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16. Abstract

This study examined the mistakes that drivers made during the different steps taken to install Child Restraint Systems (CRS). The focus of this study was to identify the reasons drivers made installation mistakes. The participants were observed during their CRS installation process where unfolding installation errors lead to clues about why participants had difficulty with their installation. Five experiments were conducted to identify common errors installing CRS using seat belts or the attachment system known as Lower Anchors and Tethers for Children (LATCH). The investigation examined the factors that contribute to these errors and identified possible improvements that could reduce them. In experiments 1 and 2, 61 participants completed an infant CRS installation to the best of their ability using the original CRS instruction manual and their vehicle owner's manual. Participants were asked to use a "talkaloud" method, where they explained whatever they were examining, thinking, doing, and feeling as they went about their task. The CRS installation was video-taped with their consent. Participants rated their confidence levels, ease of installation, and CRS usability after the installations were completed. All participants who installed the child seat using the seat belt made at least one error. There was a 95% error rate for participants who completed the infant CRS installation using LATCH. Participants expressed confusion with a feature on the CRS or vehicle approximately two times for each seat belt and LATCH installation. In experiment 3, 22 participants completed a rear-facing and forward-facing installation with a convertible CRS. Common installation problems were loose installation (85%), incorrect seat angling (81.8%), and twisted lower anchor straps (50%). Studies 4 and 5 explored CRS installations by parents and caregivers at child seat inspection events and from parents and caregivers found from local community postings. The installation errors reflected similar common errors found in studies 1-3 but to a lesser degree. Loose installation error rate ranged from 46.7 percent to 65 percent (seat belt or LATCH) and incorrect angling ranged from 27 to 50 percent in studies 4 and 5, respectively. As participants installed the child seats, they acknowledged the difficulty in installing the CRS into the vehicle and with interpreting the manuals but were overly confident that they correctly installed the CRS. Analyses were conducted on the installation errors made by installation type, feature differences across the child seats used, and user ratings.

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Executive Summary

Child restraint systems (CRS) are known to be difficult to install (Taft, 1999; Decina & Lococo, 2006; 2004). The current designs of child seats, vehicle seats, and attachment mechanisms can lead to problems in child seat installation. To reduce these problems, some studies (e.g., Rudin-Brown, C. et al., 2004; 2003) point to a need for more emphasis on improving installation procedures and designs for child restraints, instruction manuals, and warning labels. Child seats have varying designs that can contribute to installation error when they are not intuitive. Identifying why and where parents become confused during the installation process can provide insights about what improvements might help them. For example, improvements might be needed to simplify CRS instructions and vehicle owner's manuals as well as with modifications to the design characteristics of child and vehicle seating.

Research Objectives and Methodology

The objective of this research was to identify why drivers are making mistakes when installing child seats and possible improvements that might help reduce their errors. The main focus of this research was to understand what happens during the installation process that leads to errors. Potential interactions between the child seat and vehicle design were also explored. Five separate but related studies were conducted. The focus of studies 1 and 2 was on understanding novice installation errors with infant CRSs; study 3 looked at inexperienced participants installing convertible CRSs, and studies 4 and 5 observed experienced participants.

This study also aimed to capture a wide spectrum of participants. The populations sampled included novices with little to no experience installing a child seat as well as parents and caregivers who currently own and use child seats, some of whom were observed at child seat inspection events and checkups. An observational "talkaloud" method was used to record the problems that first time installers encountered during the process of installing infant and convertible child seats. Participants expressed their thoughts and insights as they installed their child seat and after the installation process was completed. This information as well as observations by a certified Child Passenger Safety Technician of mistakes participants made during the installation process was analyzed to determine the factors that contributed to any errors or difficulties in installation.

Results

Installation errors occurred when people installed child seats in vehicles using seat belts as well as when using Lower Anchors and Tethers for Children (LATCH) systems. Common installation errors such as loose installation and twisted lower anchor or seat belt straps were found frequently in the studies, regardless of the participant's experience with child seat installation and whether the child seat installed was an infant or convertible child seat. Novices were observed while they installed a rear-facing infant seat into their vehicle in studies 1 and 2. Three main errors found during the 37 LATCH

installations were as follows: (1) loose installation (73%), (2) installation of both seat belt and LATCH systems (45.9%), and (3) twisted lower anchor straps (35.1%). Other installation errors included inappropriate recline positions (30.8%) and incorrect carrying handle positions (28.2%). Most participants said they were confident that they had routed the belt system correctly (71%) during installation, secured the LATCH system correctly (72%), or believed that their CRS was installed correctly (87%). Nonetheless, only 26.9 percent correctly secured the LATCH system. Most participants shook or pushed the CRS to test whether the CRS moved more than an inch from side-to-side. The high error rate of loose combination seat belt and LATCH installations showed that participants still had problems with securing the CRS despite the feeling of "added security" that warranted many participants to use both attachment systems

Novices were observed while they installed a convertible child seat in study 3. Common errors were loose installation using the LATCH system (85%), installing the child seat at an incorrect angle (81.8%), and twisting the lower anchor straps (50%). The confusion participants had when referencing the CRS manual or label instructions led to several convertible child seat errors such as seat belt or LATCH routing problems (45%). In some cases, LATCH-twisting errors resulted from incorrectly switching the routing from the rear-facing position to the forward-facing position.

Installations by parents and caregivers with experience using child seats were examined in studies 4-5 at inspection events. Their installation errors reflected the common errors found with novice participants in studies 1-3 but to a lesser degree. In study 4, the loose installation error rate was 46.7 percent (seat belt or LATCH). Twenty-seven percent installed their child seat at an incorrect angle (3 rear-facing, 1 forward-facing, N=15). This error was also seen in study 5 where one half of the observed participants incorrectly angled the child seats (N=32). Loose installation of the CRS occurred for 65 percent of the people with convertible child seats using LATCH in study 5. Another common error that occurred in 77 percent of the installations was twisted LATCH straps.

After each installation or checkup in studies 3-5, participants were surveyed about their experience and asked for design feedback. A majority of participants said that they read the CRS manual (94.1%) while few reported reading the vehicle owner's manual (36.2%). Some parents suggested that manuals could be improved with clearer diagrams and easier set-up guides with fewer steps. Most participants were also unsure how to get their CRS installation tight. Some participants were not aware that applying their weight or additional pressure to the child seat would help achieve a tight installation. Some participants said that it was too difficult to pull the straps to secure the LATCH or seat belt system tightly.

Recommendations

Given that participants were often confused with the instruction manuals and labels, errors may be reduced by modifying their designs. Manuals can be made more readable and simplified to clearly list each of the steps to install the CRS (Wegner & Girasek, 2003). The manuals should list common installation problems and methods to check for correct fit of the CRS. Labels can provide helpful location cues to remind and inform parents and caregivers of the steps for a successful child seat installation. Participants have commented that some of the pictures in the manuals are confusing because they do not provide context and that they cannot find the equivalent objects of interest on the child seat. One approach to reduce this confusion may be to add zoomed-out pictures to the manuals to provide perspective to the installer. Using a similar color coding scheme to highlight areas of importance or numbering labels to correspond to instructions (Smith, 2003) are also possible ways to coordinate information between the manual and CRS.

Another approach that may help reduce installation errors is to put some instructions on the child seats near features that require installer adjustment, such as level indicators and seat belt lock-off systems. The manuals should provide supplementary, supporting information. Human factors design principles such as affordance, color coding, and intuitive organization may be helpful in efficiently organizing the abundance of information provided with the child seat. Numerous parents and novice participants have commented on the overwhelming choices and options with child seats. Thus, the information provided through manuals, labeling, and web content should aim to be intuitive to child seat installers through coherent instructions that are verified to be easy-to-understand with user testing.

Future research is needed to evaluate the effectiveness of design improvements in reducing installation errors. For example, what design improvements will reduce the most common error of loose installation? Participant installation differences found across CRS types allude to possible interactions between varying child seat designs and vehicle design. Understanding the variations and its effects on installation will allow achieving best fit for child seats.

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1 Background

In a Child Restraint System (CRS) misuse study sponsored by NHTSA (Decina & Lococo, 2004), field observations were conducted in six states where 72.6 percent of the 3,442 CRSs displayed one or more forms of misuse. Examples of misuse were inappropriate CRS for the child's age and weight, wrong CRS direction, loose installation, and improper placement of the CRS. The most common forms of misuse were loose harness straps when securing the child to the CRS and loose safety belts when securing the CRS to the vehicle. Harness retainer clip misuse was also prevalent, but not a severe misuse.

In a following study, Decina & Lococo (2007) focused on observed misuse with CRSs installed with Lower Anchors and Tethers for Children (LATCH) for 1,000 children less than 5 years of age. Approximately one-third of the drivers used the vehicle safety belt to attach the CRS despite the fact that LATCH was available in the seating position occupied by the child. Drivers who did not like using LATCH responded that they had difficulty with releasing from bars, hooking to bars, tightening, and difficulty seeing and finding the bars. Loose installation where the CRS moved more than one inch from side-to-side constituted 30 percent of observed misuse.

Previous studies (Rudin-Brown et al., 2004; Rudin-Brown et al., 2003) have reported comparatively higher difficulty with rear-facing child seat installations. Rudin-Brown (2004) noted that participants often had a strong tendency to install the CRS into the vehicle in the forward-facing direction despite the labels affixed to the child seat that specified infants to be installed rear-facing. Rudin-Brown and her colleagues found that optimal labels located in the front and back of the CRS with a pictogram and text improved task compliance levels to 50 percent. They also recognized that CRS installation experience level and label location were factors in label compliance. Additionally, external factors such as misconceptions leading subjects to believe a child is safe facing forward should be considered when designing instructions and labels for parents and caregivers.

If drivers were aware that their installation was incorrect, they may seek help to fix the problems. However, drivers may not know that the CRS installation was incorrect. The level of disconnect between the participant's assessment on a child seat installation is noted in studies showing high confidence levels despite mistakes made. In a report by National Safe Kids Campaign (NSKC), 96 percent of parents believed they installed their child seat correctly. However, data from child seat checkup stations consistently show that four out of five participants unintentionally made potentially hazardous installation mistakes (Decina & Knoebel, 1997; 1996; National Safe Kids Campaign, 2004).

Installation problems occur because child restraint systems are known to be complicated to install due to such factors as confusing child seat design, vehicle design, and instructions. In order to be effective, child restraint systems must be installed correctly. CRS misuse is important to correct because a correct installation can reduce the risk of fatal injury by 71 percent and hospitalization by 67 percent (Kahane, 1986).

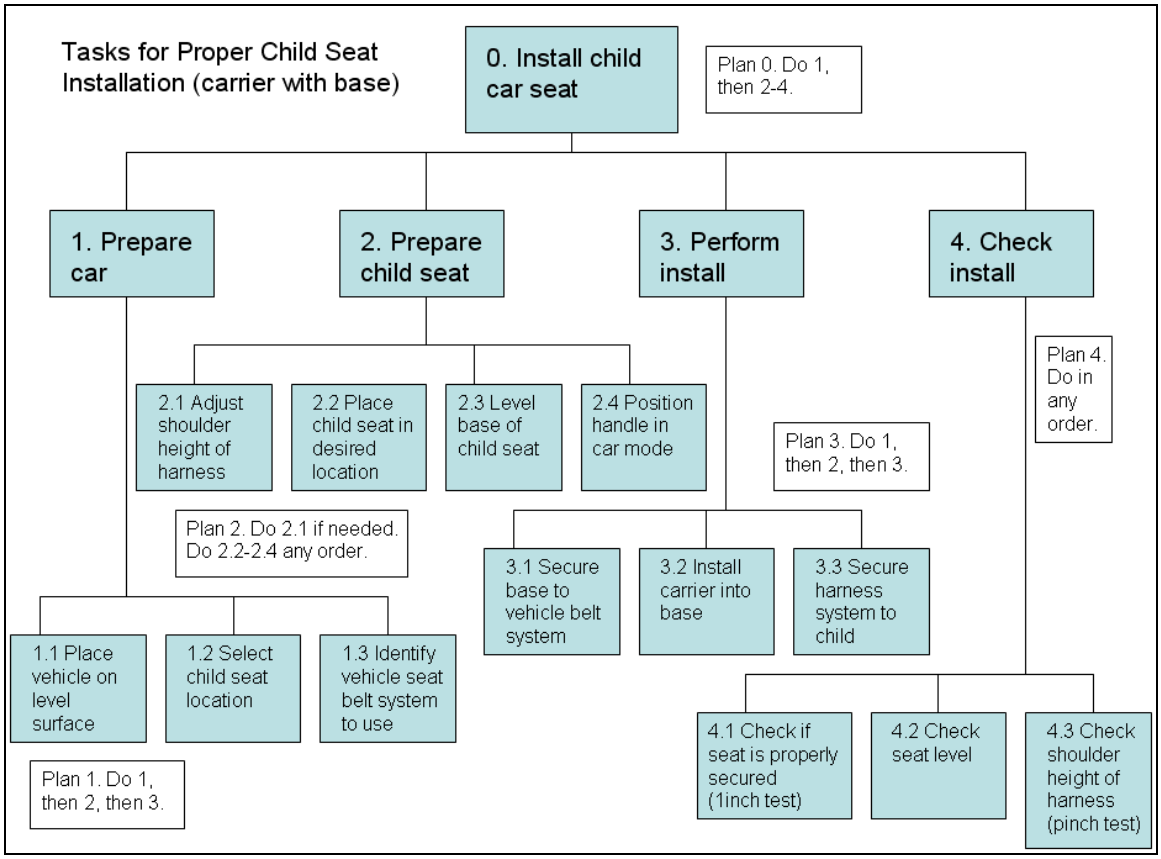

Figure 1. Hierarchical Task Analysis of proper child seat installation.

A CRS installation is complicated because of the numerous steps involved in achieving a proper fit with a vehicle and securing the child in the CRS. To examine the complexity of installing a CRS, a Hierarchical Task Analysis (HTA) was performed to document all the steps necessary to properly restrain a child. This framework is used to understand installation requirements and for identifying areas that need improvement. The goal of correctly installing a CRS requires the completion of four main sub-tasks: preparing the vehicle, preparing the child seat, performing the CRS installation, and checking the installation after completion (See Figure 1). Each sub-goal is comprised of operations that can be further broken down into smaller tasks. Because it is necessary for participants to complete each sub-task, mistakes that stem from any operation may lead to installation failure. In an effort to understand these errors, the task of installing a child seat is broken down as sequential steps in the HTA. Installation failures can occur at any step in this process and examining these steps in detail can help us understand at what points the installation problems occur.

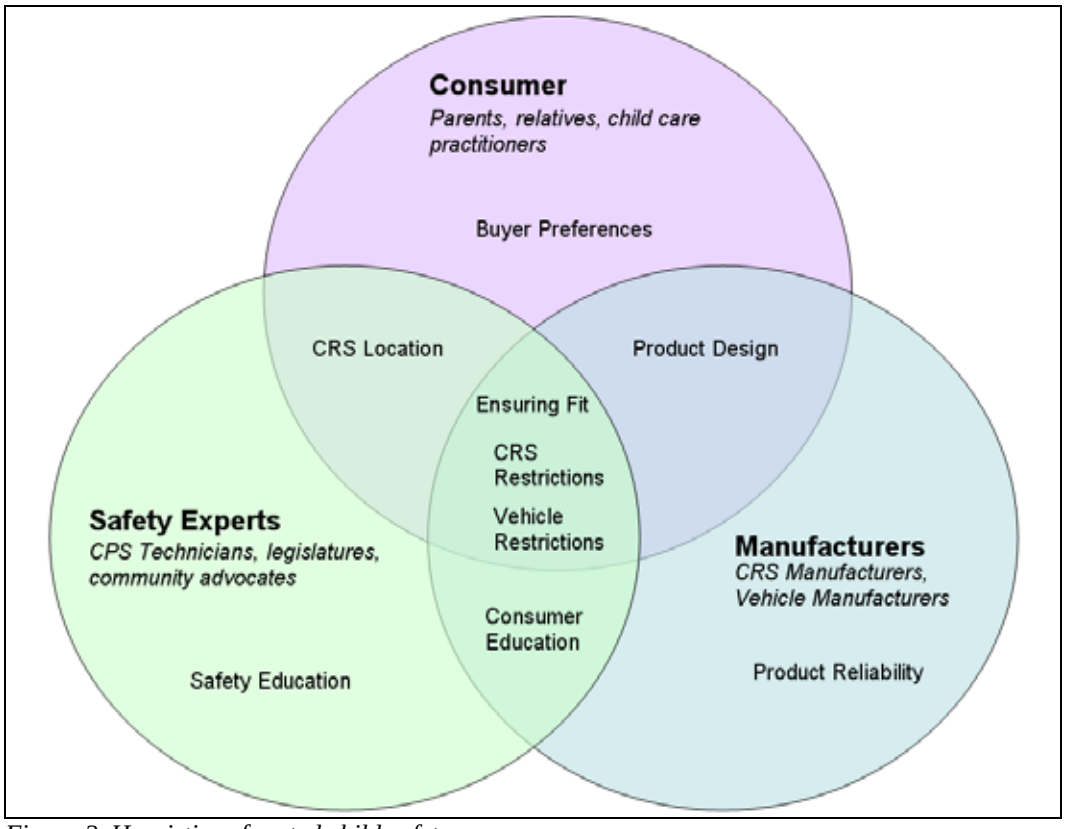

Figure 2. Heuristics of vested child safety groups

The perspectives and knowledge of consumers, safety experts, and manufacturers are needed to understand how to ensure the safest child seat installation (See Figure 2). External information that parents hear from outside sources such as from parenting classes or from friends can also influence their child seat installation. The most important group to understand is the consumers of child seats: parents, relatives, or child care practitioners. Their buying preferences and the external information they receive can influence the type of vehicle or child seat they buy and the type of installation errors they make. Child seat and vehicle manufacturers provide information to the child seat consumer through their product design and manual instructions. Safety experts are another vested child safety group comprised of community advocates and Child Passenger Safety (CPS) technicians trained to assist parents and caregivers with installing child seats and encouraging safe practices. Unfortunately, child seat inspection sites are often hard to find and the events occur infrequently. At child seat inspection sites, safety experts work with parents to understand the product and help them with their child seat installation. As mentioned previously, child seat misuse is commonly found at child seat inspection sites. Many adults are unaware that they are using the child seat incorrectly and thus, placing their children at risk (Decina, Lococo & Doyle, 2006). If parents are unaware of child seat errors, installation errors may be underrepresented in studies involving only parents surveyed at child seat inspections.

Installation errors can be prevented by recognizing the types of errors child seat installers make and most importantly, *why* and *how* they make them. This project explored potential approaches to reducing these errors by observing the behaviors of first time

child seat installers and parents or caregivers with varying experience installing child seats.

The first three studies recorded the decision-making process of participants during these installation tasks to understand the reasons why and at what point they encountered difficulty. While past studies have evaluated misuse patterns at child seat checkup locations where experience handling a child seat may vary, this project uses the scenario of a potential new parent installing a child seat for their first time. Testing novice participants increases the chances of observing errors and controls for level of familiarity with CRS. Child seat checkup locations, day care facilities, and local community groups were examined in the fourth and fifth studies to observe similarities and differences in installation errors and to receive feedback on proposed CRS designs and instruction manual information. The focus of these studies is to examine the origin of the installation errors and identify possible preventive measures. These studies did not focus on accurately estimating the magnitude of the installation errors. Larger scale, field surveys at checkup locations have quantified the prevalence of error rates.

Five related studies were conducted. The first study examined the installation process for older vehicles that were not equipped with LATCH systems as well as newer vehicles with LATCH. The first study also evaluated step 3.3 in the task analysis—placing the child in the seat harness. For the second study, data was only collected on attaching the child seat in LATCH-equipped vehicles. In both studies, participants were asked to install rear-facing child seats. In the third study, data was collected for participants who installed convertible child seats rear-facing and forward-facing in LATCH-equipped vehicles. The fourth study was an observational study conducted at day care facilities and apartment communities in the Northern Virginia area. The fifth study was also an observational study and conducted at local child seat inspection sites in the Maryland, Washington, D.C., and Virginia area.

1.1 Study Objectives

The main objective of this study was to identify child seat installation errors and understand what happens during the installation process that leads to these errors. Potential interactions between the child seat and vehicle design were also explored. To comprehend the possible ways to reduce installation errors, we focused our study on answering the following questions:

- What problems are parents and caregivers having?

  The first step is to identify where parents and caregivers become confused during the installation process and what installation errors they make. Methods to identify installation errors included videotaping, participant talkaloud, and an assessment of the installation by a certified Child Passenger Safety technician.

- Why are they having these problems?

Numerous child seat installation errors are found at child seat inspection sites. The reasons for these errors may be attributed to several factors such as confusing instructions and poor fitting of the CRS to the vehicle seat. Analyses of the participant talkaloud, videotape, questionnaires, and interviews allowed a comprehensive view of the problems and why they are occurring.

- How can the problems be prevented?

Child seats and vehicles have varying designs that can contribute to installation errors when they are not intuitive. Vehicle characteristics that affect child seat installation error rates were surveyed. Participants with varying child seat experience were interviewed about their installation thought process and rated key CRS design features such as the level indicator and lower anchors. Their feedback and ratings of the manual instructions and labeling provided insight about installation error prevention. Participants also contributed feedback on the varying CRS features and proposed design solutions.

2 Research Methodology

2.1 Participants

The first three studies involved participants who had little to no experience with child seat installation, particularly using the LATCH system (Table 1). The fourth and fifth studies involved participants who owned child seats that were recruited by flyer or emails from local day care facilities, the George Mason University (GMU) subject pool, local Making Our Mothering Significant (MOMS) groups, and child seat checkup events.

Table 1. Participant sample type by study.

Study	CRS Evaluated	CRS Experience Level	Vehicle Restrictions	Recruited From
1	Infant	Novice	None	GMU Subject Pool
2	Infant	Novice	LATCH-equipped vehicles (2002 or newer)	GMU Subject Pool
3	Convertible	Novice	LATCH-equipped vehicles	GMU Subject Pool/Flyers, Craigslist
4	Varying	Varying	None	Day Cares/GMU Subject Pool/ Libraries/MOMS groups
5	Varying	Varying	None	Child Seat Checkup Events

2.1.1 Studies 1-2: Understanding Infant CRS Errors

In studies 1 and 2, a total of 61 participants (23 males, 38 females) ranging from ages 18 to 42 installed a rear-facing CRS into their vehicle using the original CRS instruction manual and their vehicle owner's manual. Participants were recruited from the George Mason University Psychology Department subject pool and given school credit for their participation. The sampled population included drivers with a valid license but with little to no experience installing child seats to control for level of expertise and increase the chances of observing installation problems. Forty-two participants had no experience installing child seats, twelve participants previously installed a child seat less than five times, and seven participants installed a child seat (with seat belt only) more than five times previously in vehicles other than their own.

The first study observed participants installing a CRS in their vehicle and a child test dummy in the CRS. In order to observe as many types of errors as possible, vehicle make/model/year was not restricted. A majority of participants (73%) brought an older vehicle that was equipped only for seat belt installation. Twenty-six participants (M =

24.2 years old, SD = 5.1) completed the CRS installation using the seat belt only (vehicles 2001 and older). Only six subjects had LATCH-equipped vehicles and completed the CRS installation using the LATCH system.

The second study did not include the infant test dummy installation and restricted participants to those with vehicles 2002 and newer. Since LATCH is required on all vehicles manufactured after September 1, 2002, the exclusion of participants with older vehicles was necessary in order to observe installations using the LATCH system. There were thirty-one participants (M = 21.5 years old, SD = 4.4) who completed an installation with the LATCH system.

2.1.2 Study 3: Understanding Convertible CRS Errors

Twenty-two participants (10 males, 12 females) ranging from ages 18 to 34 were recruited from the George Mason University (GMU) Psychology Department subject pool, flyers posted at GMU-approved message boards, and on the volunteer section of the website Craigslist.org (http://washingtondc.craigslist.org/). Craigslist.org is an online network of free classified advertisements. Participants were given school credit or a $15 gift card for their participation. The sampled population included drivers with a valid license but with little to no experience installing child seats to control for level of expertise and increase the chances of observing installation problems. Sixty-four percent of the participants reported that it was their first time installing a child seat. No participants reported any experience installing a child seat using LATCH.

2.1.3 Study 4: Understanding CRS Installation Errors of Parents and Caregivers

Thirteen participants who owned child seats were recruited from the George Mason University (GMU) Psychology Department subject pool, day care centers in the Fairfax, VA area, and local Northern VA MOMs groups. Flyers were left at various day cares and libraries in Northern Virginia with contact information for a free child seat checkup. The study was also advertised with various local chapters of MOMS clubs (http://www.momsclub.org/) in the Northern Virginia area. Participants were either given school credit or participated voluntarily by scheduling a check up appointment with the experimenter.

Parents who currently own child seats were recruited: (1) to examine whether CRS installation errors are different for populations who have not participated in child seat inspections and (2) to combine their feedback on CRS design solutions with a more comprehensive sample of potential and current child seat installers (studies 3-5).

A total of 19 child seats were evaluated. Ten of the seats were convertible, 5 of the seats were for infants, and 4 of the seats were booster/combination child seats. All participants had vehicles 2002 and newer and completed their child seat installation prior to arriving at the child seat check up. All participants in this study were parents currently using their CRS for their child. Forty-seven percent of the parents arrived at the check up with their child.

2.1.4 Study 5: Understanding CRS Installation Errors at Child Seat Inspections

Thirty-one participants agreed to be observed during their child seat inspection and were interviewed after their experience. There were 32 child seats (14 convertible, 16 infant, 2 Forward-Facing (FF) CRS only) observed. Participants were recruited from local child seat checkup events in Maryland, Virginia, and Washington, D.C. area. These checkup events were conducted by CPS technicians from police and fire departments and community volunteers. The observed sample was limited to participants who had vehicles 2002 and newer and completed their child seat installation prior to arriving at the child seat checkup event. Twenty-two percent of participants had their child seats checked before (N= 32 child seats). Thirty-four percent of the parents and relatives arrived at the inspection event with their child.

2.2 Vehicle Characteristics

2.2.1 Studies 1-2

Of the 26 participants who completed the CRS installation using seat belts from study 1, a majority had 4-door sedans (66.7%). Participants with two-door sedans (13.3%) and SUVs (10%) also completed the study. The remaining participants brought convertible, minivan, and station wagon type vehicles (3.3%) to the study. The average year of the vehicles in the study for participants that completed a seat belt installation was 2000 (SD = 3.9) with an average 2.8 years owned. Participants that completed the CRS LATCH installation from study 2 came with 4-door sedans (53%), 2-door sedans (26%), and SUVs (21%). The average year of vehicles in the study that completed the LATCH installation was 2005 (SD=2.0). The thirty-nine participants (M = 22.1 years old, SD = 4.1) had LATCH-equipped vehicles (2002 and newer).

2.2.2 Study 3

The average vehicle year was 2005 (SD = 2.2 years). Sixty-eight percent of subjects arrived with a 4-door vehicle, 18.2 percent with a SUV or crossover vehicle, and 13.6 percent arrived with a 2-door vehicle. Seventy-three percent of the vehicles did not allow for a LATCH center position CRS installation. Approximately 68 percent of the vehicles had cloth seats and 31.2 had leather seats. Seventy-seven percent of the vehicles were observed to have LATCH "baby dot" markers that indicated the nearby location of the lower anchor system while 22.7 percent of the vehicles had no markers or dots with any LATCH marking.

2.2.3 Study 4

There were 13 vehicles examined in this study. The average vehicle year was 2005 (SD = 2.2 years). A majority of the vehicles were 4-door vehicles (61.5%). A few other vehicles types such as SUVs (23.1%), minivans, and station wagons were also examined. Only two of the vehicles were equipped with leather seats (15.4%). Most of the vehicles examined had a LATCH baby dot marker and a tether anchor marking for the tether

system that indicated the location of the LATCH system (84.6%). Eighty-five percent of the vehicles did not allow for center LATCH installation.

2.2.4 Study 5

The average vehicle year observed at the child seat checkup events was 2006 (SD = 2 years). A majority of the participants had 4-door sedans (51.6%). Other participants arrived at the checkup events with SUVs (25.8%), minivans (6.5%), crossovers (6.5%), and other vehicle types (9.7%). Twenty-two vehicles (71%) in this study did not allow for center LATCH installation. Over half of the vehicles observed had leather seats (58%) while 42 percent of the vehicles had cloth seats.

2.3 Equipment

2.3.1 Studies 1-2: Infant CRSs Used

Three commercially available rear-facing infant CRSs with 5-point harness designs were chosen that represented a range of available features (See Figure 3). Each of the CRSs have different features such as carrying handle styles, level indicators, LATCH connectors, and base adjustment levelers. CRS A has a flexible LATCH system constructed of steel that is stored inside the base. The level of the base is manually adjusted by pushing the front side of the base to the appropriate level marking with colored level indicators on the side. CRS B has flexible LATCH connectors, a base angle adjustment knob on the front of the base, and a built-in lock-off system on the base that eliminates the use of a locking clip. The CRS B side level indicator shows a correct level position when the ball inside the indicator is positioned in the marked green area. CRS B must be installed with the base while CRS A and C can be installed with or without the base. The 5-point harness system is tightened from the front of the child seat for CRS A and B. CRS C has flexible LATCH connector hooks and a 5-point harness system with a two piece chest clip. The level indicator on CRS C is a window on the side of the seat which shows orange if the CRS is installed at the correct angle.

CRS A	CRS B	CRS C

Figure 3. Child restraint systems used in studies 1-2.

A major example of feature differences in the child seat design are the LATCH connector types (See Figure 4). Both LATCH variations of CRS A and B require the participant to press and hold the red button on the connector while connecting and disconnecting to and from the anchor points. The lower connector for CRS C is a hook-on attachment where pushing down on the anchor point with the connector will open the flexible metal. Removing the connector requires manually opening the flexible metal to allow the hook to pull out from the anchor points.

Figure 4. LATCH connector variations of CRS A, B, C.

2.3.2 Study 3: Convertible CRSs Used

Two commercially-available convertible CRSs were tested in study 3: CRS D and CRS E (See Figure 5). CRS E is lightweight and has flexible LATCH connector hooks similar to CRS C. CRS D and E both have a 5-point harness system with a two piece chest clip. CRS D has several unique features such as built-in side lock-off clips, Safe Guard LATCH connectors (similar to CRS B), and a Versa-Tether that is recommended for installation for the rear-facing position and required for the forward-facing position. The Versa-Tether has two straps that are on each top side of the child seat compared to other tethers on convertible and forward-facing seats. Both tether systems anchor the top of the child seat to the tether mount in vehicles.

CRS D	CRS E

Figure 5. Child restraint systems used in study 3.

2.4 General Procedure

Participants were asked to arrive with a familiar vehicle and to bring the owner's manual for all studies. Studies 1-3 were comprised of participants installing a child seat into their vehicle while participants in studies 4-5 were interviewed about their child seat experience after their child seats were checked by a child passenger safety technician. The CRS used was randomly selected for each participant in each study. The specific instructions given to participants are listed in Appendix E for studies 1-2 and Appendix F for study 3. No specific instructions were given to participants in studies 4-5 because they arrived with their child seat installed and/or in use. The following elaborates on the specific differences and procedures for studies 1-3.

2.4.1 Studies 1-2

The participants in studies 1-2 were asked to install one of the three infant CRSs to the best of their ability to a vehicle they were familiar with (See Figure 3). In study 1, the experimenter told participants to secure an infant test dummy to the child seat in addition to installing the child seat to their vehicle. Participants were each given the scenario that they were a new parent installing the child seat for an upcoming trip with their newborn infant. In study 2, the experimenter told participants to only install the child seat in their vehicle since the focus of the study was to understand LATCH-related installation errors. Participants with LATCH-equipped vehicles (year 2002 and newer) were recruited for study 2.

Participants were given the CRS instruction manual and were told they could use their vehicle manual while performing the child seat installation. No specific information on the types of installation systems (seat belt or LATCH) was given to the subject. Participants were told to "talk out loud" and explain whatever they were examining,

thinking, doing, and feeling as they went about their task. There was no time limit specified to complete the child seat install.

The CRS installation was video-taped with their acknowledgement and consent. Each participant was video-taped with minimum identification in accordance with the George Mason University Human Subjects Review Board guidelines. The experimenter had participants install the CRS using the LATCH connection to the best of their ability if the participant completed a CRS install using the seat belt system and had a LATCH-equipped vehicle 2002 and newer.

2.4.2 Study 3

In study 3, participants were specifically told to complete an installation for a newborn and then complete an installation for a 40 lb toddler to the best of their ability. These instructions were intended to make participants complete a rear-facing installation for the newborn and a forward-facing installation for a toddler. The participant installed the CRS using the LATCH connection for their second installation if their first installation was not completed using LATCH.

2.5 Forms and Interview Process

Once the participant completed their installation(s), the experimenter completed a *Child Seat Observation Form (See Appendix A)*. All studies 1-3 participants completed 3-4 questionnaires once they finished the child seat installation:

- The *Subjective Questionnaire* assessed how easy and confident they found the task was to complete.
- The *User Confidence Ratings* assessed their confidence on each aspect of the child seat installation.
- Participants filled out a *Label and Instructions Usability Ratings* form detailing their ratings on how easy it was to understand the instruction manual and the labels affixed to the CRS.
- Study 3 participants completed an additional *Manual Usage Questionnaire* that assessed whether their CRS manual was helpful with completing their installation.

Study 3 participants were also interviewed after their installation and questionnaires were completed. Studies 3-5 participants were interviewed after their checkups were completed. When interviewed, participants were asked if they had any suggestions for manufacturers that would improve their overall experience. They then rated design, graphics and text options from a booklet of usability improvements (See Appendix G).

3 Results and Discussion

3.1 Statistical Analysis

Participant error rates and descriptive statistics were calculated. Subjective measures for manual and label usability and confidence ratings were also assessed for all studies. Mixed factorial analyses of variance (ANOVA), t-tests, and Fisher's tests were also conducted where appropriate with a .05 alpha level of significance.

3.2 Studies 1 - 2: Installation of Infant Child Restraint Systems

Studies 1 and 2 examined the types of installation errors encountered when novices installed rear-facing infant child seats and what may have caused these mistakes. This study simulated the possible experiences of a first-time parent who may not be familiar with child restraint systems. The data of studies 1 and 2 were combined where appropriate, such as with installation error rates by attachment installation type (seat belt or LATCH).

3.2.1 Use of LATCH System

Almost half of the participants having LATCH-equipped vehicles initially installed the CRS using only the seat belt. None of the participants were familiar with the LATCH system in their vehicles. Those choosing seat belts were apparently not able to understand the option for using a LATCH system the way it was presented in either of the instruction manuals. To capture a representative sample of LATCH installations, participants were asked to complete a LATCH system installation if they initially installed it with the seat belt. The initial and final installation percentages are depicted in Figure 4 for participants with vehicles having both seat belt and LATCH system capability. Of the LATCH-equipped vehicles, only 10 percent initially completed a LATCH-only installation. Some of the participants who initially completed the LATCH installation examined the vehicle owner's manual concurrently with the child seat manual while some only read the LATCH installation instructions from the child seat manual.

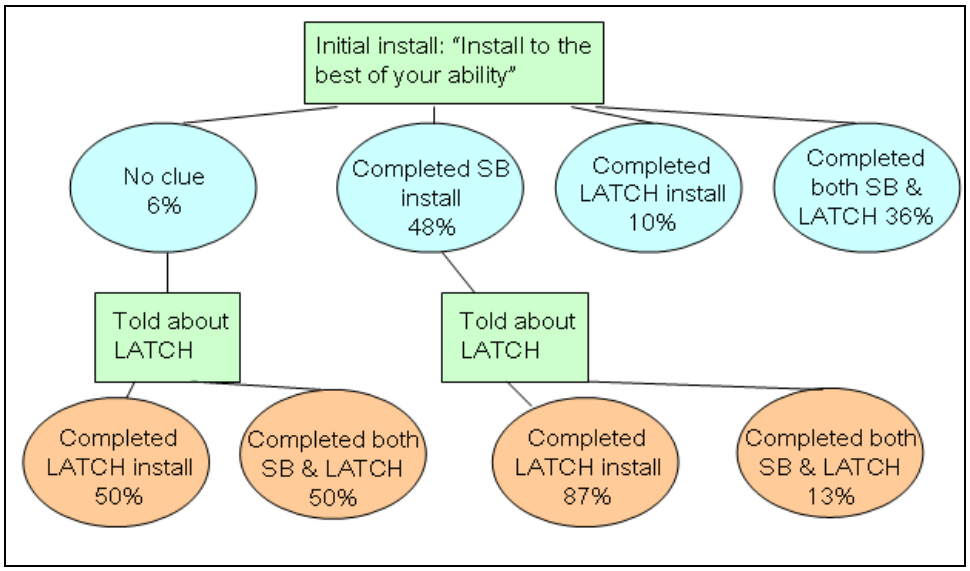

Figure 6. Diagram of initial and completed infant CRS installation for studies 1 and 2 participants with LATCH-equipped vehicles.

3.2.2 Infant CRS Installation Times

The average CRS install time was approximately 21 minutes for seat belt installation for study 1 participants, 15 minutes for LATCH installations for study 2 participants, and 25 minutes if both seat belt and LATCH systems were installed for study 2 participants. There were no significant differences in installation times across the different child seats or vehicle seat material. While participants were given both the child seat instruction manual and the vehicle owner's manual to use, only 33 percent of seat belt installation participants actually examined the vehicle owner's manual while 51 percent of the LATCH participants examined the owner's manual during installation. The participants varied with time spent reading and using the CRS and vehicle manuals. Some subjects showed better understanding when reading both the vehicle manual and the child seat instruction manual while others were confused with the directions or which instruction manual to follow.

3.2.3 Infant CRS Installation Error Rates

Few participants completed an error-free CRS installation. The types of errors that were tabulated are shown in the sample *Child Seat Observation Form* completed by the experimenter (See Appendix A). All participants completing the seat belt and child dummy installation (N=26) installed the seat with at least one error. Only two out of 39 participants (95% error rate) completed an error-free LATCH installation. These high error rates for both seat belt and LATCH installations suggest that people who have little to no knowledge about child seats, such as first-time installers, are highly likely to make an error when installing child seats.

Figure 7 gives examples of the primary errors participants made. Three main errors contribute to an unsafe child seat installation: (1) attaching the system (LATCH or seat belt) incorrectly to the vehicle, (2) securing the child incorrectly, and (3) improper

positioning of the seat in the vehicle. A fourth of the participants who installed rear-facing CRSs (studies 1 and 2) improperly positioned the carrying handle which leads to a CRS positioning error. Many participants had difficulty installing the attachment systems correctly given the high error rate of 95 percent for LATCH installs (N=37), 91 percent for all seat belt installs (N=54), and 46 percent combination installations (N=37). Fifty-nine percent of participants believed that it was "not easy to secure the CRS into the vehicle" although 72 percent were confident that they "correctly routed and adjusted the LATCH and/or seat belt" system. These ratings demonstrated that the participants acknowledged the difficulty of securing the attachment systems but were over confident in their ability to install it correctly, given the high installation error rates.

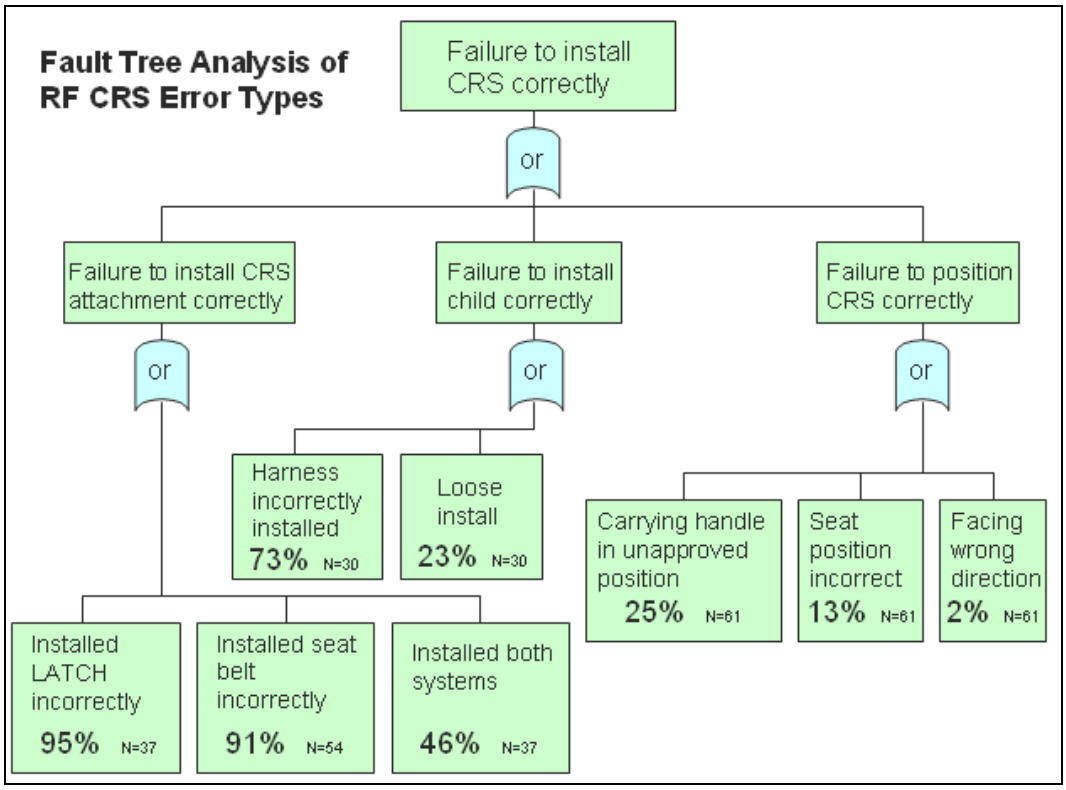

Figure 7. FTA of major errors in Rear-facing (RF) Infant CRS installation.

3.2.4 Study 1: Seat Belt Installation of Infant Child Seats

A total of 26 participants from the first study installed the child seat using the seat belt because they either chose the seat belt system over the LATCH system or their vehicle was only equipped with the seat belt system (73% of the vehicle sample were 2002 models and older). Participants who installed the CRS with seat belts could either route the seat belt through the child seat base path or through the carrier path without the child seat base, depending on the CRS. CRSs A and C allow for carrier installment to the vehicle without the base using seat belt routing through a separate carrier path located on the sides of the carrier. All participants, except for one, completed the child seat installation with the child seat base attached. The one participant chose to complete a seat belt installation of the carrier only by routing the belt through the carrier belt path

because of prior exposure to child seats as a babysitter. The top three prominent errors during seat belt installation were loose installation (69.2%), seat belt routed incorrectly (46.2%), and a twisted seat belt (more than half twist, 34.6%).

Severity scores based on Rubin and Brown's label and usability studies (2007; 2004; 2003) emphasize that the severity of error should be noted in addition to frequency. An incorrect seat belt routing error is rated a 9 out of 10 severity while a loose installation error may be in between a 1 to 7 severity rating. Severity scores of 4 or higher are considered unacceptable, with 10 indicating the most negative effect on a CRS in the event of a collision. Thus, the higher severity should be accounted for with errors like incorrect routing of the seat belt that have a lower frequency of occurrence compared to a loose installation. Severity score ratings were based on the average rating of three subject matter experts with backgrounds in CRS forensics and usability that were asked to rate on an error's probable effect on safety.

3.2.5 LATCH Installation of Infant Child Seats

A total of thirty-seven LATCH installations by participants were evaluated from study 1 and 2. The top three prominent infant CRS errors during LATCH installation were loose installation (73%), installation of both seat belt and LATCH systems (45.9%), and twisted lower anchor straps (35.1%).[1] Most participants said they were confident that they had routed the belt system correctly (71%) during installation. General installation errors made by participants were inappropriate recline positions (30.8%) and incorrect carrying handle positions (28.2%). Most participants were also confident that they secured the LATCH system correctly (72%), however, only 26.9 percent correctly secured the LATCH system while a majority of loose installation errors were made (53.9%) or a loose installation and anchor attachment errors occurred (19.2%).

Table 2. LATCH infant CRS installation error rates, N=37.

Lower Anchor Install	**Error**	**%**	***Severity Score***
	Loose installation	73	1-7
	Installed seat belt with LATCH	45.9	-
	Lower anchor strap twisted	35.1	1.6
	Not attached to designated anchor	29.7	9.4
	Installed to undesignated anchors in middle seat	19	5.75
	Connector not right side up	16.2	1.6

[1] Severity scores listed in Table 2 are based on the Transport Canada study (Rudin-Brown et al., 2007) that averaged subjective scores of CRS forensics and usability experts on an error's probable effect on safety where ten indicates the highest negative effect.

3.2.6 LATCH and Seat Belt Installation

A common LATCH installation occurrence was an attachment of both the seat belt and LATCH system after the participant was not satisfied with the installment of one system (See Figure 4). It depends on the child seat and vehicle manufacturer's directions on whether installing both the seat belt and LATCH attachment systems constitutes a CRS misuse. Some CRSs and vehicle manufacturers do allow installation of both systems, though most do not. LATCH was originally introduced as a new system that makes CRS installation easier without the use of seat belts. As a result, parents and caregivers are also given more options on methods to secure the CRS to the vehicle.

In these studies, an installation of both systems was a result of confusion with the multitude of options where participants could not differentiate between whether they should choose one or install all systems. Current CRS are tested for Federal motor vehicle safety standards compliance when attached to a vehicle using the LATCH system or attached using the vehicle belt system, not with both. Installing both systems is currently not recommended by CRS manufacturers. Out of the 46 percent of participants that completed a LATCH and vehicle belt systems installation, only three participants installed one of the systems tightly. Eighty-two percent of the combination installations had the seat belt or LATCH loosely installed (system belt/strap loose more than one inch). The high error rate of loose combination installations is an indication that participants had problems with securing the CRS despite the feeling of "added security" that warranted their placement of both systems. Loose installation can be caused by any combination of poor instructions, difficulty judging correct tightness, or lack of strength to secure the CRS. Possible interactions may also contribute to the loose installation such as with seat design, incorrect routing, or misunderstanding of manual information.

3.2.7 Infant CRS Feature Differences

Feature differences across child seats may be another factor that affects how well a participant was able to install the CRS. For example, the different LATCH connector types on the child seat may affect how easily the child seat was installed to the LATCH anchor. The findings shown in Table 3 and 4 provide an indication that certain child safety seats may be more prone to some errors than others. There was a significant association between CRS type and performing a tight CRS installation ($p=0.03$, two-tailed Fisher's test). For example, differences in child seat design may contribute to CRS A's higher loose seat belt installation error rate (87.5%) compared to the other child seats. CRS B's lock-off system was operated by placing the seat belt through the belt path and secured by a plastic mechanism that locked the belt in place compared on the CRS. In contrast, CRS A and C's lock-off system comprised of routing the seat belt through the belt path where it must go under the plastic tongue in the middle of the belt path. The two different lock-off designs also received different feedback during the installation. For example, some participants had difficulty in opening and closing the lock-off system for CRS B. Participants also had trouble interpreting the correct routing for CRS A and C's seat belt path (Table 3).

Table 3. CRS comparisons during seat belt install.

Error	CRS A	CRS B	*CRS C*
Loose installation	87.5%	55.6%	77.8%
Seat belt routed incorrectly	62.5%	33.3%	44.4%

Table 4. CRS comparisons of LATCH installation errors.

Error	CRS A	CRS B	CRS C
Loose installation	58.3%	76.9%	100%
Lower anchor strap twisted	16.7%	33.3%	46.2%

3.2.8 Vehicle Seat Feature Differences

Vehicle seat material may be a factor in the ability of a participant to achieve a tight installation. The seat design and the material may contribute to the ease of achieving traction on the base. Some parents have compensated by utilizing towels or shelf liners to maintain the grip of the base and achieve a tight installation. The standard Child Passenger Safety Technician curriculum states that shelf liner can reduce slipping on surfaces such as leather upholstery but does not aid in achieving a tighter installation. However, the use of these practices alludes to possible installation differences with leather and cloth seats. To test this possibility, a simple comparison of loose installation errors was made between cloth and leather materials. A majority of participants with LATCH-equipped vehicles had cloth seats l (64%, N=39); 36 percent had leather seats. Seat belt errors were about the same for seat belt installations across seat material type. In contrast, LATCH installation errors in vehicles with leather seats were about 10 percent higher than for vehicles with cloth seats (See Table 5). Because other factors such as CRS designs and vehicle seat shapes can influence installation errors, future studies should examine the possible interactions between them to better understand the why seat material might affect installation tightness.

Table 5. Loose installation error rate comparisons by seat material type.

Seat Material	Seat Belt	LATCH
Cloth	88.2%	75%
Leather	85.7%	84.6%

3.2.9 Reasons for Installation Mistakes

During the CRS installation, subjects performed a cognitive walkthrough or "talkaloud" which involved speaking their actions and thoughts about the installation steps out loud while videotaped. This was used to reveal points of confusion and the reasons mistakes were made. Confusion points were defined as points where the subject voiced confusion or was visibly lost when attempting to complete a subtask during the CRS installation (e.g. attach system to vehicle). On average, participants appeared confused twice during their seat belt installations and LATCH installations. Thirty percent of seat belt

installation participants looked in the wrong areas at least once in the vehicle or on the CRS for CRS components such as the base release handle, harness strap adjuster, or locking clip. For example, a participant may be guided by the CRS instruction manual to look for the base release handle to remove the base from the carrier but have difficulty locating the lever. Twenty-three percent of seat belt installation participants made a seat belt routing error due to confusing instruction manual diagrams and directions. Approximately half of the LATCH installation participants looked in the wrong areas for CRS components such as the LATCH anchor points and base release handle. Nine participants (29%) installed the CRS using both the seat belt and LATCH systems because they were confused by the explanation of the two options in the CRS manual. Furthermore, attachment errors (e.g. improper LATCH routing) resulting from confusing instruction manuals occurred for 16 percent of LATCH installation participants. A majority of verbal feedback and written comments in the usability surveys included comments such as "it was harder than expected" and "instructions were difficult to understand when looking between CRS and car manuals."

A general user decision tree is depicted in Figure 6. During the cognitive walkthrough, participants typically encountered four decision points when preparing the CRS in the vehicle. Participants typically began by selecting the desired location and position in their vehicle. The crucial component was when participants wanted to attach the CRS to the vehicle but must decide how to secure by choosing an attachment system. An example participant discourse is given as follows:

> "First thing I was doing wrong, you got to release the thing off the seat…to get from the base…make it a little easier to work with."
>
> "Now I have the base here, alright. Alright, found these LATCHes on the sides here. Figure out what I'm going to do with those."
>
> "Is this supposed to be in the middle? Does it matter? I don't think so…"

The discourse was an example of the thoughts spoken while the participant was removing the carrier from the base of the CRS. As the base was positioned into the back space of the vehicle (Figure 8, B), the participant turned the base to its side and discovered the LATCH system. The LATCH system was the method chosen by the participant as the attachment method (Figure 8, F). The user decision model illustrates the decision-making processes that are needed to complete a CRS installation. Error points or confusion are a result of participants being unable to find the information to make a correct decision or missing a step in the installation process while attempting to complete a subtask.

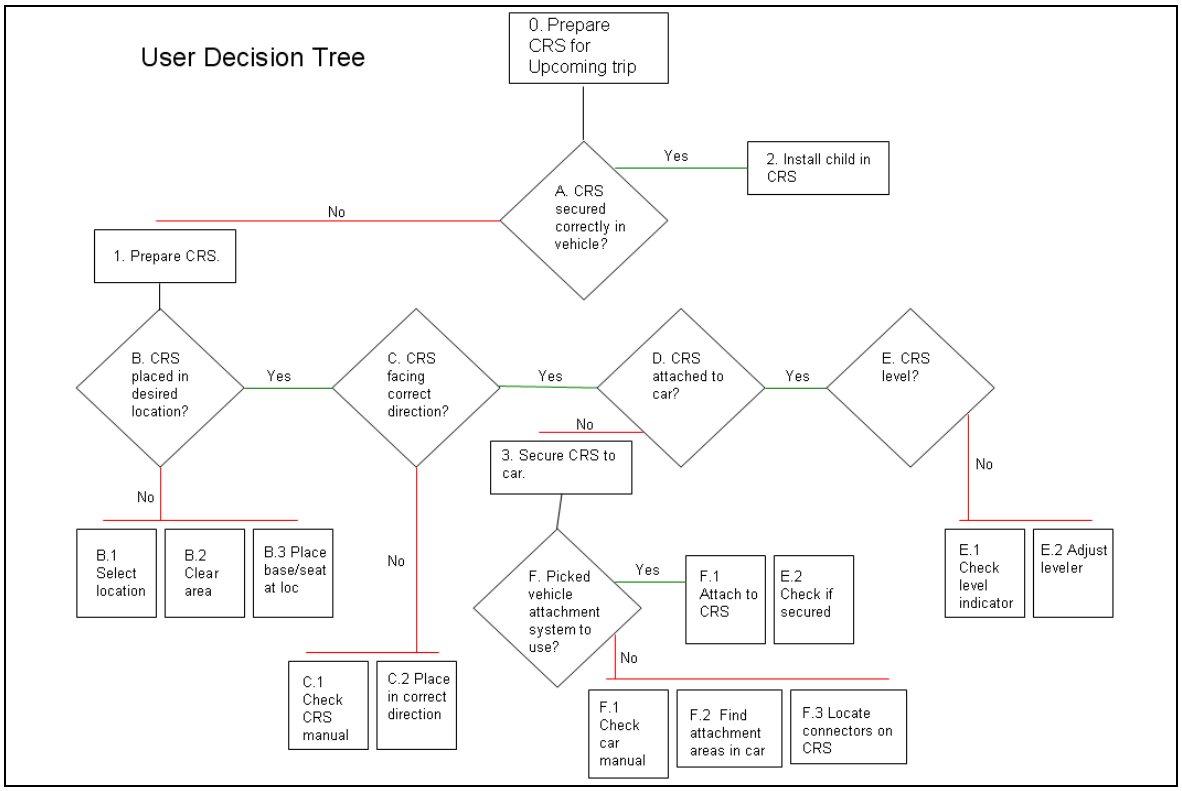

Figure 8. User decision tree example of the choices subjects make during CRS installation.

3.2.10 Study 1: Child Installation

Twenty-four participants installed a test dummy into the CRS along with the installation of the CRS to their vehicle (N=26). A majority of participants said they were confident (73%) that they secured the test dummy to the child seat correctly. One participant was not able to complete the child installation and expressed that she did not understand how to loosen the harness straps on the child seat. Overall, participants were highly confident that they adjusted the chest clip on the test dummy correctly (66%) although many of them positioned the chest clip too low on the test dummy. High confidence in the child seat installation was prevalent throughout the study despite high error rates. The top four prominent errors during child installation were improper chest clip level (60%), inappropriate recline position (36.7%), twisted harness shoulder straps (30%), and loose harnesses (20.7%).

Differences in child seat error rates can be further examined by the type of child seat used. For example, Table 6 shows that there was a 20 percent inappropriate recline position error rate for participants that installed CRS C compared to a 40-50 percent error rate for participants that installed CRS A and B. Reclining the CRS was also a function of how participants interacted with the CRS adjuster knob, manual level adjuster or the level indicator display. For example, CRS A and C have level adjustors that participants must manually adjust to an appropriate level by positioning the bottom of the base to one of three or four notches. CRS B has an adjuster knob where participants must turn the knob clockwise to adjust the seat level upward. After adjusting the seat, a participant must look at the CRS level indicator to confirm whether the CRS was adjusted properly.

CRS level indicators can also vary across seat design with some displaying whether the child seat is leveled correctly on one side versus both sides. The visibility of the dual CRS level indicators may be possible explanations of why recline errors were lower for CRS C compared to CRS B (Table 6). Another possible explanation may be the type of level indicator present such as an indicator with the location of a ball in safe or unsafe colored zones (CRS B) or a dial with different colors representing safe and unsafe levels (CRS C). The revised NHTSA ease-of-use ratings currently rate recline ability and feedback device (e.g. level indicator) together. An "A" CRS rating of this feature would have a separate recline device and the base adjustable to at least three levels. However, the possible installation combinations of CRS designs and vehicle seat designs may obscure the assessment of ease-of-use.

Table 6. CRS comparisons during child install.

Error	**CRS A**	**CRS B**	**CRS C**
Chest clip level too low	66.7%	50%	60%
Recline position inappropriate	40%	50%	20%
Harness shoulder strap twisted	44.4%	30%	10%
Harness too loose	11.1%	20%	30%

3.2.11 Infant CRS Usability Ratings

Participants expressed confusion with the terms, diagrams, wording of text, and directions in the child seat instruction manual. Participants who were confused with the manual over an extended period of time often misinterpreted or were frustrated and gave up because they were unclear about their next steps. Some participants were also not able to differentiate between installation options such as a child seat installation with or without base or a LATCH installation. Especially noteworthy is the fact that many participants did not understand that their CRS was loosely installed. Most participants shook or pushed the CRS to test whether the CRS was secured and concluded their CRS was installed correctly (87%) despite the high loose installation error rates across the attachment installation types. Correct tightness is achieved when the CRS moves less than an inch from side to side or toward the front of the vehicle.

Forty-three percent of seat belt participants agreed when asked whether "the instruction manual helped them complete the task correctly." Manual usage also varied between the types of CRS installation completed. More participants used the CRS manual for the seat belt installation (71%) compared to the LATCH installation (48%). Reading both the CRS and vehicle owner's manuals may have contributed to installing both seat belt and LATCH systems (77%) due to inconsistent information provided on securing the CRS. For example, a participant may find a diagram in the vehicle manual depicting a generic forward-facing child seat which could be confusing when installing a rear-facing infant CRS (See examples in Appendix D). The vehicle manual may also show how to route a tether strap that may not be used for certain child seat types such as the rear-facing infant

CRS. Many participants may not realize what diagrams and instructions are relevant to their particular CRS type.

Twenty-seven percent of seat belt participants believed that the labels (See examples in Appendix C) "helped complete the task correctly." There was no difference in how participants rated the labels across CRS type. Seat belt installation participants believed that the overall warnings from the labels and instruction manual were easier to understand compared to the written instructions and images in the instruction manual and on the labels affixed to the CRS (See Figure 9).

Participants mainly dealt with two types of information: warnings that expressed what not to do and CRS instruction manuals and labels that had instructions to be explicitly followed. CRS instruction manuals can include information conveyed through diagrams and written instructions. Although seat belt participants rated the images as generally difficult to understand, they also rated the images on the affixed labels as easier to understand (20%) compared to the CRS instruction manual (33%). Ten percent of the seat belt participants said they ignored the labels and mainly used the CRS instruction manual to complete the child seat installation. Seventy percent of seat belt participants were split on their opinion of whether the labels and the instruction manuals were comparable in content. The remaining participants did not notice whether the labels and manual held supportive or consistent material.

LATCH installation participants rated their understanding of the information similarly across written instructions, images, and warnings on labels and in the CRS instruction manual (See Figure 10). Images (or diagrams) for the instruction manual were rated the lowest (31%) compared to other label and manual ratings for ease-of-understanding. Most participants that completed the LATCH installation (68%) were confident that they correctly secured and routed the LATCH system to the vehicle. Slightly less than half of LATCH participants (46%) believed that the instruction manual for the CRS did not match the labels on the CRS, while 41 percent of the participants believed they did match. Participants who used CRS A and C during installation were divided on whether the labels and the CRS instruction manual were comparable in content. Only 15 percent of participants who installed CRS B agreed that the CRS instruction manual and labels had comparable information.

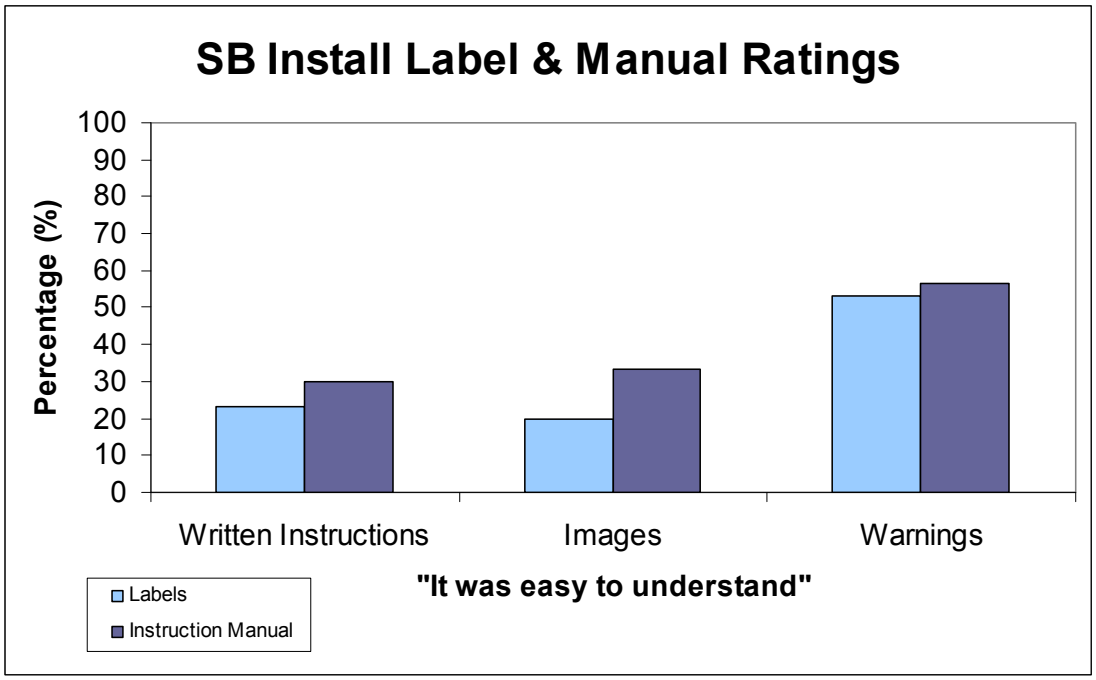

Figure 9. Ratings of labels and CRS instruction manuals from seat belt installation participants.

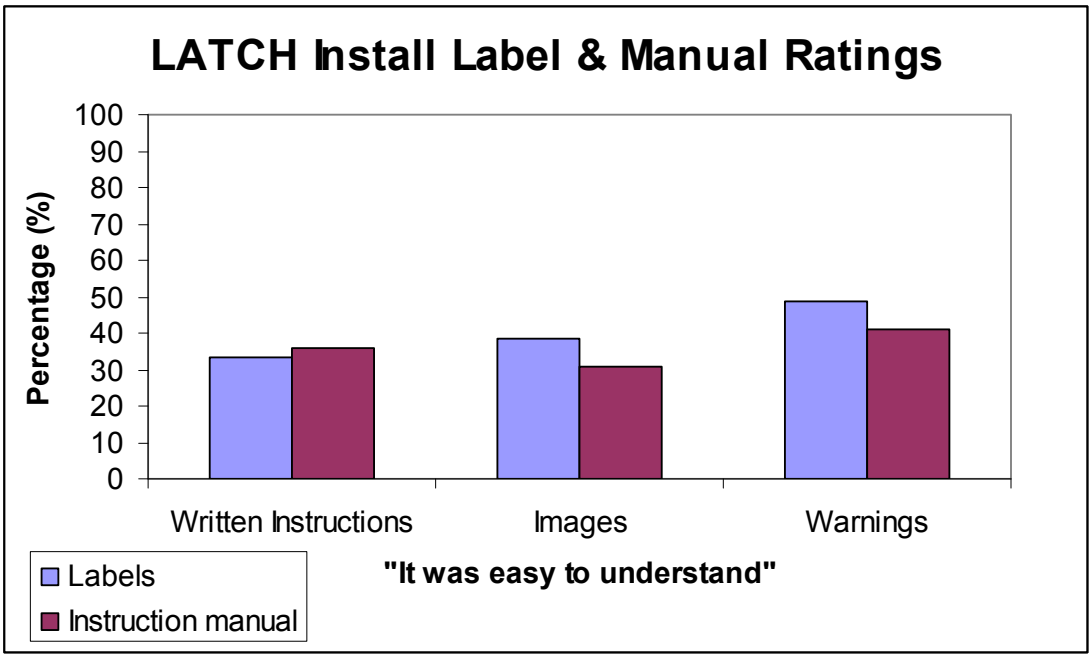

Figure 10. Ratings of labels and CRS instruction manuals from LATCH installation participants.

3.3 Study 3: Installation of Convertible CRS

Convertible CRSs were utilized in this study to investigate the installation error types associated with installing this type of CRS. Rear-facing to forward-facing routing and tether installations are examples of installations that are unique to convertible and some combination CRSs. All vehicles in this study were equipped with the LATCH system.

3.3.1 General Installation

Twenty-two participants completed the study and were asked to install a CRS in the rear-facing position and the forward-facing position. One participant was only able to complete the CRS installation of one position. Nine child seats were initially installed in the center position (40.9%), 7 seats were installed in the rear passenger side position (31.8%), and 5 seats were installed in the rear driver side position (22.7%). One child seat was installed in a middle row position in a SUV. Eighty-two percent of participants completed the installations using the seat belt or LATCH in an allowed vehicle seat location. All participants completed a LATCH installation for at least one of the positions (rear-facing or forward-facing) except for one participant that only used the seat belt to secure the CRS.

The participants were told to complete two CRS installations, an installation for a newborn and an installation for a 40lb toddler. When told to install for a newborn, 54.5 percent of participants installed the convertible CRS rear-facing with the seat belt system (See Figure 11). Four participants (18.1%) installed the CRS rear-facing with the LATCH system. Six participants incorrectly installed the CRS forward-facing for a newborn. Four of them installed the CRS forward-facing using the seat belt; two others installed the CRS forward-facing using both attachment systems. When told to install for a 40lb toddler, five participants (23.8%) completed an incorrect rear-facing installation using the seat belt or using both the seat belt and LATCH systems. Fifty-two percent of participants completed a forward-facing LATCH installation. Some participants completed a forward-facing installation with both attachment systems (14%).

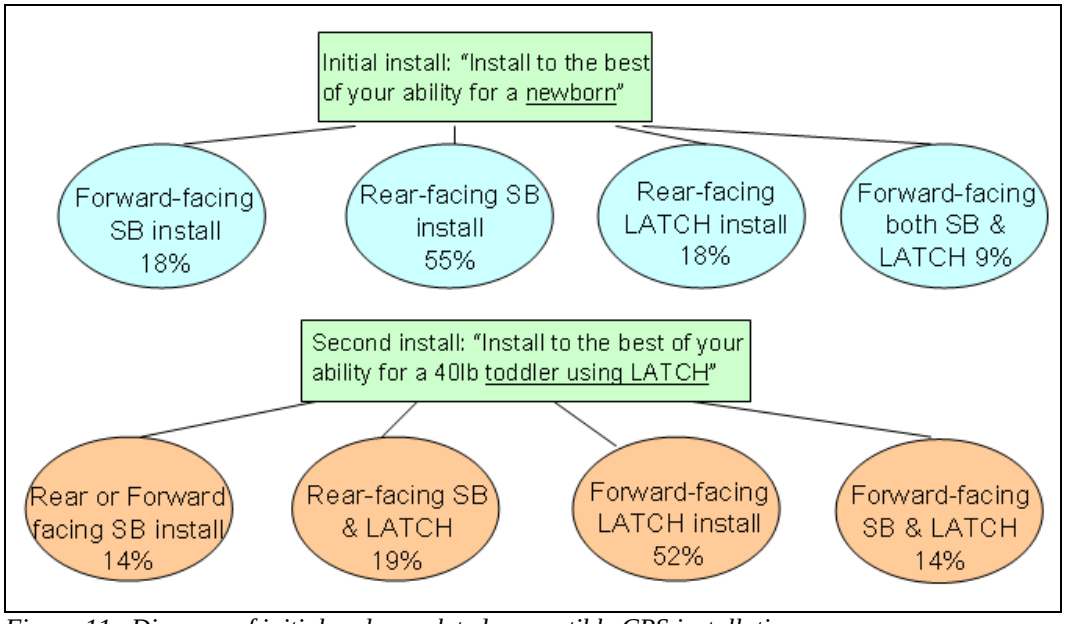

Figure 11. Diagram of initial and completed convertible CRS installations.

Participants were encouraged to complete a cognitive walkthrough as experimenters observed the participants. From the walkthrough, 41 percent of participants mentioned that they were confused with the installation steps and 22.7 percent specifically said that

the manual diagrams or instructions were difficult to interpret. Similar to studies 1-2, participants had difficulty with reclining the CRS to a correct angle. There was an 81.8 percent occurrence of the convertible CRS installed in an incorrect angle. In general, child seats should not be reclined more than 45 degrees from vertical. Angle indicators were located on the sides of the CRS that included instructions for acceptable rear-facing recline angles on the angle indicators and in the CRS manuals. For forward-facing CRS installation, a correct angle installation is considered to be flat against the vehicle seat back. Most participants had difficulty with securing the CRS rear-facing within a 45 degree recline compared to achieving a straight angle forward-facing.

3.3.2 Convertible CRS Installation Times

The average CRS install time was approximately 14 minutes. There was no significant difference between the time spent on each subject's first and second installation (13-15 minutes). LATCH participants averaged the most time spent with the installation (approximately 16 minutes) compared to seat belt installation and combination seat belt and LATCH installations (13 minutes) although the differences were not statistically significant (See Figure 12). Participants were given both the child seat instruction manual and the vehicle owner's manual to use. Subjects varied with time spent reading the CRS and/or vehicle manuals. About 41 percent examined the vehicle owner's manual in addition to the CRS manual during installation. For an in-depth analyses on the feedback and installation errors related to the manual sections read, see section *3.6.2*, Reported Manual Sections Read.

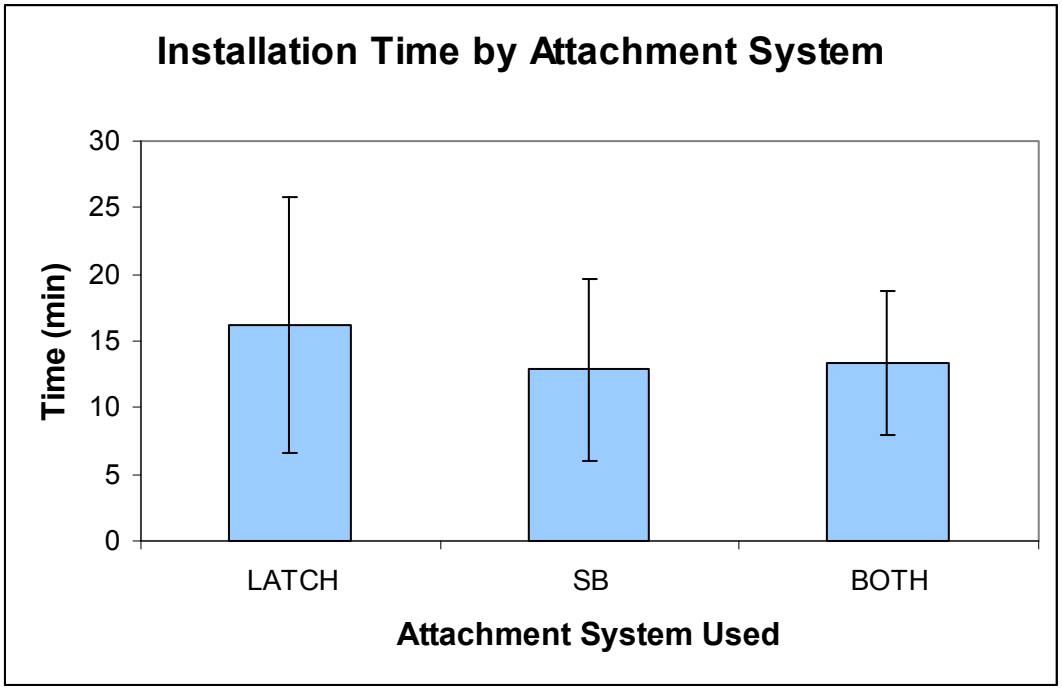

Figure 12. Study 3 convertible CRS installation times by attachment types used.

3.3.3 Seat Belt Installations

Like study 1 which examined infant CRS errors, the most common error of seat belt installation in study 3 for convertible CRSs was a loose installation (88.9%). Another prominent error was found where half of participants routed the seat belt incorrectly when completing a seat belt installation (N=18). Participants who committed this installation error either did not use the built-in CRS lock-off, did not retract the seat belt to locking mode, or did not use enough force to tighten the belt. CRS lock-offs are generally devices that lock and prevent movement of the seat belt webbing and can be found on the side of the CRS or under the center of the CRS base. There was also a 33 percent error rate for the seat belt being installed twisted.

3.3.4 LATCH Installations

A common error was a loose installation using the LATCH system (85%). Lower anchor strap twisting was found in half of the installed child seats (See Table 7). Routing errors specific to convertible child seats (45%) may stem from the confusion participants had when referencing the CRS manual or label instructions. LATCH twisting errors in some cases were a result of switching the LATCH belt routing between rear-facing and forward-facing installations. About 41 percent of participants voiced general confusion during their cognitive walkthrough on how to install the LATCH attachment systems. Four of these participants specifically mentioned that they had difficulty understanding how to route the seat belt or LATCH attachment straps to secure the CRS. This was reflected in their ratings of their installations where participants reported difficulty with routing the LATCH straps or did not acknowledge that different routing was needed for rear-facing and forward-facing installation. A serious error of not attaching the lower anchors to the designated anchor occurred for 35% of the participants. Of these participants, four participants completed a center installation on a vehicle undesignated for center LATCH use. Two participants secured the LATCH system using the most outboard anchors and one participant secured only the tether because they believed the LATCH system was only comprised of the tether and did not locate the stored lower anchors.

Table 7. LATCH convertible CRS installation error rates, N=20.

Lower Anchor Install	**Error**	**%**
	Loose installation	85
	Lower anchor strap twisted	50
	Routing error	45
	Installed seat belt with LATCH	36.8
	Not attached to designated anchor	35
	Connector not right side up	40

The patterns of LATCH-related installation errors were similar to studies 1-2 except for errors related to convertible seats, combination seat belt and LATCH installations, and with the connectors installed in an incorrect direction. Combination seat belt and LATCH installation errors decreased while the rate of connectors installed in an incorrect direction more than doubled relative to studies 1-3. These differences may be attributable to differences in feature design discussed below.

3.3.5 Convertible CRS Feature Differences

There are feature differences such as the lower anchor designs of CRS D and E that may have contributed to an installation error. However, there was no significant association between CRS type and installation errors due to a small sample size and the varying configurations that a CRS could be installed. A breakdown of the errors made and the CRS the participants used is shown in Table 8. We can examine a feature difference between CRS D and E by investigating the feature difference of routing methods between the rear-facing and forward-facing position. Although seat belt routing error rates were comparable for participants who installed CRS D and E (9.3-11.6%), lock-offs on both sides of the CRS D (Figure 13) may have contributed to seat belt routing errors while routing errors from CRS E may have resulted from following the manual directions incorrectly. Additionally, a potential design flaw that leads to higher error was CRS E's longer LATCH strap. CRS D's shorter LATCH strap did not allow for installation if it was routed in the wrong position.

Table 8. Convertible CRS comparison of installation errors, N=43.

Error	**CRS D**	**CRS E**
Seat belt loose installation	14%	23.3%
Seat belt twisted	7%	18.6%
LATCH routing error	4.7%	16.3%
Not attached to designated anchors	4.7%	11.6%
Combination installation (Seat belt and LATCH)	2.3%	16.3%

Figure 13. The lock-off on CRS D is a feature difference that contributed to seat belt routing misuse.

3.3.6 Convertible CRS Usability Ratings

Participants completed ratings of their experience after they completed the child seat installation. Most participants (82%) found it very easy to decide where to place the child seat into the vehicle. The average ratings for configuring and securing the child seat were rated as neutral ("Borderline agreement" – rating of 4 in a Likert scale from 1-7) across several of the questionnaires. Participants remained neutral in their ratings on their confidence and ability to install the child seat but rated the labels and instructions from neutral to unhelpful. More than half of participants found it difficult to understand the CRS manual instructions and diagrams (See Figure 14). Forty-one percent of the participants thought the labels on the child seat and CRS manual had conflicting information that confused them during the installation. Participants using CRS E were more confident that they secured the tether onto the vehicle compared to CRS D (average rating of 4.6 vs. 3.8). This rating disparity stems from CRS differences in tether configuration specifically from CRS D allowing for tether use for the rear-facing position.

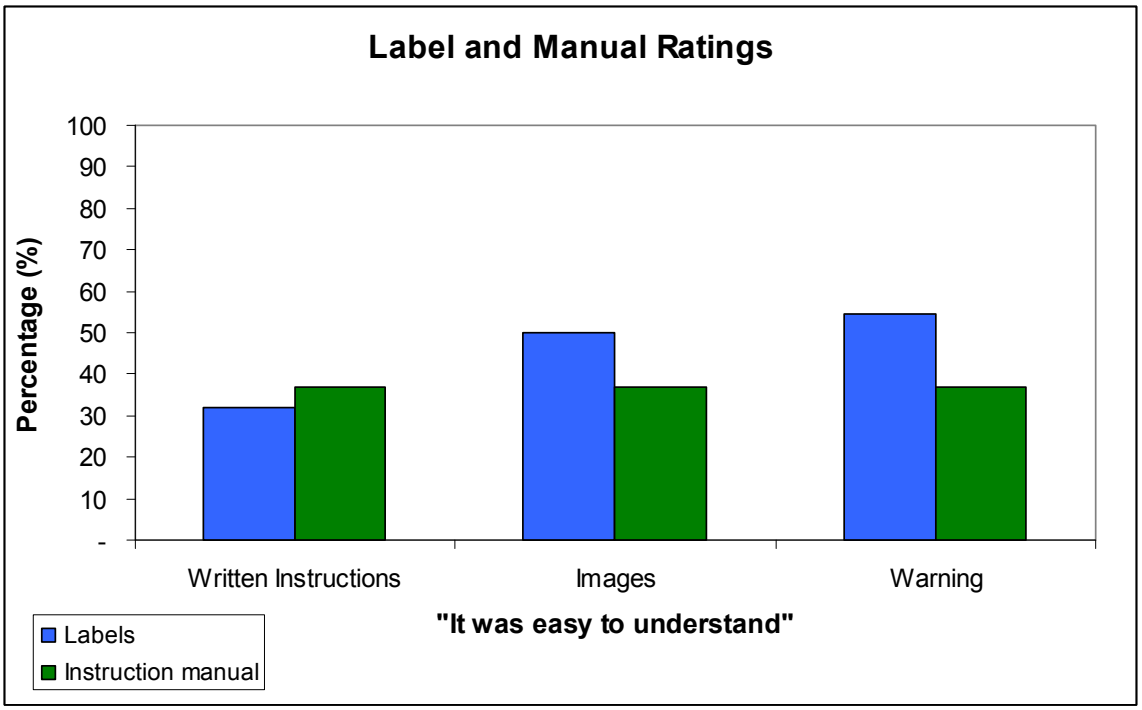

Figure 14. Ratings of labels and CRS instruction manuals from convertible installation participants.

3.4 Study 4: Installation Errors of Parents and Caregivers

Various studies (Decina & Lococo, 2007; Taft, 1999) have surveyed parents at child seat inspection sites, however, there are still populations who have never heard of child seat inspections or may choose not to attend these events. Our goal with examining child seat installations in this study was to examine whether the installations errors vary with sample populations found at child seat inspection events and people who have not previously attended a child seat inspection event. We found that loose installation error rates were common, even with parents currently using child seats for their children. Other installation errors were found such as strap twisting and routing errors. While only 15 CRSs were examined, the sampled population exhibited errors like the novices in study 1-3, but to a lesser degree. Nevertheless, this population is the most likely to be unaware of installation errors with their CRS and should be targeted to raise public awareness about the importance of correct CRS installation.

3.4.1 General Installation

Overall loose installation error rate was 46.7 percent (seat belt or LATCH). Twenty-seven percent installed their child seat at an incorrect angle (N=15). Combination seat belt and LATCH installs occurred with 26.7 percent of the child seats. Only one booster error of incorrect seat belt routing was found out of four boosters.

3.4.2 Seat Belt Installation

A total of nine seat belt installations were completed by participants. Four of the nine participants installed the seat belt with the LATCH system when it was not recommended by either child seat or vehicle manufacturer. Half of the parents surveyed with convertible seats used seat belts instead of the LATCH system (N=10 convertible seats). A common error found with seat belts was a loose installation (66.7%). Thirty-three percent of the child seats had a seat belt routing error and 22 percent of the seat belts were twisted more than two twists.

3.4.3 LATCH Installation

Sixty percent of the LATCH installations were loosely installed. Twenty percent of the LATCH connectors were not installed right-side up (N=10). One participant (10%) attached the LATCH connectors to a non-designated position and another participant had twisted LATCH straps.

3.4.4 Tether Installation

Forty-four percent of parents with convertible child seats configured their child seat forward-facing and did not attach the tether strap to the vehicle (N=9). One participant had a tether that was twisted more than two twists. No routing or loose tether installation errors were found.

3.5 Study 5: Installation Errors at Child Seat Inspections

Parents, relatives, and caregivers that participated in this study agreed to be observed while their vehicle and child seat were examined for proper installation by a certified CPS technician. Interviews were conducted with the given time constraints of the participants. The purpose of these interviews was to gain an understanding about the participant's experience with their CRS, examine whether the installation errors varied compared to the previously mentioned studies, and to obtain feedback on potential design improvement.

3.5.1 General Installation

The average child seat date of manufacture was 2006 (SD = 1.4 years). All seats with a base (N = 17 seats) were found to be installed with a base. The initial CRS positions installed were as follows: 39 percent in the center position, 39 percent in the rear passenger side, 12 percent in the rear driver side, and 9 percent in the middle row position (position 4, 6, See Appendix A) of a minivan or wagon. The CPS technicians at these checkups first worked with the participants to consider their placement of the CRS. Several concerns of participants and CPS technicians included the following:

- Frequency or likelihood of additional passengers
- Typical leg room needed for driver and front passenger

- Best fit given the contour of the vehicle seat bench with the child seat base
- Best fit using an attachment system (if the LATCH system is available)

A common installation error found during the observation of these checkup events was that half of the observed participants arrived with an incorrectly angled CRS (N=32).

3.5.2 LATCH Installation

Loose installation occurred for 65 percent of the LATCH install participants who installed convertible child seats (See Table 9). Loose installation was a common error found throughout studies 1-3 as well as in other studies (Decina & Lococo, 2007). Another common error that occurred in 77 percent of the installations was twisting of the LATCH straps. A majority of parents inquired about the center position installation and the constraints with installing a CRS in the center. Twenty-eight percent of participants installed LATCH in the center position when it was not allowed by the vehicle manufacturer (9 out of 32 participants). There was a 15 percent installation error rate of participants who routed the LATCH straps incorrectly. Unlike the novice installation studies (studies 1-3), no errors were found for installing the LATCH connectors upside down and only two child seats (6%) were found installed with LATCH and seat belt (both attachment systems). No installation errors were found for installations of more than one connector per anchor bar.

Table 9. LATCH convertible CRS installation error rates, N=26.

Lower Anchor Install	**Error**	**%**
	Lower anchor strap twisted	77
	Loose installation	65
	Vehicle center LATCH installation not allowed	28
	Routing error	15
	Installed seat belt with LATCH	6

3.5.3 Tether Installation

Some convertible CRSs have a tether that is optional but recommended for rear-facing installation. For forward-facing installation, the top tether keeps the CRS from rotating forward in a frontal crash and significantly decreases head excursion. Infant CRSs generally do not use a tethering system since they are rear-facing.

There was little data collected on CRS tether installation. Fifty-eight percent (18 participants) had infant seats or configured their convertible child seat in the rear-facing position with no tether installation needed. Five participants had unknown tether usage. Eight participants installed the tether. Five of the eight participants installed the tether on a forward-facing CRS. Three of the participants had tethers installed on a CRS that

allowed for rear-facing tether installation. It is difficult to make conclusive claims from the limited number of tether installations recorded from these child seat inspection events. Five of the eight tether installations were loose; this may be a common installation error. Two other tether errors manifested from the installations: incorrect tether routing by two participants and twisted tether straps by one participant. More research is needed to explore the extent of tether installation errors related to CRS design and instructions.

3.6 Studies 3-5: Participant Suggested Usability Improvements

The participants were interviewed about their experience installing the child seat. They were first asked about their manual and label reading preferences and if they had any suggestions that would have helped them during the installation. Participants were then asked to rate manual diagrams, text, and pictures of child seat features from a booklet of current designs and suggested improvements based on the errors found with their child seat installation. For example, a participant would answer design questions on loose installation and tethers if they had a loosely installed convertible CRS installed forward-facing with no tether attached. Representative pictures, diagrams and text were obtained from current child seat and vehicle manuals relating to six installation errors: (1) loose installation, (2) combination seat belt and LATCH installation, (3) tether error, (4) convertible routing, (5) LATCH twisting/attachment errors and (6) recline angle errors.

A total of 55 participants from studies 3-5 responded to questions from the booklet of suggested usability improvements (study 3, N=22; study 4, N=12; study 5, N=21). Approximately 60 percent surveyed were parents or caregivers; 40 percent of the participants were novices recruited from GMU and Craigslist.org.

3.6.1 Vehicle Design Preferences

Participants have suggested that they would have been able to find the LATCH locations if they were adequately labeled. Some were confused by the LATCH symbol or did not see the LATCH labels in their vehicle even when their vehicle had LATCH labeling. The type of installation completed may be affected by LATCH visibility given the level of variability from labeling across vehicle manufacturers and vehicle types.

Participants generally preferred visible, unobtrusive markings for the LATCH system. Participants rated current vehicle design preferences of top tether and lower anchor configurations seen in vehicles (See Appendix G). Participants preferred lower anchors that were labeled and hidden in the seat bight (34.4%, Option 3) or labeled and visible with a contrasting color from the vehicle seat (28.1%, Option 2). Few participants selected lower anchors with a labeled removable cover (3.1%, Option 4). A majority of participants (57.1%, Option 2) preferred top tethers to include a tether symbol and the wording “Top Tether” by the tether location. Twenty-nine percent preferred the tether symbol (Option 1) and 14.3 percent preferred an unlabeled, visible top tether (Option 3).

3.6.2 Reported Manual Sections Read

Participants were asked whether they read the labels, CRS manual and vehicle owner's manual prior to or when installing their CRS (See Figure 15). A majority of participants said they read the CRS manual (94.1%) while less reported reading the vehicle owner's manual (36.2%). Some participants reported reading the labels when installing their child seat (62.5%).

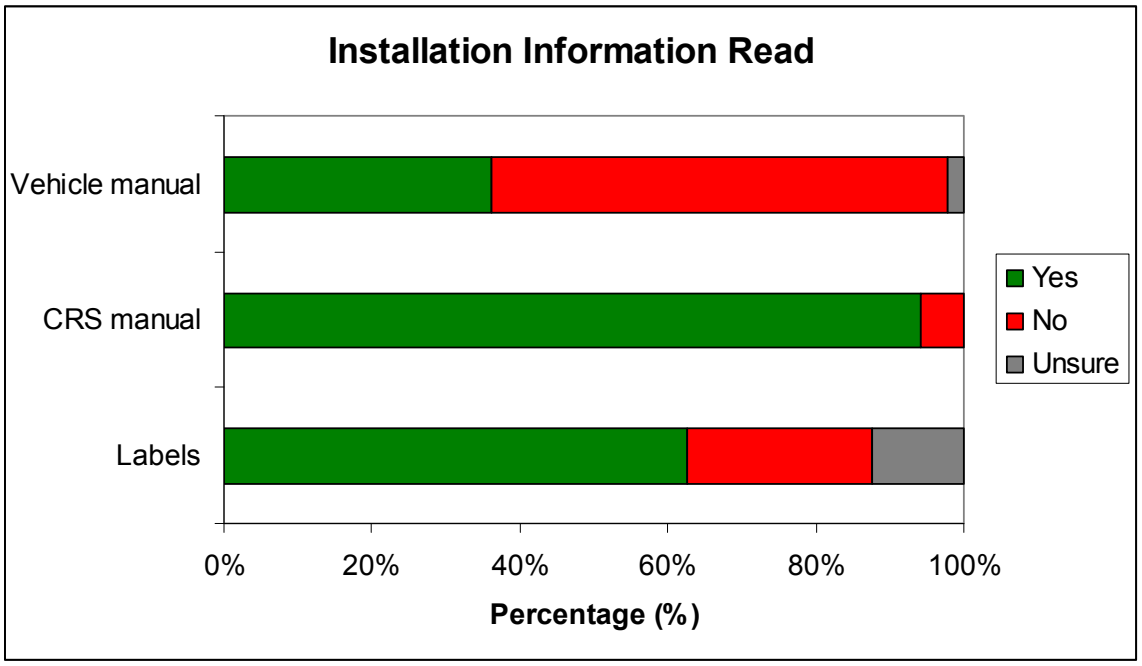

Figure 15. Reported manual or labels read by studies 3-5 participants, N=55.

Thirty-four participants were asked to specifically report what manual sections they read (See Appendix G) after they completed their installation (study 3, N=19) or when they had previously installed their child seat (studies 4-5, N=15). Parents and caregivers that participated in studies 4 and 5 did not report manual sections read if they did not remember or owned their child seat for over a year.

Participants rarely read the entire manual and chose to read sections they thought were directly related to the installation. The three highest reported manual sections read were on rear-facing (RF) installation, forward-facing installation, and child seat features (See Figure 16). They were also asked whether additional suggested sections should be included in the manual. Fifty-three percent of the participants suggested that a section that defines what LATCH is would be helpful with their installation. Other suggestions included a definition on tethers (33%), help with locating CPS technicians (20%), and CRS-related state laws (20%).

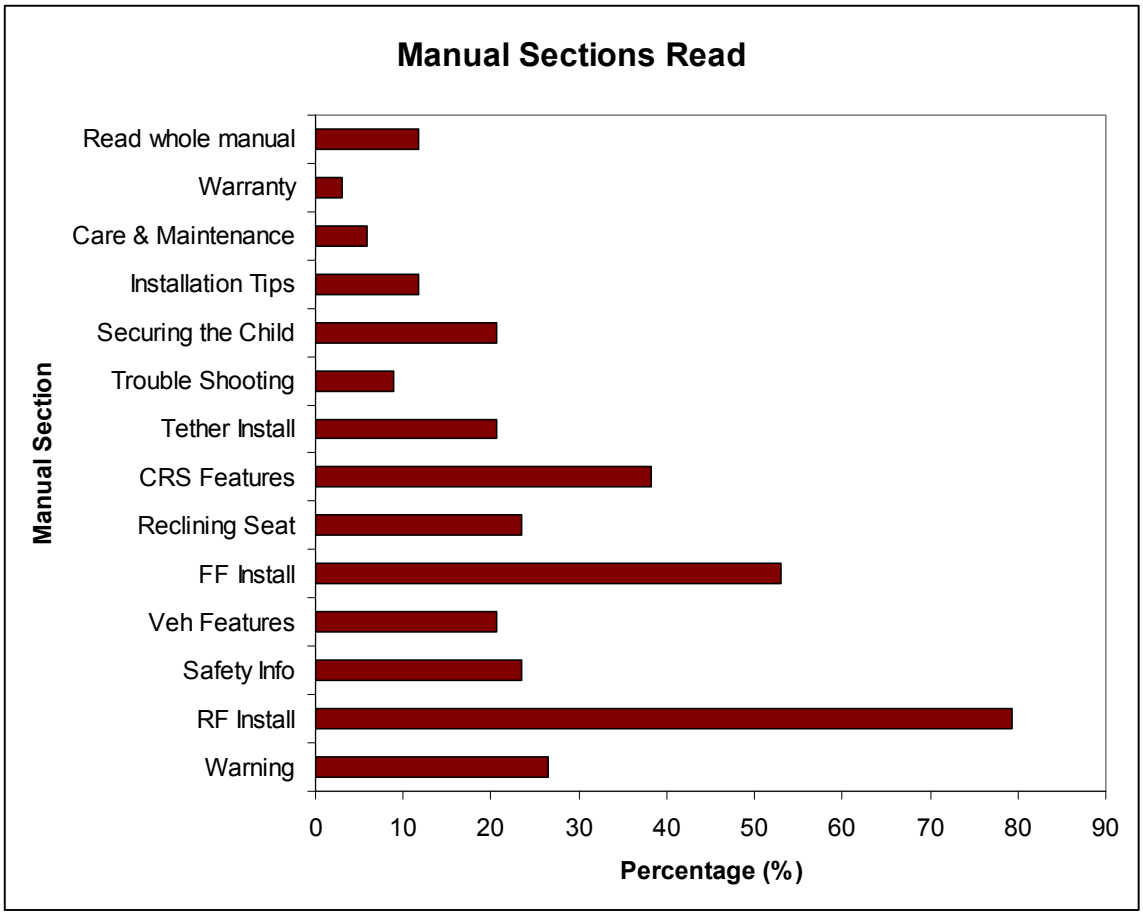

Figure 16. Manual sections read by participants from studies 3-5, N=34.

3.6.3 Manual Suggestions: Vehicle Owner's Manual

When asked if participants used the vehicle manual, some expressed that they did not think to look for CRS installation information in their vehicle owner's manual. Some parents have suggested having a separate parent's guide to child seats for their vehicle to highlight important CRS information from other vehicle information. Other suggestions included highlighting child seat features in new vehicles such as with hangtags for car buyers that denote LATCH locations.

3.6.4 Manual Suggestions: Loose Installation

Loose installation was a common error found in all of the above mentioned studies. Participants in studies 3-5 selected their preference on text and diagrams in a booklet of design improvement suggestions. Vehicle owner's manuals generally convey specific information on LATCH locations and generic information on child seat installation. Participants were asked to rate options of vehicle manual directions and diagram examples that convey to the installer that a CRS should be installed tightly. Three text options were presented (Appendix G, Question 1d, N=14) and participants preferred text that warned them on loose installation and referred them to follow the child

manufacturer's instructions (71.4%, Option 2). Twenty-nine percent preferred a warning on loose installation that included the wording that the installation must not move more than an inch ("1-inch rule") and gave suggestions such as trying a different seat position if they were unable to secure it as tightly as possible. Participants also examined example car manual diagrams (Appendix G, Question 1e, N=17) and preferred a zoomed-out diagram showing a person holding the CRS and arrows conveying the directions of movement (52.9%, Option 1) compared to diagrams with the CRS only with arrows conveying the path of belt (17.6%, Option 2) or with a CRS and hands pushing on seat and pulling on strap (29.4%, Option 3).

3.6.5 Combination Seat Belt and LATCH Installation

Ten participants who made combination seat belt and LATCH installation errors evaluated three design examples related to preventing this error (Appendix G, Question 2a). Only one participant preferred a text example (10%, Option 1) compared to a table that specifically stated weight and belt limits (50%, Option 2) or a concisely highlighted text example with a LATCH symbol (40%, Option 3). Participants who made these combination errors commented that it was difficult to decide what attachment system to use. While a table that specifically states which attachments to use may be easy for installers to understand, there may be difficulty with implementation of this format. A coordinated effort between child seat and vehicle manufacturers may be needed if weight and belt limits are variable across CRS manufacturers and vehicle types.

3.6.6 Manual Suggestions: Child Seat Manual

Some parents have suggested improvements in the pictures and text of the manuals such as clear diagrams and easier set-up guides with fewer steps. Some pictures do not provide context to the installer; the installer becomes confused because he or she cannot find the equivalent objects of interest when looking at the CRS. Pictures that give a wide view of the CRS are suggested to provide perspective to the installer. An example of a loss of perspective is shown in Figure 17. Subjects had difficulty interpreting the (b) diagrams, particularly where to look and what object they should connect the tether to. Parents have also asked for an overview of the overall goal so they'll be able to feel confident that their child seat is installed correctly.

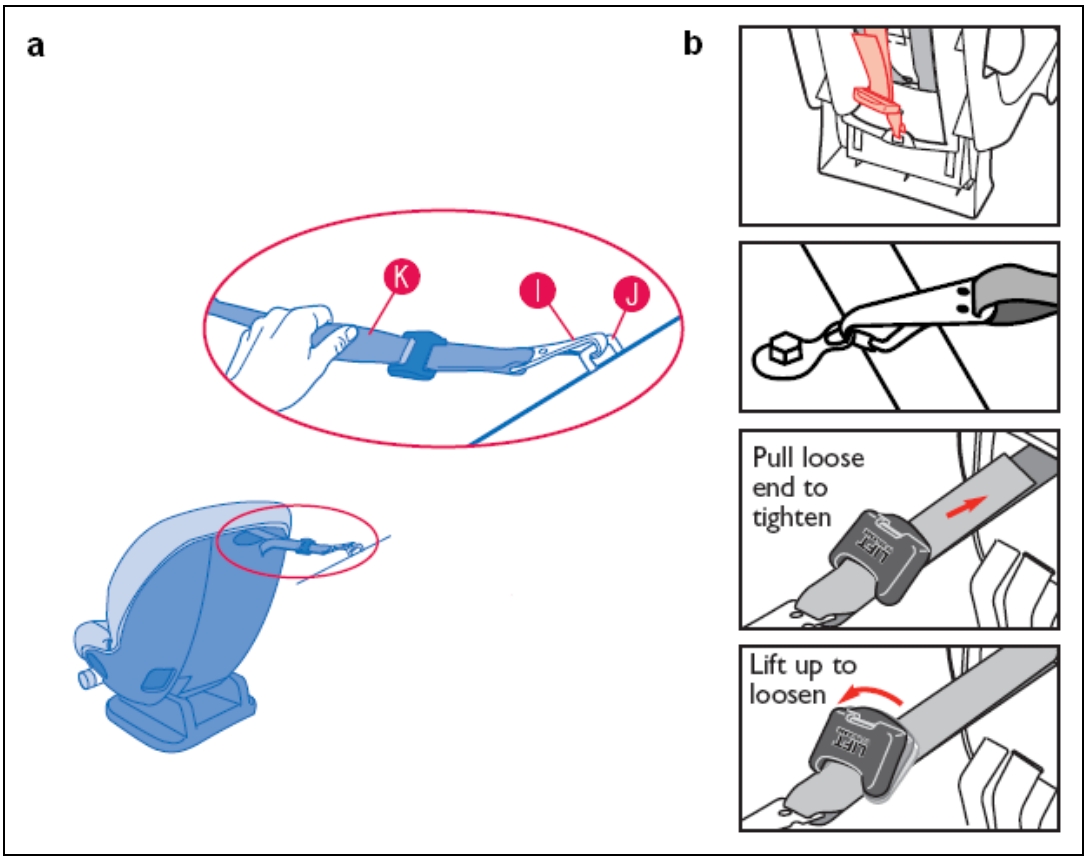

Figure 17. Examples of tether installation diagrams from two child seat manuals.

Some have noted that the CRS installation process in the CRS instruction manual seemed out-of-order. This type of confusion can be explored with user testing and task analyses like Figure 1 and 6 to understand the common steps parents and caregivers perform to complete their installation. A common remark made by the participants was the preference for a simpler naming convention of straps and CRS features to allow for an easier-to-follow installation process. Participants must refer to a diagram or glossary of the terms while following the directions if the naming conventions are difficult to recognize.

Participants with loose installations were asked about their preferences with CRS manuals and diagrams relating to completing a tight installation (N=14). All three examples of CRS Manual directions (Appendix G, Question 1b) aim to convey the importance of a tight installation and mention the "1 inch rule." A majority of participants preferred a short, concise warning which included a suggestion to try a different seat position if they were unable to tightly secure the CRS (57.1%, Option 1). Other participants preferred the same text for seat belt and LATCH installations that conveyed the importance of a tight installation (14.3%, Option 2) or customized and separate seat belt and LATCH instructions on tight installation (Option 3, 28.6%). CRS diagram examples were also evaluated (Appendix G, Question 1c, N=18) and most participants preferred a zoomed-in diagram of a hand holding a connector and a zoomed-out diagram of a person with a knee in seat to convey the importance of a tight installation (61%, Option 3). Other design options included a diagram with one hand

pushing down on the CRS and another hand pulling on a strap (11%, Option 1) or a photograph of a person's hand on the CRS and another hand pulling on a strap (27.8%, Option 2).

3.6.7 Child Seat Installation: Lower Anchors

Some participants have commented about the difficulty of holding the lower anchor hooks open while locating the LATCH connector bars. The amount of force needed to install a LATCH connector may be a method to quantify differences across various child seat designs. Some have also mentioned that it was awkward to maneuver the LATCH connectors in compact vehicles with bulky child seats.

3.6.8 Child Seat Installation: Loose Installation

Most participants were unsure how to get their CRS installation tight. Some participants were averse to placing a knee into the child seat when tightening the attachment system and some were not aware that applying pressure to the child seat would help achieve a tight installation. Some participants said that it was too difficult to pull the strap to secure the LATCH or seat belt system tightly.

Participants who had loosely installed CRSs were surveyed on their LATCH connector type preference (N=21). Participants generally preferred the LATCH connector similar to the ones found on CRS B (61.9%, See Figure 4). LATCH connector variations of CRS A (9.5%) and C (28.6%) were less preferred by participants who had loose installations. Some participants commented that the CRS A LATCH connector looked difficult to maneuver into the vehicle seat and did not look "child friendly" whereas some participants mentioned that the CRS C LATCH connector was difficult to remove from the anchor points.

3.6.9 Recline Error

Angling procedures are particularly troublesome for vehicle owners with angled seat benches or a CRS with few level angle adjustment options. Parents suggested that procedures with using towels or noodles to angle the child seat would be useful if needed but have expressed that it complicates the installation process. Some suggested that the manufacturer include these items with the child seat. The seat bench angle may be a vehicle design parameter that can be investigated for input into vehicle ease-of-use ratings.

Participants who made recline errors were asked to evaluate example text (Appendix G, Question 7a, N=16). Participants preferred text that included instructions to check the level indicator on the CRS, mentioned that the vehicle must be on level ground, suggested use of a rolled towel if necessary, and reminded that the angle must be periodically checked (43.8%, Option 3). Design examples with less specifics on improving the recline angle were not as preferred. (12.5%, Option 1; 12.5%, Option 2).

Label examples were also evaluated by participants who made recline errors (Appendix G, Question 7b, N=20). Recline ball indicators with text such as "Ball must be entirely in green!" and "Level indicator for rear-facing only" were preferred (75%, Option 3) compared to design examples with a line label with text "Use Level to Ground Rear-Facing Only" (15%, Option 1) or "Adjust base angle so this line is level with ground" (20%, Option 2).

3.6.10 Routing Error

Some participants expressed confusion with routing the LATCH or seat belt on the convertible child seats and suggested labeling parts (e.g. A-G) or nearby locations on the child seat with accompanying photos and simple text. Some participants also attributed the difficulty in changing the routing from RF to FF to the wording of the text and diagrams on the labels and child seat manual.

3.6.11 Twisted Lower Anchor Strap

Ten participants installed their CRS with twisted lower anchor straps and were asked to evaluate design examples (Appendix G, Question 5a, N=10). Six of the ten participants (60%, Option 3) preferred text that describes the process of attaching the lower anchor connectors and mentioned to check that the straps are not twisted and attached properly. Other participants preferred concise language that specified to lay the strap flat and not twisted (20%, Option 1) or text that describes the process of attaching the connectors step-by-step and verifying that the straps are not twisted (20%, Option 2).

Recommendations

Novice participants in this study made many errors when using the seat belt or LATCH system to install CRSs. The installation errors made by the novices were representative of the types of errors that were found at checkup stations and in a NHTSA misuse study (Decina & Lococo, 2004) conducted in six states. Studies 1-3 used a talkaloud methodology to examine the thought processes of novice subjects during the installation and the factors that affect the CRS installation process. Studies 4-5 surveyed installation errors made by parents and caregivers who currently own and use child seats in the local community. The ultimate goal is to make child seats more intuitively designed by investigating the types of errors and examining why participants are making these errors. Understanding why parents and caregivers make mistakes when installing child seats can help identify possible measures to reduce their occurrence. In general, the study found that participants were often overwhelmed with conflicting information or needed clarification with terms and directions used in the CRS and vehicle manuals.

Human factors design principles such as affordance, color coding, and intuitive organization may be helpful in efficiently organizing the abundance of information and numerous options provided with the child seat. Affordance, or the design of items in context of easily perceivable actions, would be ideal for future designs to alleviate installation confusion. For example, a design recommendation would be to use a recognizable universal symbol that can be integrated onto the LATCH connectors of child seats and vehicles so LATCH is familiarized among parents and caregivers.

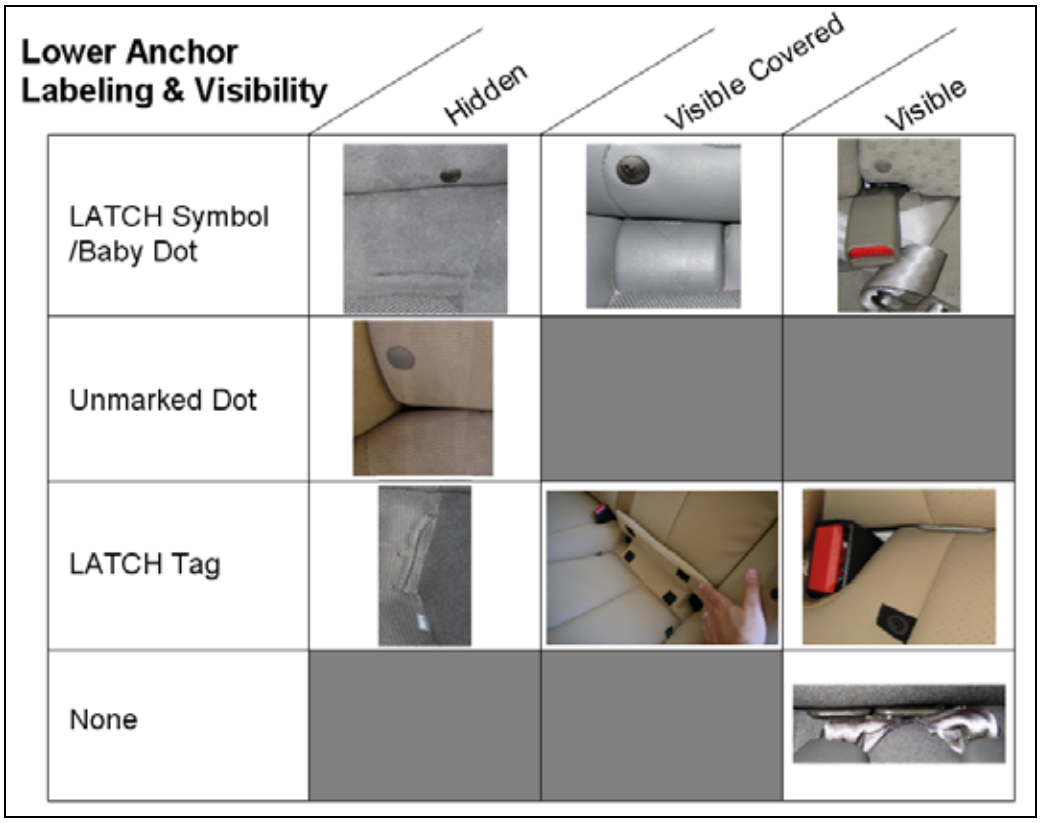

Table 10. Lower anchor labeling and visibility variations.

LATCH symbols generally vary in design across manufacturers (See Table 10). Other vehicles may have small tags affixed to the seat labeled "ISOFIX" or have no labels if the anchors are in plain view. Although the LATCH anchors may be in plain view, it may still not be understood that the anchors are used for child seat installation. Additionally, LATCH has also been given other names with some minimal standardization such as ISOFIX and UAS in other countries such as Canada. A LATCH connector and anchor point with the matching anchor symbols can give novice installers an added benefit of automatically associating both pieces to belong together (See Figure 18).

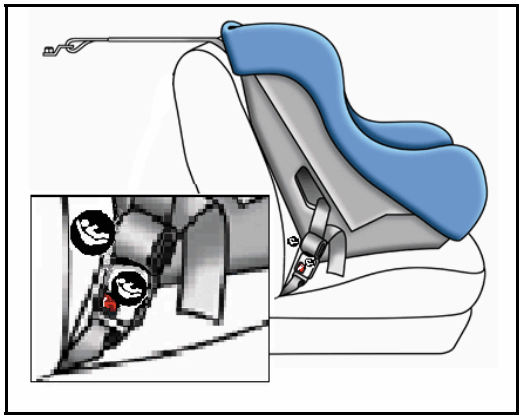
Figure 18. The usability principle of affordance can used to associate the child seats' attachment points with LATCH connectors.

Designing the instruction manuals and labels to complement one another may be helpful when participants are misguided or at a confusing point. While instruction manuals provide more real estate to detail needed information, labels also provide helpful location cues to remind and inform parents and caregivers of their steps for a successful child seat installation. Using a similar color coding scheme or numbering labels is one avenue to coordinate information. Errors such as placing the chest clip too low can be remedied if clips came marked with "Place at Armpit Level." This recommendation has been incorporated into the updated NHTSA Ease-of-Use ratings (nhtsa.dot.gov) where a CRS with no threading required and correct usage labeling will receive an A for the harness clip feature. Given the low ratings and the confusion from instruction manuals, the readability, images, and warnings can be greatly improved by simplifying text, lowering the reading level (Wegner & Girasek, 2003), and ensuring that the terminology for unfamiliar CRS design features used in the instructions are well understood by the parent or caregiver. A common comment from child seat inspection events was that the participant was uncertain whether they installed the child seat correctly according to the directions. A checklist with what constitutes a proper installation can reassure parents that a correct installation was achieved. Troubleshooting tips and additional resources are essential for parents and caregivers who seek further guidance. Additionally, evaluating the vehicle seat design and the different features on a child seat may also help differentiate how vehicle design may affect child seat installation errors.

In summary, the following are recommendations and reasons why these changes may help correct CRS installation errors:

1. **Improve the LATCH symbol to help locate the anchor point:** Many participants did not see the symbol when performing the CRS installation. Changing the salience by using contrasting colors, placing in close proximity to the anchor point or standardizing a LATCH symbol are ways parents and caregivers can better identify symbols.

2. **Make sure CRS and vehicle labels and manuals do not provide conflicting or missing information:** The design of the CRS instruction manual should be based on usability testing. This may help to identify how conflicting or missing information could lead to misuse. Information provided to the parent and/or caregiver must be clearly conveyed with easy-to-understand diagrams and clearly written text appropriate for the intended audience of parents and caregivers.

3. **Labels on the CRS should be used as location cues:** CRS labels should be placed in easy-to-see areas and in close proximity to the CRS features referred on the label as a reminder and an aid in completing the CRS installation. Labels such as a diagram showing the correct carrying handle position in a car placed on the carrying handle or a "place at armpit level" label can correct commonly neglected steps in the CRS installation process.

4. **Guide parents and caregivers on the main steps to follow when completing a CRS installation:** A checklist should be provided in the vehicle and CRS manuals that point installers to the main steps and the pages where more information is found. Figure 1 illustrates that CRS installation is multifaceted and parents or caregivers can easily become lost in the task. Providing a checklist tells them where they are in the installation and what to expect.

5. **Anticipate the type of errors made in the CRS design:** Our studies show that some errors are committed regardless of the level of experience with installing child seats. Other errors are specific to the child seat type. For example, a parent using a convertible child seat is more likely to make a routing error. Therefore, the design of the child seat should focus on improvements to minimize such known problems. If the error cannot be prevented by changing the child seat design, troubleshooting sections of the manual should address these error types. Considerations and advice should also be made for the possible configurations of passengers, additional child seats, and possible convertible CRS positions.

6. **Use objective rather than subjective feedback:** Our studies showed that participants were unsure of whether they had installed the CRS correctly. It is important to provide feedback to the child seat installer when an installation step is completed correctly. Common CRS installation problems like loose installation can be circumvented if they were given an objective feedback such as an auditory or visual cue rather than subjective feedback such as leaving it to the parent or caregiver to determine (e.g. base of child seat should not move more than 1 inch in any direction).

7. **Intuitively design the CRS:** Participants often look on the back of the CRS to find the harness strap adjusters and the base release. Parents and/or caregivers can become frustrated during the CRS installation process if they cannot find CRS features, such as when the base release is placed hidden in the front. Prevent CRS features from being counterintuitively placed. Protect parents and caregivers from CRS installation errors by placing individual features of the CRS in areas that they expect.

Future Directions

Based on the results of this study, several future research topics are recommended to identify vehicle and child seat improvements that could reduce installation errors. Research is needed to identify the effect of different vehicle characteristics (such as seat angle, anchor accessibility, instruction manuals) on ease of use and installation errors. The methodology in this study could also be extended to a larger study of installation errors associated with forward facing and convertible child seats. Finally, testing of proposed solutions is needed to demonstrate the potential improvement in installation error rates.

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Appendix A. Sample Child Seat Observation Form.

SID: _____
Date:_____

Child Seat Observation Form

1. Seat Position (circle seating position #):

3	6	9
2	5	8
D	4	7

Front

Back

2. Available Seat Belt Type for Position:
   (1) Lap & Shoulder Belt
   (2) Lap Belt only
   (3) Shoulder Belt only
   (4) None

3. Child Seat Used: _____

4. Installed with base? Y / N

5. SB latchplate type: _____

6. SB retractor type: _____

7. Cloth / Leather Seats

8. LATCH: ____ b/w, ____ in (depth)

Comments:

Time Completed

1. Time used to read manual: _____

2. SB install time: _____

3. LATCH install time: _____

4. Test dummy install time: _____

Seat Belt

1. SB routed through correct path? Y / N
   If NO, explain:

2. Tight installation (1-inch rule)? Y / N
   If NO:
   (a) User error Y / N
   (b) Base too wide Y / N
   (c) Other _____

3. SB twisted no more than half-twist? Y / N

Other

1. Carry handle in correct position? Y / N

2. Correct angle for rear-facing CRS? Y / N

3. Vehicle position installed is allowed? Y / N

Lower Anchors

1. Are lower anchors present in seat position? Y / N

2. Are lower anchors in use? Y / N / n/a

3. Correct path used for _____ strap? Y / N

4. Attached to designated lower anchors? Y / N
   If NO:
   (a) In non-designated pos., attached using lower anchors Y / N
   (b) In designated pos., attached to seat material or spring (not anchor) Y / N
   (c) In designated pos., only 1 side attached to anchor Y / N
   (d) Other _____

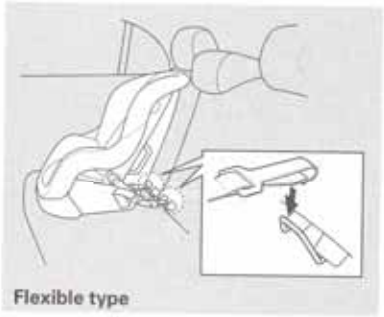
5. One connector per bar? Y / N

6. Connector installed right-side up? Y / N

7. Tight installation (1-inch rule)? Y / N
If NO:
   (a) User error Y / N
   (b) Base too wide Y / N
   (c) Other _____

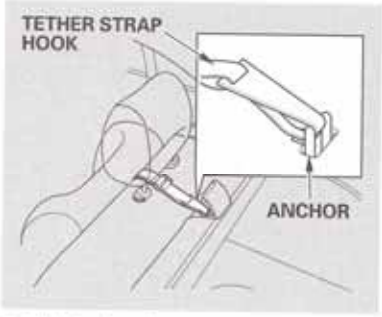
8. Lower anchor strap twisted? Y / N

Appendix B. Sample portions of a car manual and CRS (A) manual used by a participant.



Other LATCH-compatible seats have a flexible-type connector as shown above.

4. Whatever type you have, follow the child seat maker's instructions for adjusting or tightening the fit.



5. Lift the head restraint (see page 89), then route the tether strap through the legs of the head restraint and over the seat-back, making sure the strap is not twisted.

If the tether strap is too long and cannot be tightened firmly, find a route where the strap can be tightened securely.

6. Attach the tether strap hook to the tether anchor, then tighten the strap as instructed by the child seat maker.

7. Push and pull the child seat forward and from side-to-side to verify that it is secure.

15.3.6) Check that nothing is on top of the base or anything that will interfere with the proper latching of the Safety Seat to the Base. Place the Safety Seat onto the Base and push down until the Safety Seat latches securely to the Base and you hear a click. Pull upward on the Safety Seat to check that the Safety Seat is securely latched onto the base. Please see figure 28-1.

If the Safety Seat does not securely latch onto the Base, the Safety Seat will provide No Protection for your child. DO NOT use the Safety Seat with the Base if it does not securely latch onto the Base. Please call Baby Trend at (800) 328-7363 for assistance.

15.3.7) To remove the base from the vehicle, squeeze the webbing release button on the LATCH connector to loosen the webbing. See figure 49-3a. Please note that the LATCH connector can not be released from the LATCH anchor if the webbing is tight. Press the LATCH hook release button on each connector to release the connector from the anchor. See figure 49-3b.


Fig. 49-1

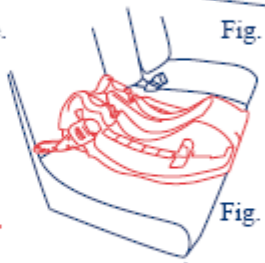


Fig. 49-2


Fig. 49-3a

Press to release
Fig. 49-3b

Appendix C. Labeling differences between CRS A, B, C (clockwise from left) from studies 1 & 2.

Appendix D. Example warning labels affixed the CRS A, B, C (top to bottom).

Appendix E. Studies 1-2 Experiment Instructions.

Evaluation of Child Safety Seats
Experiment Instructions: Studies 1 & 2

*Car should be parked within cone set-up.

Thanks for agreeing to participate in today's experiment. You will be observed while you install a child safety seat during this experiment and at the end of the session you will either be given course credit or paid for your participation. You will be given an instruction manual and a child seat (and a child dummy – Study 1 only) to install into the car to the best of your ability. You can also use your car manual to help you with the installation. As you are completing the task, please say everything that comes to mind. Say out aloud everything that you say to yourself silently. You can also refer to the manuals during the installation. Afterwards, please fill out the questionnaires evaluating your experience installing the child seat. If you have a question or problems prior and after the installation, please let me know.

Scenario task: You are a new parent who has just bought a brand new child safety seat to install into your car. You are installing the seat for the first time in preparation for an upcoming trip.

Forms Checklist:
Before experiment
- ☐ Consent Form
- ☐ Demographics Survey

After experiment
- ☐ Subjective Questionnaire
- ☐ User Confidence Ratings
- ☐ Label Usability Ratings
- ☐ GMU Credit form

Experimenter -

- Randomize child seat given to each subject
    - If subject finishes early, have them complete an additional child seat install
- Ask subject to install the child seat rear-facing to the best of their ability, then install test dummy as if it was their own child.
- Remind the subject that during the install the subjects' actions will be videotaped
- Remind the subject that they can reference car manual and child seat manual anytime during the experiment
- Remind the subject that during the install they should "think and talk aloud."
- When subjects fill out questionnaire, record install on Observation Form.

Appendix F. Study 3 Experiment Instructions

Evaluation of Child Seats
Experiment Instructions: Study 3

*Car should be parked within cone set-up.

Thanks for agreeing to participate in today's experiment. You will be observed while you install a child seat during this experiment and at the end of the session you will either be given course credit or paid for your participation. You will be given an instruction manual and a child seat to install into the car to the best of your ability. You can also use your car manual to help you with the installation. You can also refer to the manuals during the installation. Afterwards, please fill out the questionnaires evaluating your experience installing the child seat. I will also ask you a few questions about your experience after you complete the installation. If you have a question or problems prior and after the installation, please let me know.

Scenario task 1: You are a new parent of a newborn who has just bought a brand new child seat to install into your car. You are installing the seat for the first time in preparation for an upcoming trip.

Scenario task 2: You're babysitting your 3 year old niece who weighs about 40lbs and would like to install the seat for your niece in preparation for an upcoming trip [additional variation if necessary].

Additional variations
- If subject used seat belt in Scenario 1 - "using the LATCH system"
- If subject installs CRS forward-facing - You're babysitting your young niece and would like to install the seat rear-facing in preparation for an upcoming trip.

Forms Checklist:
<u>Before experiment</u>
- ☐ Consent Form
- ☐ Demographics Survey

<u>After experiment</u>
- ☐ Subjective Questionnaire
- ☐ User Confidence Ratings
- ☐ Label Usability Ratings
- ☐ Manual Usage Questionnaire
- ☐ GMU Credit form or Gift Card Sign up Sheet

Experimenter -
- Randomize child seat given to each subject
  - If subject finishes early, have them complete an additional child seat install
- First ask subject to install to the best of their ability, then install in the opposite facing configuration for the second installation. Ask subject to complete the 2nd installation with the LATCH system if they did not use the system in the 1st installation.
- Remind the subject that they can reference car manual and child seat manual anytime during the experiment
- When subjects fill out questionnaire, record install on Observation Form.

Appendix G. Design Feedback Questionnaire
*Answers or options with asterisks (*) denote most selected response

SID:_____ Date:_____ Child Seat Evaluation

1. What do you think would have helped you during the installation? What are some aspects of the child seat that can be improved?

Common answers were: Clearer diagrams, easier to use system, nothing/no problems

2. What are some aspects of the child seat manual that can be improved?

clearer pictures/diagrams, text, fewer steps, less confusing, LATCH

3. Do you typically read the back and side panels of the child seat?

a. Yes*
b. No
c. Don't remember/not sure

4. Do you typically read the manual of the child seat?

a. Yes*
b. No
c. Don't remember/not sure

5. Do you typically read the child safety section of the vehicle owner's manual?

a. Yes
b. No*
c. Don't remember/not sure

6. Please circle the sections you used when you completed the child seat installation:

Manual Sections Safety Info / Warnings / Child Seat Features* / Vehicle Features / Rear-facing Installation* (LATCH/SB) / Fwd-facing Installation* (LATCH/SB) / Tether Installation / Securing Your Child / Optional Accessories / Care & Maintenance / Reclining the Seat / Trouble Shooting / Installation Tips / Warranty

Other: _____

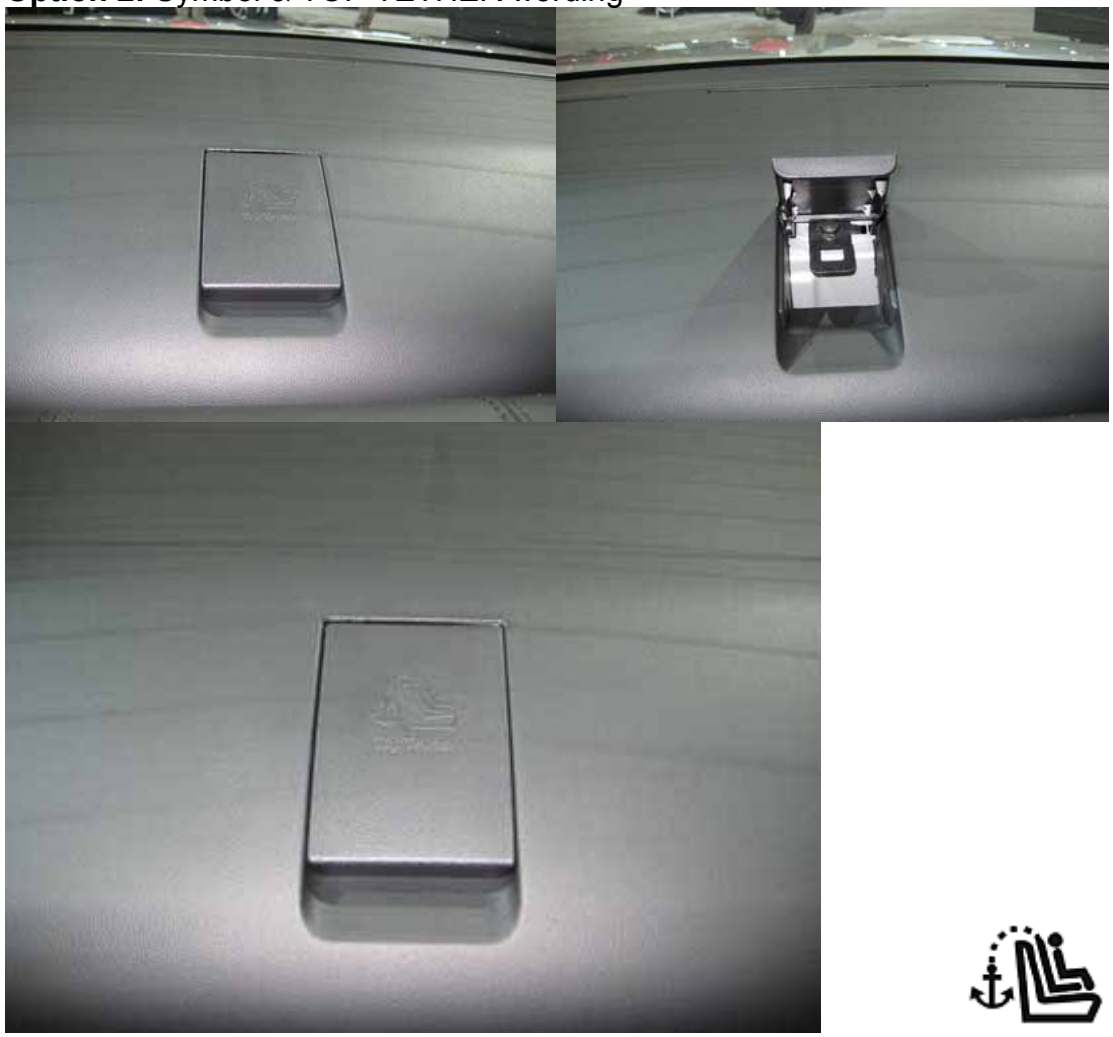
7. Please circle the appropriate additional sections that you would help you complete a child seat installation:
Manual Sections Child Safety / Locating CPS Technicians* / State Laws* / LATCH definition** / Tether def / Other:

Please select the design that best meets your expectation:

8. **Top Tether Anchors**
Option 1: Anchor symbol



Option 2: Symbol & TOP TETHER wording*



"Top Tether"

* Design selected most by participants

Option 3: Unlabeled



9. **Lower Anchors**: Select the design that best meets your expectations.

Option 1: Unlabeled - Visible

Option 2: Labeled – Visible - Contrasting seat color

Option 3: Labeled – Same color*

Option 4: Labeled on Removable Cover, Visible Uncovered

Option 5: Labeled - Visible Uncovered

CRS Installation (check CRS)

1. Loose Installation (LATCH demo)

   a. **LATCH Connector Types** (3 kinds): Which connector would you prefer?

A

B*

C

   b. **Child Seat Manual Directions** (Circle one)

Option 1: In SB and LATCH Installation instructions*

WARNING! The child restraint should not move more than 1 inch side-to-side or front-to-back at the belt (SB/LATCH) path. If you are unable to properly secure the restraint, move it to another seating position and try installing it again, or try installing a different child restraint.

Option 2: In SB and LATCH Installation instructions

Before placing the child in the seat, forcibly move the seat forward and back to make sure the seat is securely in place. To check this, grab the seat at the belt path and attempt to move it side-to-side and forward. There should be no more than 1 inch of movement for proper installation.

Option 3: In SB Installation instructions

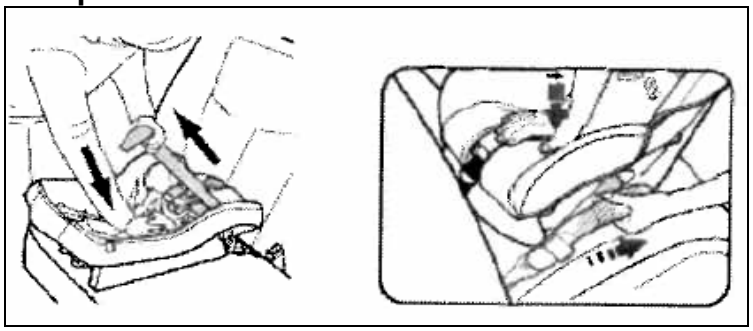
Push the child-restraint system firmly into the vehicle seat. Be sure the belt retracts as snugly as possible. Clicking from the retractor will be heard during retraction if the system is in locking mode. If the belt does not lock the seat down tight, repeat this step or try another seating position. Make sure the child seat moves less than 1 inch side-to-side and forward.

In LATCH Installation instructions

Make sure the hooks are correctly connected to the vehicle's LATCH anchors. Pull the belt(s) tight so that the child seat moves less than 1 inch side-to-side and forward. Press down or put weight on the seat as you pull the belt(s) tight. If you are unable to lock the seat down tight, repeat this step or try another seating position.

c. **Child Seat Manual Diagrams**: Rate (1-10) the following diagrams on how well they convey the importance of a tight installation:

Option 1: In Installation instructions



Option 2: In Installation instructions

Option 3: In Installation instructions*

d. **Car Manual Directions** (circle one)

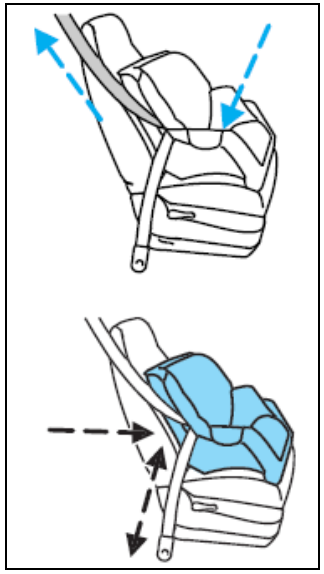
Option 1:
Text location: In Child Restraint Installation instructions
WARNING! The child restraint should not move more than 1 inch side-to-side or front-to-back at the belt (SB/LATCH) path. If you are unable to properly secure the restraint, move it to another seating position and try installing it again, or try installing a different child restraint.

Option 2*:
Text location: Warnings section at beginning of Child Restraint section
WARNING! Make sure the child restraint system is properly secured.
- Always follow the manufacturer's installation instructions.
- If the child restraint is not anchored properly, the risk of a child being seriously injured or killed in a collision greatly increases.

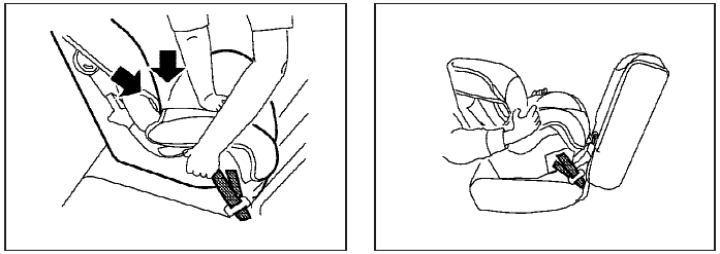
e. **Car Manual Diagrams**: Rank the following diagrams on how well they convey the importance of a tight installation:

Option 1: In Installation instructions*

Option 2: In Installation instructions



Option 3: In Installation instructions



2. **SB & LATCH Installation** (allowed/not allowed?)
    a. **Car Manual Directions** (Specific/Non-specific about install types)

Option 1: Before Child Restraint Installation instructions

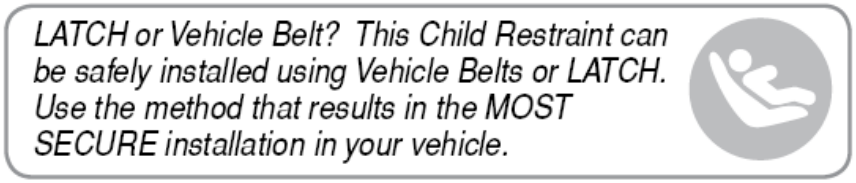
Selecting Child Seat Attachment System
A child seat may be secured to a vehicle with a seat belt **or** the lower anchors and tethers for children (LATCH) system. LATCH-compatible seats are secured by attaching the child seat to hardware built into the two outer seating positions in the back seat. Always refer to the child seat owner's manual for proper installation and height/weight restrictions.

Option 2*:

Recommendations for attaching child safety restraints for children

Restraint Type	Child Weight	Use any attachment method as indicated below by "X"				
		LATCH (lower anchors and top tether anchor)	LATCH (lower anchors only)	Safety belt and top tether anchor	Safety belt and LATCH (lower anchors and top tether anchor)	Safety belt only
Rear facing child seat	Up to 48 lb (21 kg)		X			X
Forward facing child seat	Up to 48 lb (21 kg)	X		X	X	
Forward facing child seat	Over 48 lb (21 kg)			X	X	

Option 3:

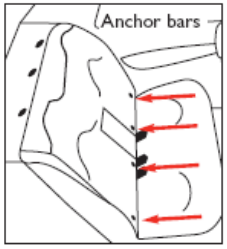


b. **Child Seat Manual Directions**

Option 1:

Choosing LATCH or Vehicle Belts

The LATCH System

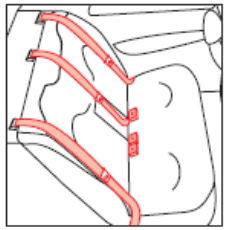


LATCH means **L**ower **A**nchors and **T**ethers for **CH**ildren. Not all vehicles manufactured before September 2002 were equipped with LATCH.

The LATCH system allows a child restraint to be secured in the vehicle without using the vehicle belt system and can ONLY be used in vehicles that have the anchor bars installed.

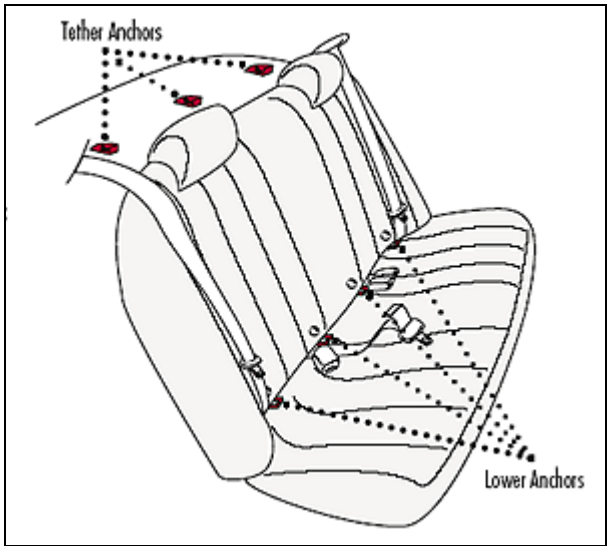
Check your vehicle owners manual to see which seating positions may be equipped with the LATCH system.

Vehicle Belts



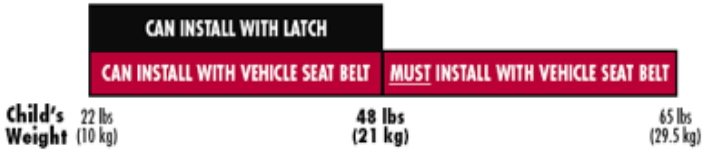
If LATCH is not an option, you will use your vehicle's belts. In most cases you will use the lap/shoulder belt combination. There are some vehicle belts that will not work with a child restraint or will require special attention. See next page for specific instructions.

Option 2*:



The vehicle **lower anchors** may be visible at the vehicle seat bight (seat crease). If not visible, they may be marked with one of these symbols.

The vehicle's **tether anchors** may be visible. If not, they may be identified with this symbol.



3. **Tether Installation**

   a. **Child Seat Manual Directions**

Option 1: In Tether Installation instructions*

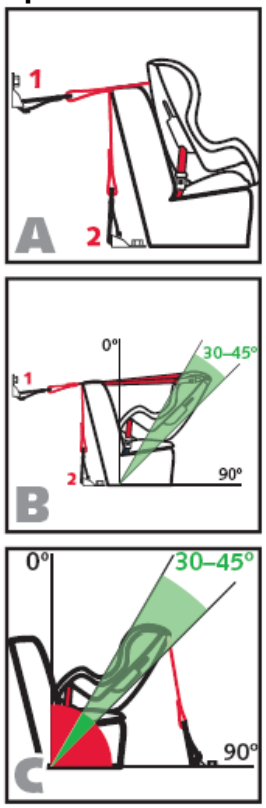
Refer to the vehicle owner's manual to determine tether anchor location. Secure tether clip to the vehicle tether anchor. If possible, route tether under headrest or remove headrest. Secure the removed headrest so that it will not become a projectile in a crash.
To tighten, pull the free end of the tether strap and remove any slack. Tightly roll or fold the excess tether strap and place out of child's reach to avoid a strangulation hazard.

Option 2: In Tether Installation instructions

Locate the hook on the tether strap. Loosely attach the tether to an approved tether anchor point for the desired restraint installation position. Secure the child restraint in the vehicle. Pull the tether adjuster strap to remove all slack. Verify that there is tension in the tether strap and that child restraint is properly secured. The child seat is secure when it cannot be moved front-to-back or side-to-side more than 1 inch (2.5 cm) at the belt path.

b. **Child Seat Manual Diagrams**

Option 1: In Tether Installation instructions*



Option 2: In FF Tether Installation instructions

c. **Car Manual Directions**

Option 1:
Route the tether strap to provide the most direct path for the strap between the anchor and the child seat. If your vehicle is equipped with adjustable rear head restraints, raise the head restraint and route the tether strap under the head restraint between the two posts. If not possible, lower the head restraint and pass the tether strap around the outboard side of the head restraint.

Attach the tether strap hook of the child seat to the anchor and remove slack in the tether strap according to the child seat manufacturer's instructions.

Option 2*:
Route the tether strap through the legs of the head restraint and over the seat-back, making sure the strap is not twisted.

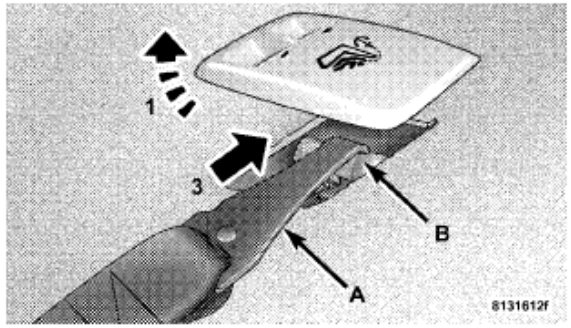
Attach the tether strap hook to the tether anchor, then tighten the strap as instructed by the child seat maker. Push and pull the child seat forward and from side-to-side to verify that it is secure.

Option 3:
Position the child safety seat on the seat cushion. Route the child safety seat tether strap over the back of the seat. Locate the correct anchor for the selected seating position. Tighten the child safety seat tether strap according to the manufacturer's instructions.

CAUTION: If the safety seat is not anchored properly, the risk of a child being injured in a collision greatly increases.

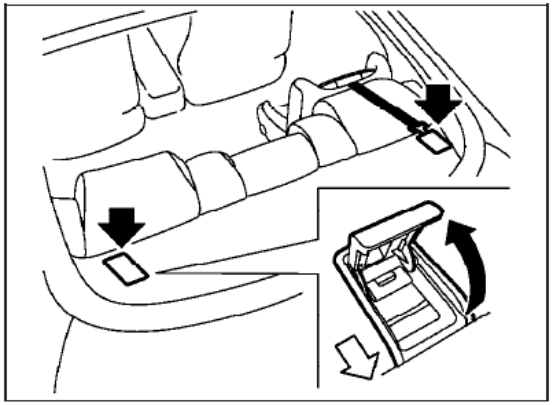
d. **Car Manual Diagrams**

Option 1:

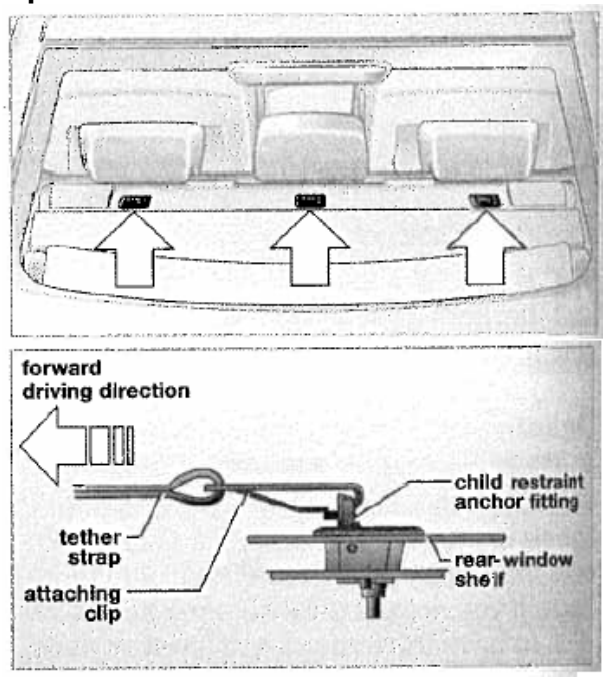


1— Cover
3— Attaching Strap
A—Tether Strap Hook
B—Tether Anchor

Option 2:



Option 3*:



4. **Convertible Routing Error**

a. **Child Seat Manual Diagrams & Directions**

Option 1:

Route ***LATCH*** belt through ***Rear-facing*** openings for:

- ***LATCH Rear-facing*** use.

or

- ***LATCH*** storage with ***Forward-facing*** vehicle seat belt use. *Pg. 25,* ***fig. q***.

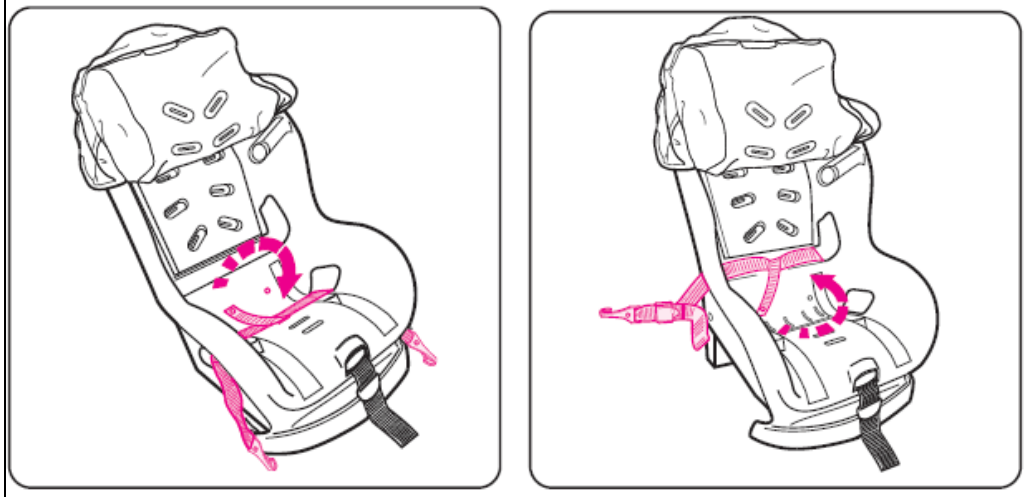
Route ***LATCH*** belt through ***Forward-facing*** openings for:

- ***LATCH Forward-facing*** use.

or

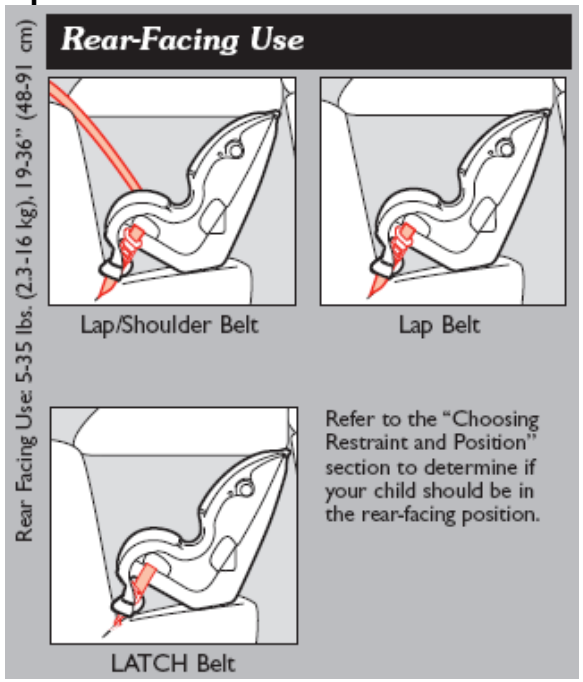
- ***LATCH*** storage with ***Rear-facing*** vehicle seat belt use. *Pg. 25,* ***fig. r***.

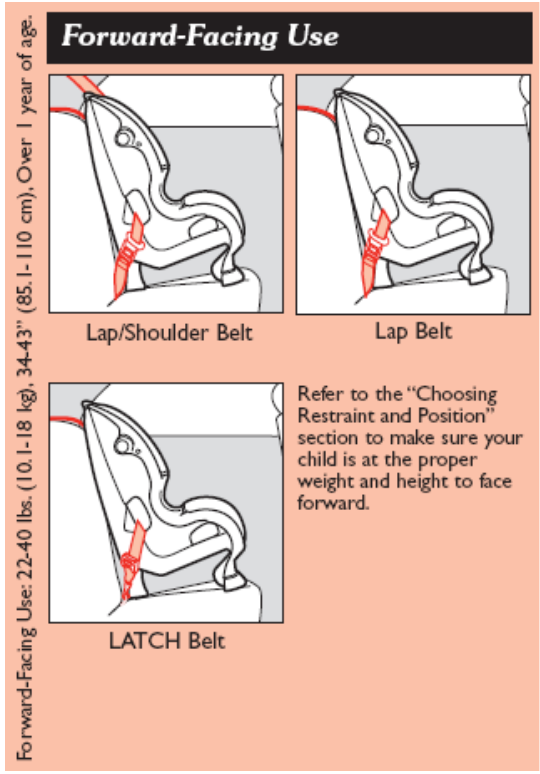
All belts must be flat and the adjuster belt must be facing out for easy adjustment.



Rear-facing openings ***Forward-facing openings***

Option 2*:

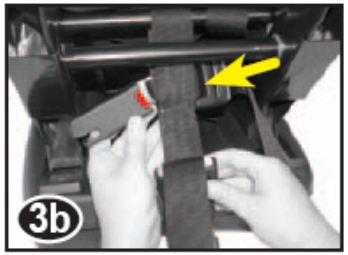

Rear-Facing Use
Rear Facing Use: 5-35 lbs. (2.3-16 kg), 19-36" (48-91 cm)
Lap/Shoulder Belt
Lap Belt
LATCH Belt
Refer to the "Choosing Restraint and Position" section to determine if your child should be in the rear-facing position.


Forward-Facing Use
Forward-Facing Use: 22-40 lbs. (10.1-18 kg), 34-43" (85.1-110 cm), Over 1 year of age.
Lap/Shoulder Belt
Lap Belt
LATCH Belt
Refer to the "Choosing Restraint and Position" section to make sure your child is at the proper weight and height to face forward.

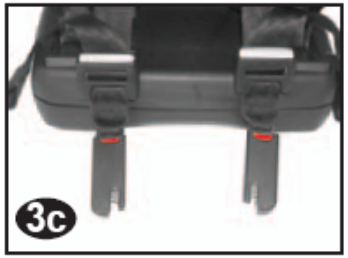
Option 3:

3. Slide each latch tether to the rear of the seat (make sure the arrow on the inside of the latch mini connector is facing up) and that the webbing is not twisted.

The latch mini connectors must be changed from one side to the other when converting the seat from rear-facing to forward-facing position.



If necessary to change the connectors from side to side: Slide each latch tether to the center of the rear of the seat (Fig. 3a). Pass the smaller loop through the larger loop (Fig. 3b), then slide the straps around to the new sides (Fig. 3c).



FORWARD-FACING

b. **Child Seat RF/FF Labels on Convertible Seats: Which label option best indicates how to convert belt paths and why?**

Option 1: Label that points to both RF and FF belt path positions*

"Toddler
FORWARD FACING BELT PATH
For Seat Belt / LATCH Harness
Forward-facing 20 and 40 lbs
(9 and 18 kg)"

"Infant
REAR FACING BELT PATH
For Seat Belt / LATCH Harness
Rear-facing 5 and 30 lbs (2.3 and 13.6 kg)"

Option 2: Label on one side that points to RF belt path and on other side that points to FF belt path position

"Child Forward-Facing Position Vehicle/LATCH Belt Goes Here"

"Infant Rear-Facing Position Vehicle/LATCH Belt Goes Here"

Option 3: Label that points to both RF and FF belt path positions

“Use Only in Reclined Position Rear-Facing”
“VEHICLE BELT HERE WHEN REAR-FACING”

“Use Only in Upright Position Rear-Facing”
“VEHICLE BELT HERE WHEN FORWARD-FACING”

5. **LATCH Strap Twisted**
    a. **CRS Manual Directions**

Option 1:
LATCH belt must be routed through opening in child restraint for forward-facing.
Belt must lay flat and not be twisted.

Option 2:
Attach the LATCH connector to the LATCH anchors indicated by the vehicle owner's manual. A positive click confirms attachment. Verify the LATCH harness is not twisted, and then attach the other LATCH anchor.

Option 3*:
Attach LATCH connector to vehicle lower LATCH anchor. Listen for an audible click when the LATCH connector is attached. Check to be sure LATCH Belt is not twisted and LATCH connector is attached properly.

6. **Not Attached to Designated Lower Anchors**
    a. **Vehicle Manual Directions**

Option 1:
The lower anchors are rounded metal bars located at the rear of the seat cushion where it meets the seatback. You can feel them if you run your fingers along the intersection of the seatback and seat cushion.

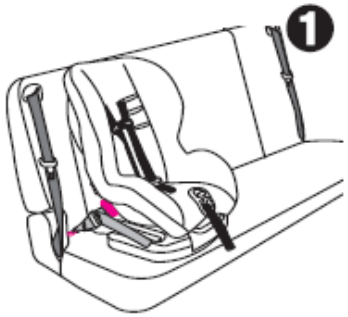
You will first loosen the adjusters on the on lower straps and on the tether strap so that you can more easily attach the hooks or connectors to the vehicle anchors. Next, attach the lower hooks or connectors to the lower anchors (rounded metal bars). Tighten these straps as you push the child restraint rearward and downward into the seat. Remove any slack in the straps according to the child restraint manufacturer's instructions.

Option 2:
Attach the child restraint's lower anchor attachments to the LATCH lower anchors in the vehicle. Make sure the straps are not twisted prior to hooking them to the lower anchors. Pull on the connectors to make sure that they are securely attached to the anchor points.

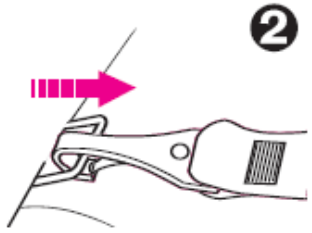
b. **CRS Manual Directions**

Option 1:

Hook **LATCH *Connectors*** to vehicle lower anchors.



Pull firmly on ***Connectors*** to be sure they are attached.



Option 2*:

Attach the farthest LATCH connector to the farthest LATCH anchor (fig. C).

- *A positive click confirms attachment.*
- *If LATCH connectors will not attach with a positive click, it may be necessary to switch the LATCH connectors as shown on page 25.*

7. **Recline Position Inappropriate** (RF)
    a. **CRS manual directions**

Option 1:
Verify the vehicle belt is tight and the child restraint is stable. The back angle of the child restraint should not exceed 45 from vertical when properly installed rear facing. If there is a problem stabilizing the restraint or achieving necessary angle, place a tightly rolled towel in the crease of the vehicle seat to help level the restraint.

Option 2:
Place child restraint rear-facing in the back seat. With child restraint in the reclined position, make sure level line on side of shell is level with ground. To recline from upright position, pull down on recline stand and rotate up into shell. Adjust child restraint if needed.

Option 3*:
Adjust child restraint to recline position. Check level indicator on child restraint. Vehicle must be on level ground and child in child restraint when checking level indicator. If necessary, place rolled towels under child restraint at vehicle seat crease. Then, re-check level indicator. Periodically check that child restraint is securely installed and properly leveled; adjust if necessary.

b. **CRS Labeling**

Option 1: “Use level to ground” “Rear-Facing Only”

Option 2: “Adjust base angle so this line is level with ground.”

Option 3*: “Ball must be entirely in green!”
“Level indicator for Rear-facing only”

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