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***Practice Test: Assessment of CRS Misuse by Experts of Child Safety***

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**Abstract**

The quality of use of Child Restraint Systems (CRS) is an important influencing factor in the area of child safety. According to several studies, misuse of CRS occurs in approx. 2/3 of all cases.

Within the CASPER project misuse field studies were conducted in different regions of Europe. Misuse field studies are also subject of several other projects. Initial analysis of the study results indicated that the perception of misuse by the investigator may influence the study results. In order to further analyse this hypothesis a laboratory study with child safety experts were conducted. The participants were asked to detect possible misuse and rate its severity for 11 installed CRS with dummies.

Although individual differences in the answers exist in most of the cases the majority of participants rated the individual situations in a comparable way and it was possible to back up the rating with misuse test results. Following that it is possible to give advice on how to rate the situations in the future. However, for some situations further research is needed.

## **1. Introduction**

Misuse of child restraint systems (CRS) is still an omnipresent and serious problem in connection of child safety in cars. Current field studies, which were conducted in the EU project CASPER show, that almost two thirds of all children are not secured in a car correctly [Johannsen, 2011]. That is a value which seems to be constant since the beginning of the first studies [Langwieder, 1997] until today.

For the analysis of the development of misuse during the last years and for the comparison of field studies from different places it is not only necessary to have a clear definition what misuse is but also of its severity.

While normally the identification of misuse is clear the definition of its severity level is blurred. Even if there is an agreement that different kinds of misuse may lead to different severe injuries, there is no clear definition how to assess different types of misuse. This can lead to the fact that the same misuse is rated differently by different experts.

For getting a better feeling of how misuse is assessed, experts of child safety were ask to rate several types of misuse. With the analysis of all this answers it might be possible to get a better definition of misuse severity. In general the objectives of this study are:

- to get overview of the opinion of child safety experts concerning the severity level of different misuse situations
- to develop a unified scheme for the assessment of misuse severity level based on the study results as well as misuse tests
- to assess the reproducibility of misuse studies

In this study it was not possible to assess all kinds of misuse. Emphasis was put on the most prevalent and momentous misuse situations.

This paper is divided into three parts. First the installed situations are described in the Chapter Test design. In the Chapter Results the ratings of the misuse types are presented and analysed. In the Discussion chapter the rating results are discussed and recommendation for the severity assessment in the future is given.

## **2. Test design**

During the 9<sup>th</sup> International Conference Protection of Children in Cars the participants were asked to take part in a study of assessment of quality of installation of CRS. In four cars eleven CRS were installed, all equipped with child dummies. All combinations of CRS and dummy were installed with a certain type of misuse (see description below) or correct. The participants were asked to detect the misuse but the main aim was to assess it. All installations were made in a reproducible way, for that it was made sure that everybody had the same securing situation.

For the assessment three different gradations were possible: slight, medium and critical. There was also the possibility to rate a seat as no misuse, if no misuse was detected.

### **2.1. The CRS installation situations**

In the following, the different types of installed misuse are described. Apart from the described misuse the installation of the CRS and the securing of the child were done in a correct way.

#### **2.1.1. Slack of vehicle belt**

Four different types of slack in the belt of the vehicle were installed, all in combination with the same CRS model for that the misuse was well comparable. In the first seat the car belt was tightened as much as possible, the CRS was firmly connected to the car. The second seat was installed in the car like required for sled tests according to ECE-R 44. The car belt was tightened with a force of 50 N, the slight slack was evenly distributed over the car belt. For the third seat some more belt slack than in the ECE-R44 was installed. It was possible to move the CRS a little bit in the car (mainly sidewise). The fourth seat was installed with much more belt slack than in the ECE-R 44. It was easily possible to move the seat a lot in the car, even a clear forward movement was possible (Figure 1).



**Figure 1: Slack in vehicle belt**

### **2.1.2. Slack in harness**

There were also four different types of slack in harness (belt system in a group 1 CRS) installed, and again all in the same CRS model. In all seats a Q3 dummy was seated. In the first seat the harness was tightened as much as possible, probably more than it could be realistic in real transportation situations. The harness in the second CRS was tightened as required for sled testing according to ECE-R 44. Between the back of the dummy and the backrest of the CRS was a 25 mm thick flexible spacer while the harness was tightened with a force of 250 N. After that the spacer was removed which caused a slight belt slack. In the third seat the harness was tightened in a way, that it was just not possible to move the harness over the shoulders of the dummy. In the fourth CRS the harness was adjusted in a way, that it was easily possible to move the harness straps of the Q3 shoulders.

### **2.1.3. Non use of top tether**

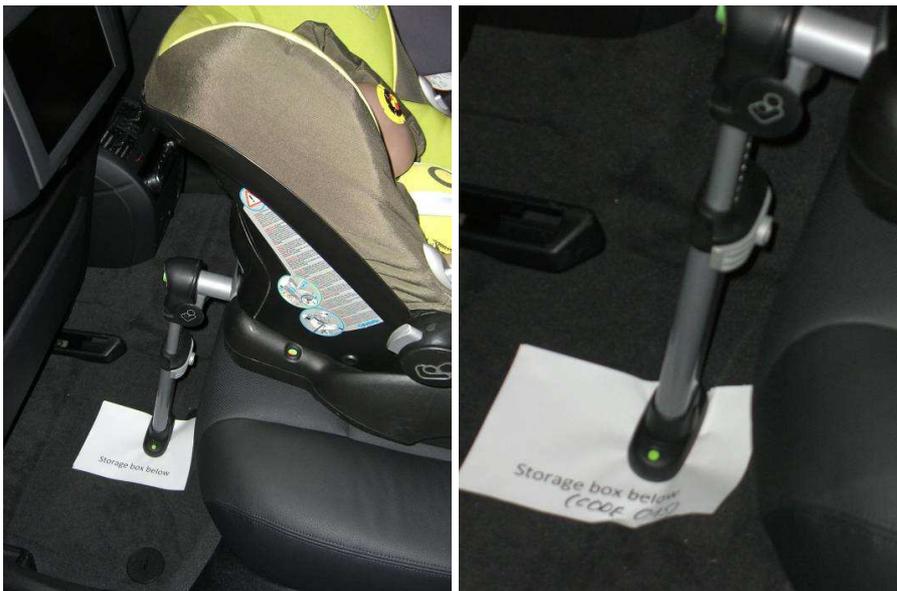
In this installation a universal forward facing group 1 CRS was secured via ISOFIX in the car. Although the CRS was equipped with a top tether and only homologated as universal CRS the TopTether was not in use. A Q 1.5 dummy was secured in the CRS correctly.



**Figure 2: Non use of top tether**

#### **2.1.4. Combination of support leg and storage box in the vehicle floor**

Goal of this installation was get an expert assessment of the combination of a support leg and a storage box in a vehicle floor. Because no vehicle with a storage box was available for this test, the box was simulated with a white sheet marked as “storage box below” on the vehicle floor.



**Figure 3: Simulated storage box**

### **2.1.5. Slight belt slack in combination with a baby shell**

In this installation a rearward facing CRS was installed with a slight slack of the vehicle belt. The baby shell could be moved on the vehicle bench, but only a little bit. The slack corresponds to the average belt slack which could be observed in the CASPER field study.

### **2.1.6. Use of both belt clamps in a group 1 CRS**

Here a group 1 CRS was installed in a car, while the car belt was guided through the belt clamps on the right and on the left side, see Figure 4. Apart from that the child seat was installed correctly and the car belt was very tight.



Figure 4: Installation with both belt clamps, view from driver's side

### **2.1.7. Interchange of car belt in a group 1 CRS**

This misuse is a very common one which was often seen in field studies. During the installation of the shell the lap belt and the shoulder belt are exchanged.

### **2.1.8. Installation of a basic CRS**

In this situation basic (low cost) group 1 CRS was installed on the front passenger seat. The child seat was installed without any misuse. Because of the sport shape of the car seat there were general fitting problems between car and CRS. Vehicle belt and harness were tightened as much as possible; a Q 1.5 dummy was in use.

### **2.1.9. Three year old child in a group 2/3 seat**

A three year old handling dummy was seated in a group 2/3 CRS. The headrest of the CRS was in the lowest possible position, the belt was guided correctly.



**Figure 5: Three year old child in a group 2/3 seat**

## **3. Results**

Before analysing the data some boundary conditions have to be considered. That study was designed in a way that for the assessment of misuse it was necessary that it was detected by the participants. Thus it is possible that the answer „no misuse” just means that the misuse was overlooked.

Additionally the assessment of misuse is strongly depended on the kind of crash or the direction of force, which is in mind of the experts. It might be possible that a certain kind of misuse is rated as slight severe, because the participant had a frontal collision in his mind, while someone else rates the same mistake as critical, thinking on a roll over accident. Both people may have the same understanding of misuse severity but rate it completely different.

Finally it has to be considered that the participants of this study have a different basis of knowledge. Some of them are experienced experts of misuse and were involved in

several field studies, while others are active in other fields like e.g., dummy development and have less experience in the use of CRS.

In the three days of the Conference and the preceding workshop 49 people took part in this study.

Below the assessment results of the single misuse cases are shown.

### 3.1. Slack of vehicle belt

The assessment of the vehicle belt slack corresponds with the four different types of slack. As less tight the belt is as more severe is this misuse assessed (Figure 6). The tight belt is rated from nearly 100% as no misuse; the belt which was tightened like described in the ECE-R 44 was rated from more than 60% as no misuse or slight misuse. On the other side nearly 40% assessed this installation as medium or critical misuse. The situation of "Some Slack" was rated from nearly two thirds as medium or critical misuse. The situation of "Much Slack" was rated from 61% as critical and from 16% as medium severe misuse. However 18% of the participants rated this installation as no misuse.

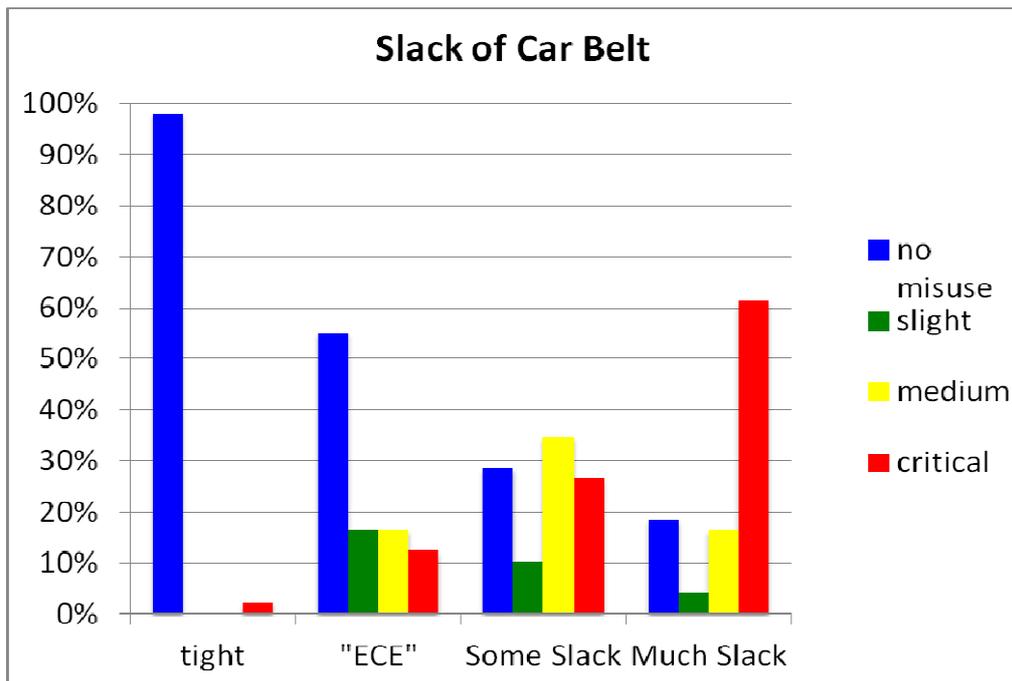


Figure 6: Slack of car belt

### 3.2. Slack in harness

The assessment of the harness slack does also correspond to the installed misuse (Figure 7). The very tight harness was rated in over 90% as no misuse, but it was also assessed by 6% (3 participants) as slight or medium misuse.

The "ECE-Slack" and the belt slack, where it was just not possible to move the belt over the shoulder, were rated quiet similar. 10% rated this misuse as critical, nearly 30% as medium misuse. The other 40% rated is as slight or no misuse, however there were more votes for no misuse in the category "Some Slack" than in the ECE group.

The group “much slack”, where the harness was adjusted that it could be moved easily over the shoulders, was rated as medium or critical misuse from more than 80%. On the other hand 14% of the participants assessed this installation as no misuse or slight misuse.

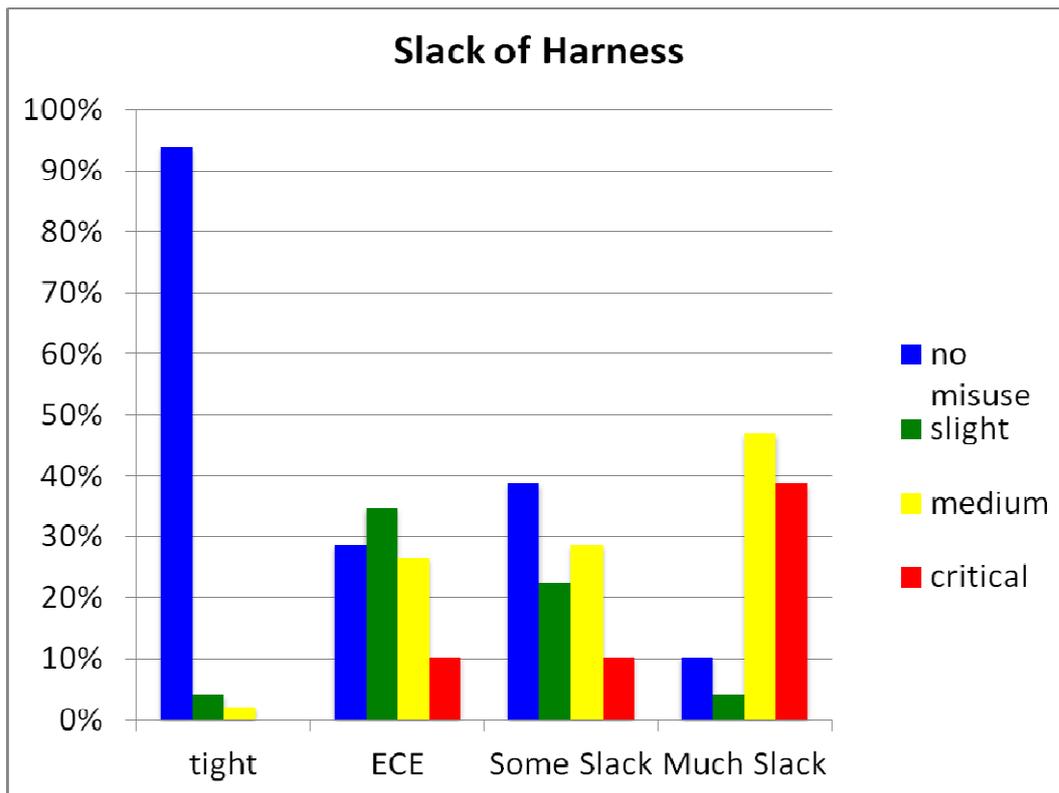


Figure 7: Slack of harness

### 3.3. Non use of top tether

For this installation again a huge range of assessments was given (Figure 8). Three quarters rated it as medium or critical misuse, while 26% assessed it as no or slight misuse.

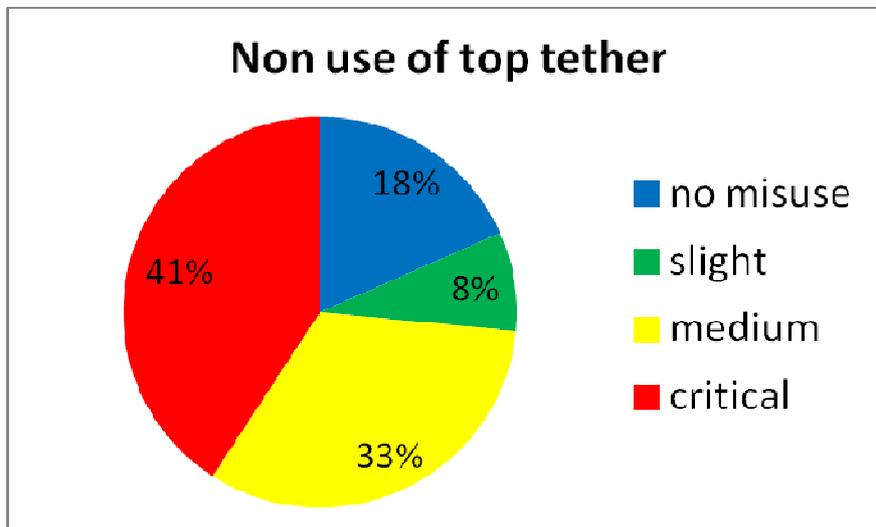


Figure 8: Non use of top tether

### 3.4. Combination of support leg and storage box in the vehicle floor

This misuse was assessed very differently. For 41% of the participants to the survey, a support leg on a storage box is no misuse, for 45% it is slight or medium misuse. 14% of the participants rated it as critical misuse (Figure 9). Some mentioned that their rating would depend on the kind of storage box. If it is a big one with a thin plastic cover it might be a critical misuse while it is no or only slight misuse if it is a smaller box with a stronger cover.

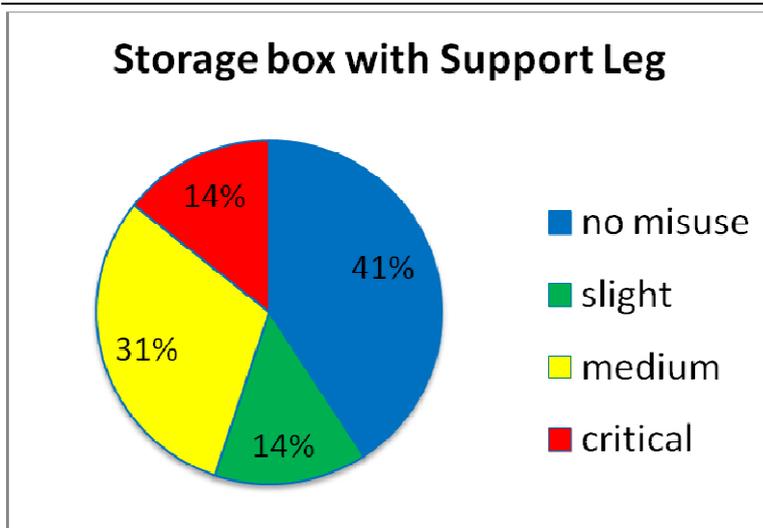


Figure 9: Storage box with support leg

### 3.5. Slight belt slack in combination with a baby shell

This misuse was rated by a clear majority as no misuse (61%). In contrast, 25% assessed it as medium or critical misuse (Figure 10).

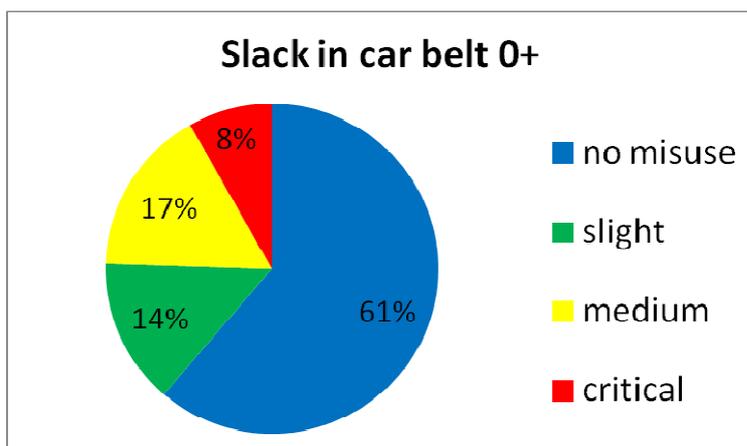


Figure 10: Slack in car belt 0+

### 3.6. Use of both belt clamps in a group 1 CRS

The assessment of this misuse was very varying again. 55% of the participants rated it as no misuse, however it is not clear whether they rated this misuse or whether they did not detected it. On the other hand 37% rated this mistake as medium or critical misuse (Figure 11).

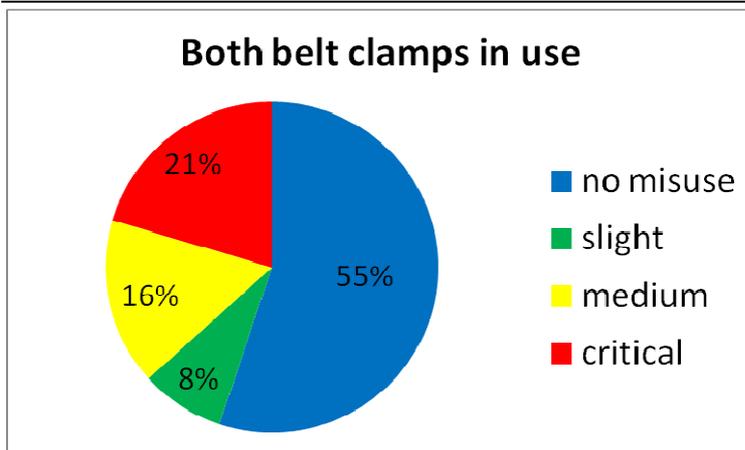


Figure 11: Both belt clamps in use

### 3.7. Interchange of car belt in a group 0+ CRS

For this misuse an interesting result was given. More than two thirds of the participants rated this misuse as critical, 2%, which was one person rated it as medium and no one as slight misuse. On the other hand 29% assessed this installation as "no misuse" (Figure 12).

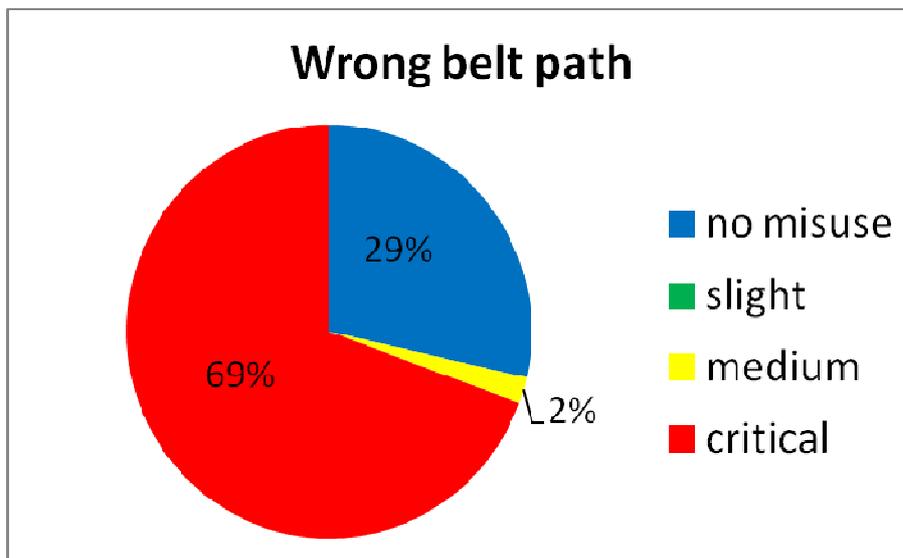


Figure 12: Wrong belt path

### 3.8. Installation of a basic CRS

The assessment of this installation was rather complex. Even if it was installed correctly according to the user's guide, a lot of mistakes were found (Figure 13). Only 20% assessed this installation with no misuse, more than 50% detected slack of the car belt which was rated as critical mostly.

Some participants selected "wrong installation position" in the misuse codebook. It is likely that these answers were given from French participants, because the installation of a forward facing CRS is prohibited in France. In contrast, it's allowed in most of the other European countries.

Other misuses which were mentioned were a wrong belt path, the twisted car belt and the twisted harness. The wrong installation direction was also mentioned as the seat was a convertible CRS that can be used forward or rearward facing according to the mass group. The child dummy installed in this CRS was representing a 18 month old child, so both group 0+ (rearward facing) and group 1 (forward facing) installations were acceptable, knowing that being transported rearward facing is recognized as best safety practice for children of that age,

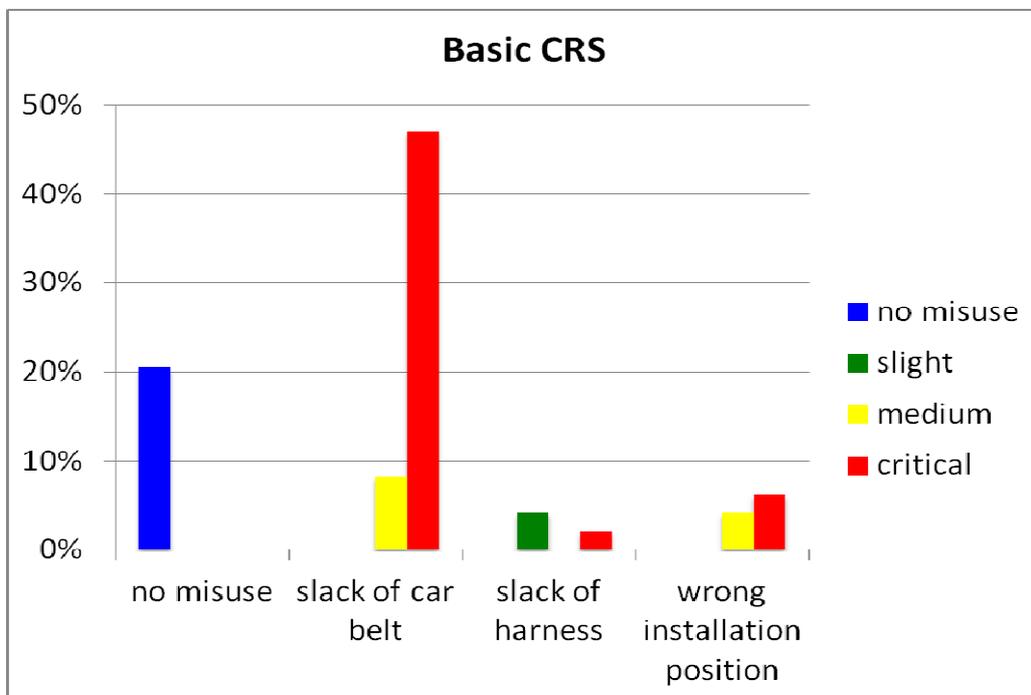
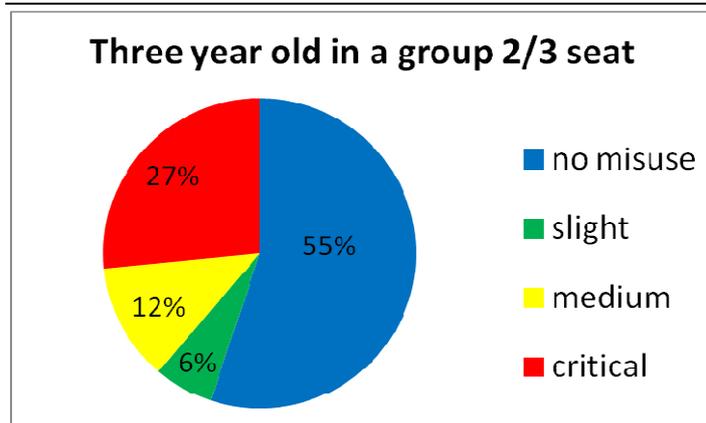


Figure 13: Installation of basic CRS

### 3.9. Three year old child in a group 2/3 seat

In this situation the assessment of the misuse was quiet different. While more of 50% considered the three year old child in the group 2/3 seat as no misuse, 27% rated it as a critical mistake. Obviously in this situation there is no clear answer to the question whether a child is too small or not (Figure 14).



**Figure 14: Three year old child in a group 2/3 seat**

#### **4. Discussion**

The misuse assessment has shown for nearly all installations a wide spread of rating. In some cases this might be due to an uncertainty of the severity of the misuse in other cases it might be possible, that the misuse was not detected. This effect was not controlled in this study.

Another possible effect which has influenced the assessment of the study may be a different level of knowledge of the participants. It might be possible, that some had experience in certain misuse constellations, for example in the use of a support leg on a storage box, while other participants saw this problem for the first time, nevertheless, most of the participants were supposed to have a sufficient knowledge to conduct a field misuse survey.

In addition one problem in the severity rating caused by the design of the experience appeared during the trials. The participants were asked to rate the severity level as “s” for slight, “m” for medium and “c” for critical. There is a risk that some of the participants anticipated the meaning severe for “s”; at least few participants commented that they realised during the trial this mistake. However, in general the results are consistent (e.g., for chapter 3.8) so it is believed that this problem did not occur often.

It might also be possible, that two types of misuse in one installation had an influence on the assessment. While there was one very critical misuse it could happen, that the other one was not realised or rated better than it would be rated if it is a single misuse.

#### **4.1. Slack of vehicle belt**

It is well known that any slack in the three-point belt and the harness system increases the forward movement of the occupant and increases the risk for contact injuries. The expert advice for tightening the three-point belt for the installation of CRS is to tighten as much as possible, i.e., when trying to move the CRS in lateral direction the CRS should not move in the car but the car should move. The installation “tight” corresponded to this advice. Except one participant all agreed that this installation is no misuse.

For the ECE like installation the situation is different. This installation is defined to be safe by regulation. That means that the CRS are designed to offer acceptable protection with this belt slack. However, it is less safe than the installation according to the consumer advice. Nevertheless more than 40% of the participants rated this installation as misuse (approx. 15% each for slight and medium misuse severity level and even 10% as severe misuse). However, more than 50% of the participants rated the situation as “no misuse”. This result underlines the difficulty for parents to know what tension is the correct one on the car seatbelt. All together it is reasonable to consider this situation as a borderline between no misuse and slight misuse but being just at the “no misuse” side.

The installation with “some slack” is less safe than the advice and even less safe than the ECE R44 definition. However, almost 30% of the participants rated the situation as no misuse. Approx. 10% assessed slight misuse while approx. 35% recognised medium misuse severity. For almost 30% the situation already accounted for critical misuse. It seems that this situation can be considered as the boarder line between slight and medium misuse severity.

For the “much slack” situation the situation is clearer. As 60% of the participants rated the installation as critical misuse severity it can be considered as critical.

#### **4.2. Slack in harness**

For the tight installation of the harness nearly all participants agree, that this is no misuse. The ECE and “some slack” installation were rated quite similar, which corresponds to results obtained for the assessment of the belt slack (see previous paragraph), where the difference was also quite small. However it was not expected, that this set up is assessed as no or slight misuse from more than 60%. Several

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misuse tests in the CASPER and CHILD project have shown, that slack in the harness increases the forward movement which makes head injuries more likely. Also other measured values at the dummy increased which corresponds to a decrease of protection for the child (or a higher risk of being injured). The installation according to ECE describes a situation for which the CRS should offer an acceptable protection level. However experts recommend to tight the harness in a way that between harness and child there is space for a flat hand or even only two fingers of a flat hand.

According to the rating of this study the ECE and some slack installation has to be considered as no or slight misuse. The much slack installation was rated by a clear majority at least as medium misuse. The risk in this configuration is that the shoulders of the child may escape from the harness, and that the upper part of the body is projected and sustained an impact with the vehicle interior. So this misuse seems to be clearly more severe than “some slack” but there is not clear tendency whether it is medium or critical misuse. For a final conclusion it seems to be necessary to backup the assessment of this study with testing results.

### **4.3. Non use of Top Tether**

The use of TopTether is mandatory for universal ISOFIX CRS. Nevertheless 18% of the participants rated this situation as “no misuse”. It is likely that the non use of the TopTether was not recognised by these participants. However, in principle there exists the possibility to homologate ISOFIX CRS without TopTether and support leg as vehicle specific (as being the case for Britax Duo for a large number of cars). It might be that participants had in mind this possibility when not rating the installed misuse. But the CRS used for this installation is only homologated as universal and ISOFIX universal. In addition there is a label at the top of the CRS that clearly indicates the need of the TopTether.

The remaining participants rated the non use of the TopTether as slight severity (8%), medium severity (33%) and critical severity (41%). That means that the estimation of severity is equally shared between critical on the one hand and medium or slight severity level on the other hand.

From test experience it is known that the harm resulting from not using the TopTether is strongly depending on the position of the ISOFIX anchorages in the car and the

“rigidity” of the seat cushion in the car. Expressed in additional head excursion it ranges from slight to critical.

Summing up it seems necessary to further discuss the rating of the severity level of this misuse mode. In principle three possibilities exist:

- Taking into account worst case and to rate it independent of the car environment as critical
- Taking into account most likely conditions and to rate it independent of the car environment as medium
- Taking into account the car environment after additional analysis of influencing factors

#### **4.4. Combination of support leg and storage box in the vehicle floor**

Especially in MPVs floor storage boxes located at the feet of rear are more and more common. In the mean time CRS with a support leg are also becoming popular. In this context some years ago car manufacturers offering floor storage boxes started to test the integrity of the storage box cover. These tests showed relevant issues resulting in the risk of increased head excursion and dummy readings for CRS with a support leg located on a floor storage box. Most of the car manufacturers reacted with one or more of the following measures:

- Increased stability of the storage box cover
- Offering filling material for the storage box if a CRS shall be used
- Requiring to fit the support leg on the floor of the storage box in the car owners manual
- Not allowing any ISOFIX CRS with support leg in combination with storage box
- Not allowing any CRS with support leg in combination with the storage box

Approx. 40% of the participants rated the situation as no misuse. As the storage box was clearly marked and even the misuse code was written on the simulated storage box cover it is unlikely that the situation was overlooked by these participants.

This result clearly underlines that non-expert people (parents for example) would not see any problem in using a support leg in combination with a storage box.

It is likely that missing information regarding the storage box and the car manufacturer's advice strongly influenced the assessment of misuse severity. In addition it might be that not all participants heard about the possible problem before.

For more than 30% the use of a support leg on top of a storage box was rated as medium severity while approx. 15% rated the severity level as slight or critical, respectively.

In principle every CRS using a support leg is homologated as semi-universal or vehicle specific, no universal homologation is possible. That means that the CRS manufacturer provides a vehicle lists with cars the CRS can be fitted in. If the car is mentioned in the semi-universal vehicle list, there should not be a problem with the storage box, unless the CRS manufacturer overlooked the situation when creating the vehicle list. That means that for field studies it can be assumed that there is no misuse, if the car is mentioned in CRS vehicle list. If it is not, then it is illegal to use the CRS anyway. This situation should then be rated as medium or critical misuse. Further analysis of support leg – storage box interaction is necessary to be more precise. However, it needs to be mentioned that a new requirement for the vehicle floor is in discussion to avoid this problem in the future.

#### **4.5. Slight belt slack in combination with a baby shell**

This misuse was rated by a large majority as no misuse. Actually there was only a slight belt slack and it cannot be excluded, that for some participants the slack was absorbed by the retractor. However the slack was adjusted in a way, that it would have a negative effect in case of a frontal collision. When assessing the results, the question arises whether the slack was overseen and rated as no misuse accordingly or whether it was consciously assessed in this way. Those, who assessed it as misuse had no uniform opinion about its severity. A clear answer of the question how do experts rate this misuse is independent form the no misuse answers not possible.

#### **4.6. Use of both belt clamps in a group 1 CRS**

For the fixation of the CRS the outboard belt clamp shall be used. The status of the inboard belt clamp is more difficult to assess, especially because the installation took place in a mini bus. Possibly, it was difficult to detect this misuse. It is unknown how many of the 55% who rated the installation as no misuse did not detect this mistake.

Additionally it has to be mentioned, that this misuse is not a very common one. There are only a few cases of this misuse in the field studies. Other participants mentioned, that they detect this misuse but they feel not able to rate its severity. Because of the fact, that this misuse occurs quite seldom, there is no experience in this misuse known. One can speculate what are possible consequences in cases of an accident. If one of the both clamps brakes it could lead to a lot of belt slack, which would cause an additional forward movement of the CRS and thus the head. In a misuse test which was conducted in the CHILD project no negative effect was observed.

#### **4.7. Interchange of car belt in a group 0+ CRS**

This misuse is a very common one, about 50% of the users of baby shells use the car belt in a wrong way. The result of this misuse is, that the child seat is nearly not secured in the car and can ejected in case of a frontal crash (Figure 15) Tests of this misuse in the CHILD project showed the same results.



**Figure 15: comparison of correctly installed babyshell (top) and installation with wrong belt path (bottom)**

This could lead to serious injuries of the child. The danger of this misuse is well known. Following that it is hard to imagine, that the interchange of the belt path in a baby shell is rated as no misuse if it is detected. It seems to be very likely, that those who rated it as “no misuse” did overlook this failure. This is also an unsatisfactory result because the combination of the frequency of this misuse and its potential risks

makes it to one of the most important problems which have to be solved in connection with the misuse of child seats.

All of the participants who detected this installation mistake agreed that this is a critical one.

#### **4.8. Installation of a basic CRS**

For this installation a clear assessment could not be expected. From a legal perspective this seat was installed correctly. However, only 20% rated it as no misuse. More than 50% rated the slack of the car belt as medium or critical misuse. Actually the CRS was installed without any belt slack. If slack is checked by pulling the CRS in a forward direction, the retractor will enable a lot of belt slack which would not happen in case of an accident, where the retractor blocks the belt. Possibly it is additionally fastened by an automatic belt tensioner. It is unknown, whether or not this functionality was considered by the participants.

This results shows that the current regulation is not sufficient to ensure that a good designed CRS has a good compatibility in a recent car fleet.

It is important to note that the CRS used in the study did not perform particular bad in sled tests when installed correctly. However, when the CRS was observed in the field (misuse field studies and accident analysis) it was not used correctly in almost all cases.

#### **4.9. Three year old child in a group 2/3 seat**

In this installation there is obviously the question of whether this is misuse. From the legal point of view the only important information is, whether or not the child has a weight of at least 15 kg. If so, than the child is allowed to sit in a group 2/3 CRS. There was no information about the child weight available for the participants. However, from estimation based on stature there was no indication that it was less than 15 kg.

From the safety point of view it seems obvious, that the child is a little bit too small for this CRS, it would be better seated in a group 1 seat. The assessment of this misuse in this study is quite different, after all 27% rated it as a critical misuse.

In the end there is the question: What is misuse? If it is the use of a child seat in a way the CRS is not designed for, this installation is (depending on the weight of the

child) probably no misuse. If misuse is defined as the not optimal use of a CRS, than this installation seems to be misuse, according to the rating of the participants.

## **5. Conclusion**

The results of this study have shown that the assessment of misuse differs strongly. For having comparable field studies it seems necessary to define clear parameters for the assessment of misuse severity. All subjective influences should be excluded as much as possible.

In addition investigators need to be very well prepared in order to detect possible misuse modes. Several clear misuse situations were not recognised by all participants (e.g., interchanged car belts for a baby shell). This is especially true because the assessment of misuse is much easier in a laboratory situation as in the study presented here than in the field with real children and parents that a short in time. Furthermore parents expect that nothing is wrong when the investigator did not detect anything, which could be dangerous.

Finally the results of the study indicate that a check of all situation with the participant after completing of the form is beneficial to better understand the rating (e.g., whether or not a special situation was overlooked or rated as correct use on purpose).

## **6. Acknowledgements**

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## **7. References**

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