D2	B2
7	C2	D1	B2	A1	B1	D2	A2	C1
8	D1	A1	C2	B2	C1	A2	B1	D2
9	B2	A1	D2	C1	D1	B1	C2	A2

After each installation, the experimenter assessed the installation using the same general criteria used in the first Insurance Institute for Highway Safety (IIHS) study on LATCH (lower anchors and tethers for children) usability factors (Klinich et al. 2012, Klinich et al. 2013a) using the form in Appendix D. Because of the focus on the tether, two additional factors were evaluated. In the current study, the experimenters documented the position of the head restraint and whether or not the tether was twisted. These factors were not assessed as part of correct use in the previous IIHS LATCH usability study.

After the subject installed the child restraint, the amount of slack in the tether was measured by pinching the excess webbing in the tether strap, measuring the height of the loop, and doubling the resulting measurement. To document installation tightness, the 1" test for looseness used by child passenger safety technicians was used. As a supplement to this test, the amount of lateral displacement that occurred when the child restraint was loaded at the belt path with a horizontal force of 40 lbf was also measured.

All of the forms completed by the subjects are included in Appendix E. In the last four trials, the subject filled out a questionnaire regarding elements of the installation. In the first four trials, the subjects did fill out the questionnaire to avoid providing education regarding LATCH. After completing all eight trials, the subject filled out another questionnaire that collected details regarding their previous LATCH and child restraint installation experience, as well as a race/ethnicity form. They also filled out a general form regarding which tether anchors were easiest to use and, if applicable, why they did not use the tether. Upon completion of the questionnaires, subjects were provided with information regarding child restraint checkups and proper installation that are included in Appendix F.

Subject Groups

Nine subjects were recruited for each vehicle group. Subjects were eligible for the study if they were currently transporting a child in a child restraint and had installed the seat themselves. The main selection criteria were whether or not the subjects had previous experience with LATCH, as well as their education level. Education level was split into college graduate and above or some college and below. During recruitment, the subjects were asked how they usually installed their child restraint in an effort to learn whether they had LATCH experience, but without educating them about LATCH. Efforts were made to have at least one and not more than three subjects in each group with the qualities of higher education/LATCH experience, higher education/no LATCH experience, lower education/LATCH experience, and lower education/no LATCH experience.

Subjects were given a questionnaire after testing that asked for more details regarding their previous experience with lower anchors, tethers, and different types of child restraint installations. Several subjects who were classified as having no previous LATCH experience were reclassified as having LATCH experience based on their post-testing questions, and vice versa. (This reclassification led us to recruit an additional subject for one vehicle group.)

Table 2 lists the percentage of subjects in each vehicle group with previous lower anchor experience, tether experience, Caucasian race/ethnicity, and gender. The only subject factor that was significantly different among groups was gender. Among subjects who did not identify themselves as Caucasian, there were one Asian, three Black, three Mixed, one Native American, and two white Hispanic.

Table 2. Distribution of subject factors for each vehicle group.

	ABCD	EFGH	IJKL	MNOP	p-value
Lower Anchor Experience?	78%	80%	56%	67%	0.640
Tether Anchor Experience?	67%	60%	56%	67%	0.952
Caucasian	78%	80%	56%	67%	0.754
Female	33%	70%	56%	100%	0.018

The distribution of subjects by age group is shown in Figure 2. The distribution of subjects by age group within each vehicle group was statistically similar (p=0.971). The majority of subjects were aged 30 to 39 years. The distribution of subjects by their previous type of child restraint experience is shown in Figure 3. The differences in subjects between vehicle groups was also not significantly different (p=0.575).

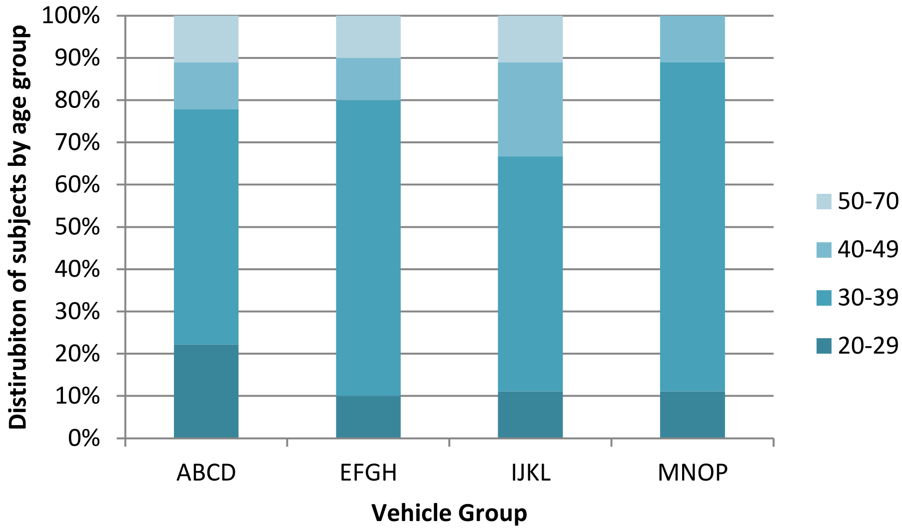

Figure 2. Distribution of subjects by age group (years).

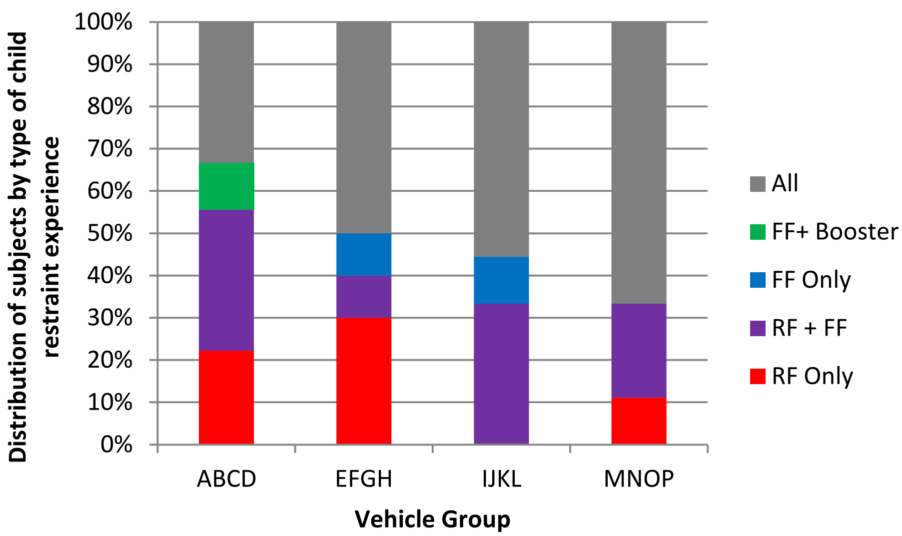

Figure 3. Distribution of subjects by previous type of child restraint experience. FF=forward-facing, RF=rear-facing

Vehicle Selection

To identify detailed characteristics regarding the tether anchors in the most recent model years, 57 popular 2012-2013 vehicles were surveyed at local dealerships. The vehicles evaluated were selected from among the top-selling vehicles of 2011.

Vehicles were categorized according to the following criteria:

- General tether location: filler panel, roof, floor, upper seatback, or lower seatback
- Distance between rear base of head restraint and the tether anchor: >165 mm or < 165 mm
- Vehicle manufacturers instructions on tether routing around head restraint: over, under, remove, around, inboard, outboard or some combination of these

Some measurements were taken to characterize the location of the tether anchor relative to the head restraint and the lower anchors. The distance between the lowest rear point on the head restraint and the tether anchor hook was recorded. Based on the measurement of typical tether hardware on child restraints, our past reports had hypothesized that tethers would be easier to use and tighten if the distance between these two points on the vehicle was at least 165 mm. Instead of measuring tether wrap distance, which requires the use of the J826 manikin or an alternate test fixture, the distance between the tether anchor and the lower anchor was used as a substitute.

Although it was not used to classify vehicles or sort them into groups, the construction and packaging of each tether anchor was described. First, the construction of the tether hook was classified as wire, stamped (anchor parallel to tether hook), stamped (anchor perpendicular to tether hook), or webbing. Pictures of each type of tether construction are shown in Figure 4. The packaging around each tether hook was described as covered recess, open recess, open, or slit in carpet. These different styles of tether packaging are shown in Figure 5.

Wire Stamped, parallel Stamped, perpendicular Webbing

Figure 4. Different categories of tether construction.

Covered recess | Open recess | Open | Slit in carpet

Figure 5. Different categories of tether packaging.

Each vehicle was evaluated for the presence of potentially confusing hardware. Vehicles were considered to have confusing hardware if there was other plausible attachment hardware such as cargo tie-downs or webbing loops (Figure 6) near the tether anchor or in a location a parent might expect to find a tether anchor.

Figure 6. Potentially confusing hardware includes cargo tie-down points (left and center) and webbing loops (right).

The 57 vehicles were classified into 16 categories based on the general location, distance to head restraint, and tether routing. Within each category, there were between one and nine vehicles. Sixteen test vehicles were selected and divided into four groups to expose each subject to a variety of tether conditions. The vehicles were selected and categorized so each group would see four different vehicle manufacturers. In addition, each group would see three or four styles of head restraint: fixed, medium, large, or large hinged. Each group had two conditions where the tether routing was “under”, and each group would see three or four different general tether locations. The three vehicles with less than 165 mm distance between tether anchor and head restraint were placed into different groups. In addition, effort was made during the vehicle selection process to avoid using more than two vehicles from a single manufacturer. The matrix was revised slightly from the original plan, because in some cases the rental vehicle that was available differed from the vehicle that was measured at the dealer. Table 3 lists the vehicles that were tested with each group, as well as their pertinent characteristics. Each vehicle is designated with a letter.

Upon receipt of the test vehicles from the rental agency, the experimenters (both certified child passenger safety technicians) installed each child restraint in the 2L position (second row behind driver) to confirm that it was possible to do so without extraordinary effort. For vehicles that allowed more than one option for positioning the head restraint or routing the tether with respect to the head restraint, the condition that led to the most secure installation was used. Appendix G contains photos of the tether hardware close-up, as well as the tether routing for each child restraint in each vehicle.

In the Chrysler 200, it was extremely difficult to install the child restraint in the 2L seating position using the lower anchors. There seemed to be some sort of metal structure within the seat that prevented attachment of the lower connectors. However, the lower anchors in the 2R seating position were more straightforward to use. For this vehicle, the subjects were asked to install the child restraints in the 2R seating position instead.

In addition to checking that each child restraint could be properly installed in each vehicle, the rear seat of each test vehicle was documented using the forms found in Appendix H. These forms include measures of items needed to apply the SAE, ISO, and IIHS protocols for assessing LATCH usability in each vehicle. An additional item that was noted for each vehicle was whether it was physically possible to install the tether hook upside-down.

Table 3. Test vehicles and tether anchor characteristics.

Code	Vehicle	Vehicle Type	Tether Location	Distance (mm) : Tether Anchor to Head Restraint	Distance (mm): Tether Anchor to Lower Anchor	Tether Anchor Construction	Tether Anchor Package
A	2013 Mazda 3 Touring	Small Sedan	Filler panel	135	845	Stamped, parallel	Covered recess
B	2012 Ford Taurus	Large Sedan	Filler panel	240	1040	Wire	Covered recess
C	2012 Nissan Rogue	Small SUV	Floor	535	1500	Stamped, parallel	Covered recess
D	2013 Toyota Highlander	Midsize SUV	Seatback Mid	270	1080	Wire	Covered recess
E	2012 Toyota Camry	Midsize Sedan	Filler panel	160	1040	Wire	Covered recess
F	2012 Kia Sedona	Large Minivan	Seatback Bottom	630	1330	Wire	Slit in carpet
G	2013 Subaru Outback	Midsize Sedan	Roof	490	1230	Stamped, parallel	Covered recess
H	2013 Ford Fiesta	Mini Sedan	Filler panel	190	850	Stamped, parallel	Covered recess
I	2013 Honda Odyssey	Large Minivan	Seatback Bottom	680	1390	Wire	Slit in carpet
J	2012 Chevrolet Malibu	Midsize Sedan	Filler Panel	130	840	Stamped, perpendicular	Covered recess
K	2013 Ford F150 SuperCab	Large Pickup	Filler Panel	380	1000	Webbing	Open
L	2013 Jeep Patriot	Small SUV	Seatback Mid	270	1340	Wire	Open recess
M	2013 Chrysler 200	Midsize Sedan	Filler panel	210	880	Stamped, perpendicular	Covered recess
N	2013 Volkswagen Jetta Sportwagen	Midsize Sedan	Floor	530	1250	Stamped, parallel	Covered recess
O	2013 Honda CR-V	Midsize SUV	Seatback Bottom	480	1190	Wire	Open recess
P	2013 GMC Acadia	Large SUV	Seatback Mid	470	1570	Wire	Open recess

Head Restraint Position and Tether Routing Instructions

The vehicle manuals were reviewed to identify the recommended position for placing the head restraint during child restraint installation and the recommended tether routing. The instructions are summarized in Table 4.

Table 4. Summary of recommended head restraint position and recommended tether routing for each vehicle.

Code	Vehicle	Recommended head restraint position	Recommended tether routing: single tether (V-shape tether)
A	2013 Mazda 3 Touring	Up	Under
B	2012 Ford Taurus	Fixed or removed	Over or removed
C	2012 Nissan Rogue	Fixed	Over
D	2013 Toyota Highlander	Down	Under
E	2012 Toyota Camry	Fixed	Over
F	2012 Kia Sedona	Down	Under
G	2013 Subaru Outback	Removed	Removed
H	2013 Ford Fiesta	Up or removed	Under or removed
I	2013 Honda Odyssey	Up	Under
J	2012 Chevrolet Malibu	Up	Under
K	2013 Ford F150 SuperCab	Up or removed	Under or removed
L	2013 Jeep Patriot	Fixed	Over
M	2013 Chrysler 200	Fixed	Outboard
N	2013 Volkswagen Jetta Sportwagen	Up	Under
O	2013 Honda CR-V	Up	Under
P	2013 GMC Acadia	Fixed	Over (Around)

In a number of trials, the only errors made by subjects were incorrectly placing the head restraint and/or routing the tether in a manner other than directed, even though the tether was tight and attached correctly to the correct hardware. In some cases, a tighter installation could be achieved with another head restraint position, or a more direct route to the tether anchor could be achieved with an alternate routing. Only one manual contained specific directions for routing the V-style tether of the Marathon. In particular, in several vehicles where the manual indicated the tether should be routed over the head restraint, routing the V-shaped tether over the head restraint naturally caused it to fall on either side of the head restraint. In other cases, the V-shaped tether could be routed over the head restraint but seemed in danger of sliding off.

We had concerns about classifying improper head restraint position as misuse, because it is not something regularly evaluated at child seat inspections. Following the directive to make sure the child leaves a seat check safely, many technicians would choose to use a head restraint position other than that recommended by the vehicle manufacturer if a tight fit could not be achieved with the head restraint position specified by the manual. However, using the incorrect head restraint position could be construed as misuse because it does not follow the vehicle manufacturer's directions. For this study, we monitored whether subjects positioned the head restraint as directed, then also considered a less strict interpretation where using an alternate head restraint position would not be considered misuse.

For the tether routing issue, we also evaluated both a strict interpretation and a more liberal interpretation of routing. For the installations using the Marathon, routing the tether anchor around the head restraint rather than over it was considered acceptable. For both child restraints, if the subject removed the head restraint in situations where they were supposed to route the tether over or under the head restraint, the routing was considered acceptable.

Before proceeding with this two-level approach to analysis, we contacted all of the vehicle manufacturers to ask if a particular head restraint position or tether routing was acceptable based on different strategies that volunteers used. We pursued this avenue, reflecting that this might be done at a car seat check if we could not get an adequate installation while following the vehicle manufacturer's directions. The experimenter making the calls stated that she was a technician who experienced a particular situation at a car seat check and wondered if the alternate position/routing was okay as long as they were able to get the child seat tight.

Table 5 summarizes the responses from the vehicle manufacturer representatives. If a vehicle is not listed, none of the subjects used an alternate head restraint position or tether routing where input was required. Only one of the vehicle manufacturers (highlighted in bold) provided any information beyond that contained in the manual. Several suggested contacting a CPST (or fire station/police station) even though our experimenter identified herself as a CPST encountering the issue at a car seat check.

Table 5. Summary of responses to inquiries by vehicle manufacturers.

Code	Advice from manufacturer representative
A	Can't advise removal of HR. Try another seat position. Contacted dealer, who said to contact a CPST.
B	Repeated instructions. Suggested contacting CPST or NHTSA.
C	Could not provide information on using V-style tether. Suggested using different CRS or contact CPST.
D	Repeated instructions. Suggested contacting dealer to make sure head restraint working properly.
E	Repeated instructions. Suggested contacting Britax to see if V-tether could be converted to a single tether.
F	Repeated instructions. Could not recommend any other HR position.
G	Suggested getting seat as tight as possible, but seemed as if he was making things up as he went along.
I	Said to follow manual or contact dealer.
J	**Representative didn't see anything in manual about final position of head restraint, but thought an alternate position (down rather than up) would be ok if the installation was tight.**
K	Repeated instructions. Suggested contacting CPST, NHTSA, or CRS manufacturer.
L	Suggested calling seat check hotline, which only lists seat check times. Suggested contacting National Safety Council for possible recall issue.
M	Suggested calling seat check hotline, which only lists seat check times. Suggested contacting National Safety Council for possible recall issue.
N	Follow manual or contact NHTSA.

Data Analysis

As a first step, univariate analysis was conducted to identify possible associations between potential predictors and child restraint installation outcomes. The following outcomes were assessed:

- Tether use: Tether on the child restraint was attached to some part of the vehicle.
- Correct attachment to tether anchor: Tether was attached to the correct vehicle hardware in the correct orientation, and webbing was flat and tightened so that there was 10 mm or less of slack (measured by pinching the slack and measuring the height of the loop).
- Correct tether routing: Tether was routed and the head restraint was positioned as directed by the vehicle manual.
- Acceptable tether routing: Tether was routed and the head restraint was positioned in a manner deemed acceptable by child passenger safety technicians because it resulted in a tight, stable installation, even if it did not follow the vehicle manual directions.

Although not used as primary outcome variables, the following installation outcomes were also documented:

- Correct use of lower anchors: Child restraint connectors were fully engaged with the correct vehicle hardware in the correct orientation, and the LATCH strap webbing was flat.

- Tight installation: Restraint did not move more than 1 inch laterally or fore/aft when tested with a moderate pull/push applied at the restraint belt path.
- Child restraint installation completely correct: Correct use of lower anchors, correct attachment to tether anchor, correct tether routing, and tight installation.
- Child restraint installation acceptable: Correct use of lower anchors, correct attachment to tether anchor, acceptable tether routing, and tight installation.

Table 6 lists the different factors that were considered potential predictors.

Table 6. List of potential predictors considered in data analysis.

Type	Potential Predictor
Subject	Age Gender Education CRS Experience LA Experience TA Experience Vehicle Group
Testing	Installation number Instruction (trials 1-4 vs. 5-8) Child restraint Vehicle Vehicle type
Tether hardware	General location Tether construction Tether packaging Tether label Distance from HR to TA Distance from LA to TA Presence of confusing tether hardware Can tether be hooked upside down?
Behavioral	Used CRS manual Used vehicle manual Positioned head restraint as directed Routed tether as directed Correctly used LA Obtained tight installation

Following univariate analysis, mixed-models logistic regression was used to identify predictors of the outcome variables. The regression models were performed using SAS 9.2 PROC GLIMMIX. Each model was used to predict the probability of installation outcomes and random effects were used to account for the within-subject elements of the experimental design. For each outcome, the initial model was built in a backward stepwise manner by entering all candidate variables and removing variables that were not significant at $p=0.05$. For consistency, subsequent models for each outcome used all non-vehicle predictors identified as significant in the initial model.

Results

Tether Use

The 37 subjects completed a total of 294 forward-facing child restraint installations, with an average of 18 installations per vehicle. As shown in Figure 7, tether use significantly increased with trial number, with the most significant increase occurring after trial 4, when subjects received education regarding the LATCH system as described in the methods (p=0.001). Rate of tether use was 83% in the first four trials and 95% in the last four trials, with an overall use rate of 89%.

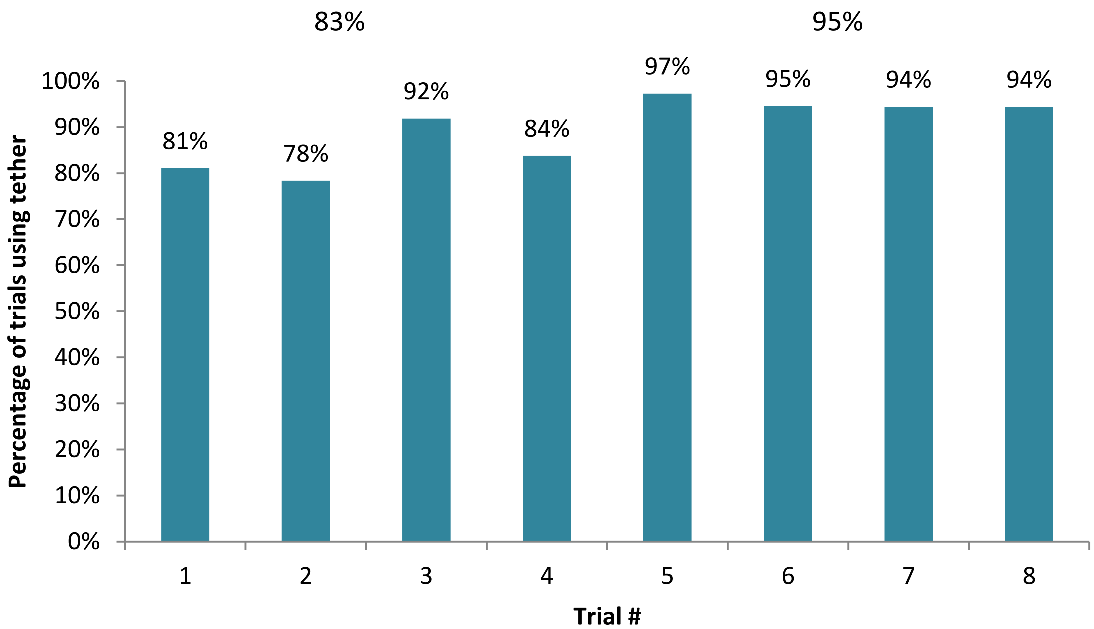

Figure 7.   Percentage of trials using tether

Tether use rates were similar for both child restraints used: 88% for the Marathon and 91% for the Triumph (p=0.342). They were also statistically the same for vehicle groups (85-94%, p=0.220) and individual vehicles (78%-100%, p=0.366).

For subject factors, tether use rates were similar for men and women (p=0.479), but were highly significant for all other subject factors. As shown in Figure 8, the younger age groups had substantially higher tether use rates than the two older groups (p<0.0001). Subjects' previous experience with child restraint installation, previous tether experience, and previous lower anchor experience were all correlated.   Subjects whose previous CRS experience was FF only had lower use rates than other experience categories.

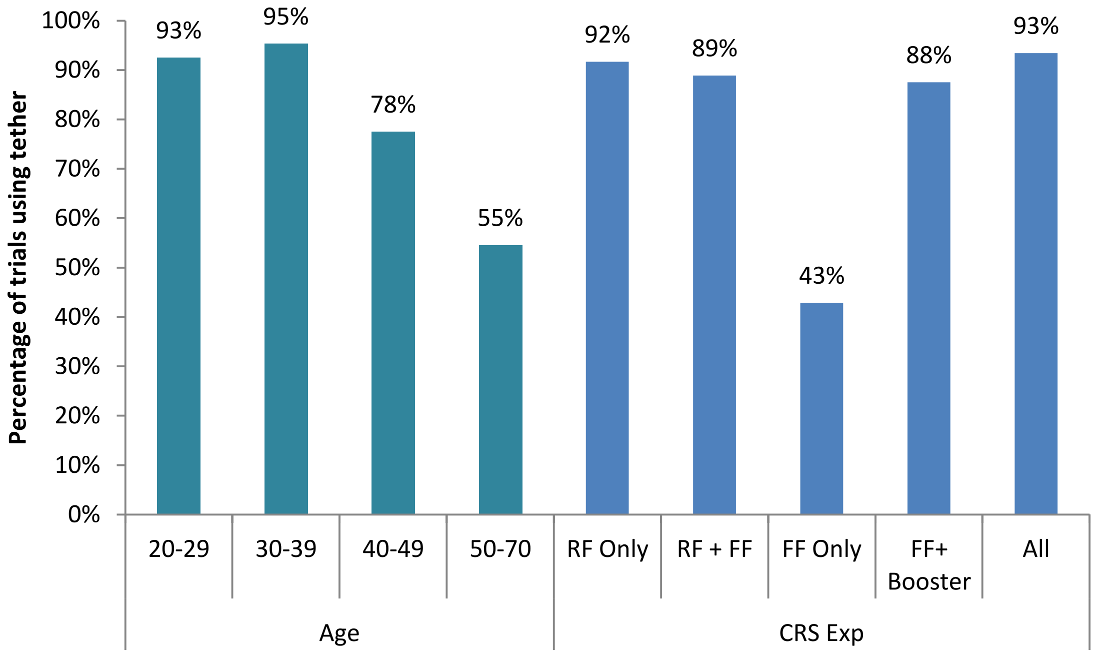

Figure 8. Percentage of trials using tether by age group and previous CRS experience.

Figure 9 shows the percentage of subjects using the tether by their previous lower anchor experience, previous tether experience, and the subjects' education. Both prior lower anchor experience and prior tether use ($p<0.0001$) led to higher rates of tether use. Education also significantly predicted tether use, but subjects with lower education had higher tether use rates than those with higher education ($p=0.023$). When looking at subjects' education and prior tether experience in combination as shown in Figure 10, previous tether anchor experience increased tether use rates in a similar manner for subjects of both education levels ($p<0.0001$).

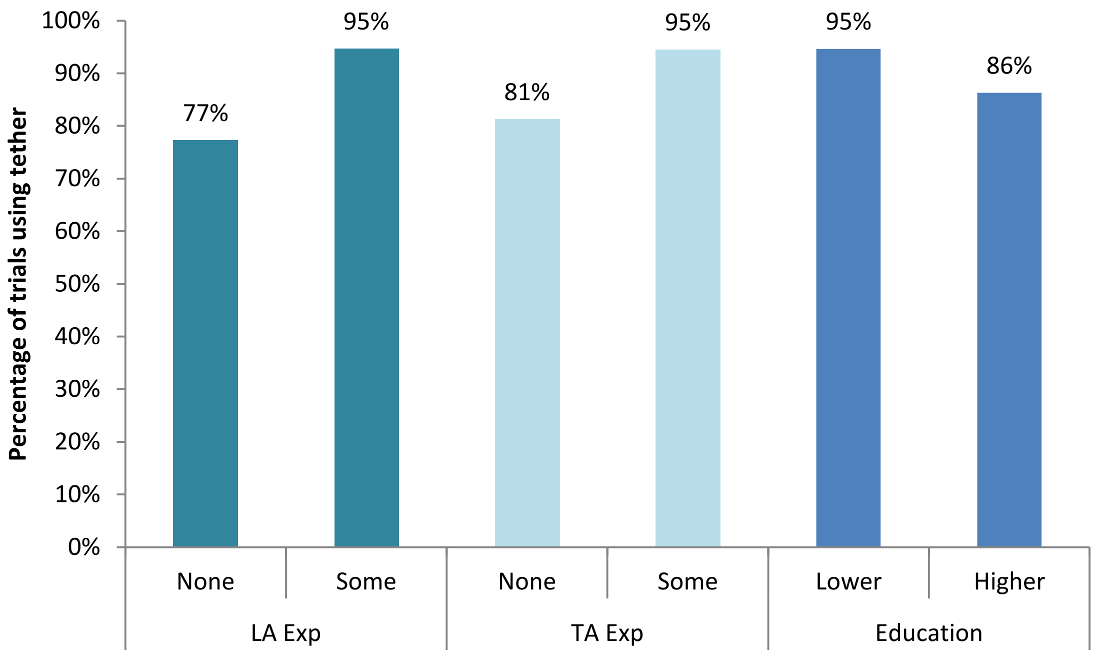

Figure 9. Percentage of trials using tether by previous lower anchor experience, tether anchor experience, and education.

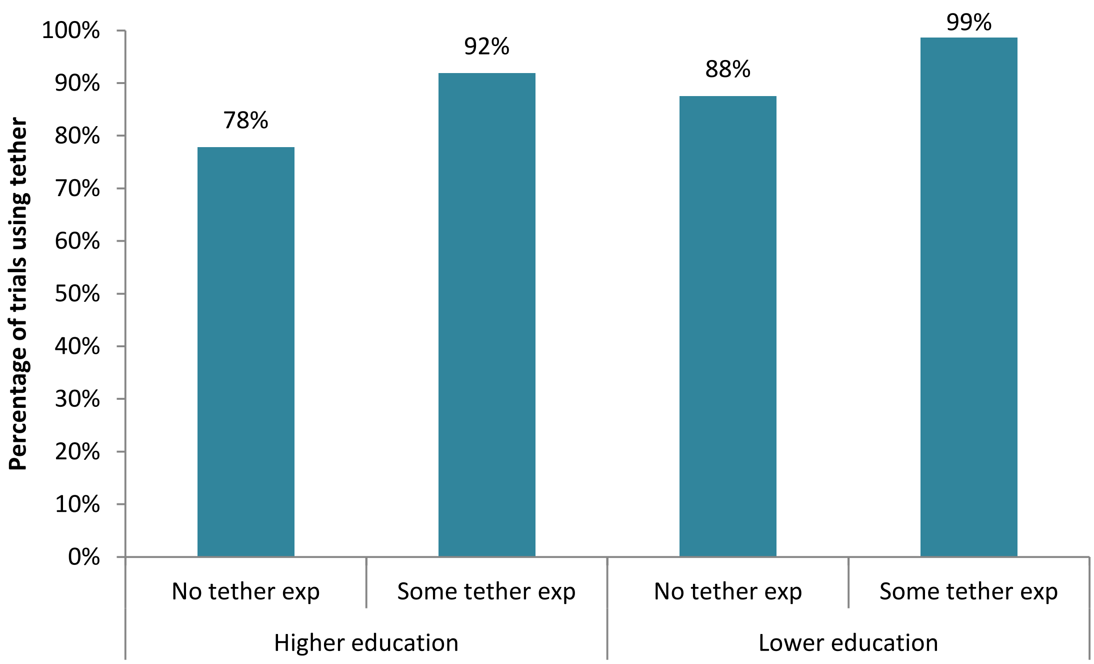

Figure 10. Percentage of trials using tether by previous tether anchor experience and education combinations.

Tether use varied with the general location of the tether anchor as indicated in Figure 11 (p=0.033). Tethers located on the filler panel had the highest rates of tether use, while those on the roof had the lowest rates.

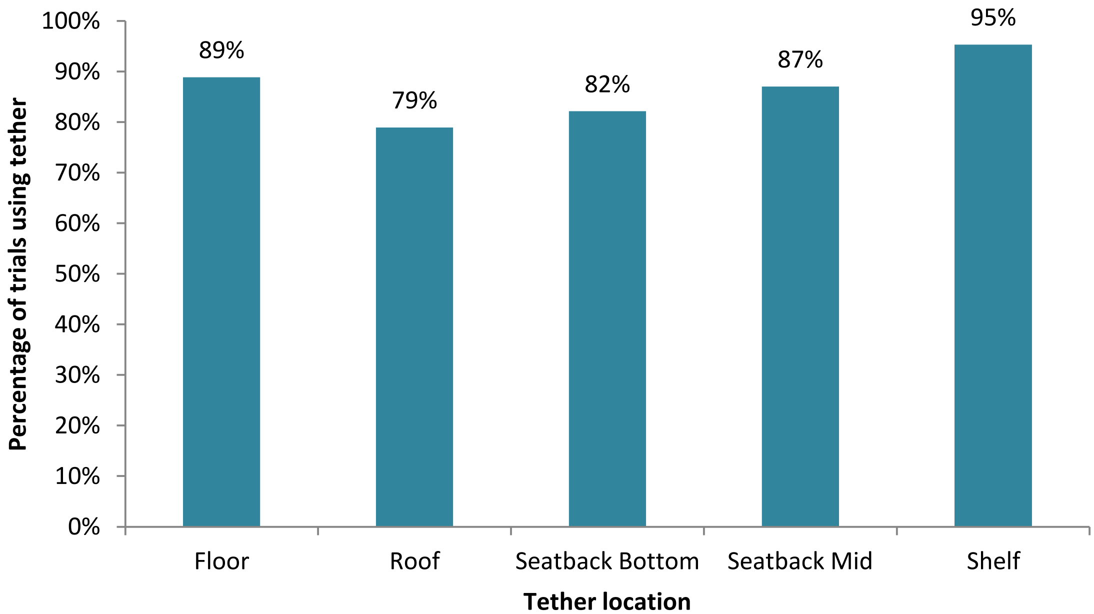

Figure 11. Percentage of trials using tether by tether location.

Subjects used the tether more often when it was marked than when it was not (92% vs. 82%, p=0.023). Tether anchors with a cover were used slightly more often than those without (92% vs. 87%, p=0.084).

The presence of hardware that could be potentially confused with the tether anchor also decreased the rate of tether use [F(3,62)=8.71, p=0.0133]. Vehicles without confusing hardware had the highest tether use (95%), while those with a router also had high tether use (94%). Vehicles with cargo tiedown hooks or visible webbing used to stow seats had lower rates of tether use of 85% and 79%, respectively.

Subjects who correctly used the lower anchors had higher rates of tether use (93%) than those who did not (76%; p<0.0001). Subjects who installed the child restraint tightly also had higher rates of tether use than those who did not (94% vs. 82%, p=0.001).

Subjects used the vehicle manual in only 22% of trials, while they used the child restraint manual in 32% of trials. Use of the vehicle manual did not affect tether use, while trials in which the subject used the child restraint manual had lower rates of tether use than those where they did not (83% vs. 92%, p=0.015).

For regression analysis, the variables assessed previously were evaluated to avoid consideration of correlated variables as potential predictors. For the subject variables, previous tether experience, previous lower anchor experience, child restraint installation experience, and use of the child restraint manual were all correlated. As a result, previous tether experience was selected as potentially the most relevant subject experience factor for consideration as a potential predictor. Installation number and instruction were also correlated, so instruction was selected as a potential predictor. Vehicle and vehicle type were correlated with tether location, so they were not included as potential predictors. The tether hardware-related variables of tether location, confusing tether hardware, tether marking, tether visible, tether construction, and tether packaging were all correlated. To perform the analysis, the first set of potential predictors included instruction, CRS, age category, tether experience, education, gender, vehicle manual use, and general tether location. Subsequent models used the non-tether variables chosen as significant predictors, but substituted other tether-related variables for the general tether location.

Results are shown in Table 7 for two models of tether use where a tether-associated variable was significant while considering subject and experimental factors. Tether use was highest for vehicles with tether anchors located on the filler panel (Model I), with the odds of using the tether reduced by 89 to 97 percent when the anchor was located on the seatback, floor, or roof. The presence of potentially confusing tether anchor hardware was negatively associated with tether use (Model II), with the odds of using the tether reduced by 88 percent in vehicles with confusing hardware present. (Vehicles without confusing hardware are most likely to be sedans where the tether is located on the filler panel.) For both models, providing instruction to the subjects after the fourth trial was the most significant predictor. Previous tether experience also increased likelihood of tether use. In both models, the subjects who were aged less than forty years had higher rates of tether use than those older than 40. In model I, subjects' education was marginally significant, with lower education subjects having higher rates of tether use than higher education subjects. Subjects who used the vehicle manual were marginally more likely to use the tether. Other tether-related variables of tether marked, tether visible, tether packaging, and tether construction were not significant once the other significant predictors of instruction, age, and tether experience were included.

Table 7. Mixed-effects logistic regression models predicting tether use. Statistically significant results indicated in **bold**.

I	Tether location		
	Filler panel	Reference	F(4,79)=3.31, p=0.0146
	Floor	**0.07 (0.01-0.58)**	
	Roof	**0.03 (0.003-0.35)**	
	Middle of seatback	**0.11 (0.02-0.64)**	
	Bottom of seatback	**0.06 (0.01-0.35)**	
	Age		
	50-70 years	**0.01 (<0.001-0.25)**	F(3,173)=3.15, p=0.0263
	40-49 years	**0.05 (0.003-0.76)**	
	30-39 years	Reference	
	20-29 years	0.56 (0.04, 7.79)	
	Tether experience		
	None	Reference	F(1,173)=4.16, p=0.0430
	Some	**9.00 (1.07-75.45)**	
	LATCH instruction		
	No (trials 1-4)	Reference	F(1,173)=11.99, p=0.0007
	Yes (trials 5-8)	**10.22 (2.72- 38.45)**	
II	Confusing hardware		
	Yes	**0.12 (0.19-0.823)**	F(1,36)=5.0, p=0.0316
	No	Reference	
	Age		
	50-70 years	**0.01 (0.001-0.51)**	F(3,164)=1.99, p=0.1177
	40-49 years	0.05 (0.002-1.23)	
	30-39 years	Reference	
	20-29 years	0.82 (0.03-21.12)	
	Tether experience		
	None	Reference	F(1,164)=3.11, p=0.0798
	Some	7.14 (0.79-64.59)	
	LATCH instruction		
	No (trials 1-4)	Reference	F(1,164)=7.8, p=0.0058
	Yes (trials 5-8)	**11.17 (2.03-61.63)**	

*Potential covariates considered: child restraint model, instruction, age, previous tether experience, education, gender, and vehicle manual use.

The results in Table 7 indicate that tether use was highest when the anchor was located on the filler panel compared to other locations. Figure 8 shows additional pairwise comparisons conducted for each combination of tether anchor location, with statistically significant differences indicated in bold. For tether use, no other locations had statistically different rates of use except for the filler panel.

Table 8. Pairwise comparisons of tether anchor locations in the mixed-effects logistic regression model predicting tether use* (F(4,79)=3.31, p=0.0146). Results shown are the odds ratio and 95% confidence interval of row title versus column title with statistically significant results in **bold**.

	Floor	**Roof**	**Filler panel**	**Middle of seatback**	**Bottom of seatback**
Floor	1	2.31 (0.19-28.59)	**0.07 (0.01-0.58)**	0.68 (0.11-4.33)	1.16 (0.18-7.64)
Roof	0.43 (0.04-5.38)	1	**0.03 (0.003-0.35)**	0.30 (0.03-3.18)	0.05 (0.06-4.14)
Filler Panel	**13.51 (1.72-111.11)**	**31.25 (2.87-333.33)**	1	**9.26 (2.86-52.63)**	**15.63 (2.86-83.33)**
Middle of seatback	1.46 (0.23-9.26)	3.38 (0.31-35.71)	**0.11 (0.02-0.64)**	1	1.70 (0.33-8.77)
Bottom of seatback	0.86 (0.13-5.65)	1.99 (0.24-16.39)	**0.06 (0.01-0.35)**	0.59 (0.11-3.05)	1

*Other covariates in the model included instruction, age, and previous tether experience.

Tether Attachment

The tether was used in 263 out of 294 trials (89%). Figure 12 shows the percent of trials where subjects attached the tether to the correct hardware, attached the hook in the correct orientation, kept the tether strap flat, and tightened the tether. The plot also includes the percentage of trials where subjects performed all four of these tether attachment tasks correctly. These plots include all trials; if the tether was not used it is considered incorrect attachment.

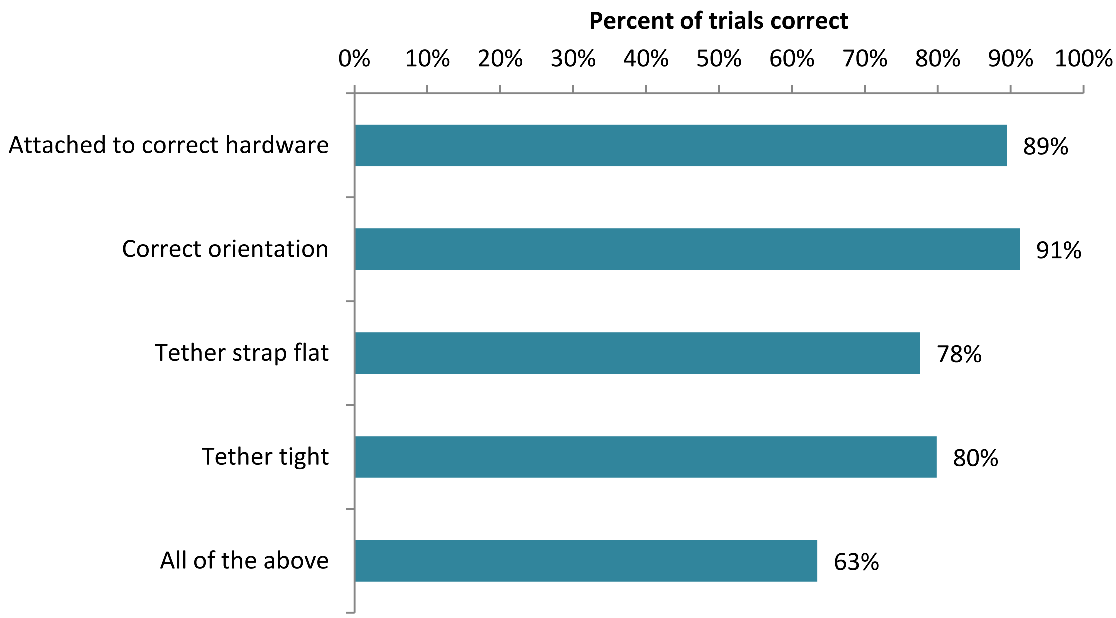

Figure 12. Percent of trials where subjects correctly performed elements of the tether attachment task.

Using univariate analyses, the child restraint model did not affect whether the tether hook was attached to the correct hardware (p=0.567) or whether it was oriented correctly (p=0.484). However, subjects more often had the tether strap flat with the Triumph (89%) than the Marathon (66%), (p=< 0.0001). They also had the tether tight more often with the Triumph as well (87% vs. 73%, p=0.014). As a result, the Triumph tether was attached correctly in 71% of trials vs. 42% of trials for the Marathon (p<0.0001).

Providing subjects with instruction after the fourth trial made a positive difference in most elements of tether installation, as seen in Figure 13 (p< 0.006 for all tasks). However, subjects did not keep the tether strap flat as often in the latter four trials as they did in the first four trials. When overall correct tether attachment is assessed separately for each child restraint before and after instruction, the single-strap tether increased from 63% correct attachment to 80% correct attachment, while the rate of correct attachment for the V-shape tether was 42% and did not change with instruction.

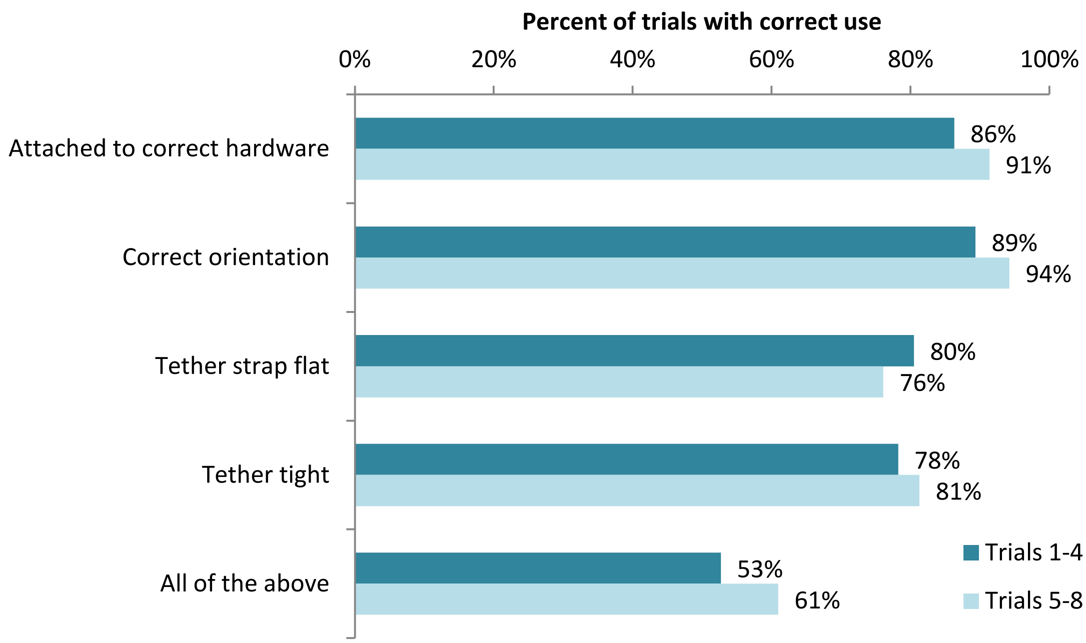

Figure 13. Percent of trials where subjects correctly performed elements of the tether attachment task, before and after they received LATCH instruction.

Table 9 shows for each vehicle the percentage of trials where the subjects attached the tether to the correct hardware, attached at the right orientation, kept the tether strap flat, and made the tether tight. It also shows the percent of trials for each vehicle where subjects correctly performed all of these installation elements. Vehicle K, the Ford F150, had the lowest rates of correct attachment. Vehicles B, D, E, I, J, and P had over 80% correct use on each attachment task, but only vehicles J and P had over 80% correct use for all tasks. The table is sorted using the column describing the tether construction and packaging.

Table 9. Distribution of correct trials by tether attachment task for each vehicle.

Vehicle	Attached to correct hardware	Correct orientation	Tether strap flat	Tether tight	All of the above	Style
J	94%	94%	94%	88%	88%	CR, SPd
M	100%	100%	82%	76%	71%	CR, SPd
A	94%	94%	78%	67%	56%	CR, SPl
C	81%	80%	60%	100%	56%	CR, SPl
G	80%	80%	67%	80%	60%	CR, SPl
H	100%	100%	94%	74%	74%	CR, SPl
N	100%	88%	56%	81%	44%	CR, SPl
B	100%	89%	83%	83%	67%	CR, W
D	94%	93%	81%	81%	69%	CR, W
E	100%	100%	83%	83%	72%	CR, W
K	12%	76%	71%	24%	12%	O, Wb
L	100%	100%	79%	100%	79%	OR, W
O	100%	100%	75%	81%	56%	OR, W
P	100%	94%	82%	100%	88%	OR, W
F	81%	88%	75%	69%	50%	S, W
I	93%	93%	86%	100%	79%	S, W

With the univariate analysis, several factors used to describe the tether hardware were examined to consider possible associations with different rates of correct tether attachment. As shown in Figure 14, rates of correct tether attachment varied somewhat with general tether location, but were not statistically different ($p=0.114$). Vehicles without potentially confusing tether hardware had rates of correct tether use of 70%, compared to 47% in vehicles with potentially confusing tether hardware ($p<0.0001$). Rates of correct tether attachment varied with the construction and packaging of the tether anchor as shown in Figure 15 and Figure 16 ($p< 0.0001$ for both). Although both plots show the lowest rates with the open webbing tether anchor found only in the pickup truck, stamped tether hooks where the hook is attached perpendicularly to the anchor had slightly higher rates than the stamped tether hooks where the hook is attached parallel to the anchor. Wire tether hooks fell between these two construction methods. For the tether packaging, tethers that were housed in either an open recess or a covered recess had higher rates of correct tether attachment than the vehicles in which the tether anchor is located within a slit in the carpeting. Tethers were more likely to be attached correctly when the tether was marked (61% vs. 43%, p=0.006), but being visible did not increase likelihood of correct use (60% not visible vs. 51% visible, p=0.115).

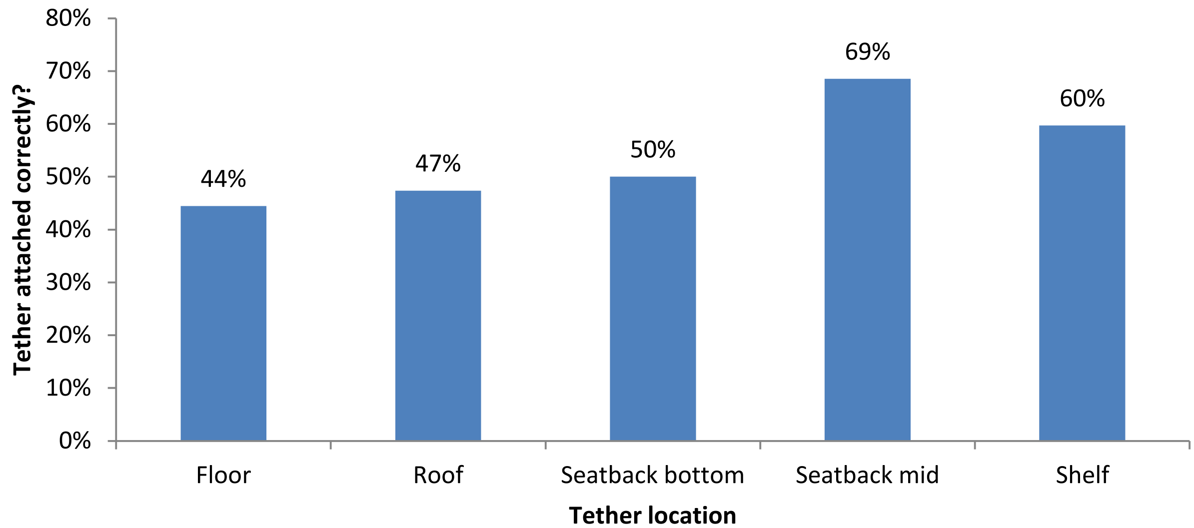

Figure 14. Rates of correct tether attachment with general tether location.

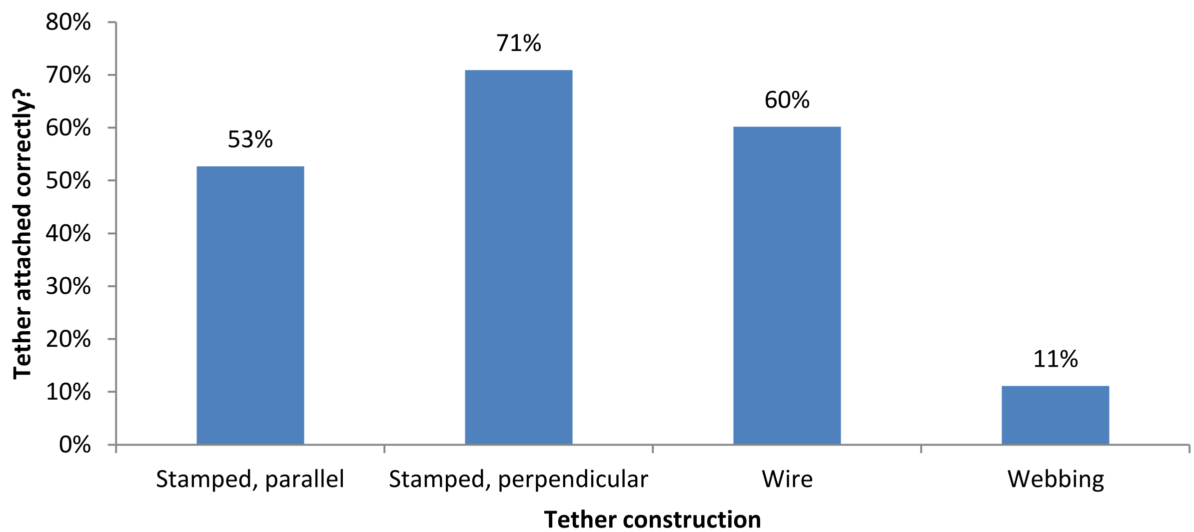

Figure 15. Rates of correct tether attachment with tether anchor construction.

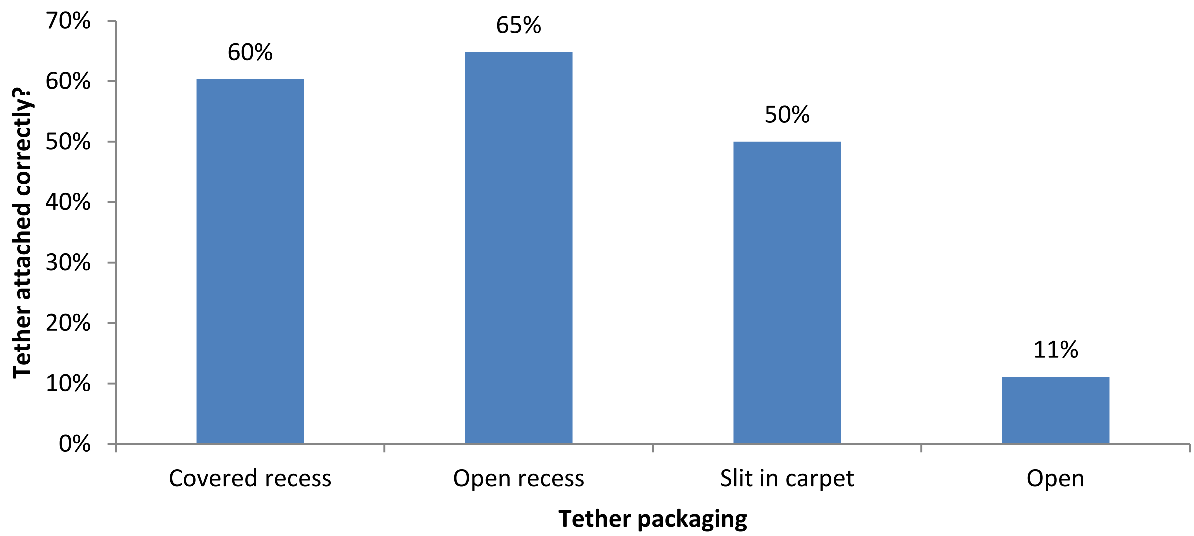

Figure 16. Rates of correct tether attachment with tether anchor construction.

Regression analysis was complicated by the correlation of several subject experience variables with each other, as well as most tether-related variables with each other. In addition, the significantly lower rate of correct attachment seen with the tether hardware found in the single pick-up truck may be dominating the analysis. As a result, the pickup truck trials were excluded from regression analysis to allow a more detailed examination of the tether hardware found more commonly across vehicles. The strategies described previously when selecting potential predictors of tether use were also applied to the analysis of correct tether attachment.

Results are shown in Table 10. Two models achieved significance using tether factors as predictors while considering the design of the study (and eliminating the pickup truck from consideration). Model I indicates that correct tether attachment varies with tether location, where correct tether attachment was associated with tether anchors located on the filler panel, with the odds of attaching the tether correctly reduced by 79 to 86 percent when the tether anchor was located on the bottom of the seatback, roof, or floor compared to the filler panel. The presence of potentially confusing tether anchor hardware was negatively associated with attaching the tether correctly (Model II), with the odds of correct attachment in vehicles with confusing hardware reduced by 79 percent. Subjects 50 years and older were less likely to attach tethers correctly. In both models, subjects were more likely to attach the tethers correctly after receiving LATCH instruction prior to the 5th trial, yet they were less likely to attach tethers correctly if they used the vehicle owner’s manual. Child restraint model was the strongest predictor of correct use, with the odds of correctly attaching the tether 10 times as likely for installations with the child restraint model equipped with the single tether.

Table 10. Mixed-effects logistic regression models predicting correct tether attachment. Statistically significant results shown in **bold**.

I	Tether location		
	Filler panel	Reference	F(4,79)=4.88, p=0.0014
	Floor	**0.14 (0.04-0.46)**	
	Roof	**0.16 (0.37-0.72)**	
	Middle of seatback	0.85 (0.31-2.38)	
	Bottom of seatback	**0.21 (0.08-0.56)**	
	Age		
	50-70 years	**0.01 (0.001-0.18)**	F(3,153)=3.88, p=0.0104
	40-49 years	0.21 (0.03-1.37)	
	30-39 years	Reference	
	20-29 years	0.83 (0.13-5.41)	
	Vehicle manual use		
	No	**2.82 (1.02-7.78)**	F(1,153)=4.09, p=0.0449
	Yes	Reference	
	LATCH instruction		
	No (trials 1-4)	Reference	F(1,153)=5.12, p=0.0250
	Yes (trials 5-8)	**2.28 (1.11-4.66)**	
	Child restraint		
	With single tether	**10.16 (4.57-22.59)**	F(1,153)=32.83, p<0.0001
	With v-shaped tether	Reference	
II	Confusing hardware		
	Yes	**0.21 (0.10-0.44)**	F(1,235)=17.35, p<0.0001
	No	Reference	
	Age		
	50-70 years	**0.02 (0.001-0.24)**	F(3,235)=3.47, p=0.0170
	40-49 years	0.28 (0.03-1.54)	
	30-39 years	Reference	
	20-29 years	0.89 (0.13-5.97)	
	Vehicle manual use		
	No	2.58 (0.95-6.99)	F(1,235)=2.49, p=0.0631
	Yes	Reference	
	LATCH instruction		
	No (trials 1-4)	Reference	F(1,235)=4.68, p=0.0316
	Yes (trials 5-8)	**2.17 (1.07-4.41)**	
	Child restraint		
	With single tether	**9.91 (4.50-21.85)**	F(1,255)=31.36, p<0.0001
	With v-shaped tether	Reference	

*Potential covariates considered for all models: child restraint model, instruction, age, previous tether experience, education, gender, and vehicle manual use.

Table 11 shows pairwise comparisons of tether anchor location and its effect on correct tether attachment. Subjects were least likely to attach the tether correctly when the tether anchor was located on the floor, followed by the roof and then bottom of the seatback. Subjects were most likely to attach the tether correctly when the anchor was on the filler panel followed by the middle of the seatback. Some differences between specific tether anchor locations were not statistically significant.

Table 11. Pairwise comparisons of tether anchor locations in mixed-effects logistic regression model predicting correct tether attachment* ($F(4,79)=4.88$, $p=0.0014$). Results shown are the odds ratio and 95% confidence interval of row title versus column title with statistically significant results in **bold**.

	Floor	**Roof**	**Filler panel**	**Middle of seatback**	**Bottom of seatback**
Floor	1	0.87 (0.16-4.81)	**0.14 (0.04-0.46)**	**0.17 (0.05-0.58)**	0.70 (0.20-2.38)
Roof	1.15 (0.21-6.29)	1	**0.16 (0.04-0.72)**	0.19 (0.04-1.01)	0.80 (0.18-3.64)
Filler panel	**7.01 (2.19-22.47)**	**6.13 (1.39-27.78)**	1	1.18 (0.43-3.24)	**4.88 (1.80-13.33)**
Middle of seatback	**5.96 (1.72-20.64)**	5.21 (0.99-27.78)	0.85 (0.31-2.38)	1	**4.15 (1.32-13.16)**
Bottom of seatback	1.43 (0.42-4.88)	1.25 (0.27-5.71)	**0.21 (0.08-0.56)**	**0.24 (0.08-0.76)**	1

*Other covariates in the model included instruction, child restraint model, age, and vehicle manual use.

Tether Routing and Head Restraint Position

Tether routing and head restraint position were first assessed separately from other tether attachment tasks. Figure 17 shows the percentage of trials with the head restraint positioned as directed as a function of the vehicle manufacturer's instructions on how to place the head restraint. In the two vehicles that directed the caregiver to route the tether under the head restraint then place it in the down position, not a single subject placed the head restraint as directed. Vehicles that directed the subject to remove the head restraint had the next lowest rate of correct head restraint position. For the vehicle with the "fixed or remove" criteria, the head restraint had only one locked position, but was not integrated with the seatback and could be removed with a tool such as a screwdriver.

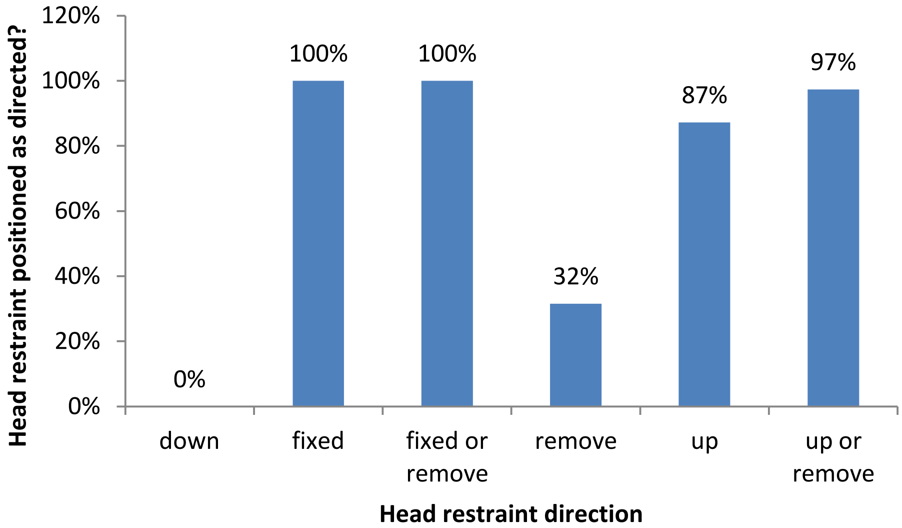

Figure 17. Percentage of trials with head restraint properly positioned as a function of the directed head restraint position.

The rate of correct tether routing as a function of the directed head restraint position is shown in Figure 18. Vehicles in which the subject was directed to remove the head restraint had the lowest rates of correct tether routing. The vehicle with the "fixed or remove" direction also had a low rate of correct tether routing. The vehicles with the directions to place the head restraint in the down, fixed, or up positions had similar rates of correct tether routing near 60% of all trials, while the directions that allowed the head restraint to be in the up or removed position had the highest level of correct tether routing. When regression analysis is used to evaluate differences, the only other significant covariate is the child restraint, with the single-strap tethered child restraint having higher rates of correct tether routing than the V-style [$F(1,147)=4.98$, $p=0.0272$]. Using the up or removed position as the reference, the fixed or removed position (estimate=-2.7981, $p=0.0022$) and the removed position (estimate=-2.667, $p=0.0043$) had lower rates of correct tether routing. The down and up positions were marginally lower (estimate =-1.3260, $p=0.0724$ and estimate=-1.0770, $p=0.0968$) than the reference, while the fixed position was statistically the same (estimate=-0.9080, $p=0.1496$).

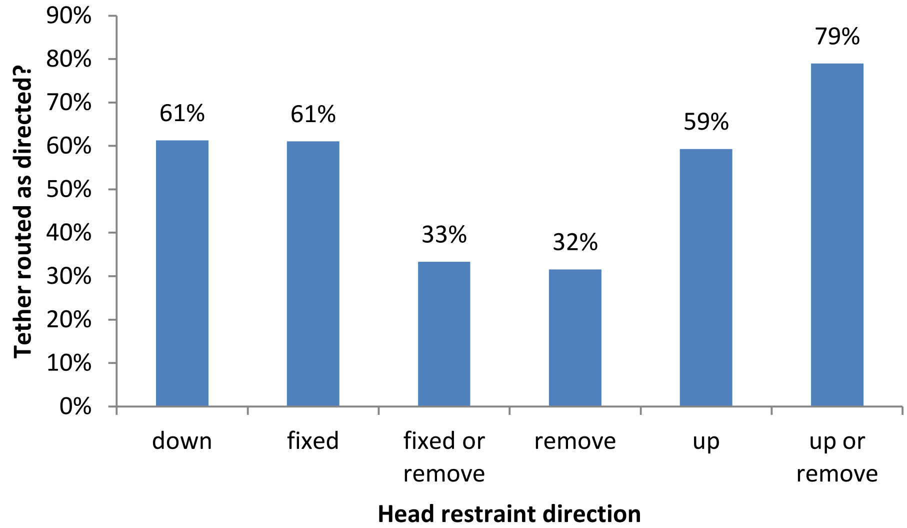

Figure 18. Percentage of trials with correct tether routing as a function of head restraint directed position.

The rate of correct tether routing as a function of tether routing direction is shown in Figure 19. The directions that subjects were most likely to follow include routing the tether around, over, under/remove, or under the head restraint. Again the only significant covariate in regression analysis was child restraint model , with the V-style tether having lower rates of correct tether routing than the single-strap style [F(1,138)=6.39, p=0.0126]. Using the under or removed condition as a reference [F(6,81)=3.97, p=0.0016], the around condition had the same level of correct routing [estimate=0.9792, p=0.478], as did the over condition [estimate=-0.3774, p=0.6207]. The outboard [estimate=-4.2517, p=0.0004], over or removed [estimate=-3.1469, p=0.0029], and removed [estimate=-3.0437, p=0.0051] conditions had significantly lower levels of correct tether routing, while the under condition was marginally lower [estimate=-1.3064, p=0.0689].

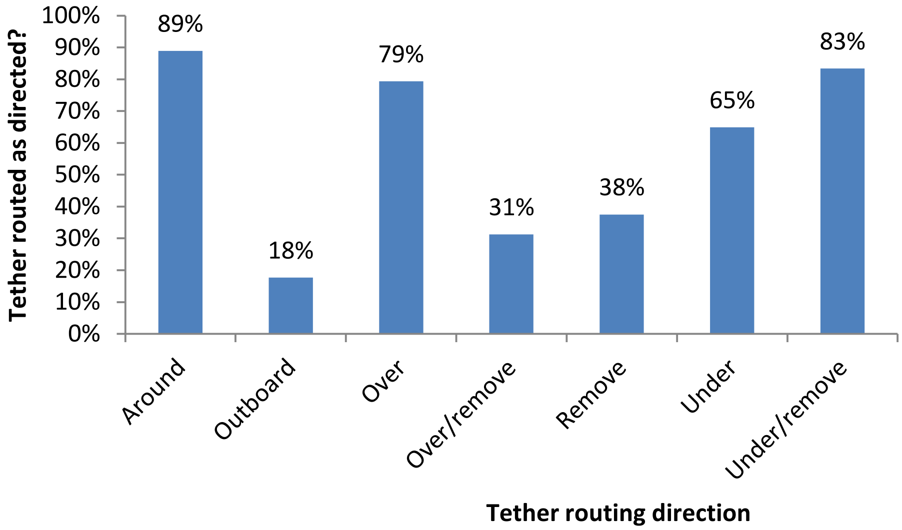

Figure 19. Percentage of trials with correct tether routing as a function of tether routing direction.

The different combinations of head restraint directed position and directed tether routing are summarized in Table 14. One vehicle directed the subject to route the tether inboard of the fixed head restraint, but only 18% of subjects did so. With vehicle B, the subject was directed to route the tether over the fixed (but removable) head restraint or to remove it; only 33% of subjects did so. Because the centerlines of the head restraint and tether are offset outboard from the centerline of the lower anchors in this vehicle, it is difficult to route the tether over the head restraint with either the single-strap or V-style tether. It is also difficult to remove the head restraint (only one subject did so). Vehicle G, where the tether anchor is on the roof, instructs subjects to remove the head restraint. About one third of subjects did so; others routed over or under the head restraint.

For the vehicles where subjects were directed to route the tether under the head restraint, almost 2/3 of subjects did so. (However, for vehicles D and F, which directed the subjects to place the head restraint in the down position, no subjects complied. So although the tether is in the correct physical location, these installations would be considered as having an error using a strict interpretation of following all the manufacturer's instructions.) Vehicle P, which was the only one that provided directions on routing a V-style tether, had about ¾ of subjects route the tether correctly. The vehicles with fixed head restraints that route the tether over and adjustable head restraints that allow the subjects to route the tethers under the head restraint or to remove it had the highest rates of correct tether routing.

Table 12. Rate of correct tether routing according to directed head restraint position and the directed tether routing.

Head restraint directed position	Directed tether routing	Vehicles	Rate of correct tether routing
Fixed	outboard	M	18%
fixed /removed	over/removed	B	33%
Remove	remove	G	38%
Down	under	D F	61%
Up	under	AIJNO	66%
Fixed	over/around	P	76%
fixed	Over	CEL	83%
up/remove	under/remove	HK	83%

Although the vehicles that directed the subjects to route the tether under the head restraint had somewhat higher rates of correct tether routing, this routing did not necessarily lead to the best tether installations. Subjects who routed the tether under the head restraint had the lowest rates of achieving a tight tether as shown in Table 13.

Table 13. Percentage of trials with tight tether according to routing used by subjects.

Routing used by subject	Percentage trials tight
Under	72%
Outboard	75%
Around	85%
Inboard	92%
Over	92%
Removed	92%

Overall Installation

With regards to installations that were completely correct, the rate of correct installation was 27% for the Triumph compared to 18% for the Marathon (p=0.050). The difference was not significant when head restraint position and tether routing were evaluated less strictly (36% vs. 27%, p=0.01)

Table 14 lists the percentage of trials for each vehicle with completely correct installations vs. acceptable installations, as well as the difference between them. For nine vehicles, there was no difference in rate of correct installation when vehicle manufacturer's directions were strictly followed, or whether some leeway was permitted in head restraint position and tether routing as long as the tether was tight, untwisted, and connected to the correct hardware in the right orientation. Two vehicles (D, the Toyota Highlander, and F, the Kia Sedona) went from 0% of completely correct installations to 39% and 30% when more lenient head restraint/routing criteria are used. For both of these vehicles (Toyota Highlander and Kia Sedona), the tether is supposed to be routed underneath the head restraint, which is then supposed to be placed in the down position. Not a single subject placed the head restraint down as directed in either vehicle. With vehicle M, which directed subjects to route the tether inboard of the head restraint, subjects did so in 18% of trials. Most of the subjects routed the V-style tether around either side of the head restraint with vehicle M; if this routing would be considered acceptable, the rate of good installations would go from 6% to 28%.

Table 14. Percentage of trials with correct installation or acceptable installation.

Vehicle	Correct (p=0.002)	Acceptable (p=0.452)	Difference	HR/Routing
C	33%	33%	0%	Fixed, over
E	47%	47%	0%	Fixed, over
L	33%	33%	0%	Fixed, over
P	28%	28%	0%	Fixed, over/around
G	21%	21%	0%	Remove
J	33%	33%	0%	Up, under
O	28%	28%	0%	Up, under
H	40%	40%	0%	Up, under or Remove
K	12%	12%	0%	Up, under or remove
B	6%	17%	11%	Fixed, over or Remove
N	11%	22%	11%	Up, under
A	28%	44%	17%	Up, under
I	33%	50%	17%	Up, under
M	6%	28%	22%	Fixed, outboard
F	0%	30%	30%	Down, under
D	0%	39%	39%	Down, under

The vehicles with the lowest rate of acceptable routing are vehicle K, the pickup truck. Only 12% of trials had the tether attached to the correct hardware, but the single subject in those trials also routed the tether appropriately. Vehicle B had the next lowest rate of acceptable installation. In this vehicle, the head restraint and tether being offset from the centerline of the lower anchors contributed to the low rate of acceptable use.

When performing regression to identify significant predictors of correct use, the child restraint model [F(1,189)=4.97, p=0.0269, estimate=-.7530) and the presence of confusing hardware [F(1,35)=3.31,p=0.775, estimate=-0.6308] approached significance, with higher rates of correct installation with C2 and no confusing hardware. Confusing hardware became insignificant when the pickup truck trials were excluded from the dataset.

Qualitative Review of Subject Comments and Installation Behaviors

To provide insight to some of the subjects' most significant comments, as well as specific challenges in each vehicle, the following section describes subjects' experiences in each vehicle from the perspective of the experimenters.

A: Mazda 3. The Mazda 3 had the tether anchor <165 mm from the head restraint, and most people could not get the tether tight without removing the head restraint since the adjuster for both child restraints ended up underneath the head restraint, as shown in Figure 20. Some left the tether loose (50%) and some removed the head restraint or left it in an unlocked position (~3%), against the vehicle instructions. One person commented on the lack of space in the vehicle to move around when installing.

Figure 20. Tether adjuster ends up underneath HR, making it difficult to tighten.

B: Ford Taurus. The Ford Taurus had lower anchors that were not centered on the 2L seating position, as they are placed inboard of the head restraint to create an improvised center LATCH position with standardized spacing. However, the tether is centered on the head restraint and is outboard relative to the centerline of the lower anchors, so the centerline of the child restraint is inboard of the centerline of the head restraint and tether anchor as shown in Figure 21. There was a slight rise in the seat surface for the 2C seat, so the child restraints tended to sit partially on this contour and lean outboard slightly when installed. Because the child restraint is offset inboard from the tether anchor, it is impossible to route both sides of the Marathon V-style tether over the top of the HR as indicated by the vehicle instructions. If the outboard side of the V was positioned over the top of the head restraint, it was very close to the edge of the head restraint and could fall off. The same applied to the single tether strap of the Triumph, which could not be routed over the head restraint without risking falling off and slackening. It was possible to go inboard of the head restraint with the Triumph with a fairly direct path. The manual allows for removal of the head restraint if needed to improve child restraint fit, so for the pretest installation we used this approach so both straps could lay flat and direct. Removing the head restraint in this vehicle was difficult and required the use of a screwdriver. Only one subject removed the head restraint for both child restraint installs due to the difficulty involved, and she noted how difficult it was in her comments. 55% of subjects using the Marathon installed the V-tether going around the head restraint on either side. This tended to make the top of the child restraint lean farther outboard in the vehicle. 44% of subjects using the Triumph managed to route the single tether over the top of the head restraint and get it tight, but none of these individuals had the LATCH belt properly tightened so the child restraint was able to shift toward the center of the seating position.

Figure 21. Example of the child restraint centerline being offset from head restraint centerline, making it challenging to rout the tether over the head restraint as directed.

C: Nissan Rogue. The vehicle instructions regarding the tether and head restraint routing were challenging to follow when installing the Marathon in the Nissan Rogue. The manual says to route the tether over the fixed head restraint, but the V-style tether origin points on the child restraint are outboard of the edges of the head restraint. Therefore a tighter install with direct path could be achieved by going around the head restraint on either side with the tether. 66% of subjects installed the Marathon top tether with the V-straps going around the outsides of the head restraint as shown in Figure 22 and no subjects installed the tether going over the top as the manual indicated. The tether anchor was located on the vehicle floor behind the seat and there was a potentially confusing cargo tiedown near the tether anchor. Four subjects (22%) could not find the tether anchor, so they either did not use it or attached to incorrect hardware. 33% of subjects accessed the tether anchor by opening the rear hatch of the vehicle. Most subjects were able to install the Triumph tether properly routed over the top of the head restraint (66%). There were no negative comments from subjects about this vehicle.

Figure 22. Most subjects routed the V-style tether around the head restraint rather than over.

D: Toyota Highlander. The vehicle manual of the Toyota Highlander instructs you to raise the head restraint, route the tether underneath, and then return the head restraint to the lowest position. With the Marathon, the head restraint could not be returned to the lowest position because of contact with the upper edge of the child restraint as shown in Figure 23. Also, the dual tether straps of the Marathon were pinched together slightly to route between the head restraint posts. Not a single subject returned the head restraint to the down position for any of the child restraint installs. Four people (22%) removed the head restraint completely. Half of the subjects correctly routed the tether under the head restraint and 66% of the subjects were able to install the tether tightly with no slack. Four of the subjects used the rear hatch of the vehicle to access the tether and none climbed into the 3rd row.

Figure 23. Example of V-style tether being slightly pinched when routed under head restraint as directed, as well as interference between CRS and head restraint.

E: Toyota Camry. The Camry had a fixed head restraint with the manual instructing users to route the tether over the head restraint. Both child restraints could be installed tightly while following these instructions. With the Marathon, routing the tether around either side of the head restraint would provide a more direct belt path to the tether anchor, but the V-style tether could be routed over the head restraint with minimal concern that it would slide off the head restraint IF the tether strap were tightened properly. 70% of the subjects chose to route at least one side of the Marathon tether strap around the head restraint as shown in Figure 24, while only 20% routed both sides correctly over the top of the head restraint. 88% of the subjects correctly installed the Triumph tether over the top of the head restraint and 100% were able to get the tether strap tight. One subject commented that the LATCH lower anchors in this vehicle were difficult to use because they were located higher on the seatback. The lower anchors were measured to be 4-6 cm deep in the seat bight. Another subject commented that it was very difficult to get the Marathon V-tether tight when correctly routed over the head restraint. Several people commented that this vehicle was easy to use overall.

Figure 24. Example of subjects routing one part of Marathon tether over head restraint and another part around.

F: Kia Sedona. The Kia Sedona manual indicates that users should route the tether under the head restraint and then return the head restraint to the lowest position. With the head restraint in the lowest position, there was a gap between the vehicle seatback and either child restraint. Not a single subject returned the head restraint to the lowest position after installing the child restraint. Half of the subjects routed the tether correctly under the head restraint for each of the child restraints. 40% of the subjects installed the Marathon tether with the V-straps routed outside the head restraint posts as shown in Figure 25. Several subjects had a hard time finding the tether anchor at the bottom of the seatback. One subject commented on it and many folded the seat forward or slid it forward in the tracks to help locate it. 75% of the subjects obtained a tight installation. Half of the subjects commented that this vehicle was very easy to use overall.

Figure 25. Example of subjects routing Marathon tether around head restraint posts.

G: Subaru Outback. Using the vehicle manual during the pretest installations, the UMTRI experimenters had no problems using either the lower anchors or tether anchor with either child restraint. The lower anchors are in pockets in the seat bight that are covered by unmarked fabric strips held closed by Velcro. 60% of subjects did not see the fabric covers, and instead routed the LATCH up through the seat bight and down to the anchor bars. This route is not a direct path and is much more difficult to achieve; several subjects commented on the difficulty. One subject mentioned dislike of the waterfall shape of the bight when installing lower anchors. The manual instructed removing the head restraint and storing it, then routing the tether strap up to the roof anchor. Only 30% of subjects removed the head restraint and 50% routed the tether under the head restraint instead. 30% subjects could not find the tether anchor. Of these, half did not use the tether at all and half connected the tether to a cargo tiedown loop near the bottom of the seatback as shown in Figure 26. No positive comments were received on this vehicle.

Of additional note, on an exemplar vehicle used in pilot testing, the owner had a dealer-installed cargo gate. The gate is designed to be attached to the tether anchors and prevents use of a tether. However, the dealer provided no input to the owner that they would not be able to use the tether anchors for child restraint installation after the gate was installed.

Figure 26. Example of subjects incorrectly attaching tether to cargo tiedown.

H: Ford Fiesta. The Ford Fiesta was one of the least favorite vehicles among the subjects. It was very difficult to install either child restraint using the lower anchors and top tether, and there is very little space to maneuver inside the vehicle. The seatback cushion is very stiff above the lower anchor bars and they are 4-6 cm deep into the seat bight. The average force required to attach the LATCH gauge to the anchors was 30.9 lbf for the outboard anchor and 37.6 lbf for the inboard anchor. The outboard anchor measured 56° of clearance and the inboard anchor measured only 36° of clearance for the 2L seating position. The hook-type lower anchor connectors of the Evenflo Triumph CRS were harder to engage on the lower anchors than the push-button type connectors of the Marathon, although they were also difficult to push into the bight space. Four subjects installed the Triumph with the lower anchor hooks anchored upside down and two subjects could not connect the lower anchors at all and gave up. 60% of the subjects commented on the difficulty of using the lower anchors in the post-test evaluation.

The Fiesta instruction manual allows for head restraint removal for better child restraint fit. This proved very helpful when tightening the top tether strap; otherwise, the adjuster for either child restraint would be underneath the head restraint and difficult to access. However, during the installs, the subjects removed the head restraint only 10% of the time. Most left the head restraint in the up position, with several leaving it in a non-locked up position against manufacturers' instructions, as shown in Figure 27. 60% of the Marathon installs were completed with the V-tether straps routed under the head restraint and 20% routed the straps around the head restraint. 80% of the top tether straps for the Triumph installs were routed under the head restraint and 10% took the tether strap outboard of the head restraint posts. 55% of the subjects were able to get the tether tight with the head restraint in place, while the 100% were tight with the head restraint removed.

Figure 27. Example of subjects leaving the head restraint in non-locked up position against manufacturer directions.

I: **Honda Odyssey.** The Honda Odyssey vehicle manual instructs you to raise the head restraint and route the tether between the posts underneath. The manual does not allow you to remove the head restraint. The top of both child restraints contacted the head restraint and created a small gap between the seatback and child restraint. However, a tight installation was possible despite this gap. The subjects placed the head restraint in the correct up position for 83% of the installs, while the head restraint was removed for the rest of the trials. The tether strap was not used for 22% of the installs. As shown in Figure 28, one subject just routed the Marathon V-tether strap around the outside of the head restraint posts and tightened it around the head restraint without attaching the tether hook. All the subjects who used the tether were able to get the tether strap tight. Two subjects looked at the vehicle manual to help locate the tether anchor; one was successful but the other could not find the information and gave up. Two subjects had positive comments about the Odyssey and one subject mentioned that the tether anchor was too low on the back of the seat.

Figure 28. Example of creative tether routing.

J: Chevrolet Malibu. The Malibu lower anchors for the 2C and 2L seat positions overlapped, which created some confusion for the subjects. The 2C seatbelt webbing also ran directly over the top of the inboard 2L lower anchor so that the marker on the seatback was not visible, whereas the left lower anchor marker for 2C was visible. As a result, the subjects connected to the 2C anchor instead of the correct inboard 2L anchor for 22% of the installs. One subject used the seatbelt instead and one connected the left end of the lower anchor strap to the storage clip on the child restraint base, while the right side of the lower anchor strap was wrapped around the outboard head restraint post and hooked to the tether anchor storage clip on the child restraint shell. The vehicle manual for the Malibu instructed users to route the tether anchor under the raised head restraint and stated that the head restraint should not be removed. However, there is only about a 25-mm gap with the head restraint in the locked up position. With the top tether anchor in the Malibu only 130 mm from the back of the head restraint, the tether is difficult to tighten with the head restraint in the locked up position. When UMTRI experimenters installed either child restraint, the tether could only be tightened properly by raising the head restraint beyond the locked upright position until the head restraint contacted the vehicle roof. Then when attempting to return the head restraint to the locked upper position, the head restraint contacted the adjusters on both child restraints, as shown in Figure 29, making it difficult to re-engage the head restraint while keeping the tether tight. With the child restraint installed, the head restraint release was not accessible and required a screwdriver to assist in temporary detachment. With both child restraints, there was a gap due to contact with the head restraint. 33% of subjects routed the Marathon V-style tether around the head restraint, 22% did not use the tether, and the other 45% were able to route the V-style tether below the head restraint. 89% of subjects installed the Triumph tether correctly routed under the head restraint, with most of them getting it tight as well. Two subjects commented that the head restraint was in the way of a good child restraint install in this vehicle.

Figure 29. Example of tether adjustment hardware interfering with proper positioning of head restraint.

K: Ford F-150. The headrest in the Ford F-150 could be raised or removed per the vehicle instructions to aid in good child restraint install. UMTRI CPSTs found that both child restraints contacted the head restraint and created a large gap between the seatback and child restraint, making it necessary to remove the head restraint to get a good child restraint fit. No subjects removed the head restraint during the study installs and all had a gap behind the child restraint as a result; 94% left the head restraint in the up position and one subject left the head restraint in the down position. The vehicle manual instructs that the top tether of the child restraint be routed through the fabric loop at the 2L position, then hooked onto the fabric loop at the 2C seating position. The instructions also say to route the tether strap behind the shoulder belt mount for 2C. When the instructions were followed, UMTRI technicians were able to get a tight tether install for both child restraints; however, the tether adjuster of the Triumph did not fit behind the 2C shoulder belt mount as shown in Figure 30. 89% of subject installs were completed with the tether incorrectly attached to the tether anchor, and of these, none achieved a tight top tether install. Of these incorrect installs, the vehicle manual was consulted 18% of the time, 69% used the 2L tether router loop to anchor the tether, 19% anchored to the metal bracket at the base of the 2L tether loop and 12% routed the tether strap around the head restraint posts without connecting to an anchor. Only one subject read the vehicle manual and correctly routed and tightened the tether strap for both child restraints. Three subjects commented that the tether was hard to use and one subject commented that the head restraint interfered with child restraint install.

Figure 30. Triumph tether adjustor hardware does not fit behind seatbelt mount as directed.

L. Jeep Patriot. The vehicle manual for the Jeep Patriot instructed routing the tether over the top of the fixed head restraint to the anchor on the seatback. With the Marathon V-style tether, UMTRI CPSTs felt a better install was achieved by going around the head restraint on either side. Routing both sides of the tether strap over the top of the head restraint could be done, but the straps would likely not stay up if the child restraint was jostled during use. As shown in Figure 31, all six subjects that used the top tether when installing the Marathon routed the sides of the tether strap around the head restraint and achieved a tight tether belt install. The other three subjects did not use the top tether with the Marathon. With the Triumph, 66% of installs were completed with the tether correctly routed over the head restraint and tight, while 22% routed the tether outboard of the fixed head restraint and 11% did not use the tether. The subjects did not seem to have any problems with using the lower anchors in this vehicle, but the seatbelt was used instead in 16% of the installs. There were no negative comments about this vehicle.

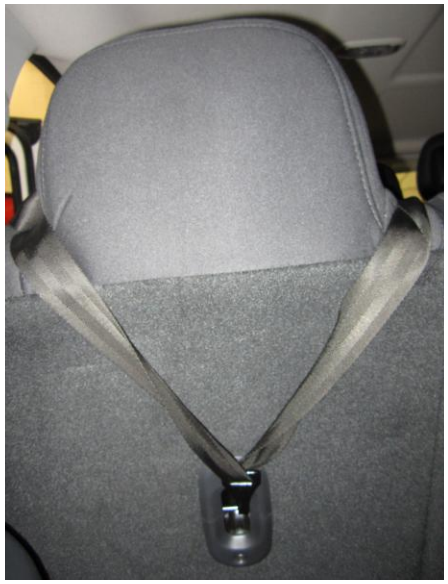

Figure 31. Method used by all subjects to route the V-style tether (when used) on the Jeep Patriot.

M. Chrysler 200. The lower anchors for the 2L seating position of the Chrysler 200 were nearly impossible to use, so the 2R seating position was used with this vehicle. When the lower anchor engagement force was measured, the 2L outboard anchor required an average force of 44.7 lbf to engage and the inboard required 48.1 lbf. The force measurement could only be made for these two anchorages by approaching the anchor with the gauge at two separate angles, first pushing toward the seatback at 4° then down hard into the bight at 60°. The 2R force values were also relatively high at 28.9 lbf for the outboard anchor and 50.3 lbf for the inboard anchor. There was confusing lower anchor hardware in the seat bight near the inboard lower anchor at both 2L/2R seating positions. One subject connected the inboard LATCH connector to a metal bar in the bight that was not the real LATCH lower anchor. The subjects often struggled with the lower anchors, but none commented on the difficulty post-test.

The vehicle manual of the 200 instructs routing the top tether belt outboard of the fixed head restraint. With the Marathon V-style tether, UMTRI technicians felt a better install was achieved by going around the head restraint on either side. Eight of the nine subjects installed the Marathon with the V-style tether going around the head restraint, and the other one took both sides of the tether to the inboard side of the head restraint. For the Triumph, 33% of installs were completed with the tether routed correctly around the outboard side of the head restraint, 33% took the tether strap inboard of the head restraint, 22% took the tether strap over the top of the head restraint and 11% did not use the tether. Two subjects commented post-test that the headrest/tether was not easy to use.

Figure 32. Some subjects incorrectly routed the tether over the top of the head restraint rather than outboard of the head restraint.

N. Volkswagen Jetta Sportwagen. The Jetta Sportwagen manual instructs routing the tether strap under the head restraint and raising the head restraint if necessary. The head restraint was left in the up position for 89% of installs and it was removed in 11%. The head restraint contacts the top of both child restraints and creates a gap between the seatback and child restraint when in either the up or down position, although the gap is worse with the head restraint in the down position. There is a cargo tiedown anchor near the floor pocket for the tether anchor that is somewhat confusing, but subjects did not use it to anchor the tether. With the Marathon V-style tether, a tight install was achieved by going under the head restraint with both straps. However, going around the head restraint on either side seemed like a more direct path. 44% of subjects routed the Marathon tether straps around the outside of the head restraint posts and 33% correctly routed both straps under the head restraint. The others either did not use the tether or removed the head restraint. For the Triumph installs, 66% correctly routed the single tether strap under the head restraint, 11% routed the strap outboard of the head restraint and the others either did not use the tether or removed the head restraint. The subject accessed the tether anchor through the rear vehicle hatch in 66% of the installs and one person could not find the tether anchor even after consulting the manual. One person commented post-test that the tether anchor should be higher so that it is accessible from the back seat instead of the trunk. Two others commented that the headrest on this vehicle was very difficult to work with. Another commented that the seat contour made the install difficult.

Figure 33. Subjects often routed V-style tether around the head restraint posts rather than in between.

O. Honda CR-V. The head restraint in the Honda CR-V is fixed in the up position and the instructions say to route the tether strap under the head restraint between the posts. With the Marathon V-style tether, a tight install can be achieved by going under the head restraint with both straps, but going around the head restraint on either side seemed like a more direct path. There is a cargo tiedown anchor near the floor pocket for the tether anchor that is potentially confusing, but subjects did not use it. 33% of subjects routed the Marathon tether straps around the outside of the head restraint posts and 44% correctly routed both straps under the head restraint. The others either did not use the tether or routed the strap around the head restraint without anchoring it. For the Triumph installs, 77% correctly routed the single tether strap under the head restraint and 23% routed the strap over the top of the head restraint. The subject accessed the tether anchor through the rear vehicle hatch in 55% of the installs. 81% of the subjects who used the tether were able to get it tight. One subject commented that they liked this vehicle.

P. GMC Acadia. The lower anchors in the GMC Acadia were difficult to use. When the lower anchor engagement force was measured, the 2L outboard anchor required an average force of 30.7 lbf to engage and the inboard required 46.4 lbf. There was buckle stalk hardware near the lower anchor hardware that made access a little difficult as well. The subjects attached the lower anchor connectors upside-down in 33% of the installs as a result of the difficulty in accessing and engaging the connectors properly. The Acadia vehicle manual had different head restraint routing paths for single versus double tether strap styles. The manual said to route a single strap over the top of the fixed head restraint and to route either side of a double or V-style tether around the outsides of the fixed head restraint. The subjects installed the Marathon V-style tether correctly around the head restraint in 89% of the installs, with 11% routing under the fixed head restraint even though the gap provided below was very tight. 56% of the Triumph tethers were installed correctly with the tether passing over the top of the fixed head restraint, while 22% passed the tether outboard of the head restraint and 11% routed under the fixed head restraint even though the gap provided below was very tight. The subjects were able to get the tether strap tight in every install where it was used regardless of routing.   Three subjects climbed into the 3rd row seats to install the tether. Two subjects commented that the head restraint was difficult to use, as it was not obviously fixed.

Discussion

Subject Factors

In this study, tether use was much higher than in previous studies where volunteers were asked to install child restraints. Most of the subjects had experience with a wide range of child restraint types, and more than half had previous experience with lower anchors and tethers.

To be eligible for the study, all subjects had to have prior experience installing child restraints. Subjects were recruited based on their education level (college graduate or less than college graduate) and their previous experience installing child restraint using the LATCH system. It was somewhat challenging to recruit subjects in the lower education category who had LATCH experience, as well as subjects in the higher education category who did not have LATCH experience. This seemed like a reasonable finding, since LATCH is only found in vehicles manufactured after September 2002 and higher education is associated with greater household income where ownership of a newer vehicle would be more likely, and vice versa. Though challenging, we were able to recruit at least one subject in each subject group that had each combination of education level and previous LATCH experience.

During screening, potential subjects were asked how they installed their child restraints, in an attempt to determine previous LATCH experience without specifically educating them about LATCH during the questioning. Subjects then filled out a questionnaire after testing to provide more detail regarding their previous experience with lower anchors, tethers, and seatbelt installations. Several subjects who had been initially classified as having no LATCH experience indicated post-testing that they had some, as well as one subject who said they had previous LATCH experience initially but then answered negatively on the questionnaire. This shows that even people who are using LATCH may not be aware of what it is called. To satisfy the experimental matrix of each subject group having at least one subject with each combination of education level and previous LATCH experience, an additional subject was recruited for one group because of the initial misclassifications.

As a result of focusing recruitment on these education and previous LATCH experience, we were unable to achieve as great of a range of subject ages as in prior test programs. Only four subjects were in their forties and only three were over age 50. The four oldest subjects frequently had installation errors in most installations. As a result, age was a significant predictor in some of the models.

All of the subject variables related to experience were correlated: previous child restraint experience, prior lower anchor experience, and prior tether experience. In addition, use of the child restraint manual was also related to subject's experience, with subjects less likely to use the manual if they had previous LATCH experience. As a result, only one of these subject predictors, tether experience, was considered a potential predictor in regression analysis.

Tether Use

Providing a minimum level of instruction offered a significant level of improvement in tether use, from 83% to 95%. It may be helpful to provide this instruction on a placard attached the tether, or have a QR code on the child restraint that links to a recording or video of the message.

The provided instruction, previous tether experience, and subject age were significant predictors of tether use. When tether location was used in the model, subject education and vehicle manual use were also significant predictors of tether use. However, lower education subjects were more likely to use the tether than higher education subjects. This finding differs from those of previous studies where higher education usually led to higher rates of tether use. We hypothesize that lower education subjects were more likely not to have tether experience and thus more likely to use the vehicle manual.

Tethers were more likely to be used when the tether anchor was located on the filler panel, a typical location in sedans, with the odds that parents use the tether reduced by 89 to 97 percent when the tether anchor was located on the seatback, floor, or roof. Pairwise comparisons suggest that anchors on the middle of the seatback may result in higher tether use rates than those on the bottom of the seatback, floor, or roof but the differences were not statistically significant. The presence of potentially confusing hardware also decreased tether use. However, because sedans with tether anchors located on the filler panel are also least likely to have confusing hardware, the significance of confusing hardware variable may just reflect the highest use rate of the tethers located on filler panels. Other vehicle factors such as tether anchor markings, construction and packaging were not associated with increased tether use when other subject and study design factors were included in the statistical models.

Tether Correct Use

The tether was attached to the correct hardware at the correct orientation in approximately 90% of the trials where the tether was used. Subjects had higher rates of correct use in the last four trials compared to the first four. After a verbal explanation of what LATCH is, including showing them the tether hardware on the child restraint, rate of correct attachment went from 53% in the first four trials to 61% in the last four trials. However, review of the improvement between child restraints showed that all the improvement came from trials using the single-strap tether; rate of correct attachment was 42% before and after instruction for the v-shaped tether.

Subjects were more likely to attach the tether correctly when the tether anchor was located on the filler panel or the middle of the seatback, with the odds of attaching the tether correctly for these locations more than 4 times the odds for locations on the floor, roof, or lower seatback. Minivans and SUVs typically do not have filler panels but locating tether anchors on the middle of the seatback instead of other typical locations in these vehicles may increase the likelihood that parents will attach the tether correctly. Tethers attached to anchors in vehicles with confusing hardware also were less likely to be attached correctly. Cargo tie-downs or other potentially confusing hardware may be desirable or necessary features in many minivans and SUVs, and therefore minimizing or removing them may not always be an option; providing clear labels on tether anchors or other attachment points may alleviate confusion when parents are installing child restraints although tether anchor marking was not predictive of tether use or correct attachment.

An effort was made to examine the construction and packaging of the tether anchors to determine if they affected subjects' ability to correctly attach the tether. Analysis is complicated by the correlation between tether location and packaging/construction, as tether anchors on filler panels almost always have a covered recess though the manufacturing method can differ. However, by summarizing the percentage of correct us across vehicles with similar construction and packaging as shown in Table 15, an argument could be made that stamped tether anchors are easier to use when the tether hook is attached perpendicular to the stamped hole, rather than parallel. In addition, when mounting a wire-style tether anchor (typically to a vehicle seatback), using an open recess packaging may be easier to use than the covered recess or slit in carpet. (The table uses red text for the lowest two scores in each column, green for the middle two, and blue for the highest two.)

Table 15. Elements of correct tether attachment by combined construction and packaging.

	Attached to correct hardware	Correct orientation	Tether flat	Tether tight	All four elements correct
Open webbing	12%	76%	71%	24%	12%
Covered recess, Stamped parallel	91%	88%	71%	80%	58%
Slit in carpet, wire	87%	91%	81%	85%	65%
Covered recess, wire	98%	94%	82%	82%	69%
Open recess, wire	100%	98%	79%	94%	74%
Covered recess, stamped perpendicular	97%	97%	88%	82%	80%

Tether Routing

Only one vehicle provided directions for using a V-style tether strap. As a result, even subjects who read the vehicle manual had to improvise on what constituted a correct tether routing on child restraint installations with this product. The child restraint manufacturer intended for the V-style tether to be routed on either side of a head restraint. This was potentially problematic when the vehicle manual instructed the user to route over the head restraint and head restraint was narrower than the spacing between the two tether connection points on the child restraint. Some subjects were able to follow this direction, but the placement of the straps near the edge of the head restraint was often somewhat precarious and would likely slip off during normal use, leading to slack in the tether. This was often difficult because the spacing between the two tether connection points on the child restraint is wider than the head restraint or its mounting posts. Thus the tether straps could not be positioned in a straight line between the child restraint and tether anchors, taking a “bend” in the path at the head restraint. When the tether routing and head restraint positioning was evaluated as acceptable by a child passenger safety technician, despite not following the vehicle manual instructions, the rates of installations with either correct or acceptable routing were equivalent between the two child restraint models. This suggests that secure routings are possible with the v-shaped tether, but the most stable routing path may differ from the vehicle manual instructions. Although v-shaped tethers are present on a small percentage of child restraint models, the models are popular and may represent a meaningful portion of the child restraint market. As a result, it is important for vehicle manufacturers to consider v-shaped tethers when providing instruction on tether routing.

For most situations with adjustable head restraints, routing the tether underneath the head restraint would provide the shortest path to the tether anchor, except for a roof-mounted tether. However, this study showed that the subjects who routed the tether beneath the head restraint had lower rates of achieving a tight tether than those who went over or around. In some vehicles, the tether anchor is close to the head restraint, such that the adjustor for the tether is located under the head restraint and difficult to access once the tether is attached and child restraint is tightened. Previous research has shown that shorter tether lengths lead to shorter head excursions, because there is less active length of webbing available to be stretched. However, slack in the tether (because the user cannot properly tighten it if the adjustor is located beneath the head restraint) can also lead to greater head excursions. Thus the benefits of directing the subject to route the tether under the head restraint (and achieve the shortest tether length) may be offset by slack in the tether if the subject cannot tighten it.

Routing of the tether and head restraint position were evaluated independently of correct tether attachment in part because incorrect tether routing was the most common tether misuse in a previous volunteer study of LATCH (Klinich et al. 2012a). A review of relevant literature did not identify any studies indicating that a particular tether routing option is better at reducing occupant head excursion, the main purpose of a tether. All vehicles provided direction on tether routing and head restraint position, but following the directions was not always possible and did not always result in the best child restraint installation, based on an assessment by certified child passenger safety technicians. When the manuals for two vehicles directed subjects to route the tether under the head restraint but place the head restraint in the down position, not a single subject followed this direction.

In vehicle B, the subjects are instructed to route the tether over the head restraint. However, since a child restraint installed with lower anchors is offset inboard from the head restraint and tether in this vehicle, it is difficult to securely route the tether over the head restraint with either a single or V-style tether. For this vehicle, instructions for routing the tether differently for LATCH and seatbelt installations may be warranted. But that could also lead to more confusion. Instead, allowing the tether to be routed over or around the head restraint would account for both LATCH and seatbelt installs as well as single and V-style tethers.

Child Restraint Differences

Child restraint model was often a significant predictor of correct tether use. Subjects were 10 times as likely to correctly attach the tether when installing the child restraint with the single-strap tether. In particular, subjects were more likely to have the single-strap tether flat and tight compared to the V-style. As noted earlier, subjects were also more likely to route the single-strap tether correctly, often because the vehicle manufacturer did not provide instructions for routing the V-style tether.

In our previous study of LATCH usability, we identified a minimum tether adjustment length of 165 mm as the typical distance that provided sufficient length for a tether hook, adjustment hardware, and connecting webbing based on measuring over two dozen child restraint products. A recommendation was made for vehicle manufacturers to place tether anchors at least 165 mm rearward (or below) the rearmost, inferior point on the head restraint. That way, regardless of recommended tether routing, the adjustor hardware should be accessible behind the head restraint.

However, the previous recommendation was based on the study that only used child restraints with single-strap style tethers. With the V-style tether, the tether hook can move along the length of the tether webbing to accommodate different tether wrap distances, and the adjustor hardware is located closer to the back of the child restraint, 145 mm from its connection point on the child restraint seatback. Thus the adjustor hardware often falls near the top of the seatback in the head restraint area, although it varies with the height of the vehicle seatback.   Examples are shown in Figure 34.

Figure 34. Location of adjustor for V-style tether varies with the height of the vehicle seatback.

The differences in location of adjustor hardware between the two child restraints likely lead to the differences in the rate of tightening the tether strap. If the tether anchor is at least 165 mm rearward or downward of the head restraint, the single-strap tether adjustor is easily accessible for tightening. On all vehicles, the adjustor for the V-style tether is located somewhere in the vicinity of the head restraint, contributing to higher difficulty in achieving a tight tether. In addition, subjects must make sure that both sides of the webbing around the tether hook are tight, and that there is no slack trapped in the hook in the side of the strap without the adjustor.

V-shaped tethers are used by a small number of child restraint manufacturers who maintain that tethers with two connection points on the child restraint provide more stability, distribute loads over a greater area, and have a longer length that allows for more energy absorption. However, if caregivers have more trouble adequately tightening this type of tether, then any safety benefits of the v-shaped tether may be diminished.

Tether marking

In this study, more subjects used the tether when the tether anchor was marked with the ISO tether anchor symbol than unmarked tethers. However, this difference was not statistically significant when other factors were included in the model. However, there does not seem to be any potential downside to marking tether anchorages even though FMVSS 225 currently does not require it. Vehicle manufacturers have stated that they will voluntarily start marking their tether anchorage hardware.

Vehicle Hardware Issues

Head restraints that are fixed, but do not appear to be continuous with the seatback were confusing to some subjects. Some will try to route the tether underneath through a very small space. In addition, subjects provided feedback that it was difficult to route the tether under a head restraint when the gap (with the head restraint in the upright position) is too small to allow a hand gripping a tether hook to pass beneath.

Some of the tether anchor hardware is designed such that it is not physically possible to attach the tether hook in the incorrect orientation. This feature did not seem to make a difference in the rate of correct attachment. However, a relatively low number of subjects had incorrect orientation as a tether installation error.

Several vehicles in this study had competing hardware near the tether anchor that could be potentially confusing. These include cargo tiedown hooks and straps used to stow vehicle seats. Subjects were most likely to use a cargo hook rather than the tether in the vehicle where the tether anchor was mounted to the roof. In several analyses, the presence or absence of confusing tether hardware was a significant predictor of use or correct use. However, since vehicles with tether anchors located on the filler panel, which have the highest rates of tether use, are also least likely to have confusing tether hardware, this effect may result from correlation between tether location and potentially confusing hardware.

With vehicle B, the lower anchors are positioned offset inwards from the outboard seating positions to allow an improvised center LATCH position with standard spacing of 280 mm. While this effort is commendable, it also has some negative consequences for tether use in the outboard seating positions. The tether routing instructions state to route the tether over the head restraint, or to remove it. This works if the child restraint is installed with the seatbelt, but if the lower anchors are used, there is almost a direct path to the tether going inboard of the head restraint. It is almost impossible to route the tether securely over the head restraint while it is attached with LATCH. While the vehicle manual instructions allow removal of the head restraint if needed, it is difficult to do so and a tool must be used.

The tether hardware in the pickup truck consists of webbing loops behind each seating position that serve as tether routers for the installed seating position and tether anchors for the adjacent seating position. Only one subject used the tether anchors correctly. Although only one pickup truck was included in this study, other pickup trucks often use similar strategies that are likely equally misused. Vehicle manufacturers should revisit the design of tether anchors in pickup trucks, as the current strategy simply doesn’t work.

Subjects seemed to prefer tether anchors located on the upper part of the vehicle seatback compared to those at the bottom of the seatback or the floor. Although FMVSS 225 allows a wide variety of tether anchor locations, placing tether anchors so they are either on filler panels or upper seatbacks would provide more consistency across the vehicle fleet and start to reduce confusion.

Vehicle Manufacturer Instructions

In general, the verbal advice provided by vehicle manufacturer representatives on child restraint installations was poor and unhelpful. They were contacted using the phone numbers provided in the vehicle manual, which are also provided in the LATCH manual. Given that the UMTRI experimenter identified herself as a CPST, the number of representatives who suggested contacting a CPST for guidance was not reassuring.

In the CPST training class, technicians are taught to follow the vehicle and child restraint manufacturers' instructions. Yet they are not supposed to let a child leave a seat check in an unsafe manner. In several cases, particularly with the V-style tether, it was not possible to route the tether as directed. In other cases, the head restraint position required by the manual interfered with optimal installation of the child restraint. If we had actually called from a seat check working with a family, it would usually not be possible to get a different child restraint as was sometimes suggested.

Vehicle manufacturers need to provide additional training on CPS to their representatives taking calls on child restraint installation. If there is a problem they cannot answer, they should have access to CPS experts within their company who they can contact for guidance, even if they must make a return call to the customer at another time.

Limitations

The current study had several limitations. While specific tether anchor locations were associated with tether use and correct attachment, it is unknown how tethers attached to different tether anchor locations perform dynamically and whether there are differences in preventing forward excursion in a crash. Also, all testing was performed with US child restraints and vehicles; findings may not apply to systems designed to meet ISOFix requirements.

Vehicle makes and models were chosen to represent a range of tether anchor characteristics and were not necessarily representative of the most common tether anchor configurations. The tether anchor configuration in the pickup truck was substantially different than in other vehicles and proved challenging for volunteers to use correctly. Since space for a tether anchor behind the rear seat is limited, tether anchors in pickup trucks often have unusual configurations that may result in decreased or improper tether use. Only one pickup truck was included in this study and installations in it were removed from statistical models of incorrect tether attachment because its unique tether anchor configuration and significant misuse dominated the analyses. However, pickups are frequently used as family vehicles so vehicle manufacturers should reconsider current design options to improve usability.

All the volunteer subjects had some experience in installing child safety seats. An effort was made to recruit subjects with and without previous LATCH experience, but the initial screening questions were not always adequate for categorizing LATCH experience. To prevent educating potential study participants about LATCH, volunteers were asked how they installed child restraints in their own vehicle, rather than asking them if they had experience with the LATCH system. After they participated in the study (and received instruction about LATCH), volunteers filled out a more detailed questionnaire regarding their previous experience. Several subjects were misclassified during the initial screening, with some initially saying they used LATCH but later stating they had not once they learned more about it. Others had used LATCH before but not realized what it was called. To satisfy the experimental matrix of each subject group having at least one subject with each combination of education level and previous LATCH experience, an additional subject was recruited for one group because of the initial misclassifications.

In this study, rates of tether use and correct child restraint installations were much higher than in previous volunteer studies. More than half of study participants were college graduates, had experience with a wide range of child restraint types, and had previous experience with lower anchors and tethers. This may limit the applicability of results to the general U.S. population. Focusing recruitment to obtain different levels of education and previous LATCH experience also resulted in less diversity of subject ages. Only four subjects were in their forties and only three were over age 50, with the four oldest subjects frequently making installation errors. As a result, age was more a significant predictor in several analyses compared to previous studies that had more distributed ranges of subject ages.

All of the subject variables related to experience were correlated: previous child restraint experience, prior lower anchor experience, and prior tether experience. In addition, use of the child restraint or vehicle manual was inversely related to subjects' experience, with subjects less likely to use the manual if they had previous LATCH experience. As a result, only one of these subject predictors, tether experience, was considered a potential predictor in regression analysis. The within-subject elements of the study design helped account for this limitation because subjects were compared with themselves across vehicles in which they were tested.

Recommendations

- Tether anchors should be marked.
- Potentially confusing hardware should not be placed near tether anchors. These include cargo hooks and loops of webbing used to stow seats. If necessary, confusing hardware should be well-labeled to differentiate it from the tether anchor.
- Another strategy is needed for the design of tether anchors in pickup trucks.
- For adjustable head restraints, allowing subjects to either remove the head restraint, or use the up or down positions would achieve the highest rate of compliance. If only one head restraint position can be specified, it should be the up position. Use of the down head restraint position or removing the head restraint should not be required. However, allowing removal or adjustment of the head restraint would help in cases where the head restraint interferes with proper child restraint installation.
- Subjects should not be instructed to route the tether under the head restraint if the gap between the head restraint and seatback is less than 50 mm.
- Instructions should be provided on routing of V-style tethers. In most cases, subjects should be directed to route each side of the V around the head restraint or head restraint posts.
- Directions for routing the tether should compromise between achieving the shortest distance to the tether and making sure subjects have access to the tether adjustor hardware.
    - For tether anchor locations on the package shelf, routing a single-strap tether over the head restraint would likely provide better access to the adjustor hardware.
    - For tether anchor locations on the vehicle seatback or floor, routing a single-strap tether under an adjustable head restraint provide a shorter tether length but allow good access to the adjustor hardware.
    - For tether anchor locations on the vehicle roof, a single-strap tether over the head restraint would provide best access to the adjustor hardware.
    - For V-style tethers, allowing each side of the strap to be routed around each side of the head restraint would provide best access to the adjustor hardware, even if tightening the tether pulls the webbing beneath an adjustable head restraint.
    - Instructions for V-style tethers should not recommend routing over a head restraint or under between the posts of a head restraint. The first case increases the length of the tether and can lead to a precarious installation if the straps are close to the edge of the head restraint, while the second case makes it difficult to access the adjustor hardware.
- Vehicle manufacturers need to improve their customer service regarding child restraint installations. If a CPST or caregiver is calling with a question that cannot be answered

using the manual, the customer service representative should have access to a CPS expert within the company to contact for consultation, even if the representative must make a return call with the answer another time.

- Further research should be conducted to confirm preliminary findings that stamped/perpendicular tether anchors are easier to use correctly than stamped/parallel tether anchors.
- LATCH education efforts should be revised to place more emphasis on tethers that have demonstrated safety benefits.

Acknowledgements

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Appendix A: Subject Screening Form

Thank you for your interest in this child seat study. The data and knowledge that we will obtain from this study will be valuable for child safety in vehicles.

This study takes place in our office located on the northeast side of Ann Arbor. It will take up to 3 hours and we pay $40 cash at the end of the session.

We will ask you to get in and out of a car and lift items that weigh up to 45 pounds. Do you think you will be able to do this several times over the course of three hours?

I need to ask you several questions to see if you qualify for our study:

How old are you? ________

Reject if less than 18

An obvious answer, but I must ask – what is your gender? ________

Are you pregnant? ________

Reject if pregnant

Have you been trained as a car seat checker? ________

Reject if certified/lapsed child passenger safety technician.

Do you travel with children in your vehicle at least twice a month?________

Reject if no

Do they use any kind of child safety seat? ________

Reject if no, boosters are ok

Did you install the child safety seat? ________

Reject if no; mention that if spouse/child did it, they would be eligible for the study

How do you usually install the child safety seat? ________

Indicate whether they state seatbelt, LATCH, or tether

What level of school have you finished? ________

Some high school, high school, some college, college, graduate school

Have you been in any other car seat studies at UMTRI? ________

Reject if they were in the 2010 NHTSA study of car seat installation or 2011 IIHS study.

What is your name and contact number?

Name: ______________________________

Contact: ______________________________

Is English your native language? ________

If no

What other languages do you speak?__________________________________

Please wear comfortable clothes and shoes. When you come, we suggest that you do not wear any jewelry on your hands or wrists that might get caught during installations.

Will you bringing anyone with you? ________

If they say that they will have to bring a child / children,

Are you the legal guardian? ________

Our address: 2901 Baxter Road. South of Plymouth Road and East off of Huron Parkway. We will meet you at the front door to provide you with a parking pass for our parking lot.

Can I send you a map? You have our phone number: (734) 763-3463

We will call you a day or so before your appointment to remind you. Thank you so much for helping in this study!

Appendix B: Consent Form

Consent to Participate in a Research Study

LATCH USABILITY SURVEY

Principal Investigator:	**Kathleen D. Klinich, PhD**
	Assistant Research Scientist
	University of Michigan Transportation Research Institute
	2901 Baxter Rd. Ann Arbor, MI 48109
Co-investigators:	**Miriam Manary, MS, Senior Research Associate**
	Carol A. C. Flannagan, PhD, Assistant Research Scientist
	University of Michigan Transportation Research Institute
	2901 Baxter Rd. Ann Arbor, MI 48109

Invitation to participate in a research study

Dr. Kathleen Klinich invites you to participate in a research study about what makes it hard or easy to install child seats. The study is funded by the Insurance Institute for Highway Safety.

Description of subject involvement

If you agree to be part of the research study, you will be asked to install different child seats in different vehicles for three hours. After each time, you will answer some questions about the installation.

Benefits

You will directly benefit from being in this study because you will learn more about installing child seats. Others may also benefit because the results of the study may lead to child seat designs and vehicle designs that are easier to use.

Risks and discomforts

The researchers have taken steps to minimize the risks of this study. Even so, you may still experience some risks related to your participation, even when the researchers are careful to avoid them. These risks may include the following:

- Minor scrapes, bruises, or sore muscles from efforts to install child seat and getting in and out of vehicles.
- Frustration from installing child seats.

Compensation

We will pay you $40 for being in the study, which should take 3 hours.

Confidentiality

We plan to publish the results of this study, but will not include any information that would identify you. There are some reasons why people other than the researchers may need to see information you provided as part of the study. This includes organizations responsible for making sure the research is done safely and properly, including the University of Michigan, government offices or the study sponsor, the Insurance Institute for Highway Safety.

To keep your information safe, the researchers will assign a code number to you so your name will only be on the consent form and subject payment form. None of the data will have your name on it.

Also, if you tell us something that makes us believe that you or others have been or may be physically harmed, we may report that information to the appropriate agencies.

Storage and future use of data

The data from your test session will be stored on a central computer requiring a password to access it. The researchers will retain the data indefinitely for research purposes. The researchers will discard your consent form and payment form after 1 year by shredding them. The data/specimens may be made available to other researchers for other studies following the completion of this research study but will not contain information that could identify your name.

Voluntary nature of the study

Participating in this study is completely voluntary. Even if you decide to participate now, you may change your mind and stop at any time. If you decide to withdraw early, you can decide if we can use the data we collected or discard it. If you decide not to finish your test session, we will pay you $12/hr for the time you have spent.

Contact information

If you have questions about this research, including questions about scheduling or your compensation for participating, you may contact Kathleen Klinich, (734) 936-1113 or kklinich@umich.edu.

If you have questions about your rights as a research participant, or wish to obtain information, ask questions or discuss any concerns about this study with someone other than the researcher(s), please contact the University of Michigan Health Sciences and Behavioral

Sciences Institutional Review Board, 540 E Liberty St., Ste 202, Ann Arbor, MI 48104-2210, (734) 936-0933 **[or toll free, (866) 936-0933]**, irbhsbs@umich.edu.

Consent

By signing this document, you are agreeing to be in the study. You will be given a copy of this document for your records and one copy will be kept with the study records. Be sure that questions you have about the study have been answered and that you understand what you are being asked to do. You may contact the researcher if you think of a question later.

I agree to participate in the study.

_______________________________________ ______________________

Signature Date

Appendix C: Test Protocol

Thanks for coming in today. We're doing a study on how people install child seats. We are going to ask you to install different child seats in different vehicles today. You can use the instructions for the child seat and the vehicle. Let me know each time when you are done. When you are done, I will take some measurements, and for some trials you will answer some questions. Then we will go on to the next child seat and vehicle.

You might want to remove your jewelry. Please remember that most people make mistakes when installing child seats. We want you to do your best, but not get frustrated. We are testing the child seats and vehicles, not you.

This is a consent form for you to be in our study. Please look through it and let me know if you have any questions. I will give you a copy of the form to keep.

Give subject consent form to read and sign.

This cart has things you can use for installing the child seat. The instructions for the vehicle are stored in the glove compartment (or where they are), and the instructions for the child seat are here on the cart.

The child restraint and its unstored manual will be on test cart.

Please install this seat forward-facing in the 2nd row driver's side position of this vehicle. By forward-facing, I mean the child is facing the same direction as the driver. We want you to install the child seat using LATCH.

Recline should be adjusted for forward- facing. LATCH belt should be routed for forward-facing. LATCH belt and tether should be stored.

For each trial, record start time of installation.

> *If subject tries to install CRS in a different position, note it on check form and say*
>
> **For today's study, we would like you to install the child seat in the left rear position.**
>
> *If subject can't find the instructions for the child seat or vehicle and asks for help, experimenter can show them where they are.*
>
> *If the subject asks the experimenter questions, say*
>
> **"I'm not allowed to help you, but you can find information about that in the manuals for the child seat and the vehicle."**
>
> *If subject asks if they have to use the instructions, say*
>
> **"You don't have to, but they are here if you need them."**

If the subject asks the experimenter to assist with a particular task, say

"I'm sorry I'm not allowed to help you. Just do your best without hurting yourself or getting too frustrated."

If subject says, "I can't do this," state

"OK, please try and finish the installation except skip this part."

Record end time of installation.

After trials 1-4, ask subject to sit behind a screen while experimenter checks installation and takes photos. Assess installation using check form. Prepare for next installation.

After the fourth trial, provide some education:

The LATCH system lets you install the child restraint with two connectors on the child restraint that attach to bars located in the vehicle seat, plus a top tether on the child restraint (show it to them) that connects to a tether anchor in the vehicle. You can find out information about the vehicle anchors in the owner's manual.

After trials 5-8, give subject assessment form and direct them to fill it out behind a screen so they can't view the experimenter checking installations.

Assess installation using check form. Prepare for next installation.

If you want to look at the vehicle or child seat to answer the questions, let me know.

If so, experimenter will pause assessment while subject reviews labels on installed child seat. Experimenter can answer questions about filling out the form, such as identifying CRS features (e.g. this is the tether).

Repeat installations until 8 installations are complete or less than 15 minutes left in the test session.

Give subject the final assessment form to complete after installations are complete.

Thanks for being in our study today. Please fill out this form so we can pay you.

If subject decides to drop out of the study, pay $12/hour rate for their participation so far.

If subject asks how they did, experimenter is allowed to provide a general assessment such as

"You did pretty good," "You improved between the first and last," or "There are some areas that could be improved like tightness of the installation."

Here is some information about the things we are looking at, and here is information about how you can get your car seat checked at the UM hospital.

Provide subject with SafetyBeltSafe handout on "Quick Checklist for Safety Seat Misuse" and flier for Mott Buckle Up Hotline (fitting station at UM hospital.)

We would also like you to fill out this form. You can still participate if you do not want to fill out this form.

Ask subject to fill out subject questionnaire and race/ethnicity form.

Appendix D: Experimenter Evaluation Form

Subject ID: Installation number: 1 2 3 4 5 6 7 8

CRS: C1 C2 **Method:** L SB Both

Installed position: 2L 2C 2R 3L 3C 3R **Vehicle:** A B C D E F G H I J K L M N O P

Start time: End time: Date: Evaluator:

MANUALS/	**Yes**	**No**	**NA**	**Comment**
Did subject use vehicle manual?				
Did subject use child restraint manual?				
Installed as directed (LATCH)?				
Installed in directed position?				
Installed in directed orientation (FF)?				
TIGHTNESS	**Yes**	**No**	**NA**	**Comment**
Does CRS pass 1” movement test?				
Tightness measurement				
LOWER ANCHORAGES	**Yes**	**No**	**NA**	**Comment**
Fully engaged				
Connectors oriented properly				
Attached to correct vehicle hardware				
LATCH belt flat?				
TETHER	**Yes**	**No**	**NA**	**Comment**
Used?				
Attached to correct vehicle hardware?				
Oriented correctly?				

Tether belt flat?					
Tightness measurement:					
HEAD RESTRAINT POSITION	**Removed**	**Fixed**	**Up**	**Down**	**Mid**
Vehicle manual directions					
Position chosen by subject					
ROUTING (wrt head restraint)	**Over**	**Under**	**Inboard**	**Outboard**	**Removed**
Vehicle manual directions					
Method used by subject					
SEATBELT	**Yes**	**No**	**NA**	**Comment**	
Routed correctly through belt path					
Seatbelt flat (not twisted)?					
LOCKED WITH	**Retractor**	**Locking Latchplate**	**Locking Clip**	**CRS Lockoffs**	
Method recommended					
Method used by subject					

Appendix E: Subject Evaluation Forms

Subject Assessment Forms

Subject ID: Date:

Installation number: 5 6 7 8 **CRS:** C1 C2

Method: L SB Both **Vehicle:** A B C D E F G H I J K L M N O P

Check one answer for each question

Do you agree with these statements?	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Don't know**	**NA**
I attached the child seat to the vehicle correctly.							
The vehicle manual is consistent with the child seat manual.							
This installation was harder than what I do at other times.							
The vehicle headrest made it hard to install.							
The stiffness of the vehicle seat made it hard to install.							
The shape (or contour) of the vehicle seat made it hard to install.							
The seatbelt buckles got in the way of using LATCH.							

Subject Assessment Forms

For LATCH installations

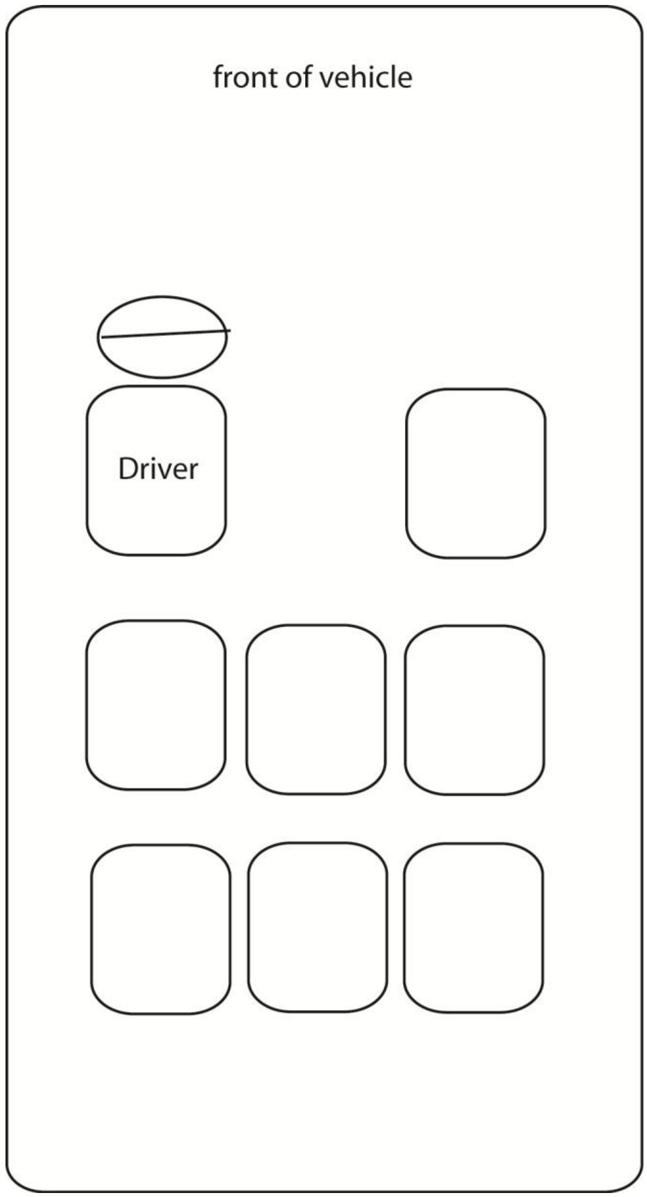
How hard or easy was it to:	Very Hard	Hard	Easy	Very Easy	Don't know	NA
Understand the vehicle instruction manual about installing the child seat						
Find the lower anchorages in the vehicle						
Find the tether anchorage in the vehicle						
Attach the LATCH belt connectors to the lower anchorages						
Tighten the LATCH belt						
Figure out what angle the child seat should be						
Adjust the angle of the child seat						
Attach the tether strap on the top of the child seat to the vehicle						
Tighten the tether strap on the top of the child seat						
Store the tether (if not used)						

Subject Assessment Forms

Put an S in all the positions where you could install a child seat using the seatbelt.

Put an L in all the positions where you could install a child seat using LATCH.

Put a T in all the positions where you can attach a top tether.



Subject Final Assessment Form

Subject ID: Date:

When thinking about installing child seats, please give each vehicle a rating about how much you liked it. 1 is worst, 10 is best.

Order	Vehicle	Child Seat	1	2	3	4	5	6	7	8	9	10
1												
2												
3												
4												
5												
6												
7												
8												

Do you have any suggestions or comments on the vehicles?

Subject Questionnaire

Subject ID: Date:

Before today, I have installed these types of car seats (check all that apply):

- ❑ Infant seat
- ❑ Convertible seat, with the child facing the rear of the vehicle
- ❑ Convertible seat, with the child facing the front of the vehicle
- ❑ Forward-facing seat with harness
- ❑ Booster seat

Before today, I have installed car seats using (check all that you have used)

- ❑ Seatbelt
- ❑ Lower anchors (part of LATCH)
- ❑ Tether (part of LATCH)

In how many vehicles have you installed a car seat? (A guess is OK) ________

Can you list the vehicles you currently transport a child in?

___________________________________ ___________________________________

___________________________________ ___________________________________

Can you list the child seats you are currently using?

___________________________________ ___________________________________

___________________________________ ___________________________________

What level of school did you finish?

- ❑ Some high school
- ❑ High School
- ❑ Some college
- ❑ College
- ❑ Graduate school

Race / Ethnicity Questionnaire

Race/Ethnicity Questionnaire

The University of Michigan Transportation Research Institute

Child Seat Installation Study

Date: Subject ID:

Please check **1** of the following 3 options

- ☐ Hispanic or Latino
- ☐ Not Hispanic or Latino
- ☐ No Response

Please check **one or more**:

- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☐ White
- ☐ No Response

Appendix F: Subject Handouts

Car Seat Program

Child safety is a priority at C.S. Mott Children's Hospital. That's why Mott champions one of the most important child safety tools: the car seat. But you must **use the car seat correctly** in order for it to be effective! Statistics show that 90 percent of car seats are installed incorrectly. Educate yourself so that your child can be as safe as possible in a vehicle. Call 734-763-2251 to find out about Car Seat Inspections at Mott.

Buckle Up! Hotline - 734-763-2251

We care so much about car seat safety that we created the Buckle Up! Hotline. Operated by our Pediatric Trauma Program staff, the Hotline is an easy way to find out dates and times for free community car seat inspections or to enroll in a one-hour car seat class at Mott Children's Hospital.

During the classes, Mott provides certified Child Passenger Safety Technicians to verify that your car seat is:

- not on the recall list
- appropriate for the child's height, weight and age
- installed correctly
- securing the child safely

The Buckle Up! Hotline also is the number to call if you need assistance purchasing a low-cost, convertible car seat for your infant or toddler.

Learn more at

http://www.med.umich.edu/yourchild/topics/carseat.htm

Quick Checklist for Safety Seat Misuse

Check for these common and dangerous mistakes:

❒ 1. Child not using the safety seat or sitting in the seat without using the harness.
❒ 2. Baby facing the front of the car. Children should face the rear until at least age 2.
❒ 3. Rear-facing child riding in front seat of car with passenger air bag. Air bags are fatal for infants!
❒ 4. Toddler or older child riding in front. If car has passenger air bag and back seat is full, slide front seat back as far as possible, adjust shoulder straps snugly, make sure child does not lean forward.
❒ 5. Too many people in the car. There must be one safety belt per person.

Car seat problems:

❒ 6. Unsafe used seat (rusty, cracked, broken, bent, past expiration date, involved in crash or not known).
❒ 7. Child too big for seat (weight above limit, strap slots below shoulders, or head not supported).
❒ 8. Child too small or too young for seat (strap slots above shoulders; 2-year-old in booster).
❒ 9. Harness straps threaded incorrectly (check instructions) or too loose (should not be able to pinch a fold in the strap between the thumb and finger).
❒ 10. Harness straps on the arms or under the arms (straps must go over the shoulders).
❒ 11. Harness not buckled securely. Listen for the "click."

Installation problems:

❒ 12. Safety seat attached to car incorrectly. See label for correct location of belt or LATCH strap.
❒ 13. Loose installation (should not move more than 1" when pushed toward front of car or sideways).
❒ 14. Older child using safety belt incorrectly. Lap belt should touch thighs; upper belt on shoulder/chest.
❒ 15. Booster used with only a lap belt (lap-shoulder belt must be used).

Important: This is a partial list designed to help parents, drivers, and law enforcement officers recognize obvious misuse. It is not to be used as the basis of a detailed inspection.

How to find out more about keeping your child safe in the car

Nine out of ten of the car seats inspected at checkups have something wrong, and some of the problems could cause serious injuries to the child. Read the manufacturer's instruction booklet carefully to make sure you are using your seat correctly. To order the instruction booklet or to find out if your seat is covered by a recall, call the company that made the seat. Most recalled seats can be fixed by ordering free replacement parts from the manufacturer. When you call, have the seat in front of you so you can describe it. Look for the label stuck to the side or back of the seat and write down the following information:

Manufacturer _______________ Model name and # _______________ Date made _________

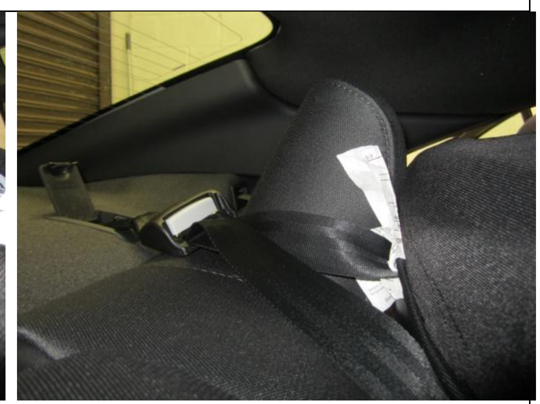
Contact information for some major car seat companies:

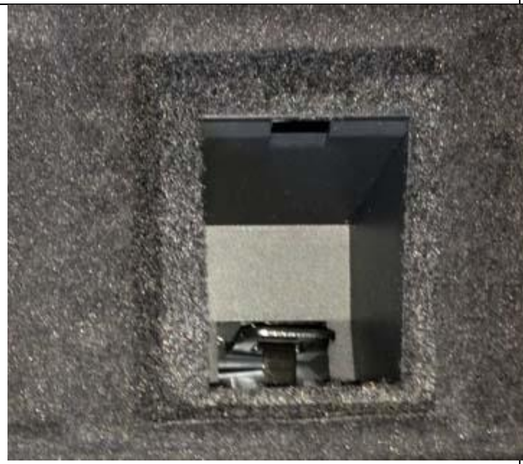
Britax 888-427-4829 www.britaxusa.com	**Chicco** 877-424-4226 www.chiccousa.com	**Combi** 800-992-6624 www.combiusa.com	**Diono** 855-463-4666 www.diono.com
Dorel Juvenile Group 800-544-1108 www.djgusa.com	**Evenflo Company** 800-233-5921 www.evenflo.com	**Graco** 800-345-4109 www.gracobaby.com	**Learning Curve** 888-899-2229 www.learningcurve.com
Peg Perego U.S.A. 800-671-1701 www.perego.com	**Recaro** 888-973-2276 www.recaro-cs.com	**Team-Tex America** 877-912-1313	

***SafetyBeltSafe* U.S.A.** P.O. Box 553, Altadena, CA 91003 www.carseat.org
310/222-6860, 800/745-SAFE (English) 310/222-6862, 800/747-SANO (Spanish)

#75 (3-31-12)

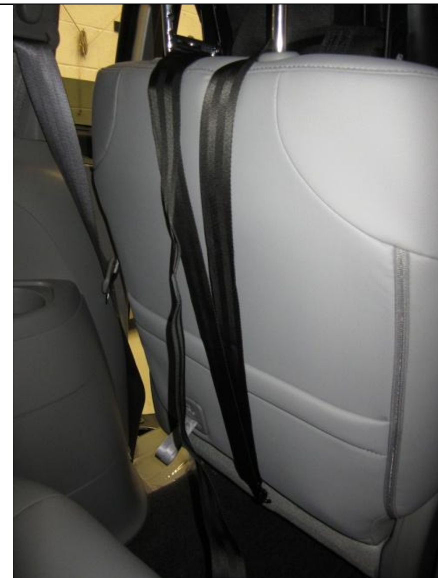
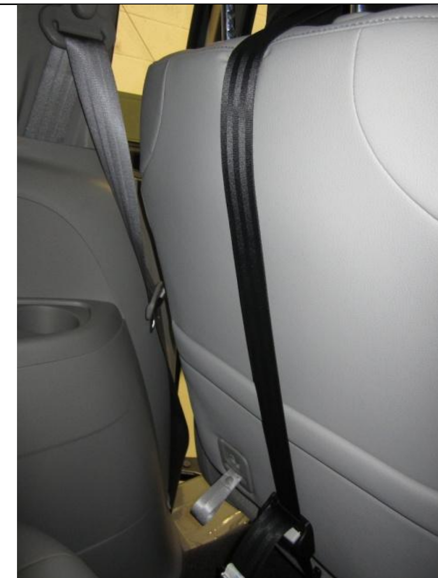
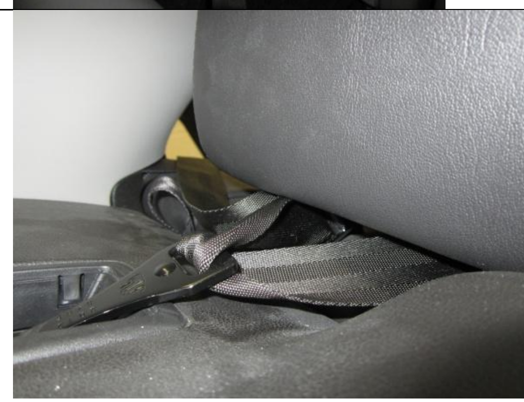
Appendix G: Photos of vehicle tether hardware and installations with each child restraint

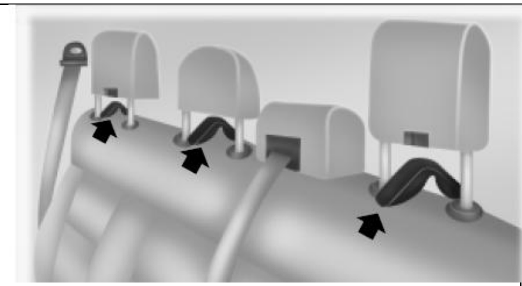
Vehicle	Tether Close-up	CRS 1 Install	CRS 2 Install
A: Mazda 3	 Stamped, covered recess		
B: Ford Taurus			

	Wire, covered recess		
C: Nissan Rogue	 Stamped, covered recess		
D: Toyota Highlander	 Wire, covered recess		

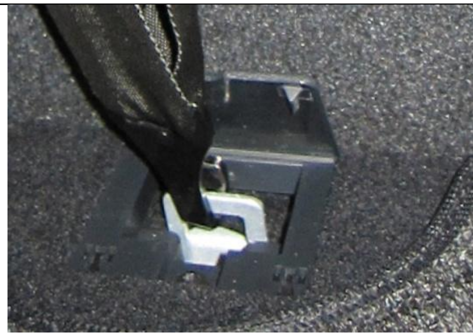
E: Toyota Camry	 Stamped, covered recess		
F: Kia Sedona	 Wire, slit in carpet		

G: Subaru Outback	 Stamped, covered recess		
H: Ford Fiesta	 Stamped, covered recess		

I: Honda Odyssey	 Wire, slit in carpet		
J: Chevrolet Malibu	 Stamped, covered recess		

K: Ford F150	 Webbing, through router	 	 

L: Jeep Patriot	 Wire, open recess		
M: Chrysler 200	 Stamped, covered recess		

N: Volkswagen Jetta Sport Wagen	 Stamped, covered recess		
O: Honda CR-V	 Wire, open recess		

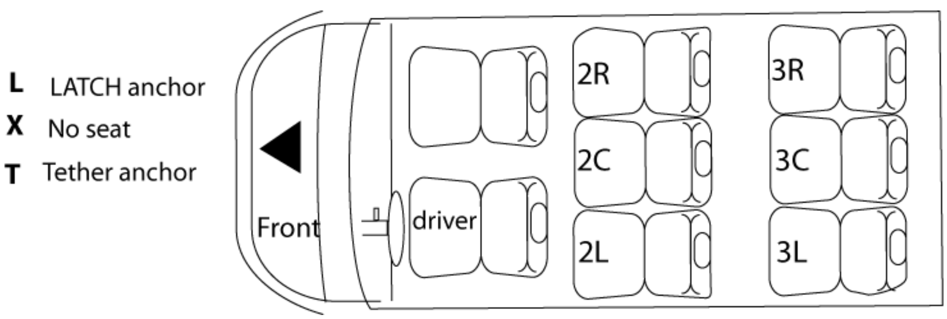
P: GMC Acadia	 Wire, open recess		

Appendix H:

Forms used to document vehicle characteristics

Vehicle Information:

Year/Make/Model:					
Vehicle Type:					
VIN:					
Number of seating positions:	☐ 4	☐ 5	☐ 6	☐ 7	☐ 8
Number of doors:	☐ 2	☐ 3	☐ 4	☐ 5	



Seat location/ Lower anchorage (LATCH) / Tether Anchorage

Seat number	Is there a seat	LATCH Lower Anchors?	Moving Headrest?	Tether Anchorage?	Tether Location (package shelf, etc)
2L	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
2C	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
2R	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
3L	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
3C	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	
3R	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	

Notes:

Can you use CSS in center using LATCH:

LATCH weight limits:

Headrest Routing Instructions:

Category		Target	2L		2R		Other:	
			Outboard	Inboard	Inboard	Outboard	Inboard	Outboard
Manual Assessments	Manual shows LA locations clearly with illustrations?							
	Required to read text?							
	Manual shows TA locations clearly with illustrations?							
	Required to read text?							
	Manual clear on tether routing							
	Tether routing wrt HR?							
	HR final position?							
Tether measures	Tether gauge fits through router?	Yes						
	TA Marking?	ISO						
	TA covering?							
	TA visible?	Yes						
	Actions to use TA?	None						
	Distance TA to HR?	>165 mm						
	Distance LA to TA?	< 1650 mm						
	TA confusing hardware?	No						
	Can tether hook be engaged upside down?							

Category		Target	2L		2R		Other:	
			Outboard	Inboard	Inboard	Outboard	Inboard	Outboard
Lower anchor measures	LA marking?	ISO						
	LA covering?							
	LA visible?	Yes						
	Actions to use LA?	None						
	LA confusing hardware?	No						
	Depth	0-2 cm						
	Lateral distance to nearest belt hardware?	> 70 mm						
	Clearance (15# pull)	>54°/75°						
	Rigid contact?	No						
	Target force angle							
	Force / Angle 1		/	/	/	/		
	Force / Angle 2		/	/	/	/		
	Force / Angle 3		/	/	/	/		
	Mean Force	<40#/<17#						
	Collinearity tool attach?	Yes						
CRF measures	Attach fixture?	Yes						
	Lateral CRF angle (anchors removed)	<5°						
	Installed CRF pitch angle	5°-20°						
	Cushion to Z-point	<51 mm						
	Cushion to CRF @ 350-400 mm forward							