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Technical options for reduction of misuse of group 1 CRS

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1. Abstract

Since the first design of child seats they have been improved more and more over the years. Development of child restraint systems (CRS) was pushed additionally by legislative requirements and several test procedures. Hence, modern CRS, especially expensive models, are perfected technical systems, but they are also complicated in handling.

Accident analyses and field studies show that injury risk of children depends more on the quality of usage of the CRS than on the quality of the CRS itself. Cheap CRS, which are properly installed, offer a better protection than child seats with good test results, which are used incorrectly.

This paper presents results of a project aiming at designing a CRS, which can prevent it’s users from common kinds of misuse in a reliable way with simple technical solutions. Several techniques are introduced. Finally the findings of a comparison of the modified with the original CRS by test persons are shown.

2. Introduction

The number of children who have been severely injured or killed in car accidents has significantly decreased since Germany's commitment to carry children under the age of 12 and a height smaller than 1.50m in an approved child car seat. In 2008, 41 children died in car accidents in Germany, and there were approximately 8,000 cases of children as car occupants sustaining minor to severe injuries due to accidents. The number of children sustaining injuries following car accidents is significantly higher than the number of death cases due to such accidents. Statistics show that a high percentage of children are carried in appropriate child car seats, but also notes that inappropriate use of child car seats continues to be a problem that interferes with child safety [Fastenmeier, 2006]. Research has shown that an inexpensive Child Restraint System (CRS) installed correctly provides better protection than a highly rated child car seat that is misused [e.g. Weber, 2008].

The aforementioned cases of child seat misuse as well as crash analyses show a need of improving the usage of child restraint systems to make them easier to use and to reduce the risk of misuse.

The aim of this study is to analyse possibilities to prevent the users of CRS from common kinds of misuse in a reliable way with simple technical solutions. Finally the described measures were assessed by laymen installation tests.

3. Misuse and Non-use of CRS

Several studies show that two thirds of the children travelling in cars in Germany are not properly restrained [e.g. Hummel, 2008]. This includes all kinds of misuse and non-use starting from less severe slight belt slack in the harness system to very severe non-use of any restraint system. In between everything one can imagine happens on the road (e.g. restraining children in unrestrained CRS, placing children in CRS without closing the buckle, etc.).

The non-use of CRS is strongly dependent on the age of the children. While most of the children up to 5 years of age are travelling in child restraint systems, the share of the children from 6 to 11 years using a CRS drops down to less than 50% (in Germany children need to use a CRS up to an age of 12 years or a height of 150 cm), see Figure 1.

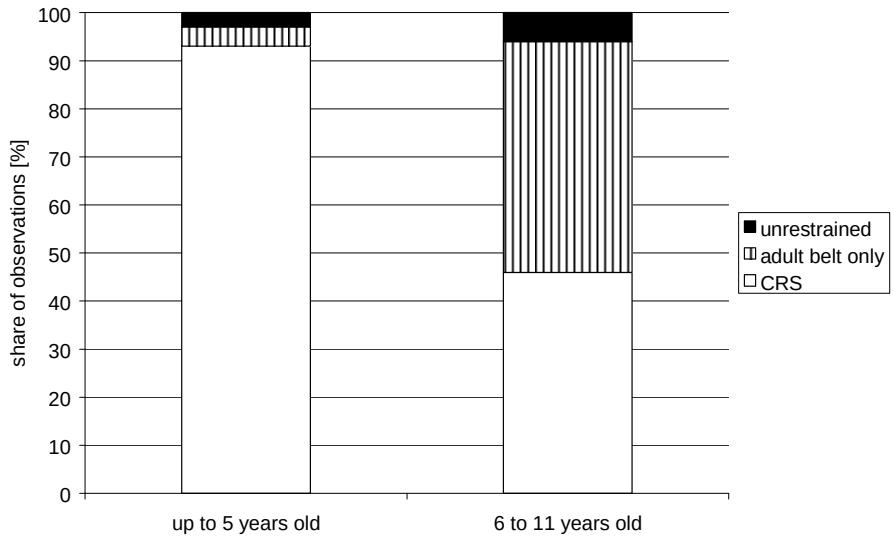

Figure 1: CRS use dependent on age groups [BASt, 2005]

Looking at those children using a CRS one must distinguish between misuse while installing the CRS and while restraining the child. For several CRS these are independent actions resulting in different kind of mistakes. Following a recent German study approx. 30% of the used CRS are installed incorrectly, while approx. 70% of the children are not restrained properly in their CRS [Fastenmeier, 2006]. For further analysis it is important to distinguish between the different types of CRS. It is obvious that the misuse rate is higher for baby shells and harness type CRS compared to booster type CRS, see Figure 2.

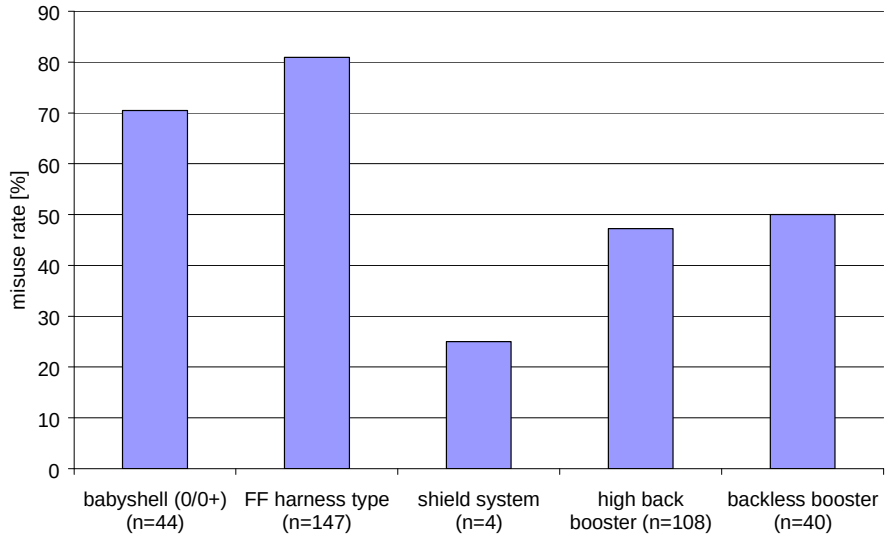

Figure 2: Misuse rates depending on CRS type [Fastenmeier, 2006]

This does not necessarily mean that parents of younger children, who are travelling in these kinds of CRS, do care less than those of older children. There are more possibilities to make mistakes with these CRS as installing the CRS and restraining the child are two independent actions, while it is only one for booster type CRS.

When analysing the details of the misuse it becomes evident that belt slack either in the vehicle's belt or in the harness are happening most often (approx. 40 to 60%) [Fastenmeier, 2006].

The field studies were performed three times showing the same overall share of misuse for all studies see Figure 3.

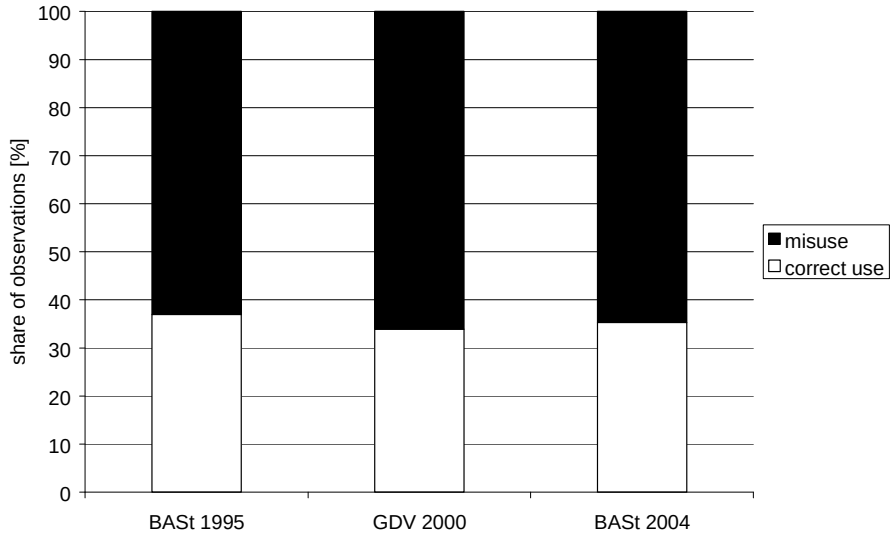

Figure 3: Overall misuse rate in different studies [Fastenmeier, 2006]

However, the severity of misuse has been reduced during the last ten years, see Figure 4.

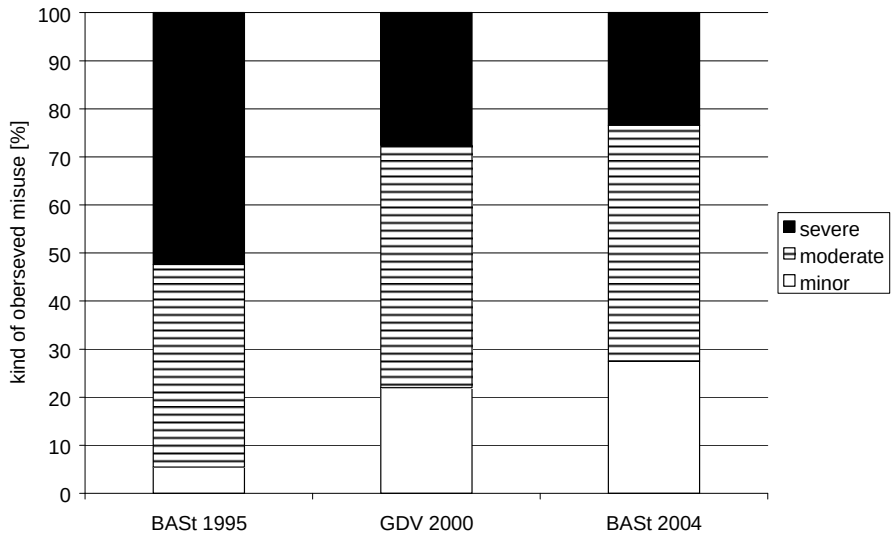

Figure 4: Severity of observed misuse in different studies [Fastenmeier, 2006]

4. Automatic Detection and Prevention of Misuse

The purpose of this project was to advance a suitable CRS to demonstrate technical possibilities to avoid all possible misuse because of its functionality.

Taking into account the misuse risk of different types of CRS, see Figure 2 it is sensible to chose a group 1 CRS as example.

During the improvement process the following principles were attended:

- The system should be easy to use
- All improvements must not cause any reduction of the safety properties of the CRS
- The system should work with a high reliability
- The system should conform to ECE-R 44

The definition of the system is based on a thoroughly analysis of misuse modes of relevant CRS types.

4.1. Analysis of Misuse

The first step of this project was to identify the most common and momentous kinds of misuse that occur when of children are secured in child seats. Two main instances of misuse were identified: Securing the child seat in the car and securing the child in

the CRS. The detailed misuse modes are discussed together with the technical solutions to avoid the different problems below in chapter 4.2.

4.2. Technical Approach

For the detection of misuse numerous sensors have to be integrated into the CRS. Sensors must have the following features:

- low error ratio
- small and durable form factor
- low energy consumption
- low costs
- maintenance-free

In the following, common forms of misuse and sensors to detect them will be specified.

4.2.1. Fastening the CRS with the seat belt

Possible types of misuse that occur when mounting the CRS to the seat are wrong seat belt path, insufficient belt tension or wrong positioning of the seat. These misuse modes probably results in an increase in forward movement in case of accidents or partial ejection of the CRS.

Detecting a wrong seat belt path can be achieved by placing push-buttons and/or light barriers at important points along the correct path. The diagonal part of the belt has to be guided through one of two belt clamps. Misuse will be detected if the belt is guided through both clamps. It is necessary to ensure that the appropriate clamp is closed (Figure 5, sensors 1 & 2).

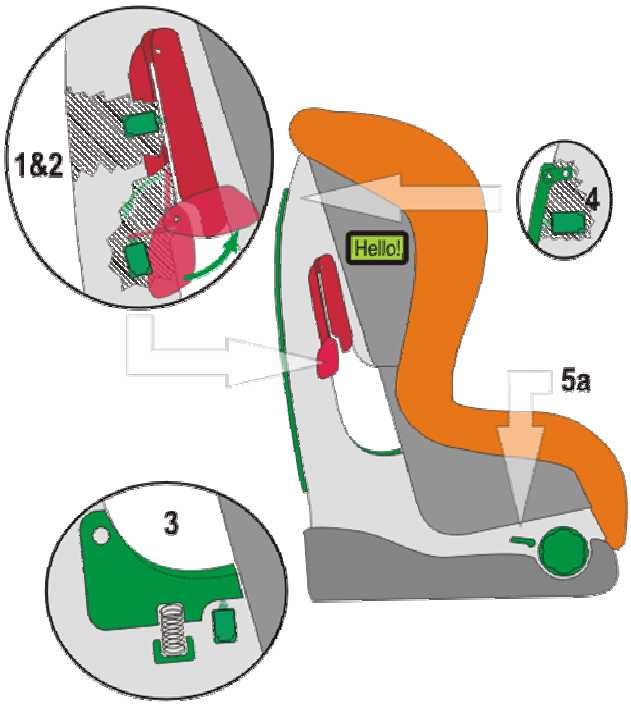

Figure 5: Belt Detection and Display

Spring-loaded levers with integrated push-buttons on both sides of the seat belt guide are able to detect a sufficient belt tension as well as the correct belt path (Figure 5, sensor 3). To ensure that the CRS is mounted upright and in the right direction push-buttons on the rear side of the CRS will detect whether it is fixed evenly on the back of the seat (Figure 5, sensor 4).

4.2.2. Fastening the child in the restraint

Various errors are made in fastening the child in the CRS. Test with laymen in this project emphasises the findings of previous surveys, that the 5-point belt is often improperly tightened resulting in shoulder belt slack. Some of the reasons found for insufficient tightening of the child safety seat, were concerns with respect to the child's comfort, a poorly designed operating system, and difficulty to use the tensioning mechanisms. Slack in the harness system also results in increased forward movement of the child in case of a frontal accident.

Consequently, it was decided to develop a new harness tension device which is easy to use for everyone. This includes large turning handles on both sides of the seat allowing an ergonomic posture and reduced operating force. An integrated slipping

clutch will detect sufficient belt force and give a haptic feedback to the user (Figure 6, sensor 5; release lever: 5a).

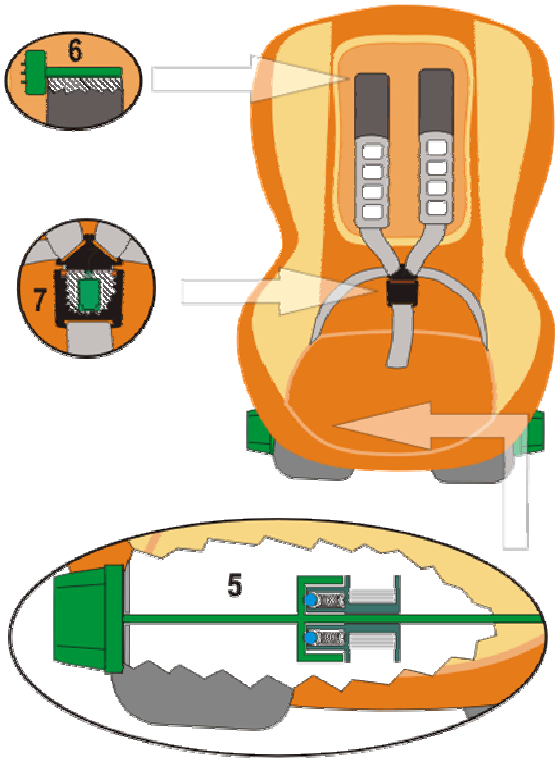

Figure 6: Belt Tension System

Shoulder belts must be adjustable taking into account the children's growth. The correct belt position is also influenced by the child's clothing (e.g. thick winter jackets). Wrong adjustment of the shoulder belt height results in additional slack of the harness system. The correct position of the shoulder harness can be attained by the angle between the shoulder harness and the back of the seat. This angle can be controlled by two accelerometers (Figure 7).

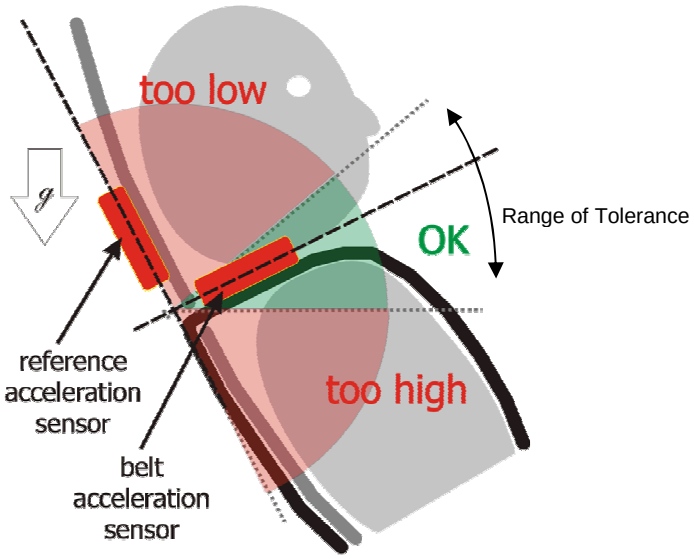

Figure 7: Principle of Shoulder sensor

From a certain age children are able to unlock the buckle of the harness by themselves. A miniature switch inside of the buckle connected to a sound interface warns the driver when the buckle is unlocked (Figure 5, sensor 7).

4.2.3. Other sensors

Using a CRS that was involved in an accident is dangerous. Due to the fact that many child restraint systems are bought second hand a sensor should be installed to give an indication if it has been exposed to an acceleration peak like that caused in car accidents. A simple solution for this sensor could be a very thin conductor with a small weight attached. In case of exceeding a certain acceleration level the conductor would break. (Figure 8, Sensor 8).

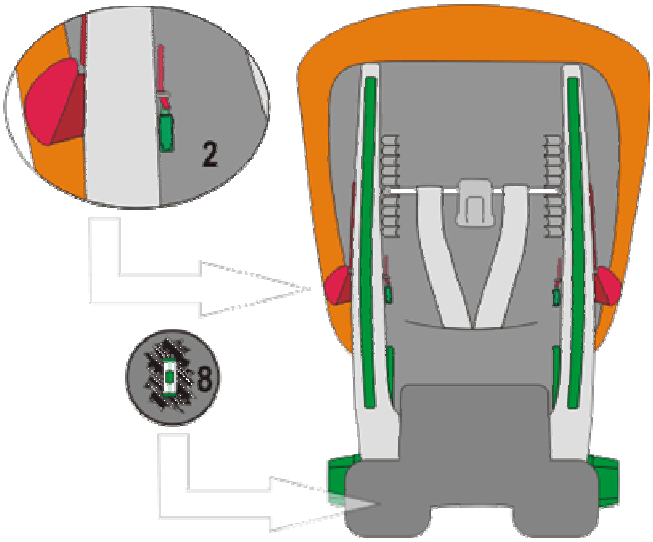

Figure 8: Back side of modified CRS

4.2.4. Visual Interface

In Chapter 4 proposals for detecting misuse were shown. To ensure positive results for child safety, the users must be informed about any mistakes they make. The information about misuse should be clear and comprehensible. The following criteria should be taken into account while creating an interface for users:

- Accessibility – must be visible from every position at least from both sides of the CRS
- Reference to the solution – has to show how to fix the problem
- Visibility by day and night

A simple and easy to use possibility is a LC-Display. This kind of interface can give a direct feedback to the user and can inform him about possible misuse and the way how to fix it. The text, which is shown on the display depending on the kind of misuse, can be found in Figure 9. To perform the requirement of accessibility it is necessary to put a display on both sides of the seat or to make it possible to fix one display either on the one or the other side. For retail and distribution world wide it would have to be made available in various languages.

4.2.5. Sequence of misuse check

In order to give a feedback to the users, allowing them to handle the given information in a reasonable way, the signals of the sensors must be processed in a logical order. Figure 9 shows a draft of such a schematic diagram.

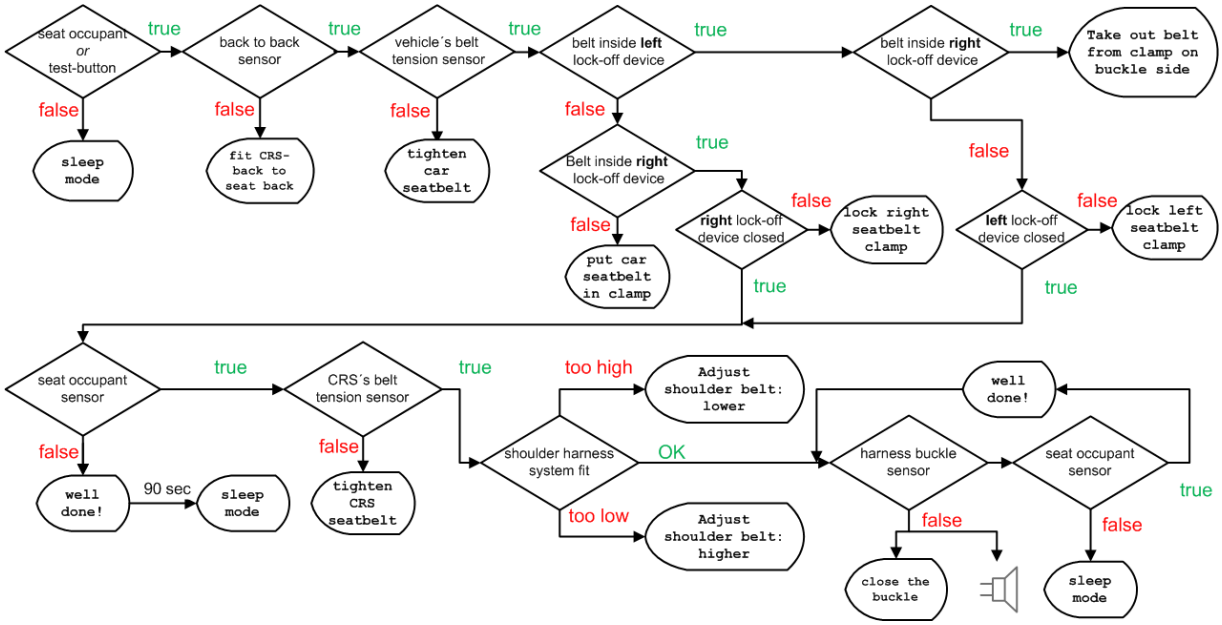

Figure 9: Schematic Diagram of Misuse check

In general, the installation works in two steps. First, the user can make sure that the CRS is well installed in the car. In the second step the user can control, whether the child is well secured in the CRS. Later on the buckle is observed all the time. Unexpected opening will be signalled by a warning sound.

5. Comparison of modified and original CRS

Within this project, a comparative study was carried out, in order to compare the original CRS with the advanced one. Therefore, several test persons had the task to save a three year old child (Q3 dummy) either in the old or in the new CRS. The following diagram shows the kind and frequency of misuse, which occurred with the original group 1 seat.

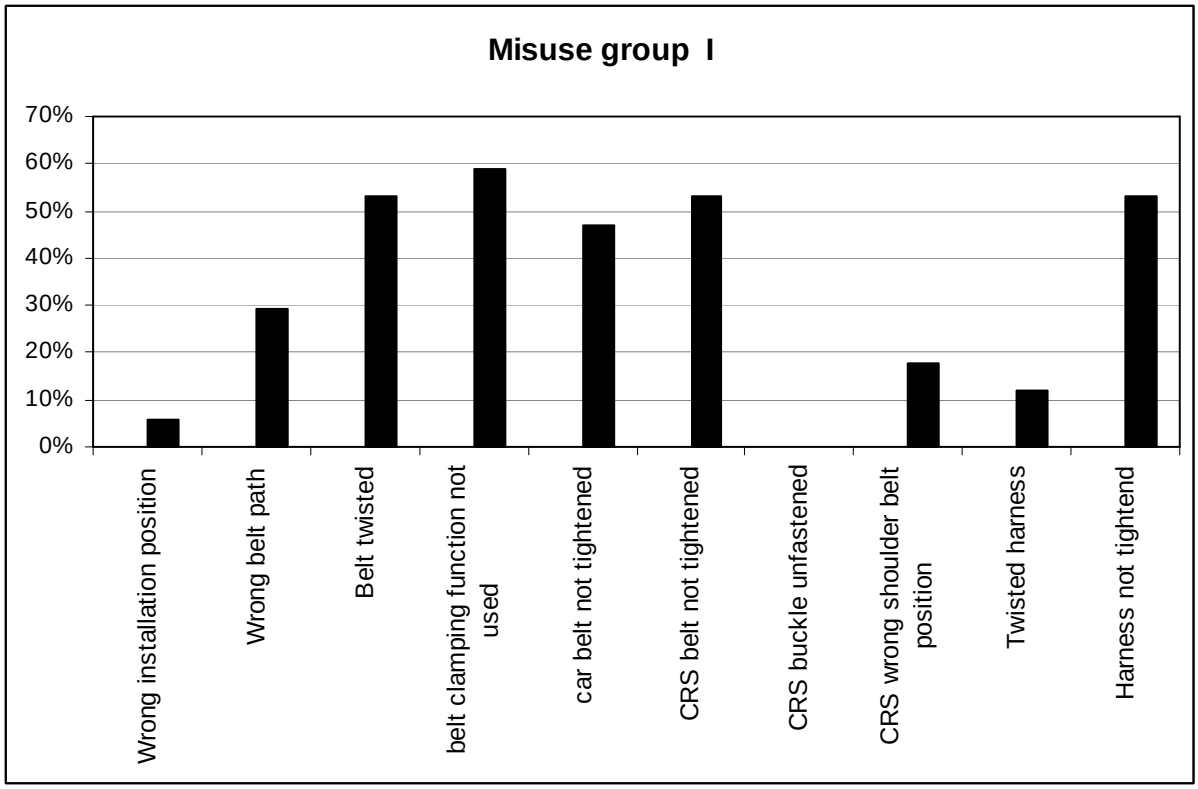

Diagram 1: Frequency of Misuse in group 1 CRS

As expected and seen in many other studies, problems with the car belt occurred very often: wrong belt path, insufficient belt force or non-use of belt clamps.

With the new CRS no misuse was observed. Because of clear information to the probands on the next steps to be taken including information concerning correct completion the user knows about existing problems and solutions to fix them. This confirms the results of many studies which showed that misuse mainly is a problem of lack of knowledge. Most of the parents do not know that they installed the CRS incorrectly and that there is a need for correction. It seems, if users have enough and clear information there is a good chances to reduce the rate of misuse considerably.

6. Conclusion

The comparison of the original CRS and the modified CRS shows that simple improvements can lead to a considerable reduction of misuse. Apparently there is a huge potential of improvements in the field of ease of use of child seats. Even if not all technical ideas may be applicable for serial production the results of the project show that there are many simple and useful possibilities to prevent misuse. This aspect should be considered by further developments of CRS. A number of studies in

the last years have pointed out, that the misuse of child seats is the main reason for injured and killed children in cars. Hence, it should be the most important aim not only to improve the safety potential of child seats, but also to reduce the risk of being misused.

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