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Results of Task 1, Labels, Instructions and Features of Convertible Child Restraint Systems (CRS): Evaluating their Effects on CRS Installation Errors are reported in a separate publication UMTRI-2010-37.

16. Abstract

This report documents a study of how vehicle features contribute to CRS installation errors. Thirty-two subjects were recruited based on their education level (low or high) and experience with installing CRS (none or experienced). Each subject was asked to perform four child restraint installations in three vehicles. Each subject first performed a CRS installation with a seatbelt in one vehicle, followed by three CRS installations using LATCH, one in each of three vehicles. One child restraint with a hook-on LATCH connector and one with a push-on LATCH connector were used. All installations were forward-facing, using an 18-month-old CRABI anthropomorphic test device (ATD). Six vehicles were used in testing, with half of subjects testing with each vehicle. Conditions were selected to provide a range of LATCH locations (visible, above seating surface, buried in bight), buckle stalk types (webbing vs. rigid), and tether locations (package shelf vs. seatback). After each installation, the experimenter evaluated 28 factors for each installation (such as tightness of installation, tether tightness, and LATCH belt attached correctly).

Analyses used linear mixed models to identify the CRS installation outcomes associated with vehicle features. For LATCH installations, vehicles requiring higher forces to attach connectors to lower anchorages were more likely to be attached incorrectly. Vehicle seats with a bightline waterfall (which places the lower anchorage above the seating surface) increased rates of tight CRS installation for both seatbelt and LATCH installs. Seatbelt installations were tight (and locked) more frequently when the buckle stalk was located close to the bight rather than further forward.

Subjects used the tether correctly in 30% of installations. Subjects used the tether more frequently during LATCH installations compared to seatbelt installations. The tether was used more frequently in sedans (with anchorage locations on the package shelf) than in vehicles with the tether anchorage located on the seatback. However, when the tether was used, it was routed correctly more often in vehicles with the tether anchorage on the seatback. A tether wrap around distance of 210 mm was sufficient to allow tightening of the tether with the two CRS tested, but additional testing showed that 5/16 CRS could not be tightened sufficiently with this wrap around distance.

Installation time decreased with successive trials, but installation time was longer when subjects used the vehicle or CRS manuals. Subjects used the vehicle manual in 38% of installations, and were more likely to do so when the tether anchorage was located on the vehicle seatback. Subjects used the CRS manual in 88% of installations.

In questionnaire responses, subjects indicated that the head restraints affected installations, and vehicle manuals varied in their ease of understanding. They also noted that tether anchorages on seatbacks were more difficult to locate than those on the package shelf.

Results from this study do not fully support SAE and ISO recommendations for LATCH usability in vehicles. Recommendations are made regarding tether anchorage markings, minimum tether wrap around distance, and lap belt anchorage locations.

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Metric Conversion Chart

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
In	inches	25.4	millimeters	Mm
Ft	feet	0.305	meters	m
Yd	yards	0.914	meters	m
Mi	miles	1.61	kilometers	km
AREA				
in^2	squareinches	645.2	square millimeters	mm^2
ft^2	squarefeet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
Ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
TEMPERATURE (exact degrees)				
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
FORCE and PRESSURE or STRESS				
Lbf	poundforce	4.45	newtons	N

lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
LENGTH				
Mm	millimeters	0.039	inches	in
M	meters	3.28	feet	ft
M	meters	1.09	yards	yd
Km	kilometers	0.621	miles	mi
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
Ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
MASS				
G	grams	0.035	ounces	oz
Kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
TEMPERATURE (exact degrees)				
^{o}C	Celsius	1.8C+32	Fahrenheit	^{o}F
FORCE and PRESSURE or STRESS				
N	Newtons	0.225	poundforce	lbf
kPa	Kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

Acknowledgments

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Executive Summary

This document reports on a study that evaluated the effect of vehicle features on child restraint system (CRS) installation errors and installation experiences. This Task 2 effort complements the work of Task 1, which assessed the effect of CRS features, labels, and instructions on CRS installation errors.

Thirty-two volunteers were recruited based on general education (either "have not attended college" or "graduated from college") and CRS installation experience levels (none or experienced). People who had attended a child car seat check or who had been trained as a NHTSA CPS technician were barred from participation. Each volunteer was assigned to perform four forward-facing installations: one using a seatbelt and one using LATCH in one vehicle, as well as LATCH installations in two other vehicles. The installations were performed in the right second-row seating position (five vehicles) or right third-row seating position (one vehicle).

Two child restraints used in Task 1 were selected for testing. One has a push-on style of LATCH connector (Recaro Signo), while the other has a hook-on LATCH connector (Evenflo Triumph). The harness of each CRS was configured to fit the 18MO CRABI dummy used in testing, so subjects could focus on attaching the CRS to the vehicles rather than restraining the dummy.

Six vehicles were selected for testing, with each subject performing installations in three of the vehicles. The vehicles were selected to provide a variety of lower anchorage locations (visible or buried, and at or above seating surface), forces required to attach the lower connectors (high, medium, or low), seatbelt buckle locations (at or forward of the bight), head restraint prominence (more forward or more rearward), and tether locations (package shelf or seatback).

Following each installation, the experimenter assessed the installation, checking for key installation factors such as tightness, correct attachment of tether and LATCH belt, and locking the seatbelt. Subjects also answered questions regarding the ease of the installation. Table 1 summarizes different installation factors and the predictor variables associated with each.

Table 1. Summary of vehicle and subject factors that affect installation

	Percentage Correct	**Predictors**	**F-test**	**p-value**
Installation tightness (1" test)	67%	LA location (above seating surface > bight)	F(1,30)=15.12	0.0005
		Buckle location (seatbelt only; bight> forward)	F(1,30)=5.65	0.0241
		CRS x installation method (C6>C10 for LATCH, C10>C6 for belt)	F(1, 94.44)=5.04	0.0271
Lower anchorages attached correctly	90%	LA attachment force (low, med > high)	F(2,55)=5.84	0.0050
		LA visibility (visible > hidden)	F(1,56)=4.38	0.0409
Tether attached correctly	30%	TA location (SB>PS)	F(1,80)=10.27	0.0019
		Installation method (LATCH > seatbelt)	F(1,80)=21.86	<0.0001
		HR fore-aft location (RW>FW)	F(4,80)=3.26	0.0157
Tether tight	82%	Installation method (LATCH > seatbelt)	F(1,92.73)=29.66	<0.0001
		HR fore-aft location (FW>RW)	F(4,75.03)=2.15	0.0833
		Tether location (SB>PS)	F(1,39.1)=4.87	0.0332
Seatbelt locked	50%	Buckle location (at bight>forward)	F(1,29.38)=8.65	0.0063
Installation time	NA	Trial (1>2>3>4)	F(1,94.7)=44.77	<0.0001
		Use of vehicle manual (use>nonuse)	F(1,22.1)=20.31	0.0002
Use vehicle manual	38%	TA location (SB>PS)	F(1,31)=10.58	0.0028
Use CRS manual	88%	CRS experience (inexperienced > experienced)	F(1,32.13)=5.94	0.0205

* LA = lower anchorage; TA = tether anchorage; HR = head restraint; SB=seatback; PS=package shelf; FW=forward; RW=rearward; C6=Recaro Signo; C10=Evenflo Triumph.

Visible lower anchorages (LA) were associated with higher rates of correct attachment of the LATCH belt compared to lower anchorages that were buried within the bight, but LA visibility did not affect the rate of achieving a tight CRS installation. The same is true of the force required to attach the lower connector, with vehicles requiring lower/medium forces having more correct LATCH belt attachments than those requiring higher securement forces.

Some vehicles had a bightline waterfall feature (a bolster cushion located directly behind the seated pelvis location) that places the lower anchorages above the seating surface. This higher location was associated with a higher rate of tight installation for both LATCH and seatbelt installations, suggesting that the shape of the seat may help installers to obtain a tight installation. This finding does not support the SAE CRS committee recommendation to keep lower anchorages close to the seating surface as a means of improving LATCH usability.

For seatbelt installations, buckle locations closer to the bight resulted in tight installations more often than those located forward of the bight (83% vs. 35%). However, location of seatbelt buckle did not have an effect on LATCH installs, indicating that the seatbelt buckle locations tested did not interfere with use of lower anchorages.

The tether was used correctly in only 30% of all installations, and not used in 26% of all installations. Subjects used the tether in 85% of LATCH installations and 48% of seatbelt installations. When used, it was used correctly in 45% of LATCH installations and 30% of seatbelt installations. The most common error in tether use was routing the tether strap over an adjustable head restraint, instead of routing underneath or removing the head restraint as directed by the vehicle manual prior to installation.

The location of the tether anchorage had a major effect on tether use. The tether was more likely to be used in both LATCH and seatbelt installations in sedan-type configurations where the tether anchorage is located on the package shelf. Tether use was lower when the anchorage was located on the vehicle seatback, where it is usually found in minivans and crossover vehicles. Subjects overwhelmingly indicated that the seatback location for the tether anchorages was more difficult to find in these three vehicles. As a result, subjects were twice as likely to use the vehicle manual in these vehicles compared to sedans. These findings support requirements for uniform marking of tether anchorages in vehicles.

The tether anchorage zone is defined in FMVSS 225 relative to an R-point determined using the H-point machine (SAE J826). FMVSS 225 also defines a wrap around distance that describes the path length between the tether anchorage and an estimated top of the child restraint. A problem reported from the field is that some tether anchorages in the most forward portions of this zone do not permit enough space for the tether hook and attachment hardware to allow adequate tightening of the tether. In the vehicle with a tether wrap around distance of 210 mm, all of the tether installations were tight. In the vehicle with the tether wrap around distance of 180 mm, less than 40% of the installations were tight, and tight installations could only be achieved by incorrectly routing the tether over the head restraint. Additional evaluations with 14 additional CRS indicated that 5 of 16 CRS cannot be tightened with a tether wrap around distance of 210 mm. Additional research is needed to determine a minimum tether wrap around distance in vehicles that is compatible with tether hardware and attachment location on CRS.

Subjects used the vehicle manual in 38% of installations and consulted the CRS manual in 88% of installations. Subjects gave different ratings for each vehicle as to whether the vehicle manual agreed with the CRS manual. Subjects also gave a variety of scores to each vehicle with regard to understanding the CRS installation instructions included in each vehicle manual. The two vehicle owner manuals with the shortest CRS sections, which also had the fewest diagrams, had the highest scores, while the manual with the longest CRS section (and the most diagrams) received the lowest rating on ease of comprehension.

The only vehicle feature noted in the subject questionnaires as making it harder to install the CRS was the head restraint. The two questions having the widest range of responses were the ease of finding the tether anchorage and understanding the vehicle manual. After performing one seatbelt installation and three LATCH installations, a preference for LATCH installation was expressed by 80% of subjects at the end of their session.

Unlike Task 1, no subjects withdrew from the study, and only one did not finish all four trials. In Task 2, dummy installation was much less complicated, because the harness height was already adjusted to fit the dummy. This seemed to reduce subjects' frustration levels, making them less likely to give up once they reached the CRS installation portion of the trial. In addition, installations were all forward-facing. In Task 1, although performance did not generally vary between forward-facing and rear-facing installations, rear-facing installations averaged twice as long to install. Finally, the two CRS selected for the current study had the highest rates of correct installation in Task 1.

The results of both Task 1 and Task 2 of this study indicate that the vehicle and CRS features recommended by experts in child passenger safety may not lead to correct performance by regular CRS users. This finding suggests that testing with non-expert volunteers should be performed to validate any recommendations by experts intended to improve ease of child restraint installation.

Introduction

Overview

This document reports on the second portion of a two-part study examining the effects of child restraint system (CRS) features, labels, and manuals and vehicle features on CRS installation errors and installation experiences. Results of Task 1 are reported separately (Klinich et al., 2010). The first phase of Task 1 compared volunteer installation experiences using 16 different CRS installed either forward-facing or rear-facing in a single vehicle. The second phase of Task 1 tested volunteer installation experiences using different modified labels and manuals for two CRS. In Task 2, documented in the current report, the focus was on the influence of vehicle features on seatbelt and LATCH installations.

Scope of the Problem

In the U.S., motor-vehicle crashes are the leading cause of death for children ages 3-18 (CDC 2007). In 2008, 1633 children under the age of 16 died and 220,000 were injured as a result of motor vehicle crashes (NHTSA, 2009 Early Edition of the 2009 Traffic Safety Facts Annual Report). The use of a child restraint system (CRS) is an effective countermeasure that reduces the likelihood of a child crash fatality by 71% for infants and 54% for toddlers, depending primarily on the restraint type and orientation (NHTSA, 2002). Misuse has been shown to markedly reduce the effectiveness of CRS (Carlsson et al., 1991; Decina et al., 1994; Johnston at al., 1994; Ruta et al., 1993; Bilston et al., 2007). Several studies have estimated CRS misuse rates ranging from 73 - 94% (Eby and Kostyniuk, 1999; Decina and Lococo 2005; Koppel and Charlton, 2009; Lane et al., 2000). Some of the variation in these estimates originates in the study designs, subject recruitment methods, and the level of inspection that is used to determine misuse.

Identified types of misuse observed in the field include:

- Loose vehicle seatbelt
- Loose harness straps
- Incorrect selection of CRS for height/weight/age of child
- Improper positioning of harness strap
- Improper harness belt routing
- Improper vehicle belt path
- Unbuckled vehicle seatbelt
- Harness not used
- Harness not buckled
- CRS broken or damaged
- Less than 80% of the CRS base footprint located on/above the vehicle seat
- Inappropriate CRS installation angle

- Incorrect CRS direction (i.e. using an infant seat forward-facing)
- Nonuse of a tether, when available and appropriate
- Incorrect tether strap tensioning
- Use of both LATCH (Lower Anchors and Tethers for Children) and seatbelt to secure a CRS
- Placement of a rear-facing (RF) CRS in front of an active frontal airbag.
- Improper harness retainer clip position
- Improper retainer clip threading
- Attachment of aftermarket products to the restraint

Loose CRS-to-vehicle installation and loose occupant restraint harness have been consistently observed across studies as the most frequent types of misuse. Lane (2000) surveyed the CRS installations for 109 subjects and found that 84% had between one and three installation errors, with an average of two errors per installation.

Several studies have identified factors correlated with misuse. Koppel and Charlton (2009) found statistically significant differences in misuse rates between CRS types, with forward-facing (FF) harness restraints having a higher observed level of misuse than rear-facing seats or belt positioning boosters. Eby and Kostyniuk (1999) found that higher levels of misuse were associated with: lower educational levels, situations where the driver was not the child's legal guardian, the number of times that the seat was moved/reinstalled into different vehicles, and with children who were younger and smaller. Lane et al. (2000) found a trend for less misuse with higher education attainment level and participation in a private insurance program.

The LATCH System and Misuse

The Lower Anchors and Tethers for Children (LATCH) system, consisting of two lower anchors and an anchorage for a tether attached to the top of the child restraint, was phased into the US market beginning in September 1999. Federal Motor Vehicle Safety Standard (FMVSS) 225, *Child Restraint Anchorage Systems*, specifies requirements for tether and lower anchorage system hardware to be installed in vehicles. The standard, which establishes requirements for the locations and strength of the anchorage systems, was first established in 1999 and was revised most recently in 2004. Two of the main reasons to implement LATCH were (1) to provide an easier method for CRS installation that would eliminate the need to know how to lock the seat belt system or use a locking clip and (2) to increase the use of top tethers to reduce forward head excursion, and in turn, head contacts during crash events.

In 2007, Decina and Lococo published the results of a misuse survey focusing specifically on LATCH. Their findings show that in situations where tether use was required and all the tether hardware was available, only 51% of those surveyed were using the top tether. Loose tethers were observed in 18% of cases and loose LATCH straps were seen in 30% of cases. In 20% of cases, CRS were installed using both

LATCH and seatbelt. This study highlighted that the availability of LATCH did not eliminate CRS misuse.

LATCH hardware has been implemented in the vehicle fleet such that it meets the requirements of FMVSS 225, which are summarized in Appendix A. However, a number of problems have been reported, including:

- Unclear labeling of top tether anchors
- Presence of other hardware (such as cargo tie downs) with a similar appearance that are mistakenly used as tether anchorages
- Some combinations of lower anchorages and CRS attachment hardware that are incompatible and prevent securement of the CRS using LATCH,
- Lower anchorage locations that are buried so deeply in the bight that they are inaccessible,
- Interference with use of an adjacent vehicle seating position when a CRS is installed with LATCH.

Issues regarding the shape of the vehicle seat and head restraint and how they interact with a CRS installed with LATCH have also been identified. A CRS installed with flexible LATCH may tip laterally an unacceptable amount because of the shape of the vehicle seat contour. Vehicle head restraint design changes stemming from the recent revision of FMVSS 202 (Head Restraints) may lead to interference between the head restraint and an installed CRS or the child restraint fixture (CRF). The test procedure for FMVSS 225 does not dictate the position of the head restraints when using the CRF or a maximum permissible force for CRF installation.

Child passenger safety advocates indicate a need for additional LATCH anchorages in vehicles, particularly in center seating positions (Stewart et al, 2009). In most cases, the width of vehicle seats prevents accommodation of three pairs of lower anchorages spaced 280 mm apart. Instead, some, but not all, vehicle manufacturers indicate that the inboard lower anchorages from two outboard seating positions can be used to secure a CRS in the center seating position. Installing additional lower anchorages in a seating row may block access to the lower anchorages or vehicle belts in adjacent seating positions.

The location requirements for tether and lower anchorages have led to some CRS installation problems in the field. In some cases, there has been a discrepancy between the length of tethers provided with the CRS and the allowable tether anchorage zone that may result in tethers that are too short to reach the tether anchorages. Some tether anchorages subject the tether hook to bending loading or require twisting of the tether to attach the hook. No procedure or requirement is available to ensure sufficient space between the lower anchorages and the CRS to allow adjustment of flexible attachment length.

Since FMVSS 225 was enacted, ISO has developed standardized symbols for marking lower and tether anchorages that might be beneficial to include in the U.S. standard. The requirements for positioning labels for lower anchorages in FMVSS 225 is focused on visibility of the symbols while the ISO labeling requires the symbol to be within a specified distance of the hardware location. In some cases a symbol that is close enough to the lower anchorages to meet the ISO requirement is not visible per FMVSS 225.

Although FMVSS 225 indicates that tether and lower anchorages must be accessible at all times, the level of accessibility varies. Some vehicles have tether anchorages that cannot be accessed when the CRS is installed on the vehicle seat. The wide variety of tether anchor locations in the cargo areas of SUVs and minivans can make them difficult to find, and lack of uniform labeling requirements make them difficult to distinguish from other vehicle structures such as cargo tie-down points. In some cases, the “tunnel” devices intended for improving lower anchorage accessibility may hinder access, especially when releasing the LATCH attachments.

Ease of Use Ratings

The current NHTSA Ease of Use (EOU) Rating system (NHTSA, 2006) was developed to identify CRS with features that enhance usability and to provide consumers with this information. NHTSA does not currently address vehicle features in its ease-of-use program.

In the field, some misuse modes arise from features of the vehicle environment and others result from interactions between specific CRS and vehicle combinations. A usability rating scheme under development in the ISO Child Restraints Group has rating forms for all three situations: the CRS, the vehicle, and specific combinations of the two (ISO, 2008). This rating system currently focuses on LATCH-type systems that are called ISOFIX systems in the international arena. Some of the vehicle features that are rated in the current version of the ISO document include the vehicle manual instructions on how to identify the number and location of seating positions available for CRS installation, the visibility and labeling of the LATCH anchors, the presence of other hardware elements that could be mistaken for LATCH anchors, the actions required for preparing the seating position for CRS installation, and conflicts between LATCH and seatbelts. Adding a vehicle ease-of-use rating to the current NHTSA evaluation could present another opportunity for reducing CRS installation errors.

Procedures and tools for assessing LATCH usability and compatibility with CRS have been drafted by the SAE Child Restraint Systems Subcommittee (SAE, 2009). Although the procedures have been evaluated by some subcommittee members, no widespread testing of the procedures has been conducted. Thus the procedures have not been validated to determine if their recommendations result in more usable LATCH anchorages that reduce errors in CRS installation. The SAE CRS committee has developed the following recommendations to improve LATCH usability: (SAE CRS Committee 2009)

1) The distance between tether anchorage and CRS must be large enough to allow tightening of the tether.
2) Tether routing devices must be sufficiently large to accommodate all types of tether hook and adjustment hardware.
3) Lower and tether anchorages should be visible or clearly marked by standard symbols.

4) The seat cushion contour should allow most of the base of the CRS to contact the seat cushion and permit placement of the CRS at reasonable lateral and pitch angle.
5) Components around the lower anchorages should not interfere with attachment of lower connectors.
6) The stiffness of the seat components near the lower connectors should not require excessive force to attach the lower connectors.
7) Lower anchorages should be close to the seating surface to permit good contact between the vehicle seat and the bottom of the CRS.
8) Visible lower anchorages are considered the easiest to use, because hidden anchors increase likelihood of incorrectly attaching to other hardware.
9) Using LATCH in a particular seating position should not affect use of seatbelts or LATCH in adjacent seating positions.
10) To allow use of rigid LATCH CRS connectors, each pair of lower anchorages must meet a collinearity specification.

A summary of the SAE tools and procedures that are included in the draft SAE recommended practice for assessing these points is included below.

1) At each seating position, completely engage the SAE child restraint fixture (CRF) specified in FMVSS 225 with the lower anchorages.
2) Install the CRF using rigid connectors. Measure the distance between the seat cushion and lower reference point on the CRF (maximum recommendation of 5 cm [2 in]). Measure the pitch angle of the CRF (recommendation of 15° +5°/-10°).
3) Measure the gap between the installed CRF base and the seat cushion at a point 400 mm forward of the rear reference point on the CRF. (Currently no recommendation.)
4) Place the CRF at each LATCH seating position with the CRF rigid connectors retracted. Measure the lateral angle of the CRF seat (recommendation of +/-5°).
5) Attach collinearity gauge shown in Figure 1 to ensure that the anchorages have been manufactured within an acceptable tolerance.

Figure 1. SAE tool for checking anchorage collinearity.

6) Measure the force required to attach the SAE tool shown in Figure 2 to each lower anchorage (recommendation less than 15 lb).

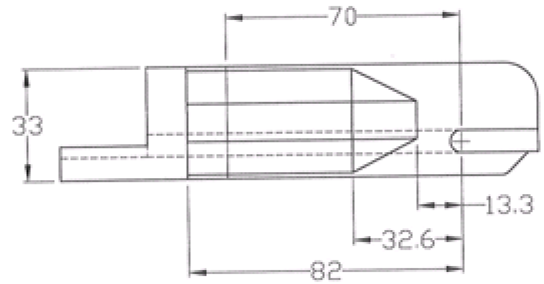


Figure 2. SAE tool for measuring force required to attach lower connector.

7) When 15 lb of force is applied to the tool shown in Figure 3 while it is attached to the lower anchorages, measure the angle relative to horizontal (recommendation is 75 degrees above horizontal).

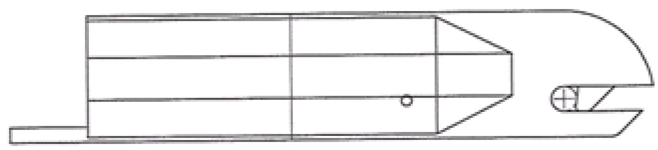


Figure 3. SAE tool for checking clearance around lower anchorages.

8) When attached to lower anchorage, rotate gauge shown in Figure 3 to make sure it does not contact any rigid structure (which would demonstrate potential for releasing a push-button LATCH connector).

9) Ensure that any tether routing guides are large enough to accommodate the SAE gauge shown in Figure 4.

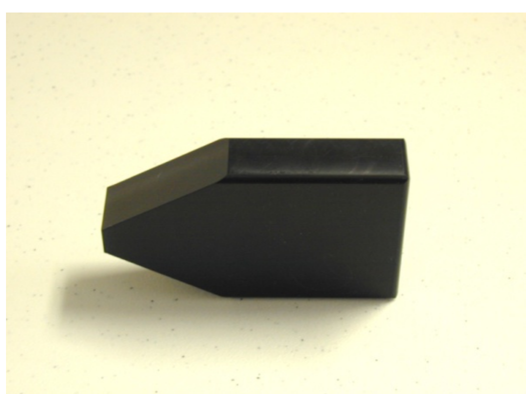


Figure 4. SAE tool to determine if any tether routing device provides sufficient clearance for tether hook and adjustment hardware.

Vehicle Manuals

An issue repeatedly identified as leading to misuse of CRS is the difficulty of understanding instructions and labels. A review of the literature on this topic is found in the companion report on Task 1 (Klinich et al., 2010). However, most research has focused on the labels and instructions provided with the CRS, and no researchers have studied the role of vehicle manuals on CRS installation.

As described earlier in this introduction, FMVSS 225 specifies requirements for vehicle manuals regarding use of the LATCH system. However, no other federal regulations specify requirements regarding CRS installation using the seatbelt. Information provided by vehicle manufacturers is voluntary, and the content varies widely.

One attempt to provide clear consumer information about CRS installation using LATCH is *The LATCH Manual* published by Safe Ride News (Stewart et al., 2009). It is a comprehensive reference guide published every other year that provides basic information for Child Passenger Safety technicians and consumers who want to use the LATCH system to secure a child restraint in their vehicle. The manual covers general CPS background information with a focus on LATCH and top tether best practices. It also provides a make and model guide to LATCH-related vehicle features and their recommended usage. One of the strengths of the publication is that it provides specific LATCH information that is difficult to obtain and is not always supplied in the vehicle or CRS owner's manual. For example, the LATCH manual gives specific part numbers for vehicle retrofit tether anchor kits and explicitly states the manufacturers' mass limit for use of LATCH to secure CRS.

Methods

Recruitment and Subject Selection

The recruitment process and target subject pool for Task 2 were the same as those used in Task 1. Subjects were primarily recruited through Internet advertisements on Craigslist and AnnArbor.com, the local online newspaper, as well as through online mailing lists of local elementary and high schools.

Thirty-two volunteers were recruited based on general education and CRS experience levels. Subjects were classified in a lower education level if they had not gone to college, and in the higher education level if they had graduated from college. Subjects were also classified by their child restraint installation experience as either "none" or "experienced." To be considered experienced, the subject had to have installed at least two different types of CRS in two different vehicles multiple times in the last five years. People who had completed the NHTSA CPS course or had attended a child seat check up event were disqualified from participation. The same subject recruiting script and consent form used in Task 1 (Klinich et al., 2010) were used in Task 2.

All testing conducted for this project was approved by a University of Michigan institutional review board (IRB) that reviews protocols of research programs involving human subjects.

CRS Selection

One CRS with each of the two common types of LATCH connectors (push-on and hook-on) was selected from the pool of 16 different CRS models used in Task 1 of the study. Also, because the focus of Task 2 is on the vehicle factors, two CRS that were relatively uncomplicated to install were selected.

Table 2 shows the average rate of correct installation among trials for four of the best-performing CRS from Task 1A. These two CRS with push-on connectors and two CRS with hook-on connectors had the highest average rate of correct installation among all these factors. These data suggested that the best candidate CRS for this study were the Signo and Triumph because they had higher average scores on installation tasks compared to the Boulevard and Scenera. Trial installations with these CRS in the proposed test vehicles indicated that they could be installed well with either LATCH or seatbelt, so they were selected for use in the remaining testing. To maintain consistent coding with Task 1, the Signo is labeled C6 and the Triumph C10. Pictures of these two CRS are shown in Figure 5.

Table 2. Percentage of correct installations: average Task 1A results for four CRS

	Connector type	1" test	Belt routing	Angle	LATCH correct	Harness slot	Harness snug	Mean
Signo	Push-button	43%	100%	100%	100%	29%	57%	72%
Boulevard	Push-button	63%	75%	88%	83%	50%	63%	70%
Triumph	Hook-on	29%	100%	86%	86%	57%	86%	74%
Scenera	Hook-on	29%	100%	71%	71%	43%	43%	60%

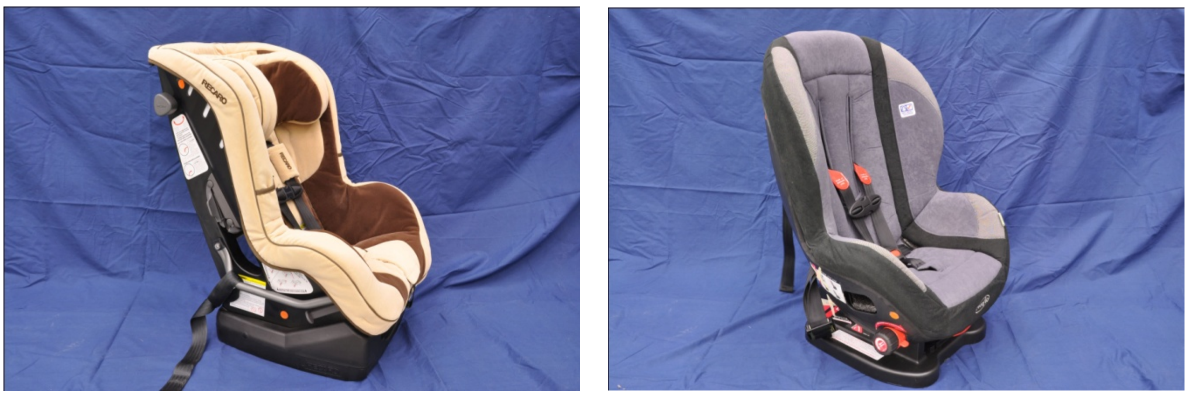


Figure 5. Recaro Signo (left) [C6]
and Evenflo Triumph (right) [C10] CRS used in Task 2 testing.

Vehicle Selection

Six vehicles were selected for testing. Ideally, for each factor under consideration, two vehicles should have a similar relevant feature. Each subject performed four installations in three of the test vehicles, which allowed subjects to perform two installs within a single vehicle (one seatbelt and one LATCH).

The factors considered for vehicle selection were prioritized based on input from NHTSA, recommended SAE practices for improving LATCH compatibility in vehicles, factors considered in the ISO vehicle assessment rating, and the researchers' experience as CPS technicians. When choosing the vehicles for testing, the goal was to find six vehicles with the following range of features, listed by highest priority:

1) Different lower anchorage locations, such as above seating surface, visible, buried
2) Different seat stiffness around the LATCH anchorage
3) Different seatbelt buckle characteristics, such as rigid and webbing and location relative to the bight
4) Protruding and non-protruding head restraints
5) Variable tether locations

The ability to rent a vehicle for the applicable test period while staying within the project budget was also considered. Other vehicle factors that may contribute to CRS installation were documented, but not necessarily used as a main factor in vehicle selection, including seat contour, seat stiffness, different manufacturers, covers over the lower anchorages, leather vs. fabric seats, number of available seating positions, method of locking seatbelt, cushion angle, and seatback angle.

Thirty vehicles were evaluated for consideration in the study. One measurement in the vehicles was the force required to engage the SAE tool shown in Figure 6 with the lower anchorages. The tool combines a generic LATCH connector shape with a digital force gauge. The SAE recommended practice for LATCH usability suggests that the measured force should be no more than 15 lb.

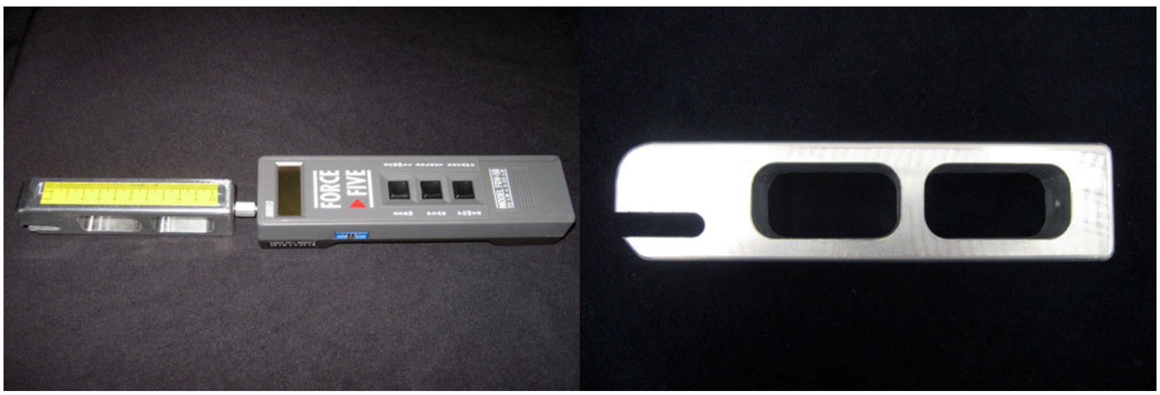


Figure 6. Tool to measure force required to engage lower anchorage (top view with force gauge on left and side view of connector portion on right).

Seatbelt factors include whether the buckle stalk is flexible or rigid, and the location of the belt anchor relative to the bight. The type of buckle stalk can potentially affect access to the lower anchorages in LATCH installations, and also affect the ability to route the seatbelt and get a tight seatbelt installation. Based on the researchers' experience, buckle locations forward of the bight can sometimes be more difficult to use with CRS installation than those located at the bight, because the belt geometry does not allow the CRS to be pulled back towards the vehicle seatback.

Table 2 shows the list of vehicles selected for this study, as well as a description of some key characteristics. Data for the vehicle used in Task 1 (2006 Pontiac G6) are also included and labeled vehicle G. The data shown are for the seating position the subjects were directed to use, which was the second row right for all vehicles except the Sienna, which was the third row right. Appendix B shows detailed photos of each vehicle used in testing. The locations of the lower anchorages and seat belts relative to the bight were qualitative assessments. For the measured forces, low corresponds to attachment forces of 2-13 lbf, medium 14-18 lbf, and high corresponds to 26-29 lbf.

Table 3. Characteristics of vehicles selected for study

Vehicle	Code	Lower Anchorage	Lower Anchorage Force	Head restraint Protrude?	Seat belt	Tether Location
Ford Flex	A	Buried at bight	High	No	Rigid, Forward	Back of seat
Honda Civic	B	Buried, bight above seating surface	Low	No	Webbing, Forward	Package Shelf
Toyota Sienna	C	Visible at bight	Low	Yes	Rigid, Bight	Back of seat
Ford Fusion	D	Buried at bight	Medium	Yes	Webbing, Forward	Package Shelf
Dodge Avenger	E	Buried, bight above seating surface	High	Yes	Webbing, Bight	Package Shelf
Chrysler Pacifica	F	Visible at bight	Medium	No	Rigid, Bight	Back of seat
Pontiac G6	G	Visible at bight	Medium	No	Webbing, Forward	Package shelf

Subjects performed installations in either vehicle group ABC or DEF. Each of these groups exposes the subject to three lower anchorage locations. For each pair of vehicles with the same lower anchorage position, the vehicles have different lower anchorage forces (high/medium, low/high, low/medium). The vehicles were selected so half had protruding head restraints and the other half did not, based qualitative assessment of protrusion. In addition, half have tether locations on the vehicle seatback and half were on the rear package shelf. For the seatbelt, half of the vehicles have the anchorage at the bight, with the other half forward of the bight. At least one vehicle in each group had a rigid seatbelt stalk, while the rest were anchored with flexible webbing.

For the purposes of designing the matrix, tether locations were classified as either on the package shelf or on the back of the seatback. The actual locations and implementations of the tether anchorages vary within these categories. While the main comparisons in analysis were between the two main categories of tether anchorages, possible effects of different tether locations/implementations were also considered. In a similar manner, the Civic and Avenger both have the bights located above the seating surface and are in one LATCH location category even though the heights above the seat differ. The potential effect of this was considered in analysis.

Test Setup

For each vehicle, the experimenter prepared the vehicle environment for testing by adjusting the rear head restraints to the lowest position and adjusting the front seats to their mid-track fore/aft location and adjusting to the seatback angle to the seatback recline one notch back from upright, pre-test position. The indoor testing area was arranged with the three vehicles in a semicircle so the subject could approach all three test vehicles from the right side. Both rear-side doors and the right-front door were left open throughout the session. In the one vehicle where testing was performed in the third row, the second-row seats were removed or folded flat.

Still cameras were used to record side and isometric views of each CRS installation. Exceptional or unusual installations were also photographed. A digital video camera was located on a tripod near the driver door to record installations in the right-rear seat. A wireless microphone placed in the vehicle enhanced sound recording. During subject recruitment, subjects were asked if they agreed to be videotaped, and none of them declined. The subjects were encouraged but not required to “think aloud” during the installation. The videos were used to check notable installations, but complete analysis of the videos was beyond the scope of the project.

The 18MO CRABI crash test dummy (ATD) was used for testing. The dummy was dressed in a sweatshirt and sweatpants and was placed in the CRS by the subjects for each installation. In Task 1, many subjects experienced frustration when trying to adjust and secure the ATD in the harness. To focus subjects’ effort on installing the CRS rather than securing the ATD in Task 2, the CRS harness was initially configured to accommodate the 18MO ATD, meaning the harness slot height was adjusted to the position closest to the shoulders, and the crotch strap was pre-positioned to fit the dummy. This approach is different from Task 1, where the subject had to configure the CRS to fit the ATD. Because the CRS was configured to fit the dummy, the only two child securement factors that were assessed were the harness snugness and whether it was buckled properly.

Each CRS was marked with the subject ID number, the trial number, the CRS code, the test vehicle code and the date for photographs. Optional padding and cupholders were removed from the CRS. However, the CRS was otherwise configured in its “out-of-the-box” state for the recline position, tether position, and LATCH belt position. The original labels and manuals for each CRS were used.

The experimenter prepared a test cart that contained potentially helpful materials available to the subject during the test session. The cart held the CRS instruction manuals, the test dummy and a flathead screwdriver. The vehicle manuals were stowed in their normal storage location in the vehicle. The subjects were told they could use the vehicle and CRS manuals, and the experimenter was allowed to help the subject find the vehicle manuals if needed and identify parts on the CRS.

Testing Sequence

Appendix C contains the script that was used during testing. If asked questions, the experimenter told the subject that the information could be found in the CRS and vehicle manuals. The experimenter helped the subject to find the vehicle manual if help was requested.

Because Task 1 did not identify any factors predicting whether subjects chose to use LATCH or seatbelt to install the CRS, each subject was assigned a method of installation for each trial. They were asked to install the CRS with the seatbelt in the first trial and to use LATCH for the remaining three trials. If the subject could not perform an installation with the directed method, they were asked to try to use the other method instead. For all test vehicles but the Sienna, subjects were asked to install the CRS in the right second-row seating position, because the vehicle was selected for the study based on the characteristics of the LATCH system in that seating position. For the Sienna, the subjects were directed to install the CRS in the right third-row position.

Because Task 1 did not find any difference in correct installation rates between forward-facing and rear-facing on key tasks such as obtaining a tight installation and routing the belt, the subjects were asked to perform all installations forward-facing. Choosing to use forward-facing installations for the test conditions meant that all trials should involve tether use. Focusing on one direction of installation also allowed more statistical power for assessing the vehicle factors.

Appendix C also contains the forms used to evaluate the CRS installation, which were revised slightly from Task 1 to clarify some items regarding how the subject locked the seatbelt. In addition, factors regarding child securement (harness slot position, chest clip height) were not documented. The methods of measuring CRS tightness and tether slack used in Task 1 were also used in Task 2. Definitions of each measure are also included in the Appendix.

Testing Forms

Appendix D contains post-test evaluation forms that were filled out by the subject. The first part of the subject form asks the subjects whether they agree or disagree with statements about installing the CRS. The second part asks them to rate the ease of different parts of the installation. The forms are modified slightly from those used in Task 1, partly to address more vehicle factors and partly to clarify points where subjects were confused in Task 1. For example, separate forms were prepared for LATCH and seatbelt installations, because subjects were often confused during Task 1 when using previous questionnaires (i.e., responding to questions about lower anchorages for seatbelt installations). If the subject had questions about terminology when filling in the form, such as “Is this the tether?” the experimenter identified the item for the subject. The subject filled out the form behind a screen so they could not see the experimenter assessing the CRS installation, but was allowed to come and look at the vehicle, CRS, labels, or instructions if they wanted to do so.

To gauge the subjects’ ability to identify LATCH hardware in the vehicle, the final part of the assessment asks the subject to indicate on a diagram of vehicle seating positions which ones can be used to install LATCH, which ones can be used for seatbelt installation, and which ones have a tether anchorage.

After the last installation, subjects were asked whether they found LATCH or seatbelt to be easier to use. In addition, they were asked to rate each vehicle installation on a scale of one to ten.

Test Matrix

Table 4 shows the test matrix for Task 2, based on a split plot design. Because more of the key vehicle selection factors are related to LATCH, the matrix is weighted towards more LATCH installations than seatbelt installations. Each subject was asked to install the CRS using the seatbelt in the first vehicle, then perform LATCH installations in the other two vehicles for the second and third installations, and perform a LATCH installation in the first vehicle for the fourth installation. Each subject performed two installations with each child restraint.

Vehicle Manual Assessment

The child restraint installation section of each vehicle manual was reviewed to generate potential predictor variables for data analysis. The readability of the CRS section of each manual was calculated using readability tools in Microsoft Word. The number of pages dedicated to CRS installation, as well as the number of diagrams in the CRS section, were also counted to describe each section.

Table 4. Test matrix *

	Subject	Installation order			
		First	Second	Third	Fourth
X0L	1	AS2	BL2	CL1	AL1
	2	BS2	CL2	AL1	BL1
	3	CS1	AL2	BL1	CL2
	4	AS1	BL2	CL1	AL2
	5	DS2	EL2	FL1	DL1
	6	ES2	FL2	DL1	EL1
	7	FS1	DL2	EL1	FL2
	8	DS1	EL2	FL1	DL2
X2L	1	CS2	AL2	BL1	CL1
	2	AS2	BL2	CL1	AL1
	3	BS1	CL2	AL1	BL2
	4	CS1	AL2	BL1	CL2
	5	DS2	EL2	FL1	DL1
	6	ES2	FL2	DL1	EL1
	7	FS1	DL2	EL1	FL2
	8	DS1	EL2	FL1	DL2
X0H	1	BS2	CL2	AL1	BL1
	2	CS2	AL2	BL1	CL1
	3	AS1	BL2	CL1	AL2
	4	BS1	CL2	AL1	BL2
	5	FS2	DL2	EL1	FL1
	6	DS2	EL2	FL1	DL1
	7	ES1	FL2	DL1	EL2
	8	FS1	DL2	EL1	FL2
X2H	1	AS2	BL2	CL1	AL1
	2	BS2	CL2	AL1	BL1
	3	CS1	AL2	BL1	CL2
	4	AS1	BL2	CL1	AL2
	5	ES2	FL2	DL1	EL1
	6	FS2	DL2	EL1	FL1
	7	DS1	EL2	FL1	DL2
	8	ES1	FL2	DL1	EL2

*ABCDEF=vehicles; L,S= LATCH/Seatbelt; 1,2=CRS

Data Analysis

Table 5 lists the variables that were considered as potential predictors in analysis. The analysis methods used in Task 1 were also used in Task 2. Prior to performing the main statistical analysis using linear mixed models and generalized linear mixed models, each dependent measure was reviewed using univariate analysis to identify the most relevant potential predictors for each dependent variable. In addition to the types of misuse documented for each installation, dependent variables included the responses from the subject assessment forms completed for each test session.

Table 5. Factors considered as predictors in analysis

Type of factor	Variable
Subject	Education CRS Experience Gender
Vehicle	Head restraint protrusion Seat contour Seat stiffness Distance from estimated H-point to base of head restraint Angle from estimated H-point to base of head restraint
Test Conditions	CRS Trial Attachment method (seatbelt/LATCH/both)
Lower Anchorage	Visible/buried At or above seating surface Depth into bight Attachment force (low, medium, high)
Tether	Overall location (package shelf or back of seat) Approximate wrap distance Design style (under door, visible, hidden)
Seatbelt	Buckle stalk type (webbing/rigid) Buckle location (at or forward of bight) Locking method (retractor or latchplate)
Vehicle Manual	Grade Level/Reading Ease # diagrams in CRS section # pages in CRS section

Results

Installation Assessment

Overview

Table 6 summarizes different installation factors and the predictor variables associated with each. More details about each factor are found in the following sections.

Table 6. Summary of CRS and subject factors that affect installation

	Percentage Correct	Predictors	F-test	p-value
Installation tightness (1" test)	67%	LA location (above seating surface > bight)	F(1,30)=15.12	0.0005
		Buckle location (seatbelt only; bight> forward)	F(1,30)=5.65	0.0241
		CRS x installation method (C6>C10 for LATCH, C10>C6 for belt)	F(1, 94.44)=5.04	0.0271
Lower anchorages attached correctly	90%	LA attachment force (low, med > high)	F(2,55)=5.84	0.0050
		LA visibility (visible > hidden)	F(1,56)=4.38	0.0409
Tether attached correctly	30%	TA location (SB>PS)	F(1,80)=10.27	0.0019
		Installation method (LATCH > seatbelt)	F(1,80)=21.86	<0.0001
		HR fore-aft location (RW>FW)	F(4,80)=3.26	0.0157
Tether tight	82%	Installation method (LATCH > seatbelt)	F(1,92.73)=29.66	<0.0001
		HR fore-aft location (FW>RW)	F(4,75.03)=2.15	0.0833
		Tether location (SB>PS)	F(1,39.1)=4.87	0.0332
Seatbelt locked	50%	Buckle location (at bight>forward)	F(1,29.38)=8.65	0.0063
Installation time	NA	Trial (1>2>3>4)	F(1,94.7)=44.77	<0.0001
		Use of vehicle manual (use>nonuse)	F(1,22.1)=20.31	0.0002
Use vehicle manual	38%	TA location (SB>PS)	F(1,31)=10.58	0.0028
Use CRS manual	88%	CRS experience (inexperienced > experienced)	F(1,32.13)=5.94	0.0205

* LA = lower anchorage; TA = tether anchorage; HR = head restraint; SB=seatback; PS=package shelf; FW=forward; RW=rearward; C6=Recaro Signo; C10=Evenflo Triumph.

CRS installation tightness

The percentage of installations passing the 1" tightness test is shown in Figure 7 for each education/experience group. Neither subject CRS experience level nor subject education level had a statistically significant affect on installation tightness.

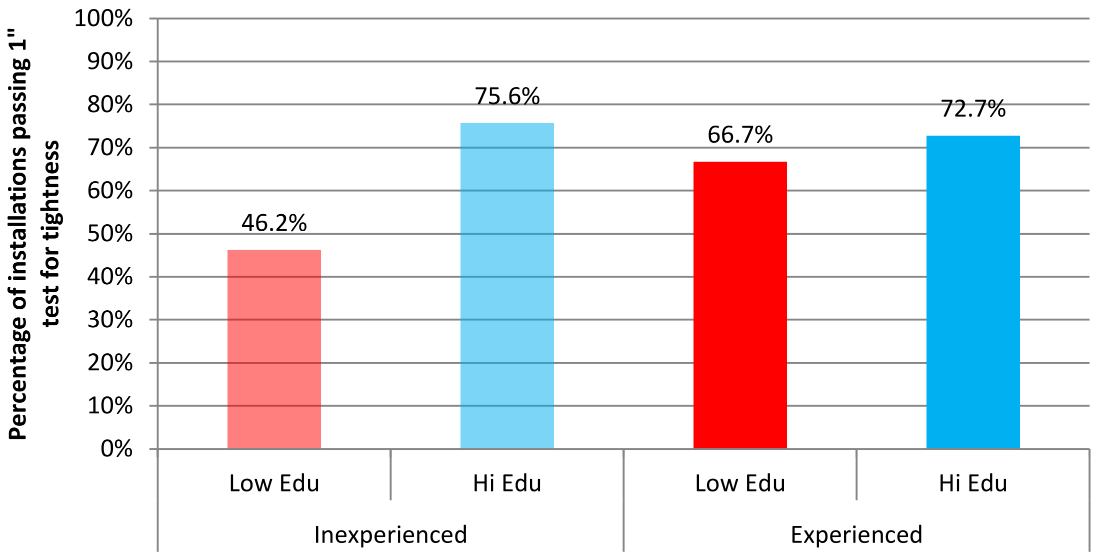


Figure 7. Percentage of installations passing 1" tightness test by subject education and experience.

The rate of tight installation is shown separately for LATCH and seatbelt installations in the subsequent graphs as a function of different vehicle features. Figure 8 shows the rates for vehicles where the lower anchorage location is above the seating surface compared to vehicles where the lower anchorage is at the seat bight located at the intersection of the vehicle seat cushion and seatback. Lower anchorage location was a significant predictor of installation tightness for both LATCH and seatbelt installations [$F(1,30)=15.17$; $p=0.0005$]. Since lower anchorage location would not be expected to be associated with the tightness of seatbelt installations, this suggests that the shape of vehicle seats which result in the lower anchorage being positioned above the seating surface is likely responsible for the higher rates of tight installation. The two vehicles with the lower anchorages above the seating surface have a bightline waterfall feature as shown in Figure 9.

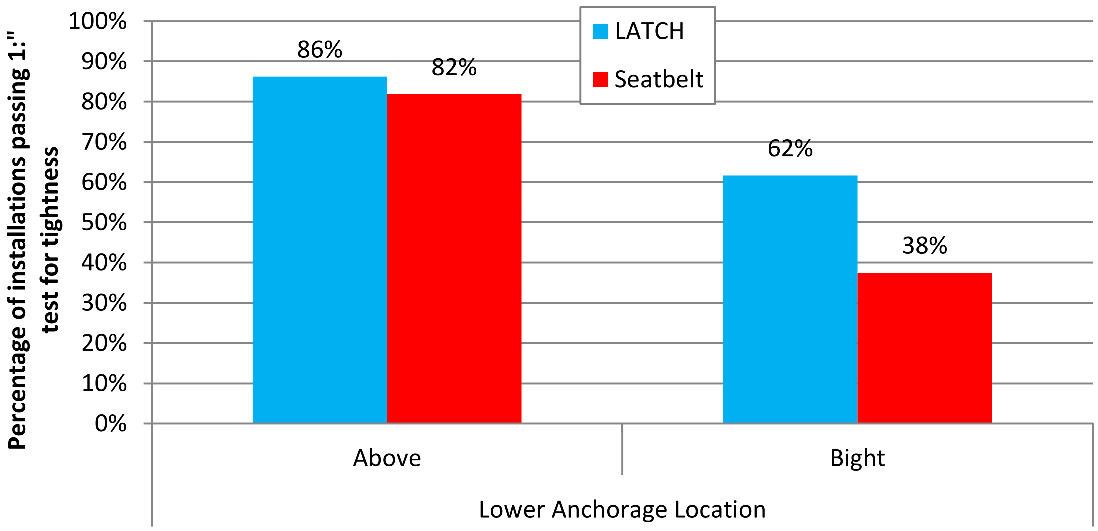


Figure 8. Percentages of installations passing 1" tightness test for LATCH and seatbelt installations by lower anchorage location.

Figure 9. Illustration of vehicle seats with a bightline waterfall with vertical lower anchorage locations indicated.

The percentage of tight installations in relation to the lower anchorage force (see Table 3) required to attach the lower connectors is illustrated in Figure 10. The difference in tight installation rates did not vary significantly with the amount of force required to attach the lower connectors. This is expected for seatbelt installations (which should have no dependence on force required to attach the LATCH belt), but is somewhat unexpected for the LATCH installations, as the SAE recommended practice recommends a force of 15 lb or less to attach the LATCH connectors, which corresponds to the low force category.

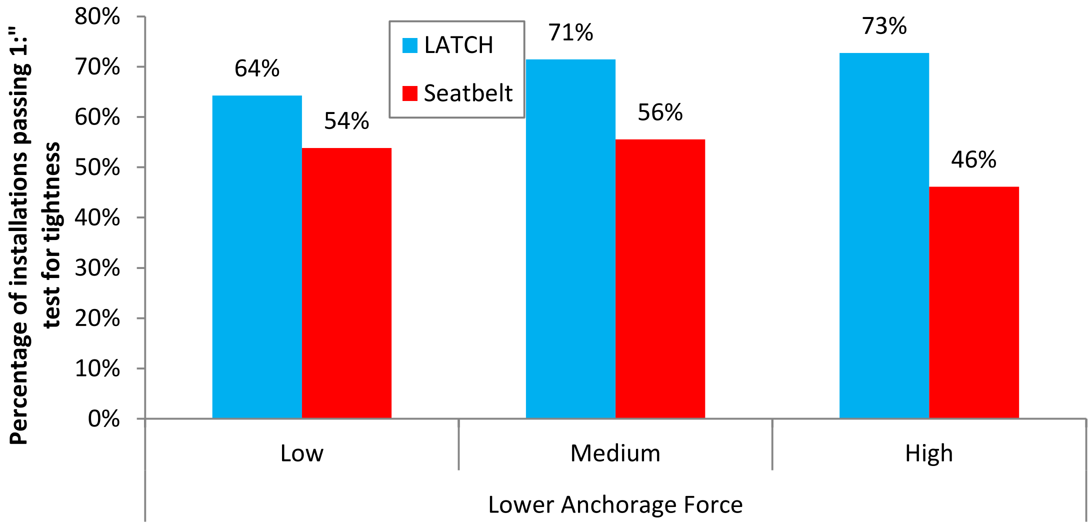


Figure 10. Percentages of installations passing 1" tightness test for LATCH and seatbelt installations by lower anchorage force.

The rates of correct installation according to the depth of the lower anchorage placement within the vehicle seat bight are shown in Figure 11. Vehicles with the deepest lower anchorage locations (4-6 cm) had slightly higher rates of tight installation compared to those that were visible (0-2 cm) or slightly buried within the bight (2-4 cm). However, these differences were not statistically significant once other factors are included in the model.

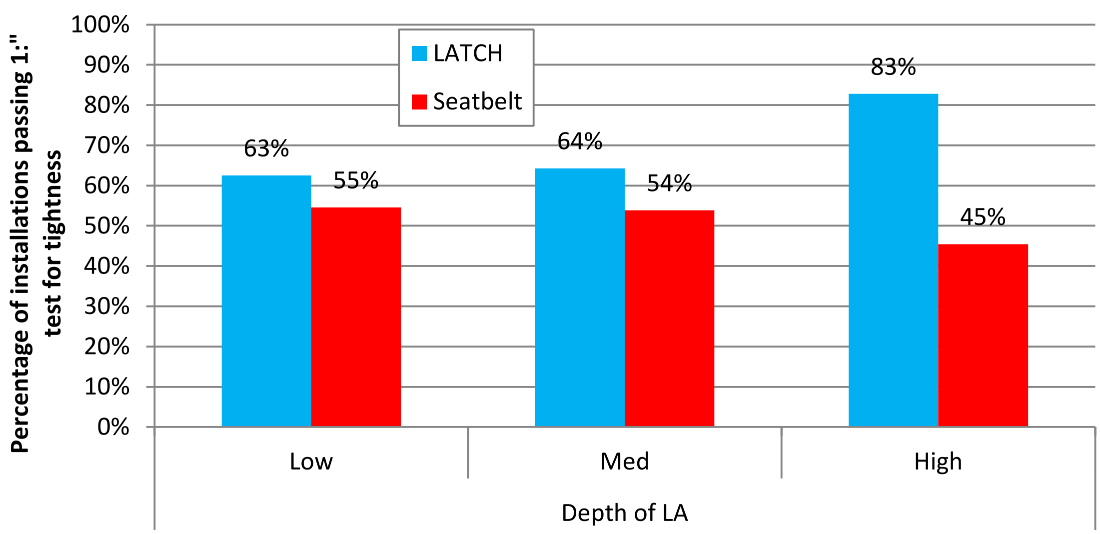


Figure 11. Percentages of installations passing 1" tightness test for LATCH and seatbelt installations by lower anchorage location depth within the bight.

The type of buckle stalk (webbing or rigid) did not affect installation tightness. However, the rate of tight installation according to the location of the seatbelt buckle (either at or forward of the bight) is shown in Figure 12. Tight installation rates were higher for seatbelt installation when the buckle is located at the bight, but were similar for LATCH installation [F(1,30)=5.65; p=0.0241]. This suggests that seatbelt locations do not interfere with LATCH installations, but that tight seatbelt installations are more likely when the belt buckle is closer to the bight.

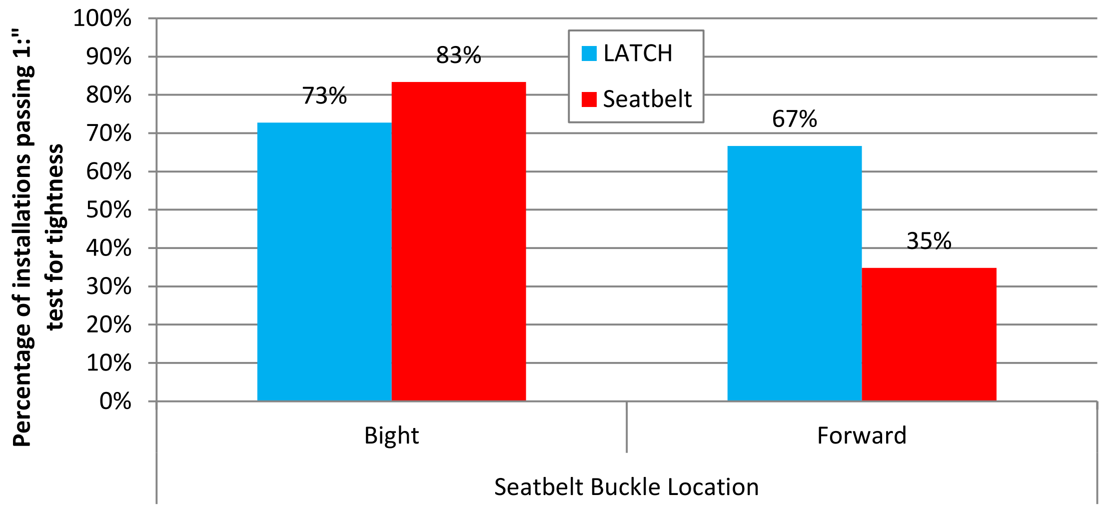


Figure 12. Percentages of installations passing 1" tightness test for LATCH and seatbelt installations by seatbelt buckle location.

Rates of tight installation varied with CRS and the installation method [F(1, 94.44)=5.04; p=0.0271]. As shown in Figure 13, CRS C10 had similar rates of tight installation for LATCH and seatbelt installations, while CRS C6 had a higher rate of tight installation with LATCH compared to seatbelt. Side views of each CRS are shown in Figure 14. C10 has the same belt path for both the seatbelt and LATCH. C6 has different belt paths, with the path for the vehicle belt higher than the LATCH belt path.

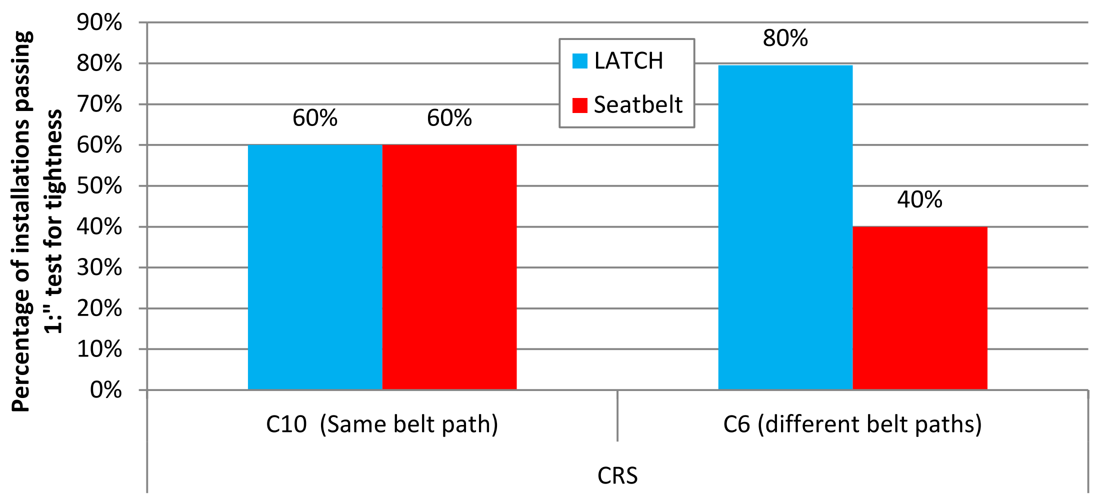


Figure 13. Percentages of installations passing 1" tightness test for LATCH and seatbelt installations by CRS model.

Figure 14. Side views of C10 (left) and C6 (right).

Lower anchorages

Overall, the lower connectors were attached correctly to the lower anchorages in 90% of LATCH installations. Correct attachment is defined as appropriately attaching the CRS hardware to the correct vehicle hardware in the correct orientation. As shown in Figure 15, there are slight differences in correct use of the LATCH belt associated with lower anchorage force. Rates of correct LATCH belt attachment were higher when the force required to attach the anchorages was in the low or medium range compared to the high range [$F(2,55)=5.84$; $p=0.005$]. In addition, when the lower anchorages were visible, the LATCH belt was correctly attached in all cases, whereas it was attached correctly in 88% of installations where the lower anchorage was buried within the bight [$F(1,56)=4.38$; $p=0.0409$].

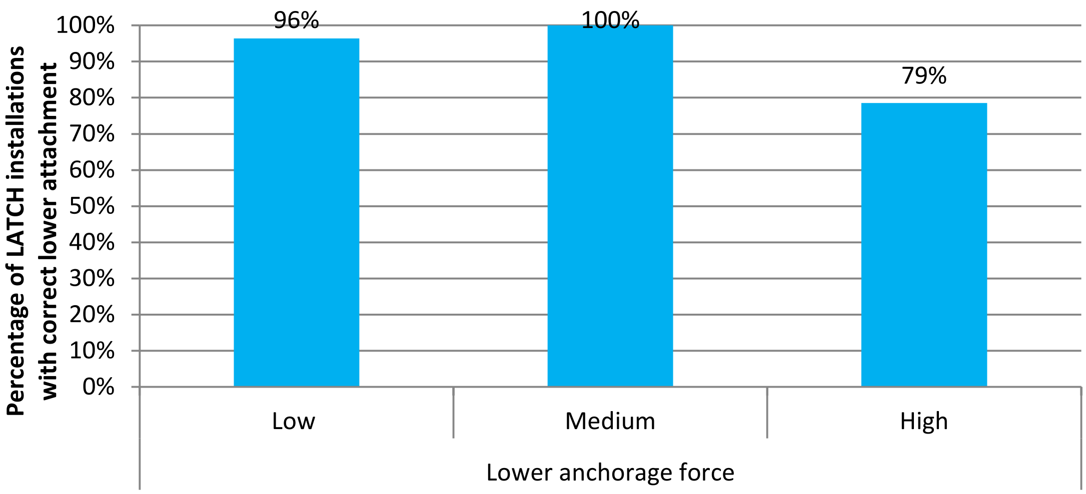


Figure 15. Percentage of LATCH installs with correct lower attachment by lower anchorage force

The rate of correctly attaching the CRS to the lower anchorages also varied slightly with the model of the CRS, although results were not statistically different. C10, which has a hook-type LATCH belt connector, was correctly used 89% of the time. In comparison, C6, which has a push-on LATCH belt connector, was attached correctly 95% of the time.

Tether

Tether use was considered correct if the subject used the correct anchorage, attached the hook correctly, and routed the tether relative to the head restraint as directed by the vehicle and child restraint manuals. The tightness of the tether was evaluated separately because attachment and tightening can be considered separate installation steps.

Overall, 30% of installations used the tether correctly, 44% used it incorrectly, and 26% did not use the tether at all. The percentage of installations where the tether is used correctly is shown in Figure 16 for each education/experience group. Although the higher education, CRS-experienced subject group had the highest rates of correct tether use, subject education and experience were not significant predictors.

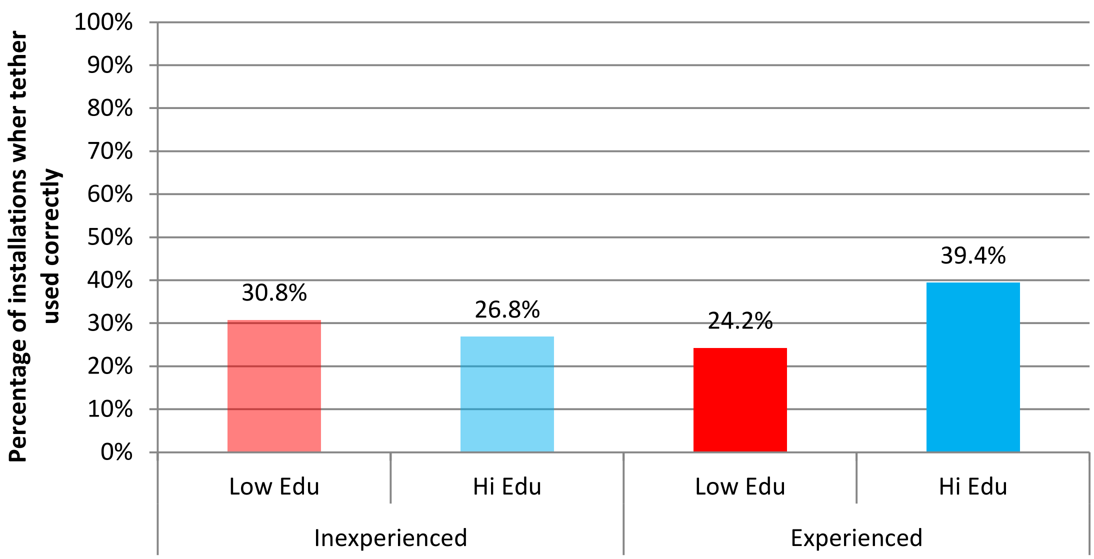


Figure 16. Percentage of installations where tether is used correctly by subject education and experience.

Figure 17 shows the percentage of installations where the tether was tight, given that the tether was used, for each subject education/experience group. The inexperienced subjects were slightly more likely to tighten the tether appropriately than the subjects with CRS experience.

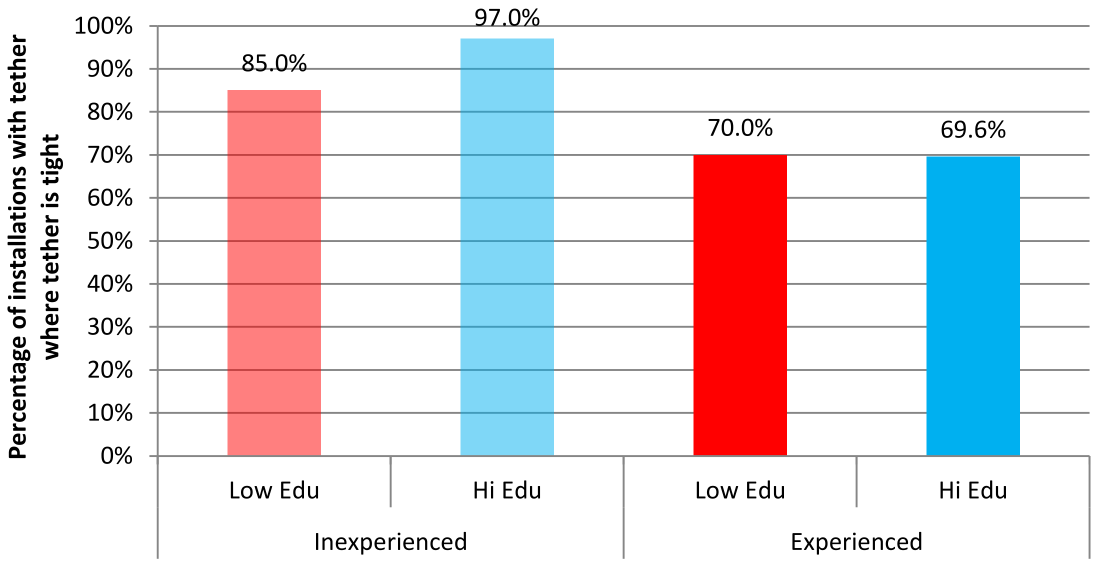


Figure 17. Percentage of tether installs where tether is tight by subject education and CRS experience.

Tether use according to the installation method and location of the tether anchorage are shown in Figure 18. This plot shows the percentage of installations where the tether was used correctly, the tether was used incorrectly, and the tether was not used. Overall, subjects were more likely to use the tether with LATCH installations compared to seatbelt installations [$F(1,80)=21.86$; $p=<0.0001$]. They were also more likely to use the tether in sedans (where the tether anchorage is located on the package shelf and easier to see from the point of installation) than in minivans/crossover vehicles (where the tether anchorage is located on the seatback). However, they were more likely to use the tether correctly when the tether anchorage location was on the seatback rather than the package shelf [$F(1,80)=10.27$; $p=0.0019$]. The most common error in tether use was routing the tether over the top of the head restraint, rather than routing it underneath or removing the head restraint as directed by the vehicle user manual. When used, tethers were more likely to be tight in LATCH installations compared to seatbelt installations [83% vs. 73%, $F(1,92.73)=29.66$, $p<0.0001$]. (The denominator for this percentage excludes conditions where the tether was not used).

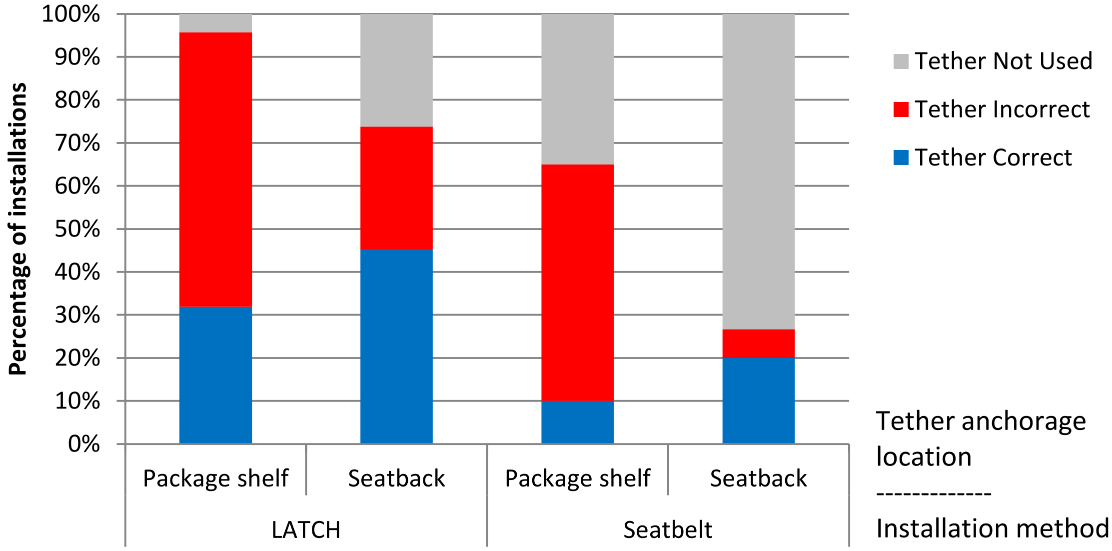


Figure 18. Percentage of installations according to tether use by installation method and tether anchorage location.

The vehicles tested were categorized qualitatively according to whether the head restraint was more forward or more rearward. Vehicles with the base of the head restraint more rearward had a higher rate of correct tether use than those when the base of the head restraint was more forward, in both LATCH and seatbelt installations [$F(4,80)=3.26$; $p=0.0157$]. However, as shown in Figure 20, the rate of tight installation when the tether was used was marginally higher for the vehicles when the base of the head restraint was more forward [$F(4,75.03)=2.15$, $p=0.0833$].

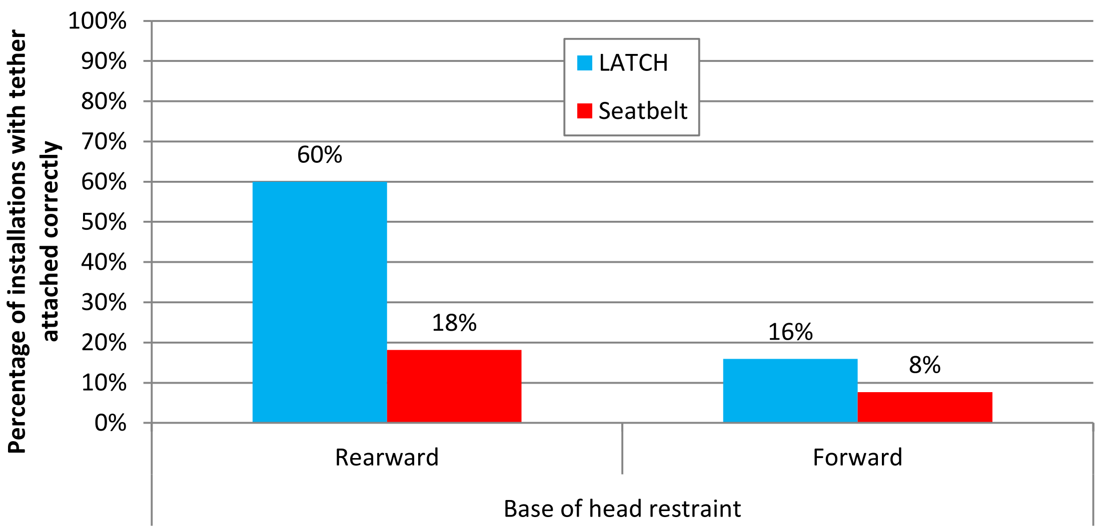


Figure 19. Percentage of installations where tether is attached correctly by fore-aft location of base of head restraint.

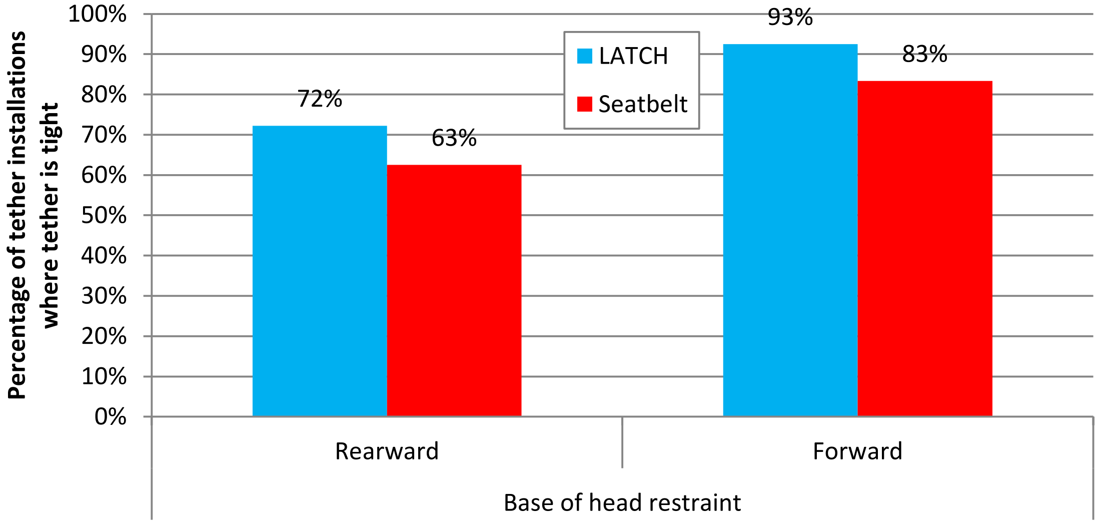


Figure 20. Percentage of installations using tether where tether is tight by fore-aft location of base of head restraint.

When the tether was used, it was tight in 76% of installations when the tether anchorage was located on the package shelf, and in 86% of installations when the tether anchorage was located on the seatback [$F(1, 39.1)=4.87$, $p=0.0332$]. Examination of the percentage of tether installations where the tether is tight vs. the tether wrap around distance as shown in Figure 21 helps explain why this is the case. The tether wrap around distance was measured relative to an approximate R-point, with the tether routed relative to the head restraint as directed by the vehicle manual. The lowest rates are found for the vehicle with a wrap around distance of 185 mm. The 100% rate of tight tether installation for the vehicle with a wrap around distance of 210 mm indicates that the threshold for the minimum required distance for achieving a tight tether installation may lie somewhere between these two values. As a check to determine how much the minimum wrap around distance depends on the CRS used, the fourteen other CRS used in Task 1 were installed using LATCH in the vehicle with the wrap around distance of 210 mm. Overall, 11 out of 16 CRS tethers were able to be tightened with this wrap around distance.

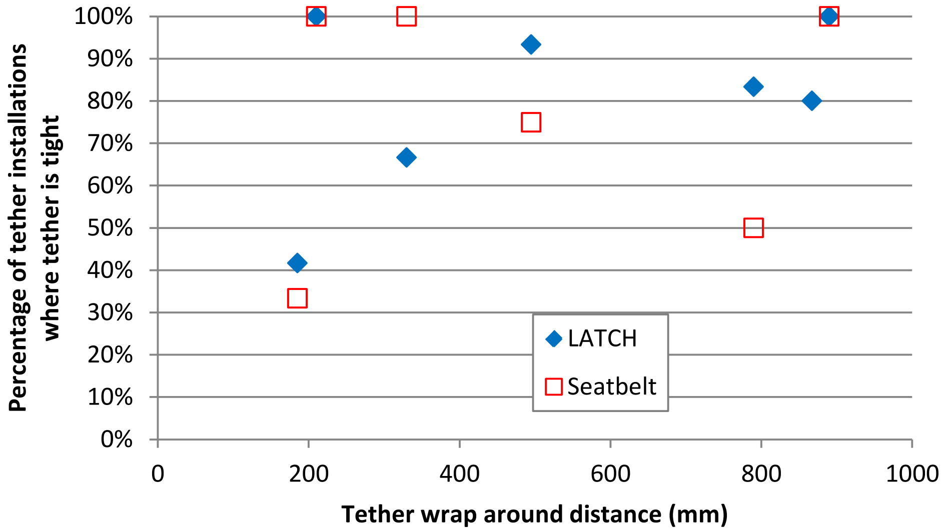


Figure 21. Percentage of tether installations where tether is tight vs. tether wrap around distance.

Seatbelt installations

Overall, subjects locked the seatbelt in 49% of seatbelt installations, either by using the lockoffs on the CRS, switching the retractor to locking mode, or using a locking latchplate. Figure 22 shows the percentage of seatbelt installations where the subjects locked the seatbelt by subject experience and education levels. Education level made a difference with experienced subjects but not inexperienced subjects.

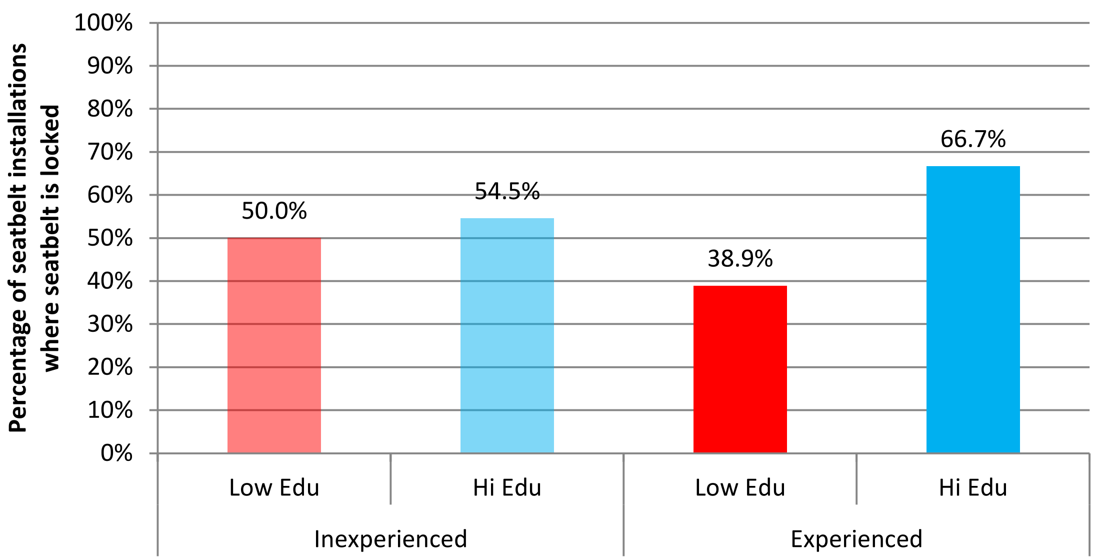


Figure 22. Percentage of seatbelt installations where the seatbelt is locked by subject experience and education level.

As shown in Figure 23, subjects more often locked the seatbelt in conditions where the buckle was located near the seat bight rather than more forward on the seat bench [$F(1,29.38)=8.65$; $p=0.0063$)]. In addition, rates of locking the seatbelt were slightly higher with CRS C6 than C10 (53% vs. 45%), probably because C6 is equipped with belt lockoffs. However, these rates were not statistically different.

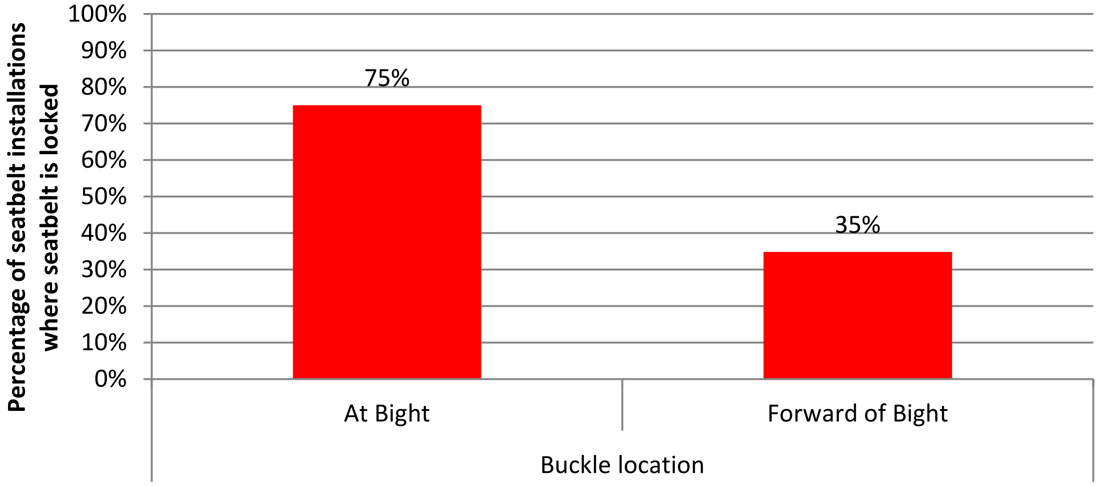


Figure 23. Percentage of seatbelt installations where the seatbelt is locked by buckle location.

One vehicle had a locking latchplate (where little or no action is required by the installer to lock the seatbelt) and the belt was locked 100% of the time when seatbelt installations were performed in this vehicle (n=4). When the vehicle had a switchable retractor, seatbelts were locked in 42% of seatbelt installations, likely because this type of locking mechanism requires the installer to take steps to change the seatbelt into the locked usage mode. Because of the small number of cases and the strong differences from seatbelt location, the differences in locking mechanism are not statistically significant.

Another factor assessed was whether the subjects locked the seatbelt as they were directed to do so by the instructions, which occurred in 13 out of 15 cases. For the two cases where the subject used an alternate locking method to the one suggested, one subject used the locking clip, and in the other case, the subject did not use the lockoffs provided on the CRS.

In designing the study, half of the selected vehicles had webbing-mounted buckles, while the other half had rigid buckle stalks. The type of buckle stalk did not affect the quality of the CRS installations.

Manual use

Subjects consulted the vehicle manual in 38% of installations. Subjects used the vehicle manual but not the CRS manual in only two trials. The percentage of installations where the subject used the vehicle manual is shown in Figure 24 according to subject experience and education level. Experienced, low education subjects were less likely to use the vehicle manual than subjects in the other categories, but there were no significant differences with subject education or CRS experience.

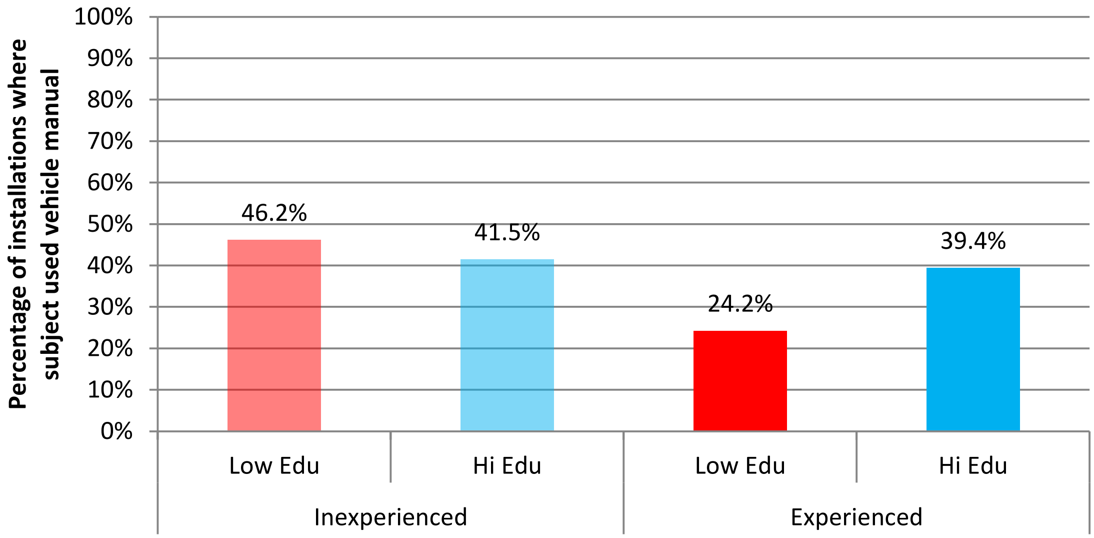


Figure 24. Percentage of installations in which subject used vehicle manual by subject education and experience.

Only one vehicle factor had a significant effect on whether subjects used the vehicle manual. When the tether anchorage was located on the package shelf, 25% of subjects consulted the vehicle manual. In contrast, when the tether anchorage was located on the seatback, 52% of subjects used the vehicle manual [$F(1,31)=10.58$; $p=0.0028$].

Overall, subjects consulted the child restraint manual in 88% of installations. Figure 25 shows the percentages of installations where the subject used the CRS manual by subject education and experience. Experienced subjects, particularly those with lower education, were less likely to use the child restraint manual [$F(1,32.13)=5.94$; $p=0.0205$]. No other vehicle factors made it more likely for subjects to use the child restraint manual.

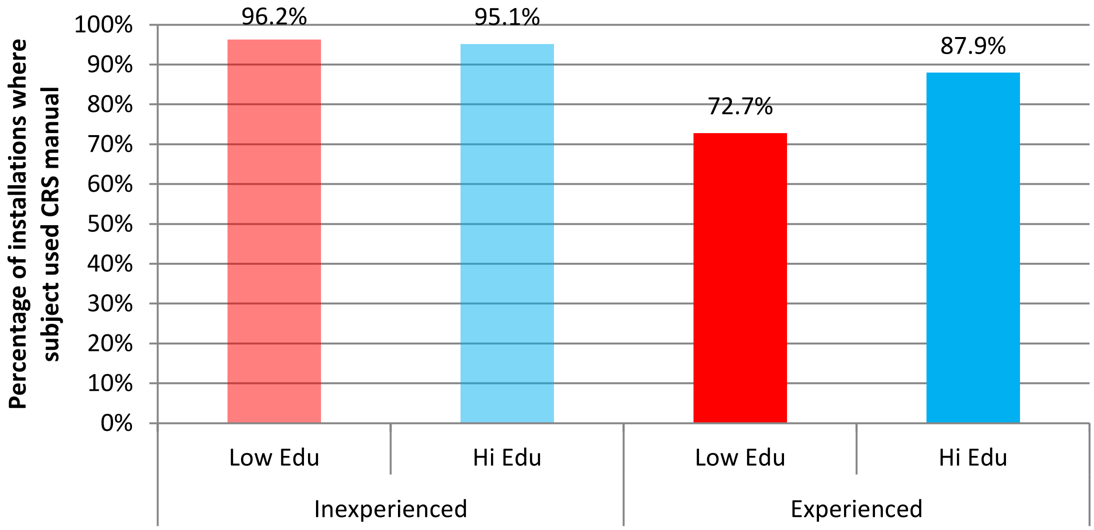


Figure 25. Percentage of installations in which subject used CRS manual by subject education and experience.

Securement factors

The CRS harness was correctly buckled around the dummy in 91% of trials. No potential predictors were significantly associated with this performance measure.

Subjects were able to achieve a snug harness in 70% of installations. The distribution of snug harnesses by subject education and experience is shown in Figure 26. The differences between subject groups were not statistically significant.

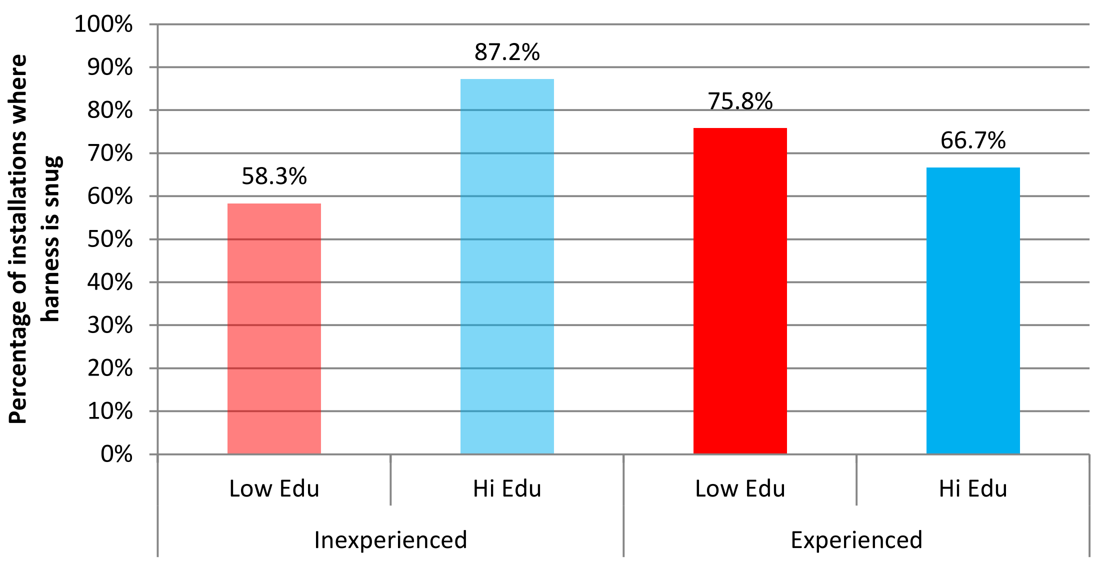


Figure 26. Percentage of installations where harness is snug by subject experience and education level.

No vehicle factors predicted the rate of harness snugness. However, as shown in Figure 27, a slight correlation was observed between the rate of tight installation and the rate of snug harness [F(1, 121.5)= 13.82; p=0.0003]. This trend could be associated with the skills and effort of the subjects, but it could also suggest that the subjects may try harder to correctly secure the dummy if they have not become overly frustrated during the CRS installation. In this phase of testing, the adjustments needed to fit the harness to the ATD, such as routing the harness through the correct slots in the CRS shell, were properly adjusted before the installation trial began. This eliminated additional steps needed by the subjects and likely contributed to the shorter installation times and higher incidence of correctly snugged harness.

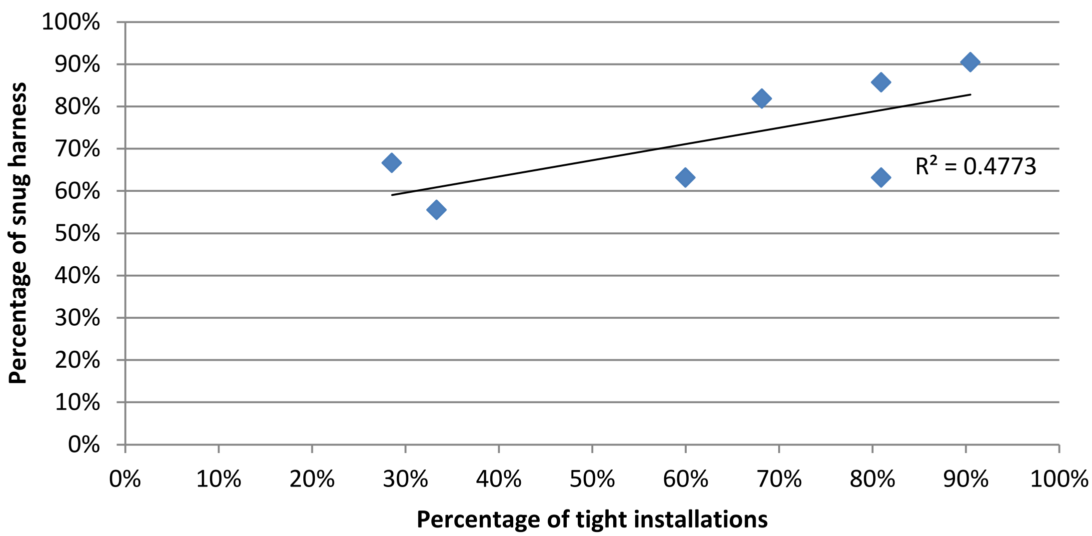


Figure 27. Percentage of installations where harness is snug vs. percentage of tight installations for each vehicle.

Subject installation time

In this phase of testing, none of the subjects withdrew from the study, and only one subject did not complete all four installations. The average time of installation is shown in Figure 28, showing that subjects improved their installation time with each trial [F(1,94.7)=44.77; p<0.0001].

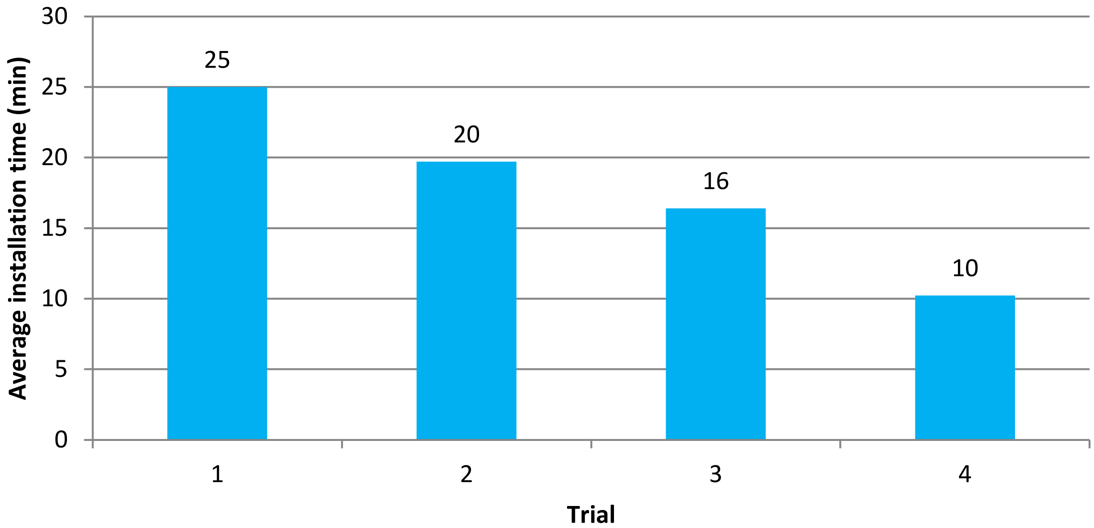


Figure 28. Average installation time by trial.

Average installation times were shorter for LATCH (16 minutes) compared to seatbelt installations (23 minutes), but this likely results from most subjects performing seatbelt installations first. Use of vehicle manuals also affected mean installation times. Subjects who used the vehicle manual averaged installation times of 23 minutes vs. 15 minutes for those who did not [$F(1,22.1)=20.31$, $p=0.0002$]. Subjects who used the CRS manual averaged 19 minutes, vs. 9 minutes for those who did not, but this difference is not statistically significant once effects of trial and vehicle manual use are considered. (Subjects used the vehicle manual but not the CRS manual in only two trials).

The experimenter's qualitative assessment of subject performance was compared to testing in Task 1. Subjects in Task 2 exhibited less frustration than those in Task 1, probably because all of the installations were performed forward-facing and the harness height was already adjusted to fit the dummy.

Subject Questionnaires

Subject ratings of installations

Subjects filled out an evaluation form following each CRS installation. Mean values of subject assessments were calculated for each vehicle, and ANOVA tests were performed to determine if there were significant differences in subject assessments between vehicles. Mean results for the first set of questions are shown in Figure 29 for the questions where the mean values did not vary with vehicle type. Subjects did not think that the vehicle seat shape, the vehicle seat stiffness, or the seatbelt buckles caused a problem during installation. They also believed that they attached the child seat to the vehicle correctly, and what they did during testing is similar to what they would do at home.

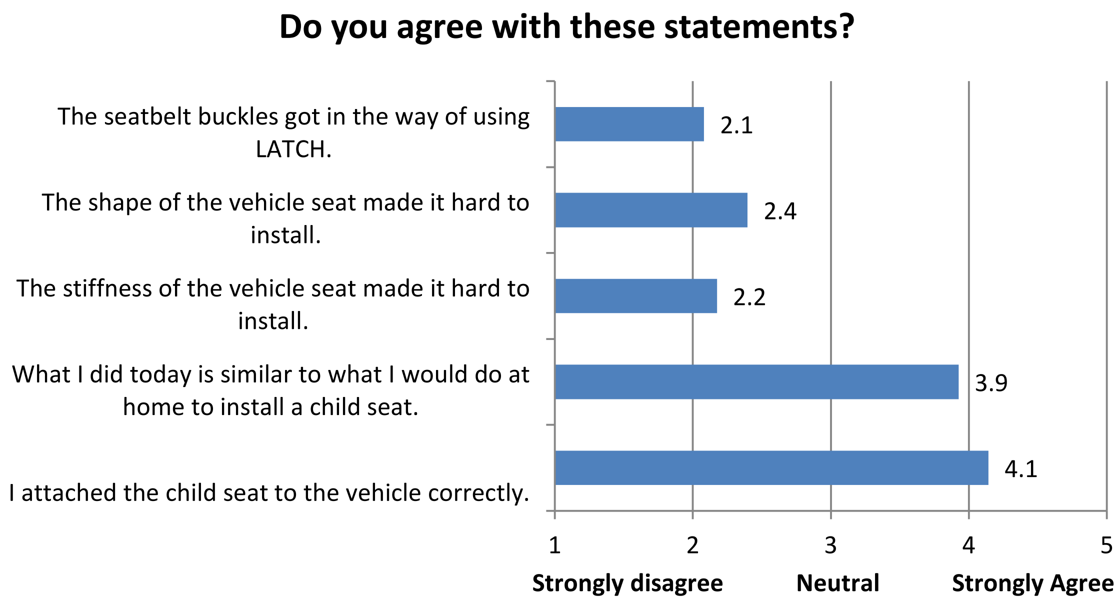


Figure 29. Subject assessments that did not vary with vehicle type.

As shown in Figure 30, when the subject asked whether the vehicle manual matched the CRS manual, results were marginally different among vehicles (p=0.054). Different colors represent different manufacturers. Mean results ranged from neutral to positive.

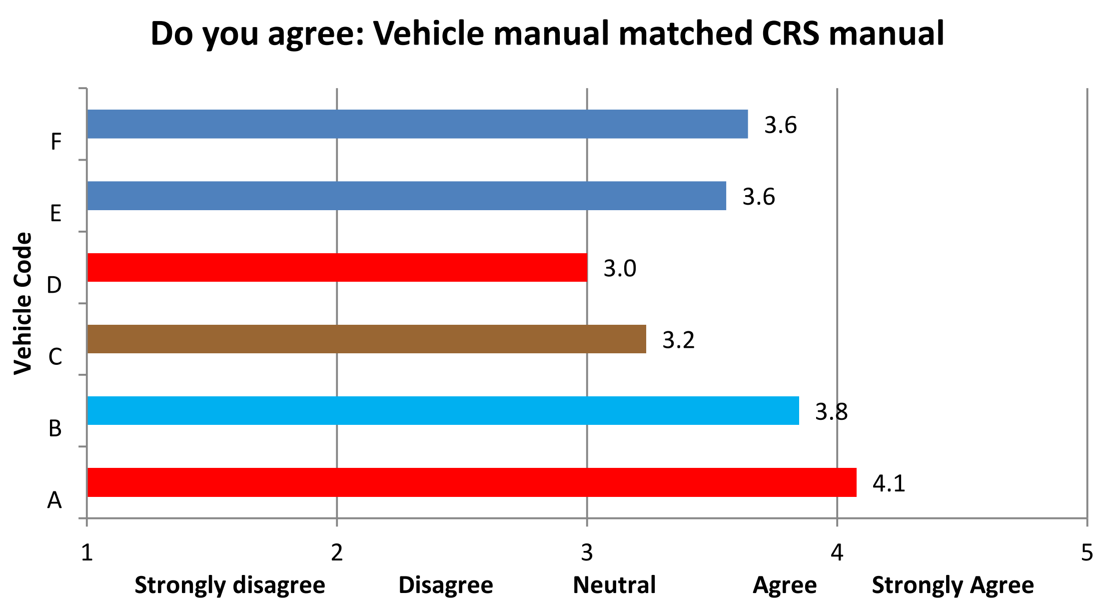


Figure 30. Mean subject rating of whether vehicle manual matched CRS manual by vehicle (each color represents a manufacturer).

Subjects also assessed whether they thought the head restraint on the vehicle seat made it hard to install the CRS, as shown in Figure 31 (p=0.006). Vehicle E, which subjects considered to be the most challenging in terms of the interaction with the head restraint during CRS installation, has a fixed head restraint.

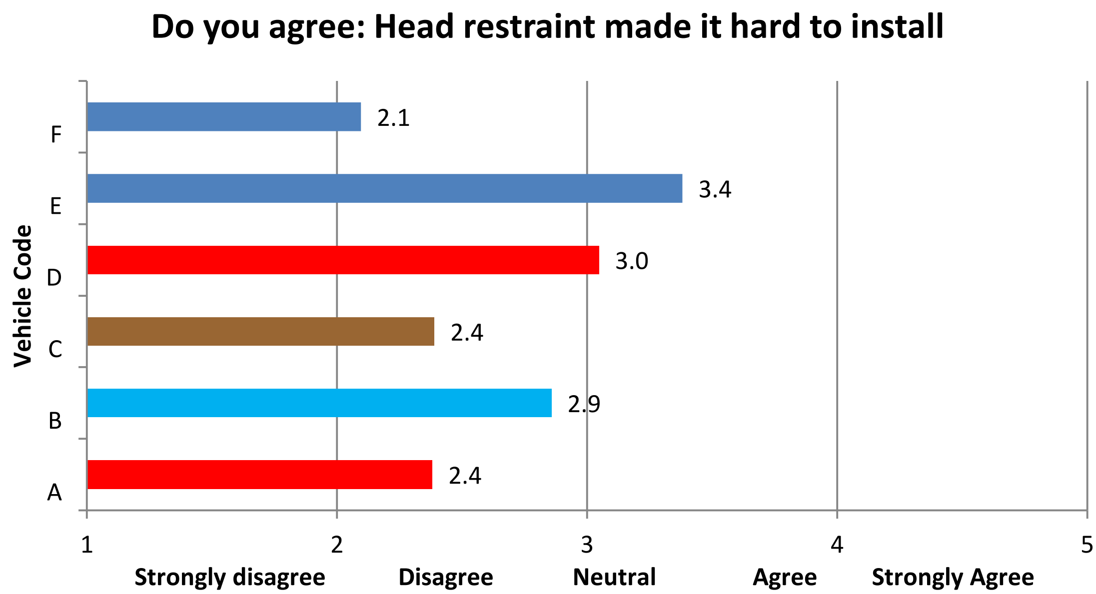


Figure 31. Mean subject rating of whether head restraint made it hard to install by vehicle (each color represents a manufacturer).

For most of the remaining subject questions, there were no differences in mean values by vehicle tested. Figure 32 shows mean subject responses for questions related to all installations, Figure 33 shows mean subject responses for questions relating to LATCH installations, and Figure 34 shows mean subject responses for questions relating to seatbelt installations. All mean values for these subject responses ranged from neutral to easy.

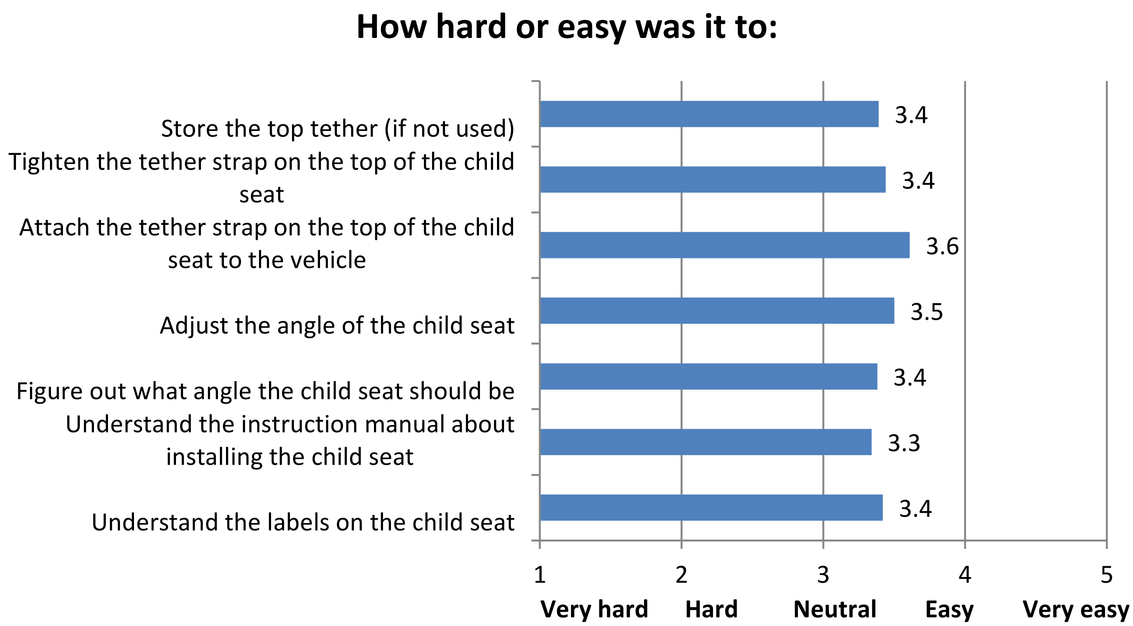


Figure 32. Subject responses to questions regarding all installations.

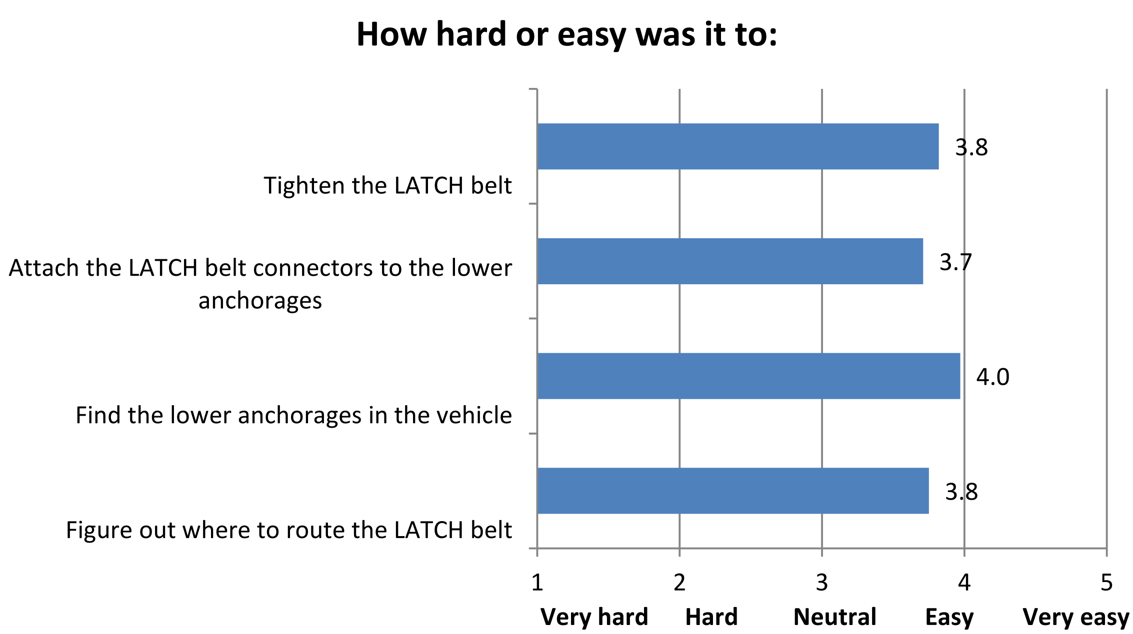


Figure 33. Subject responses to questions regarding LATCH installations.

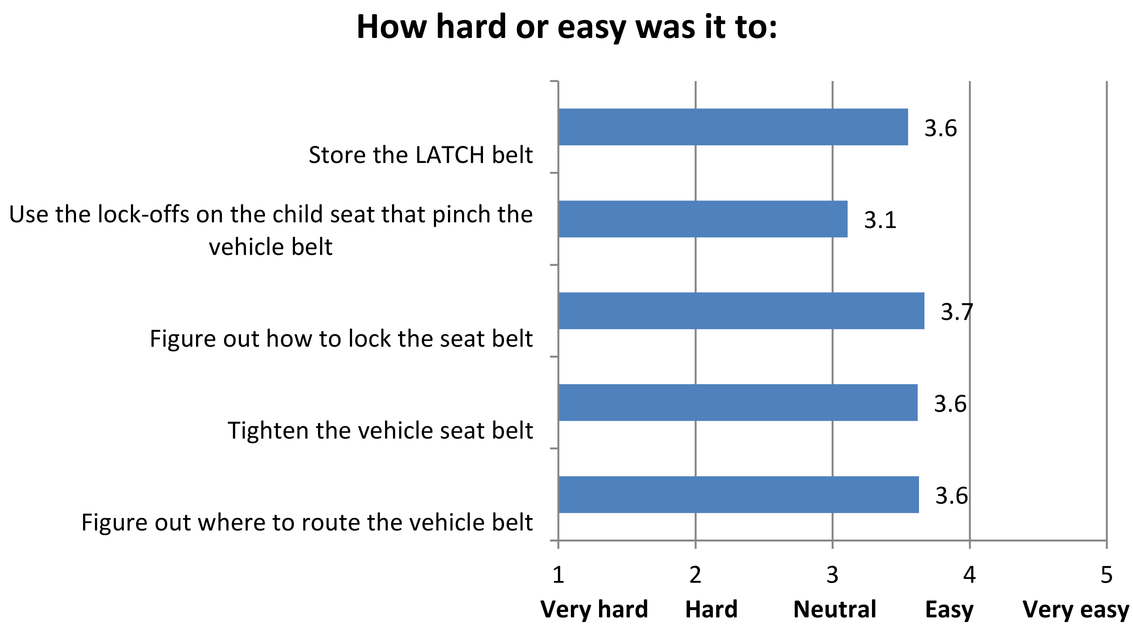


Figure 34. Subject responses to questions regarding seatbelt installations.

Two subject questionnaire responses varied with vehicle type. Figure 35 shows mean subject responses to ease of understanding the vehicle manual regarding the child restraint installation (p=0.066). Each color corresponds to a vehicle manufacturer. The manual with the worst rating (Vehicle C) had the highest number of diagrams in the CRS section (n=47). Vehicles E and F, which had two of the best ratings, had the least number of pages in the vehicle manual regarding CRS installation (11 pages), and only 2 or 5 diagrams in the CRS installation section.

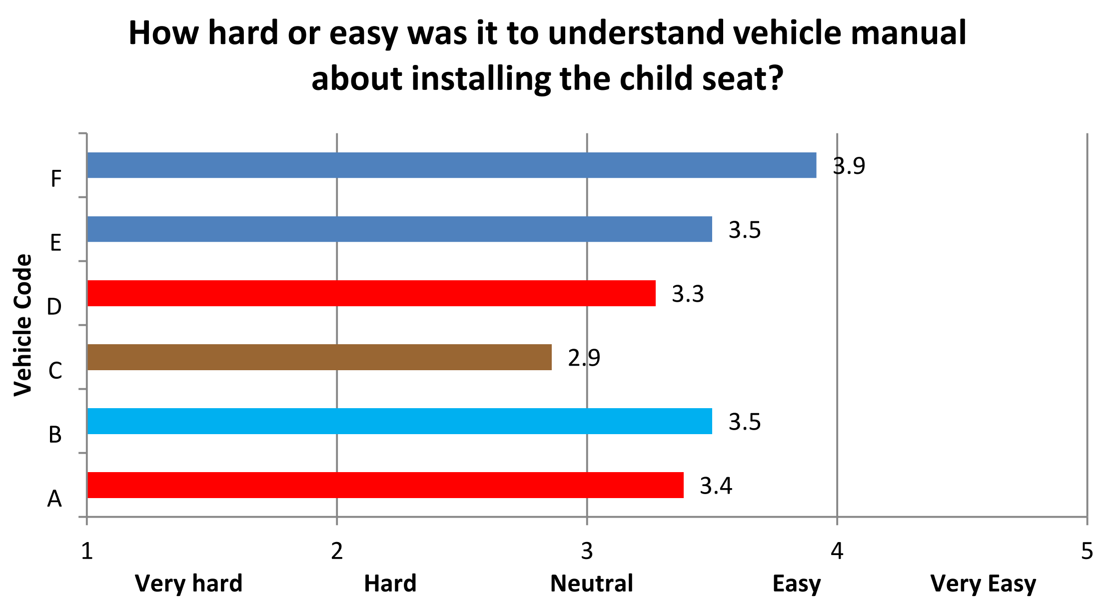


Figure 35. Mean subject responses about understanding vehicle manual by vehicle.

Subject assessments of ease of finding the tether anchorage is shown in Figure 36, with different colors corresponding to vehicles with tether locations on the package shelf or vehicle seatback. Subjects gave significantly lower ratings to tether anchorages located on the seatback compared to those located on package shelves ($p<0.0001$). For the vehicles tested, the tether anchorages located on the package shelves were also more clearly labeled than those on the vehicle seatbacks.

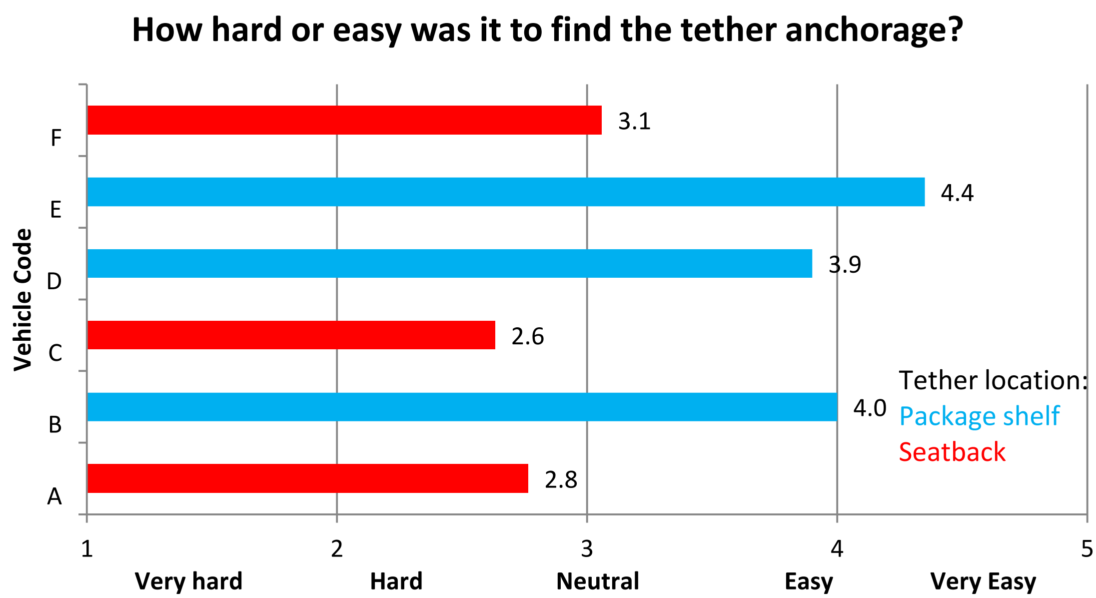


Figure 36. Subject responses to ease of finding tether anchorage by vehicle and tether location.

Subject ratings of vehicles and methods

When asked to choose which installation method they preferred, 79% of subjects chose the LATCH method. When giving each installation a rating (scale of 1-10, 10 best) on how much they liked the vehicle based on child restraint installation, the mean value for seatbelt installations was 5.1, while the value was 6.7 for LATCH installations. Figure 37 shows the average subject rating of vehicles for LATCH and seatbelt installations. Installations performed in vehicles A and C had the largest difference in subject assessment of seatbelt and LATCH installs.

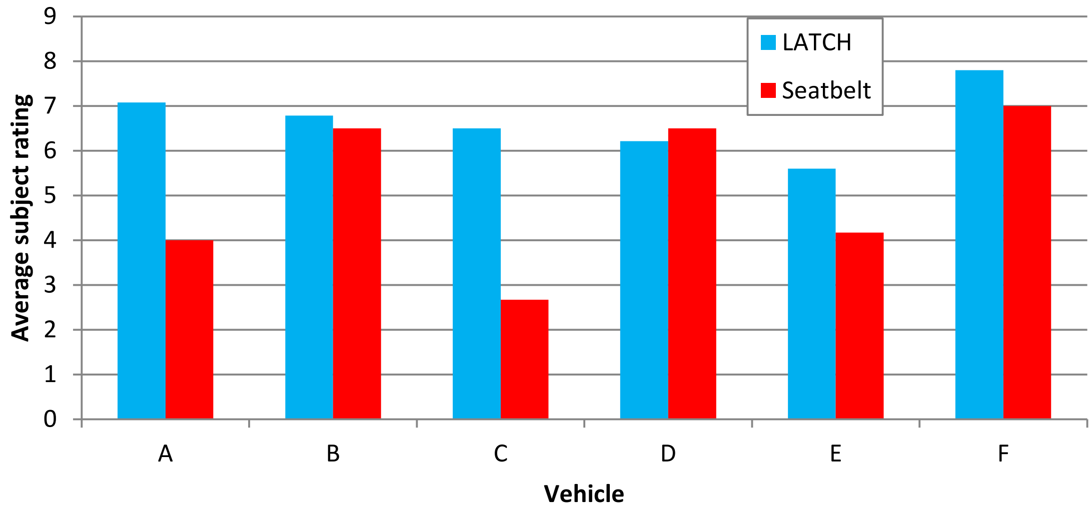


Figure 37. Average subject ratings of vehicles for LATCH and seatbelt installations.

Subject identification of CRS installation methods

Part of the subject questionnaire involved assessing whether subjects could identify available methods of CRS installation for a particular vehicle. After each installation, the subject was asked to mark a vehicle diagram as follows:

> 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.

Figure 38 shows a diagram of the correct answers for each vehicle used in the study. While they vary for each vehicle, all vehicles can use a seatbelt to install a CRS in the right-front position, and can install with seatbelt, LATCH, and tether in the second-row outboard positions.

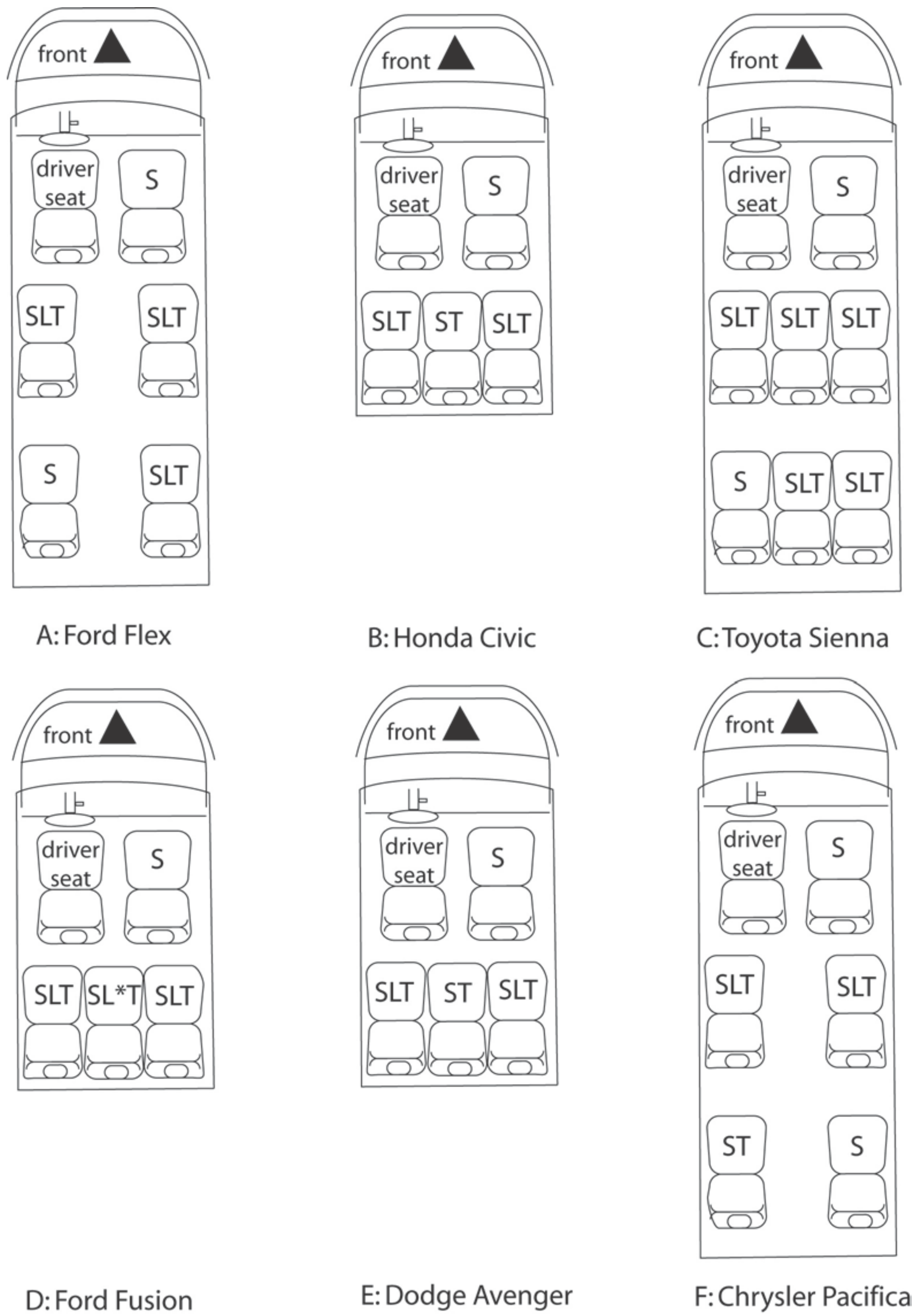


Figure 38. Diagram of options for installing CRS in each test vehicle. S: seatbelt, L:LATCH, T: tether, *:Center LATCH installation with inboard LA from outboard positions

Figure 39 shows a distribution of the subject answers for these three seating positions. For the right-front position, about 20% of subjects correctly answered that a CRS could be installed with a seatbelt in that position. Almost 75% incorrectly answered that a CRS could not be installed in that position. Based on these answers, the message that rear seating is best for CRS installation is being interpreted that front-seat installation is not possible. Less than 10% of subjects indicated that it was possible to install CRS in the front seat using LATCH.

Responses for the two outboard positions were similar but not identical. About 60% of subjects correctly indicated that seatbelt, LATCH, and tether could be used in the outboard second-row seating positions. About 5% incorrectly indicated that it was not possible to use a seatbelt for the installation. About 15% indicated that seatbelt or LATCH could be used, but did not separately mark that a tether could be used. Almost 10% indicated that only a seatbelt could be used for installation.

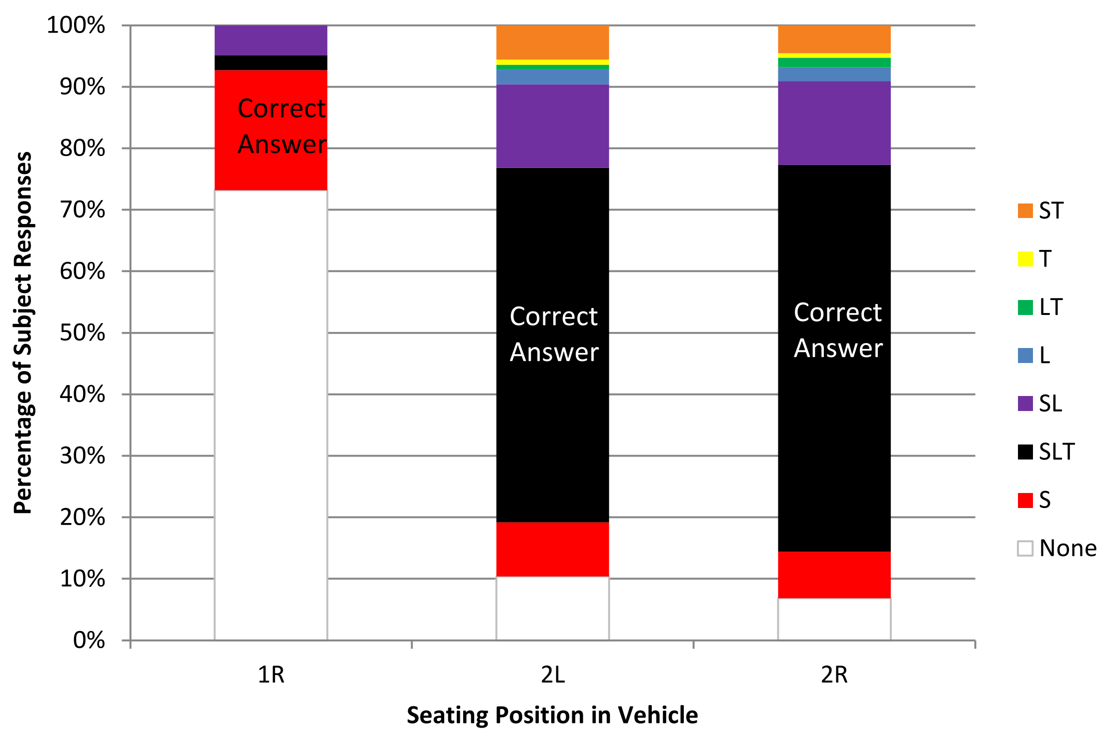


Figure 39. Distribution of subject responses regarding available methods for CRS installation in different vehicle seating positions.

Figure 40 shows the percentage of correct responses regarding allowable methods of CRS installation in each seating position for each trial. For positions 2L, 2R, and 3R, subjects' correct response rate improved over the four trials. Results do not show a trend for the 2C, 3L, and 3C seating positions, while they are consistently low for the right-front seating position.

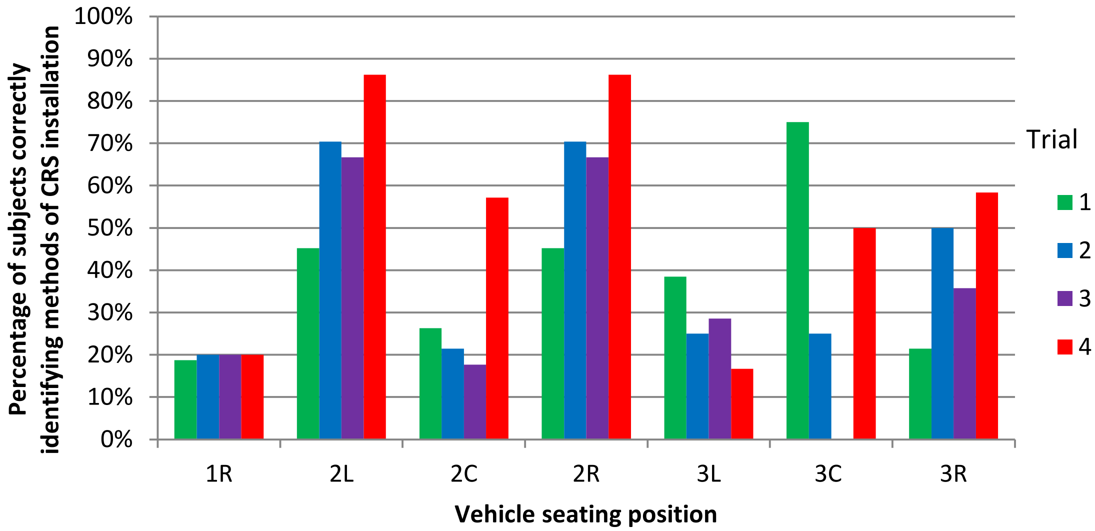


Figure 40. Percentage of subjects correctly identifying allowable methods of CRS installation for each seating position by trial.

The percentage of correct subject answers is shown in Figure 41 for each seating position according to the number of diagrams in the CRS section of the vehicle manual. For positions 2L and 2R, the rate of correct answers is inversely proportional to the number of diagrams. For position 1R, the rate of correct answer is lowest for the two manuals with the fewest diagrams and similar for the manuals with a higher number of diagrams.

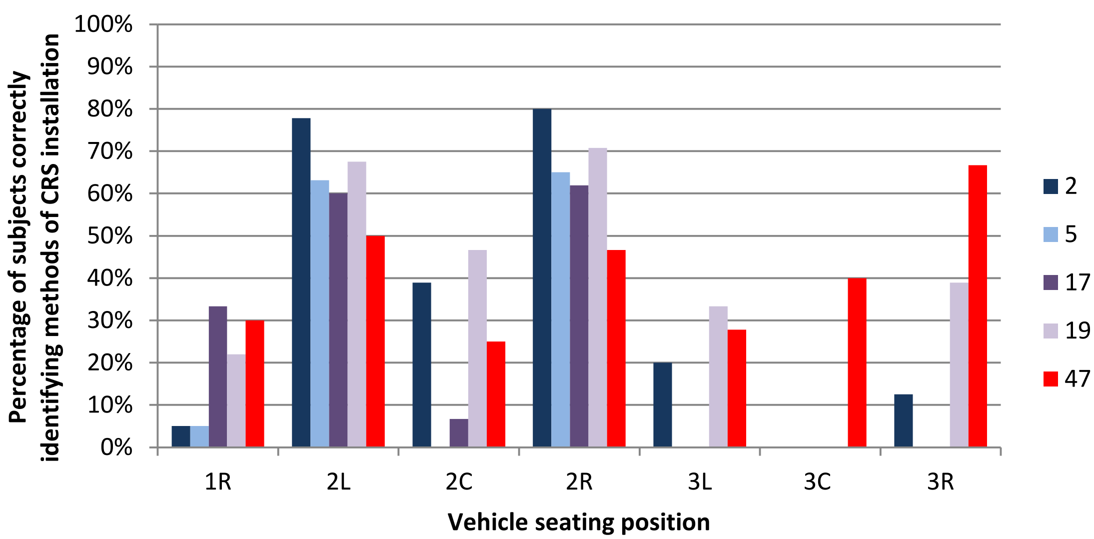


Figure 41. Percentage of subjects correctly identifying allowable methods of CRS installation for each seating position by number of diagrams in the CRS portion of the vehicle manual.

Figure 42 shows the percentage of subjects correctly identifying allowable methods of CRS installation for each seating position by vehicle. Vehicles D, E, and F have lower rates of correct identification for position 1R than vehicles A, B, and C. In positions 2L and 2R, vehicle C has the lowest rate of correct identification compared to the other vehicles.

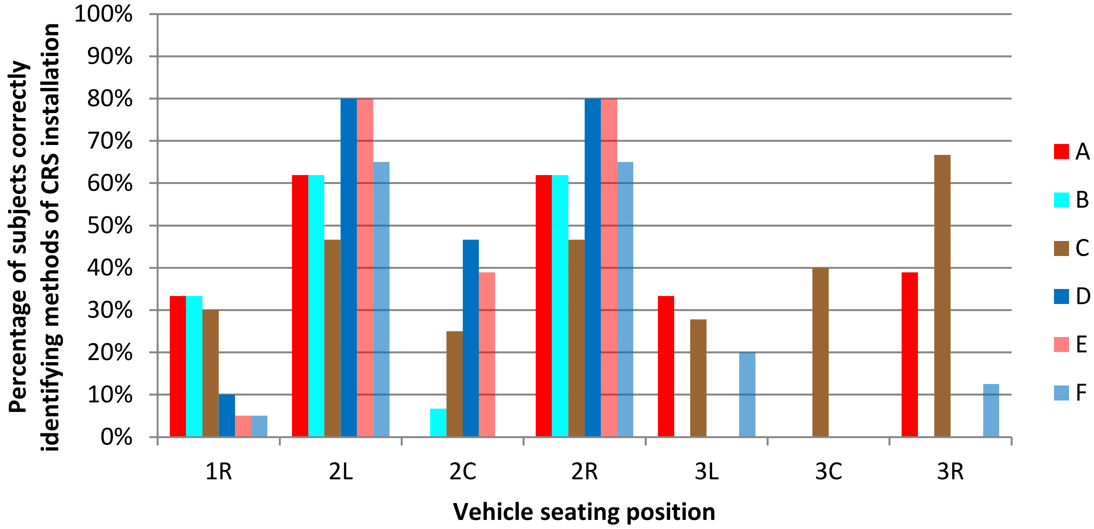


Figure 42. Percentage of subjects correctly identifying allowable methods of CRS installation for each seating position by vehicle.

Evaluation after last install

As a follow-on to the evaluation of CRS instructions and labels performed in Task 1, after the last installation was performed and assessed, the subject was given the placard shown in Figure 43 and their response was recorded.

Most people make mistakes when installing car seats.

The biggest problem: getting the car seat in tight enough.

- Grab the car seat near the belt path and try to move it.
- It should not move more than one inch.
- To make it tighter, kneel on the car seat while you tighten the belt.

The next biggest problem: making the harness snug around the child.

- You should not be able to pinch any of the strap.
- Use the harness adjuster to tighten it.

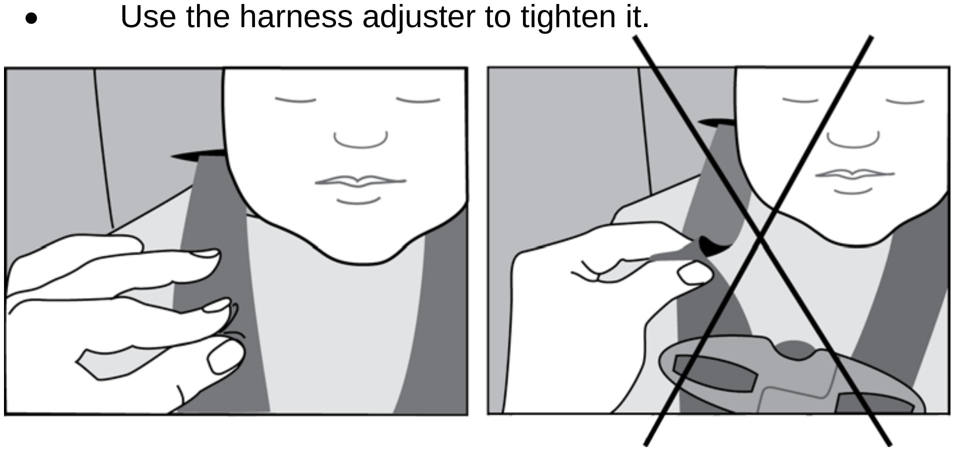


Figure 43. Post-test instruction placard.

Figure 44 shows the distribution of actions regarding tightening the installation, almost all of which were LATCH installs because of the design of the study. In two-thirds of cases, the subject checked again that it was tight even though it was sufficiently tight. In 13% of cases, the subject did not check the tightness because it was already good. In 9% of cases, the installation was loose but the subject tried again successfully. For 6% of cases, the installation was loose and the subject did not try to fix it. For the last 6% of cases, the installation was loose and the subject was unsuccessful at making it tighter.

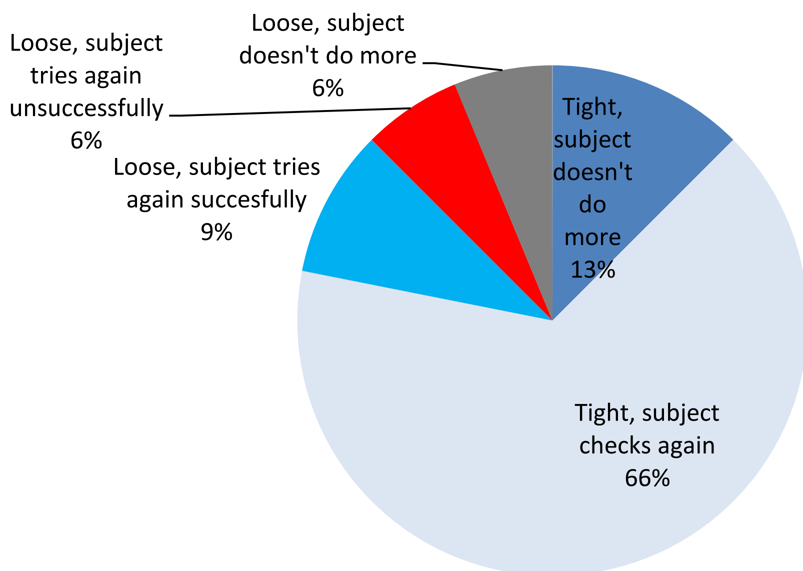


Figure 44. Subject responses to instruction placard on tightening.

Subject responses to the placard regarding snugness of the harness are shown in Figure 45. In 19% of cases, the harness was snug and the subject did not check it again. In 72% of cases, the harness was snug but the subject checked again. In 9% of cases, the harness was loose but the subject was unable to adjust it to be snug.

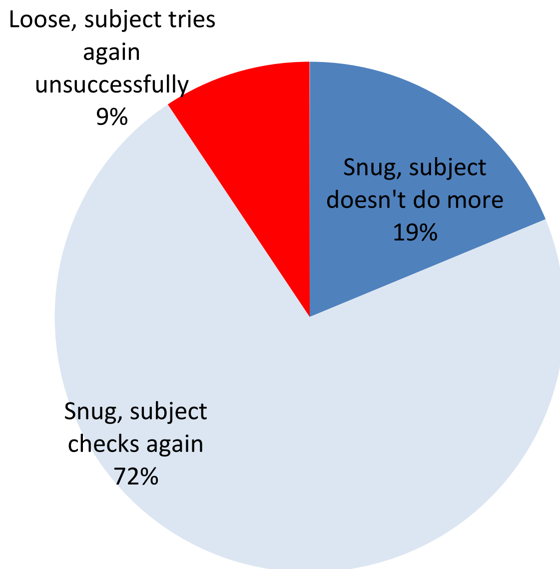


Figure 45. Subject responses to instruction placard on harness snugness.

Discussion

Summary and comment on results

Installation tightness

The SAE Child Restraints Committee has developed draft recommended practices to reduce LATCH incompatibilities between CRS and vehicle seating positions. One of the factors considered important by this group is the location of lower anchorages above seating surface, where the recommended distance between the installed CRF fixture and the seating surface is 50 mm or less. Another SAE recommendation is that the force required to attach LATCH belt connectors to lower anchorages be less than 15 lb. The vehicles selected for this study were chosen to differ on these factors. Two vehicles have lower anchorages located above the seating surface (B and D). Two vehicles had attachment forces below 15 lb, two were near 15 lb, and two were above 15 lb. In addition to the SAE recommended practices, there is a perception that visible lower anchorages may improve usability compared to lower anchorages that are located within the vehicle seat.

When assessing the tightness of the CRS installations (the most frequent type of misuse), installation performance did not correspond with any of these three recommendations. The force required to attach the lower anchorages was not a significant predictor of installation tightness. Vehicles with visible lower anchorages did not have improved installation tightness compared to those with lower anchorages buried within the vehicle seat. However, as discussed below, these two factors did positively affect correct use of lower anchorages.

In addition, the two vehicles with lower anchorages located above the seating surface had higher rates of tight installation for both LATCH and seatbelt installations compared to vehicles with lower anchorages at the seating surface. The two vehicles with the lower anchorage above the seating surface have a feature called a bightline waterfall (shown in Figure 9). Because the two vehicles with this feature had improved rates of tight installation for both LATCH and seatbelt installations, but had different levels of seat stiffness, seat contour, and buckle location, it suggests that the shape of the vehicle seat with this feature may have a greater effect on installation tightness than the location of the lower anchorages. The improved installations with these vehicle seats is at odds with the SAE CRS committee recommendation to have the lower anchorages close to the seating surface to allow good contact between the CRS and vehicle seat.

In this study, seatbelt buckles that were located closer to the seat bight led to a substantially higher rate of tight seatbelt installations compared to buckles located forward of the bight (83% vs. 35%). However, the location of seatbelt buckles did not have an effect on LATCH installations, indicating that subjects are able to access lower anchorages even if the seatbelt buckle is located nearby. In addition, subject questionnaires responses indicated that subjects did not find the seatbelt buckles to cause a problem when performing LATCH installs.

Only two CRS were used in Task 2 testing. CRS C10, which uses the same belt path for routing the seatbelt and the LATCH belt, had the same 60% rate of tight installation for seatbelt and LATCH installs. CRS C6 has the vehicle belt path located slightly higher than where the LATCH belt is attached. With C6, the rate of tight installations with LATCH was twice the rate of tight installations with seatbelt (80% vs. 40%). The differences in performance with these two CRS over a range of vehicles indicate that belt path location on the CRS plays a key role in achieving tight installations in vehicles. On the FMVSS 213 buck, the geometry of the lap belt anchors and the LATCH lower anchorages are similar. In vehicles, lap belt anchorages are almost always located more forward than the LATCH anchorages. If the typical lap belt geometry implemented in vehicles is different from that found on the FMVSS 213 test buck, CRS manufacturers may be optimizing the design of their belt paths for unrealistic conditions.

The vehicles tested were selected to provide a variety of head restraint conditions, because problems with head restraints interfering with CRS installation have been reported by CPS technicians in the field. Since the majority of the vehicles used in this study were manufactured before the phase-in of the new FMVSS 202 head restraint requirements, it is not known whether this finding applies to compliant designs. However, no factors related to head restraints were significant predictors of installation tightness. Subject questionnaire responses did indicate that the head restraints in the different vehicles had different effects on the subjects' perception of the installations, even if they did not affect installation tightness.

Lower anchorage use

Subjects were assessed as correctly using the lower anchorages if they attached the LATCH connectors to the appropriate lower anchorages and attached the connectors correctly (i.e. not upside-down). Overall, subjects attached the LATCH belt correctly in 90% of LATCH installations. Subjects were less successful in correctly attaching the LATCH belt if the lower anchorages were buried rather than visible, or if the force required to attach the connectors was high. These findings support two of the SAE recommended practices for LATCH usability. However, correct use of the lower connectors was relatively high for vehicles not meeting the SAE recommendations: 88% for buried anchors and 79% for high lower anchorage force.

The main selection criteria for the two CRS used in Task 2 were to provide examples of hook-on and push-on LATCH connectors. Consistent with the results of Task 1, subjects were more likely to correctly attach to the lower anchorages using the push-on style of LATCH connector rather than the hook-on style.

Tether use

Tether use was evaluated in two parts: correct attachment and tightening. The tether was used correctly in only 30% of all installations, and not used in 26% of all installations. Subjects used the tether in 85% of LATCH installations and only 48% of seatbelt installations. When it was used, it was used correctly in 45% of LATCH installations and 30% of seatbelt installations. The most common error in tether use was routing the tether strap over the head restraint, rather than under it or removing the head restraint to accommodate the CRS.

The location and conspicuity of the tether anchorage had a major effect on tether use. The tether was more likely to be used in both LATCH and seatbelt installations in sedans where the tether anchorage is located on the package shelf and visible from the point of installation. Tether use was lower when the anchorage was located on the vehicle seatback, where it is often found in minivans and crossover vehicles. A factor that may be contributing to this difference is that the tether anchorages located in three of the four sedans were located under clearly marked doors as shown in Figure 46, whereas all three tether anchorages located on the seatbacks were not marked as shown in Figure 47. Subjects overwhelmingly indicated that tether anchorages were more difficult to locate in the three vehicles where they were mounted on the seatback. As a result, subjects were twice as likely to use the vehicle manual in these vehicles compared to sedans.

Figure 46. Representative tether anchorage under marked door in sedans.

Figure 47. Representative unmarked tether anchorage often found in minivans/crossover vehicles.

One of the measures used to describe head restraint geometry was the fore-aft distance between an estimated seat H-point and the base of the head restraint in its lowest adjustment position. The vehicles with the base of the head restraint more forward had higher rates of correct tether attachment than the vehicles with the head restraint more rearward, while the opposite is true when evaluating rates of tight tether installation. There is a perception that more forward head restraints are bad for CRS installation, but it is not as straightforward as that. More research is needed to determine if more forward head restraints permit greater visibility and thus use of the tether anchorages.

The tether anchorage zone is defined in FMVSS 225 relative to an R-point determined by using the H-point machine. A problem reported from the field is that some tether anchorages in the most forward portions of this zone do not permit enough space to allow adequate tightening of the tether. An example of this condition is shown in Figure 48.

The tether wrap around distance was measured in each vehicle relative to an estimated R-point. In the vehicle with a tether wrap around distance of 210 mm, all of the tether installations were tight. In the vehicle with the tether wrap around distance of 180 mm, less than 40% of the installations were tight, and could only be achieved by incorrectly routing the tether over the head restraint as shown in Figure 49. Thus the threshold for sufficient space for tightening the tether (based on these two CRS) likely lies between 180 and 210 mm. When the other 14 convertible child restraints were installed in the vehicle with the wrap around distance of 210 mm, 5 others could not be tightened.

Figure 48. Tether anchorage located too close to allow space to tighten tether.


Figure 49. Incorrectly routed but tight tether installation.

The minimum wrap around distance required to tighten tether depends on the length of tether hardware (hook plus adjustment mechanism) as well as the attachment location of the tether on the child restraint. Two child restraints with the same length tether hardware could require different minimum wrap around distances in the vehicle if they were attached at different heights on the child restraint. Additional work is needed to develop a specification in FMVSS 225 for minimum vehicle wrap around distance that is compatible with a specification in FMVSS 213 for a maximum tether hardware length.

Seatbelt installations

As mentioned previously, subjects had tight installations using the seatbelt twice as often when the seatbelt buckle was located at the bight rather than forward of the bight. Subjects were also more likely to lock the seatbelt when it was at the bight rather than forward of the bight. It is not clear if the subjects were unable to tighten the belt with a forward buckle, and thus did not bother to lock the seatbelt, or if the locking options were less evident in vehicles with buckles forward of the bight. When locking the belt, most subjects used the method they were directed to use by the CRS manual. One of the vehicles had a locking latchplate (where no action is needed to lock the belt), whereas the rest had switchable retractors. In the four seatbelt installations performed in the vehicle with the locking latchplate, the seatbelt was locked in all cases and the CRS was tight in three of four cases.

Instruction manual use

Subjects used the vehicle manual in 38% of installations and consulted the CRS manual in 88% of installations. The more difficult-to-find tether anchorages in the minivans/crossover vehicles doubled the frequency of subjects consulting the vehicle manual.

Subjects gave different ratings for each vehicle as to whether the content of vehicle manual agreed with the CRS manual. (Only ratings from subjects who had used the vehicle manual were included.) One of the vehicle manufacturers had consistent ratings from subjects on two of its vehicles, while the other manufacturer with two vehicles had the highest and lowest ratings.

Subjects also gave a variety of scores to each vehicle with regard to understanding the CRS installation instructions included in each vehicle manual. The two shortest manuals with the fewest diagrams had the highest scores, while the manual with the longest CRS section (and the most diagrams) received the lowest rating on ease of understanding. The manual that would likely be considered the most thorough was the one rated most difficult to understand.

Installation times increased substantially if subjects used the vehicle or CRS manual compared to those who did not. Experienced subjects were less likely to use the vehicle manual, especially those with lower education levels. Subjects who did not use any manual had more installation errors than subjects who used the vehicle manual, CRS manual, or both.

Education/experience

Education and experience affected few CRS installation factors. Rate of tight installations was somewhat lower for lower education subjects, while rate of tight tethering (once it was used) was higher for lower education subjects. In Task 1, the effect of education on tight installations had the same trend, but was not a factor in achieving a tight tether. Inexperienced subjects were more likely to use the vehicle and CRS manuals, but this was not found in Task 1.

Subject assessments

Data from the post-installation questionnaire identified only a few areas where the average response differed among vehicles. Since their installation performance varied among vehicles, this indicates that subjects are not aware of when they are making errors during CRS installation. Overall, subjects rated themselves as correctly installing the child restraints (average score of 4.1/5 corresponding to agreement with “I attached the child seat to the vehicle correctly”). However, when reviewing subject performance, over half made two or more errors on key installation points (CRS tight, harness snug, buckle correct, tether correctly attached, tether tight, LATCH belt correct/seatbelt locked). These results show a disconnect between subject self-evaluation and actual performance.

Subjects did not identify the vehicle seat stiffness or vehicle seat shape as contributing to the difficulty of the installation. They also did not find that the seatbelt buckles got in the way of using LATCH. The only vehicle feature noted as making it harder to install was the head restraint. Table 7 shows pictures of each head restraint in order from hardest to easiest as rated by subjects, together with the instructions for routing the tether relative to the head restraint. The head restraint considered most challenging to CRS installation was the one with a fixed design. Vehicles D and A have similar head restraint designs, but the tether anchorages for vehicle D are located on the package shelf while those for A are on the seatback, which may contribute to the different ratings despite the similar head restraint design. The same may be true for vehicles B and F.

Table 7. Vehicle head restraints with average subject rating of difficult (hardest to easiest)

Vehicle E (3.4)
Route belt to outboard side

Vehicle D (3.0)
Route under

Vehicle B (2.9)
Route under, or around if tether cannot be tightened

Vehicle A (2.4)
Route under

Vehicle C (2.4)
Remove HR

Vehicle F (2.1)
Route under

Subject ratings on most questions addressing LATCH installation, seatbelt installation, and CRS instructions were similar for all vehicles and generally positive. As discussed previously, the two questions having the widest range of responses were the ease of finding the tether anchorage and understanding the vehicle manual. A preference for LATCH installation was expressed by 80% of subjects at the end of their session.

Subject understanding of CRS installation options

Subjects were asked to indicate on a diagram the allowable methods of CRS installation at each seating position in the vehicle. About three-quarters of subjects incorrectly stated that child restraints could not be installed in the front seat. This error likely results from interpreting vehicle manual instructions prohibiting installation of rear-facing CRS in the front seats as covering all CRS installations, or that subjects have received the child passenger safety message that kids should sit in the back seat.

Based on both subject responses and their performance on installations, many people do not realize that tethers can be used when the seatbelt is the primary method of installing the child restraint. This suggests an opportunity for improved education.

Subject responses on identifying CRS installation options for each seating position tended to be correct most often for the 2nd row right seating position, where they were asked to install the CRS in most vehicles. They also had a high rate of correct answers in the 2nd row left position, which for all of the vehicles tested, had the same CRS installation options as the 2nd row right position.

Post-test evaluation of subject feedback

Results of Task 1 and Task 2 both indicated that subjects did not recognize when they made installation errors, because their assessments of how they did had minimal correlation with how they performed. As a quick experiment to determine if providing post-installation feedback would lead subjects to improve their installation, subjects were given the placard shown in Figure 43 after performing their last installation and their response was tabulated. The placard focuses on correcting the two most frequent misuses: loose installation, and loose harness. After giving the subjects the placard, 80% went back and checked their installations. The subjects improved the tightness of the installation in three of the seven cases where it was not tight, but none of the subjects who needed to make the harness tighter were able to figure out how to do so.

Comparison to Task 1 results

Compared with subjects in Task 1 where four subjects quit the study and seven did not finish all four trials, no subjects withdrew from this phase of the study, and only one did not finish all four trials. Factors thought to contribute to these differences are:

1) Dummy installation was much less complicated, because the harness height was already adjusted to fit the dummy. This seemed to reduce subjects' frustration levels, making them less likely to give up once they reached the CRS installation portion of the trial.
2) Installations were all forward-facing. In Task 1, although performance did not generally vary between forward-facing and rear-facing installations, rear-facing installations took twice as much time. Achieving the correct installation angle rear-facing was shown to be more challenging than in forward-facing installations.
3) The CRS selected for this study had the highest rates of correct installation in Task 1.

Table 8 compares misuse rates on key variables between Task 1A and Task 2. In Task 2, misuse rates were substantially lower for all items except correct buckling and the CRS being installed with both seatbelt and LATCH. The decrease in incorrect belt routing and incorrect recline angle likely results from performing only forward-facing installations. The decrease in loose harness rate likely results from setting the harness to the correct height for the dummy prior to testing, as well as choosing two of the easiest-to-use CRS from Task 1 for use in Task 2.

Table 8. Comparison of misuse rates (percentages) in Task 1A and Task 2 testing

Observed Misuse	**Task 1a (n=116)**	**Task 2 (n=132)**
Study design	**16 CRS 1 vehicle 50/50 LATCH/Seatbelt 50/50 RF/FF**	**2 CRS 7 vehicles 75/25 LATCH/Seatbelt All FF**
Incorrect belt routing	17	2
Incorrect recline angle	22	2
Loose CRS install	72	33
CRS installed with both seatbelt and LATCH	4	7
Harness incorrectly buckled	9	8
Loose harness	48	26

Rates of loose CRS installation in Task 1 were more than double the rate of loose CRS installation from Task 2. This partly results from choosing easy-to-use CRS, and partly from the vehicle factors. Vehicle G was chosen for Task 1 because it had vehicle factors expected to result in uncomplicated installations such as flat seat contours, visible lower anchorages, and seat belt anchorages near the bight. However, these features did not turn out to be as uncomplicated as anticipated. Comparing the installation errors using CRS C6 and C10 from Task 1 testing to that of the other vehicles in Task 2, Vehicle G had the lowest rate of tight LATCH installations and the second lowest rate of tight seatbelt installations. However, some of this difference may result from fewer trials with these two CRS in Task 1 testing compared to the number of trials in each vehicle in Task 2 testing.

The experimenter noticed a marked reduction in frustration levels of subjects during this phase of testing compared to the previous testing. She believes that it contributed substantially to the improved performance of subjects. This may suggest that improving ease-of-use in one area of child restraint design (such as making harnesses easier to adjust) may indirectly reduce installation errors in other aspects of installation (such as tightly installing the child restraint.)

Limitations

Because the project constraints only allowed testing with six vehicles, the number of vehicle features that could be examined was limited. In addition, only 30 vehicles were evaluated as potential candidates for testing because of time and budget constraints. Although efforts were made in analysis to evaluate each feature separately, actual CRS installation is affected by all features together.

Only two convertible CRS were used during testing. They were selected to be relatively easy to use based on results of Task 1 testing, and had different external contours, belt paths, and LATCH belt connectors. However, findings based on these two CRS may not apply to all CRS. In addition, all installations were performed forward-facing, because this meant all installations could be used to examine tether use, and more degrees of freedom in the experimental design could be applied to vehicle factors. Findings may not apply to rear-facing installations.

Some of the draft SAE procedures on LATCH compatibility were used to assess the potential vehicles for testing. As written, the method for measuring the force required to attach the LATCH belt connectors to the lower anchorages is not very repeatable, because the attachment force is highly dependent on the angle at which the gauge is applied, and it is physically impossible to use the same measurement angle in all vehicles. We have confidence in the force categories used as predictors in this report because they are based on multiple measures in the vehicles. However, further refinement of the procedure is needed before it could be used in assessing vehicles.

Because of time constraints resulting from renting the test vehicles for a limited period of time, we were not able to take the time to recruit as wide of an age range of subjects in each education/experience group. Thus the X0L group (no experience, have not gone to college) is mainly composed of recent high school graduates, almost all of whom will be attending college in the fall. This makes them younger than the X0L groups in the prior phases of testing, which included more older subjects who never attended college. Another limitation of the subject pool is that all subjects could speak and read English, with their performance likely better than subjects who would not have the language skills to understand the labels and manuals.

There was a significant effect on tether use between vehicles with tether anchorages located on the package shelf, most of which were clearly marked, and those located on the vehicle seatback, which were all unmarked. The design of the study is not able to determine whether it was the location or the marking (or some combination) that led to the improved tether use in sedans.

An effort was made to test vehicles with fabric rather than leather seats, because field reports generally indicate that leather seats contribute to difficult CRS installation. Unfortunately, vehicle model A was only available with leather seats, and this factor may have contributed to its performance.

The results of both Task 1 and Task 2 of this study have indicated that opinions of experts in child passenger safety on what makes CRS installation hard or easy does not necessarily lead to poor or good performance by regular CRS users. Some particular examples:

- The vehicle chosen for testing in Task 1, because it was considered to have easy-to-use vehicle features, had among the lowest rates of tight installation compared to the other vehicles in Task 2.
- Two of the key recommendations by the SAE CRS committee (avoid lower anchorages above the seating surface and limit force required to attach lower anchorages) did not have a significant effect on installation tightness, although they slightly improved rates of correctly attaching the LATCH belt.

- Child restraint manuals and labels designed according to human factors principles recommended by experts (evaluated in Task 1) did not have a significant effect on improving CRS installation.

These findings are cause for some concern, as the NHTSA ease-of-use rating system and ISO rating systems of CRS ease-of-use have primarily been based on consensus by child passenger safety experts. Testing with non-expert volunteers should be performed to validate any recommendations by experts intended to improve ease of child restraint installation. Narrowing the range of recommendations to those factors demonstrated to affect CRS installations may improve the responsiveness to those recommendations by CRS and vehicle manufacturers.

Recommendations

The results of volunteer testing to evaluate effects of vehicle features on CRS installation errors support the following recommendations:

- Clear marking of tether anchorage locations should be required. Because existing ISO recommendations for tether anchorage markings have been adopted by some vehicle manufacturers, use of the ISO specifications is suggested. The substantial safety advantages of tether use, combined with the current finding that hard-to-find anchorages dramatically reduce tether use, suggest that a strong emphasis on improving tether anchorage marking would yield safety benefits.
- Further testing should be conducted to identify an acceptable minimum tether wrap around distance for the tether anchorage zone that is compatible with tether hardware lengths and attachment locations.
- Because forward seatbelt buckle locations had lower rates of tight installation than buckles anchored more rearward, the effect of lap belt anchorage location on CRS installation should be assessed. Implications for both FMVSS 210 and FMVSS 213 should be considered.
- Lower anchorages requiring less force to attach lower connectors, as well as visible lower anchorages, led to improved rates of correctly attaching lower anchorages.
- The potential for negative interaction between head restraints and child restraints should be monitored as more vehicles are redesigned to meet FMVSS 202a requirements.
- Education efforts targeting increasing LATCH use should also emphasize the benefits of using a tether with a seatbelt installation.
- New requirements intended to improve CRS ease-of-use should be validated with testing by non-experts.

References

Bilston, LE, Yuen, M, Brown J (2007). Reconstruction of crashes involving injured child occupant: the risk of serious injuries associated with sub-optimal restraint use may be reduced by better controlling occupant kinematics. *Traffic Injury Prevention* 8:47-61.

Carlsson, G, Norin, H, Ysander, L, (1991). Rearward facing child seats – the safest car restraint for children? *Accident Analysis and Prevention* 23:2-3:175-182.

Code of Federal Regulations (2005) Title 49, Transportation, Part 571.213; *Child restraint systems*. National Archives and Records Service, Office of the Federal Register Washington, D.C.

CDC (2007). http://www.cdc.gov/injury/wisqars/pdf/Death_by_Age_2007-a.pdf

Decina, LE, Lococo, KH, (2007). Observed LATCH use and misuse characteristics of child restraint systems in seven states. *Journal of Safety Research* 38:271-281.

Eby, DW, Kostyniuk, LP (1999). A statewide analysis of child safety seat use and misuse in Michigan. *Accident Analysis and Prevention* 31:555-566.

International Standards Organization (2008) *Road Vehicles – Methods and Criteria for Usability Evaluation of Child Restraint Systems and Their Interface With Vehicle Anchorage Systems – Part 1 Vehicles and Child Restraints Equipped with ISOFIX Anchorages and Attachments.* CD 29061-1, Geneva, Switzerland.

Johnston, C, Rivara, FP, Soderberg, R (1994) Children in car crashes: analysis of data for injury and use of restraints. *Pediatrics* 93:960-965.

Klinich, K. D., Manary, M. A., Flannagan, C. A. C., Ebert, S. M., Malik, L.A., Green, P. A., and Reed, M. P. (2010). Labels, instructions, and features of convertible Child Restraint Systems (CRS): Evaluating their effects on CRS installation errors. UM-2010-xx.

Koppel, S, Charlton, JL (2009). Child restraint system misuse and/or inappropriate use in Australia. *Traffic Injury Prevention* 10:302-307.

Lane, WG, Liu CL, and Newlin, E (2000) The association between hands-on instruction and proper child safety seat installation. *Pediatrics* 106(4):924-928.

National Highway Traffic Safety Administration (2006). *Consumer Information Rating Program for Child Restraints* Docket NHTSA-2006-25344, US Department of Transportation, Washington DC.

National Highway Traffic Safety Administration (2009). *Traffic Safety Facts 2008,* DOT HS 811-170, National Center for Statistics and Analysis, Washington DC.

Ruta D, Beattie T, Narayan, V (1993). A prospective study of non-fatal childhood road traffic accidents: what can seat restraint achieve? *Journal of Public Health Medicine* 15:88-92.

SAE Child Restraints Systems Committee (2009). Guidelines for Implementation of the Child Restraint Anchorage System or LATCH System in Motor Vehicles and Child Restraint Systems. Draft Recommended Practice.

Subramanian R (2003). *Motor Vehicle Traffic Crashes as a Leading Cause of Death in the United States, 2001* DOT HS 809 695 National Center for Statistics and Analysis, Washington DC.

Stewart, D. D., Anderson, M., Lang, N. J., Rose, K. and White, L. (2009). The LATCH Manual: Using lower anchors and tethers for child restraints. Sixth Edition. Safe Ride News Publications.

Appendix A

Overview of Federal Motor Vehicle Safety Standard (FMVSS) 225

FMVSS 225 requires that instructions for use of LATCH be provided by the vehicle manufacturer in the vehicle manual. For all vehicles manufactured after September 1, 2002, tether anchorages are required in three rear seating positions in any vehicle with three or more rear seating positions, including at least one location that is not outboard. Lower anchorages are required in at least two positions in vehicles with at least three rear seating positions. If a vehicle has three or more rows of seats, at least one tether anchorage and one set of lower anchorages must be in the second row. If a vehicle has two or fewer rear seating positions, they must all have tether anchorages and lower anchorages. If there is no rear seating position, each front-passenger seating position must have a tether anchorage. Tether and lower anchorages must be accessible at all times that the associated vehicle seating position is available for use (i.e. when the seat is not stowed for cargo).

Tether anchorages must accept a tether hook that complies with FMVSS 213, be accessible to the consumer with nothing more than a screwdriver, and be sealed to prevent exhaust fumes from entering the passenger compartment. Tether anchorages must be positioned in a zone defined relative to the seating reference point (SgRP) for the associated seating position. If it is not possible to install tether anchorages in this zone, tether-routing devices can be installed that redirect the tether to an anchorage outside the zone.

FMVSS 225 uses two types of Static Force Application Devices (SFAD) and a Child Restraint Fixture (CRF) in test procedures. To assess tether anchorage strength, SFAD 1 is used to apply static load to the tether anchorage in seating positions without lower anchorages, while SFAD 2 is used in seating positions with lower anchorages. The SFAD is attached to the vehicle seat and the tether strap is secured to the anchorage. Force is applied through point X on the SFAD at an angle of 10 +/-5 degrees above horizontal. The procedure requires application of a force of 15,000 N within a 24 to 30 second loading event, and a sustained peak loading of at least 1 second. The anchorage must not separate from the vehicle structure to which it is attached, but there are no maximum hardware displacements specified. Tether anchorages in the same row must be tested simultaneously if they are located at seating positions whose centerlines are 400 mm or greater apart.

For evaluating strength of lower anchorages, SFAD 2 is attached to the lower anchorages (without using a tether) and a force of 11,000 N is applied in the fore-aft direction +/- 10 degrees of horizontal within a loading period of 24 to 30 seconds and maintained at peak load for at least 1 second. For lateral loading, the procedure is repeated except that the maximum load is 5000 N and the pull angle tolerance is +/- 5 degrees. The strength requirement is that point X on the SFAD 2 cannot displace more than 175 mm under fore-aft loading or more than 150 mm under lateral loading. Lower anchorages whose seating position centerlines are 400 mm or more apart must meet the requirements when tested simultaneously.

Other requirements for lower anchorages include specifications for the diameter, shape, length, and depth of the anchor bars that comprise the lower anchorages. The bars must be rigidly attached to the vehicle such that they will not deform more than 5 mm when 100 N is applied in any direction. In addition, there are requirements for the pitch, roll, and yaw of a Child Restraint Fixture (CRF) when attached to the lower anchorages, as well as a specification for the fore-aft location of the lower anchorages relative to the CRF and vehicle SGRP. The CRF must be able to fit in the vehicle seat and be attached to the lower anchorages.

There are specifications for the conspicuity of the lower anchorage locations. Either the lower anchorage bars, a guide device to reach the bars, or a label indicating the lower anchorage locations must be visible from a specified angle. The label must include a 13-mm-diameter circle, have some indication of lower anchorages that is defined in the vehicle manual, and be permanently attached to the vehicle. The regulation also contains requirements for written LATCH instructions in the vehicle manual. Instructions must be in English, state which seating positions have lower anchorages and tether anchorages, and describe the markings used to designate the anchorage locations. The instructions must also include a procedure for attaching the tether strap.

Appendix B:

Photos of test vehicles

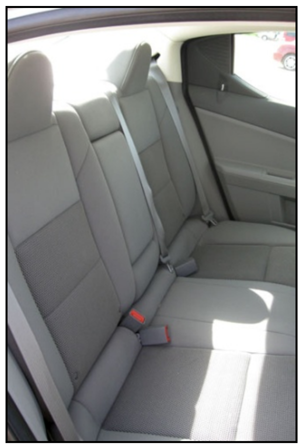
Appendix B: Photos of test vehicles

A: 2010 Ford Flex

B: 2008 Honda Civic

C: 2008 Toyota Sienna

D: 2010 Ford Fusion



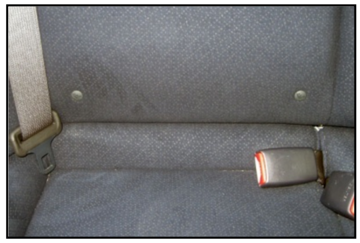
E: 2008 Dodge Avenger

F: 2008 Chrysler Pacifica

Photos of rear seats of proposed test vehicles.

Appendix B: Photos of test vehicles

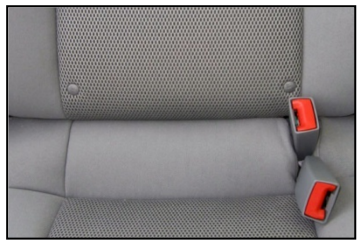
A: 2010 Ford Flex



B: 2008 Honda Civic

C: 2008 Toyota Sienna

D: 2010 Ford Fusion



E: 2008 Dodge Avenger

F: 2008 Chrysler Pacifica

Photos showing LATCH markings/locations of each vehicle.

Appendix B: Photos of test vehicles

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Appendix C

Installation Evaluation Forms and Test Protocol

CRS Installation Evaluation Form (completed by experimenter)

Subject ID: Installation number: 1 2 3 4

Vehicle: A B C D CRS: C6 C10 **Configuration:** RF FF **Method:** L SB Both

Installed position: 1R 2L 2C 2R 3L 3C 3R

Start time: End time: Date: Evaluator:

	Yes	**No**	**NA**	**Comment**
Did subject install CRS in directed position?				
Did subject install with both LATCH and seatbelt?				
Did subject use vehicle manual?				
Did subject use child restraint manual?				
Did subject adjust front seat (where)?				
Does CRS pass 1" movement test (measure)?				
Is CRS touching front seatback?				
Did subject use noodles or towels (what, #)?				
Is recline angle set correctly?				
Is belt routed through correct path?				
Is belt twisted?				
Did subject use locking clip?				
Did subject use lock-offs correctly?				
Did subject use retractor to lock belt?				
Did subject use locking latchplate to lock belt?				
LATCH attached to correct lower anchors?				
Lower connectors attached appropriately?				
Is tether hook attached to anchorage?				
Is tether hook attached correctly?				
Is tether routed correctly wrt headrests?				
Is tether tight? (measure)				
Is tether stored?				
Is LATCH stored?				
Did subject remove vehicle headrest?				
Did subject buckle harness correctly?				
Is harness snug (measure)?				

Testing Script / Protocol
Definitions of assessed items

Did subject install CRS in directed position?	
Did subject install with both LATCH and seatbelt?	
Did subject use vehicle manual?	Subject locates and opens vehicle manual
Did subject use child restraint manual?	Subject locates and opens child restraint manual
Did subject adjust front seat (where)?	
Does CRS pass 1" movement test (measure)?	Experimenter grasps child restraint near belt path and determines if it moves less than 1" in any direction. For quantitative measurement, masking tape is used to mark the location of the CRS relative to the seat cushion. The experimenter applies a horizontal force of 40 lb to the CRS near the belt path and measures the amount of displacement.
Is CRS touching front seatback?	
Did subject use noodles or towels (what, #)?	
Is recline angle set correctly?	For forward-facing installations used in this study, the subject uses the forward-facing recline position.
Is belt routed through correct path?	The belt is routed through the forward-facing path.
Is belt twisted?	The belt is not flat and/or has twists in it.
Did subject use locking clip?	Identify whether subject used the supplemental locking clip provided with the CRS to lock the seatbelt.
Did subject use lock-offs correctly?	If CRS comes with lockoffs for locking the seatbelt, the subject used them as indicated in the child restraint manual.
Did subject use retractor to lock belt?	If subject locked seatbelt by using the switchable retractor (when available) in locked mode.
Did subject use locking latchplate to lock belt?	If subject used locking latchplate (when available) to lock seatbelt.
LATCH attached to correct lower anchors?	The lower connectors are attached to the correct vehicle hardware.
Lower connectors	The lower connectors are fully engaged in the right orientation with

attached appropriately?	the LATCH webbing flat.
Is tether hook attached to anchorage?	Tether hook attached to the correct vehicle hardware.
Is tether hook attached correctly?	The tether hook is fully engaged and in the correct orientation.
Is tether routed correctly wrt headrests?	The tether is routed with respect to the head restraints in the manner specified by the vehicle owners manual.
Is tether tight? (measure)	Pinch the slack in the tether webbing into a loop and measure the height of the loop. Tether is tight if height of loop is 5 mm or less.
Is tether stored?	If tether is not used, is it stored in the location provided on the child restraint.
Is LATCH stored?	If LATCH belt is not used, is it stored in location provided on the child restraint?
Did subject remove vehicle headrest?	
Did subject buckle harness correctly?	
Is harness snug (measure)?	Pinch the slack in the harness webbing into a loop and measure the height of the loop. Harness is snug if webbing cannot be pinched.

Testing Script / Protocol

CRS should be set up with harness position closest to dummy's shoulders. Rest of components should be in "out-of-the-box" configuration, including:

Recline
Tether storage
LATCH storage
Instruction storage

<u>Introduction</u>

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

We will videotape some of the installations. When we do, we would like you to talk about what you are doing and thinking.

You might want to remove your jewelry (watch, large rings, etc.).

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. I am not allowed to help you install the child seat. If you ask me a question, I might not be able to give you a clear answer.

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.
We would also like you to fill out this ethnicity form. You can still participate if you do not want to fill out this form.
Give subject consent form to read and sign; give subject ethnic/race form to fill out.

The top of this cart has tools you can use for installing the child seat. This is your baby for today. He is 18 months old and weighs 25 pounds and we have set up the harness on the car seat so he will fit in it. Here are the instructions for the child restraint, and the vehicle instructions are stored in the glove compartment (or where they are).
Pool noodles and flat screwdriver will be on test cart.

<u>Installation #1</u>

Please install this seat ______________ facing for this child at the *(right rear/center)* ______________ position in the vehicle. We would like you to try installing the car seat using (LATCH/the seatbelt).

- ☐ By forward facing, I mean the child is facing the same direction as the driver.
- ☐ By rear facing, I mean the child is facing the trunk.

Point subject towards first child restraint/vehicle to be tested.
Record start time of installation.

If subject cannot install using the method in that position, try having them install using the other method.

Record end time of installation.
Give subject questionnaire – direct them to fill it out behind a screen so they can't view the experimenter checking installations.
Assess installation using check form.

If you want to look at the labels or instructions 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 or vehicle features (e.g. this thing is the harness clip, this is the tether anchorage).

<u>Installation #2</u>

Please install this seat ______________ facing for this child at the *(right rear/center)* ______________ position in the vehicle. We would like you to try installing the car seat using (LATCH/the seatbelt).

- ❑ By forward facing, I mean the child is facing the same direction as the driver.
- ❑ By rear facing, I mean the child is facing the trunk.

Point subject towards second child restraint to be installed.
Record start time of installation.

If subject cannot install using the method in that position, try having them install using the other method.

Record end time of installation.
Give subject questionnaire – direct them to fill it out behind a screen so they can't view the experimenter checking installations.
Assess installation using check form.

If you want to look at the labels or instructions 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 or vehicle features (e.g. this thing is the harness clip, this is the tether anchorage).

<u>Installation #3</u>

Please install this seat ______________ facing for this child at the *(right rear/center)* ______________ position in the vehicle. We would like you to try installing the car seat using (LATCH/the seatbelt).

- ❑ By forward facing, I mean the child is facing the same direction as the driver.
- ❑ By rear facing, I mean the child is facing the trunk.

Point subject towards third child restraint/vehicle to be tested.
Record start time of installation.

If subject cannot install using the method in that position, try having them install using the other method.

Record end time of installation.
Give subject questionnaire – direct them to fill it out behind a screen so they can't view the experimenter checking installations.
Assess installation using check form.

If you want to look at the labels or instructions 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 or vehicle features (e.g. this thing is the harness clip, this is the tether anchorage).

<u>Installation #4</u>

Please install this seat ______________ facing for this child at the *(right rear/center)* ______________ position in the vehicle. We would like you to try installing the car seat using (LATCH/the seatbelt).

- ❑ By forward facing, I mean the child is facing the same direction as the driver.
- ❑ By rear facing, I mean the child is facing the trunk.

Point subject towards fourth child restraint/vehicle to be tested.
Record start time of installation.

If subject cannot install using the method in that position, try having them install using the other method.

Record end time of installation.
Give subject questionnaire – direct them to fill it out behind a screen so they can't view the experimenter checking installations.
Assess installation using check form.

If you want to look at the labels or instructions 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 or vehicle features (e.g. this thing is the harness clip, this is the tether anchorage).

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

If subject decides to drop out of the study, pay $12/hr rate for the participation so far.
If subject does not complete all four installations within 3 hours, they can stay longer if possible or just finish the third installation.

Testing Script / Protocol

Questions

If subject can't find instructions for the child seat and asks for help, experimenter can show them where they are.

If subject asks 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 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, why don't you try putting it in using (*LATCH/seatbelt*) instead.

If subject asks what LATCH is, state:
You can find out about LATCH in the manuals for the child seat and the vehicle.

If subject asks how they did, experimenter is allowed to provide a general assessment such as:
You did pretty good *or* You improved between the first and last *or* There are some areas that could be improved like tightness of the installation
Here is 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 flyer for Mott Buckle Up Hotline (fitting station at UM hospital).

Testing Script / Protocol
<u>Questions</u>

If subject can't find instructions for the child seat and asks for help, experimenter can show them where they are.

If subject asks 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 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, why don't you try putting it in using (*LATCH/seatbelt*) instead.

If subject asks what LATCH is, state:
You can find out about LATCH in the manuals for the child seat and the vehicle.

If subject asks how they did, experimenter is allowed to provide a general assessment such as:
You did pretty good *or* You improved between the first and last *or* There are some areas that could be improved like tightness of the installation
Here is 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 flyer for Mott Buckle Up Hotline (fitting station at UM hospital).

Appendix D

Subject Evaluation Forms

Appendix D: Subject Evaluation Form – Task 2

Subject ID: Installation number: 1 2 3 4

Vehicle: A B C D CRS: C6 C10 **Configuration:** RF FF **Method:** L SB Both

Check one answer for each question

Do you agree with these statements?	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**NA**
I attached the child seat to the vehicle correctly.						
The vehicle manual matched the child seat manual.						
What I did today is similar to what I would do at home to install a child seat.						
The vehicle headrest made it hard to install.						
The stiffness of the vehicle seat made it hard to install.						
The shape of the vehicle seat made it hard to install.						
The seatbelt buckles got in the way of using LATCH.						

Appendix D: Subject Evaluation Form – Task 2

For seatbelt installations

How hard or easy was it to:	**Very Hard**	**Hard**	**Neutral**	**Easy**	**Very Easy**	**NA**
Understand the labels on the child seat						
Understand the instruction manual about installing the child seat						
Understand the vehicle instruction manual about installing the child seat						
Figure out how to lock the seat belt						
Figure out where to route the vehicle belt						
Tighten the vehicle seat belt						
Figure out what angle the child seat should be						
Adjust the angle of the child seat						
Use the lock-offs on the child seat that pinch the vehicle belt						
Find the tether anchorage in the vehicle						
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 LATCH belt						
Store the top tether (if not used)						

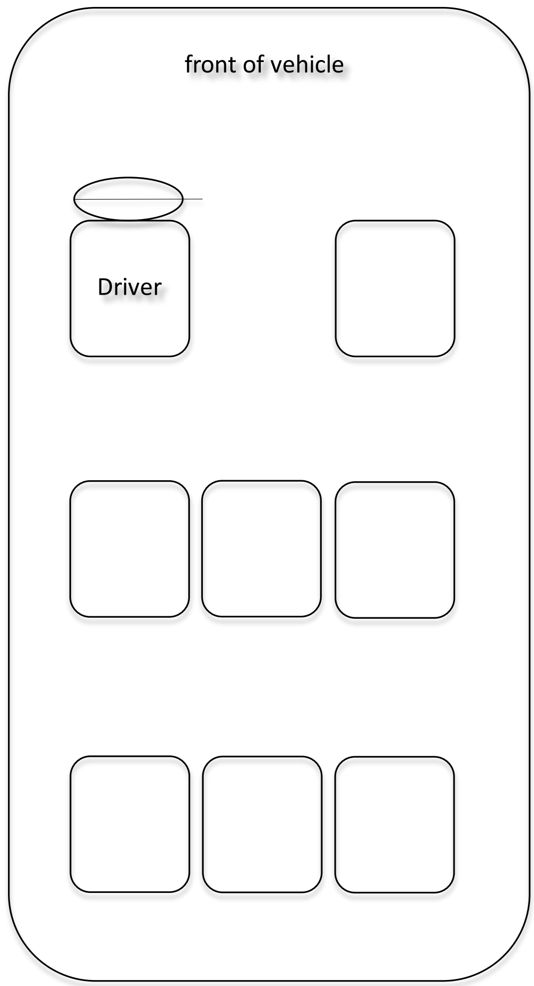
Appendix D: Subject Evaluation Form – Task 2

For LATCH installations

How hard or easy was it to:	Very Hard	Hard	Neutral	Easy	Very Easy	NA
Understand the labels on the child seat						
Understand the instruction manual about installing the child seat						
Understand the vehicle instruction manual about installing the child seat						
Find the lower anchorages in the vehicle						
Find the tether anchorage in the vehicle						
Figure out where to route the LATCH belt						
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)						

Appendix D: Subject Evaluation Form – Task 2

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.



Appendix D: Subject Evaluation Form – Task 2

Subject ID: Date:

Which method did you like best for installing child seats forward-facing (circle one)

LATCH Seat belt

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	Name of Vehicle	1	2	3	4	5	6	7	8	9	10
1											
2											
3											
4											

Do you have any suggestions or comments on the vehicles?

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