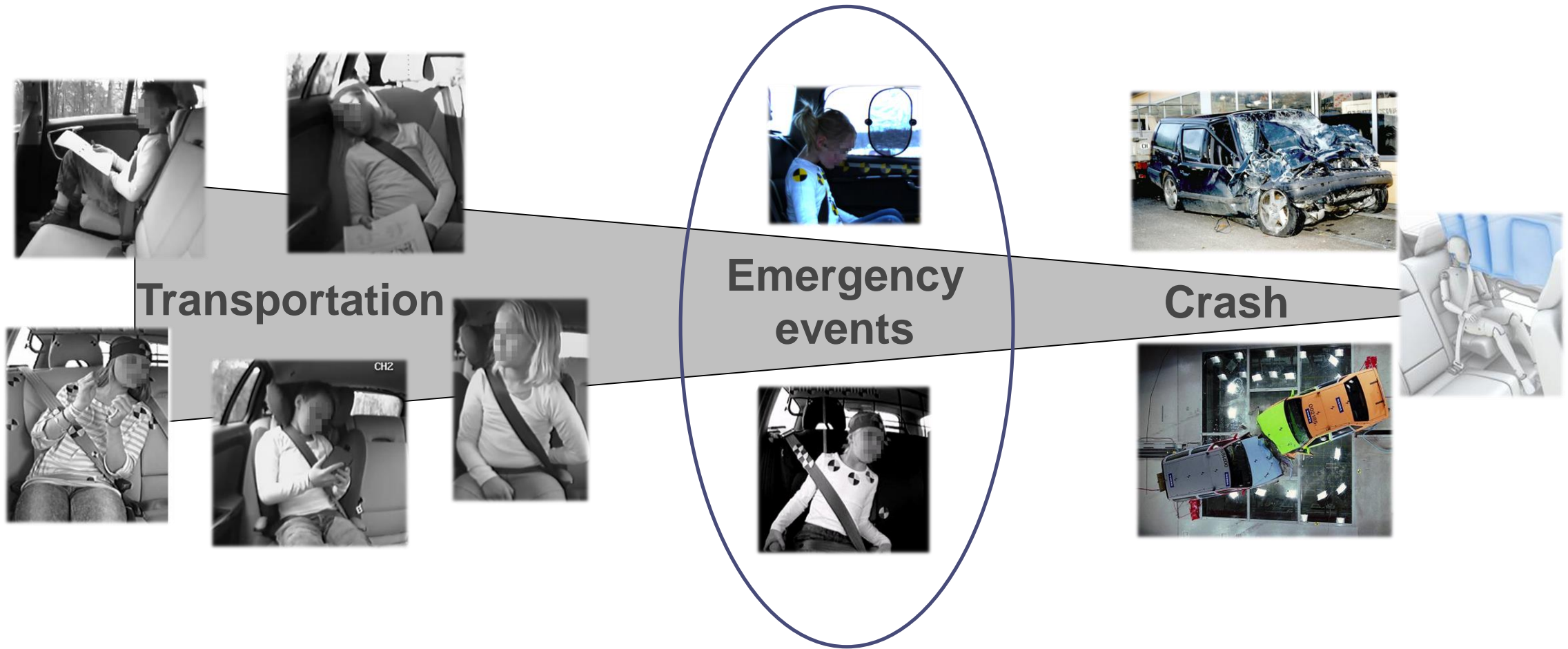
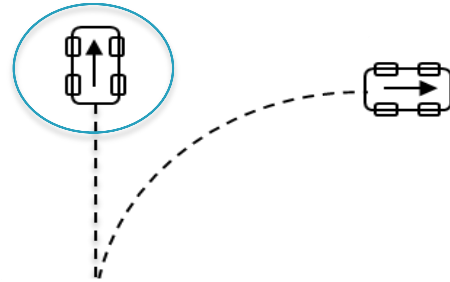


Children's kinematics in evasive events and countermeasures

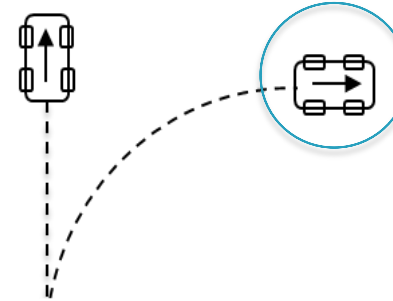


Braking Maneuvers



70 km/h to full stop
Deceleration 1 g

Steering Maneuvers

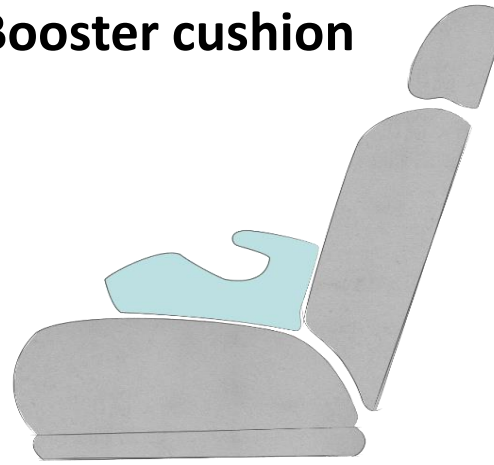


50 km/h right turn

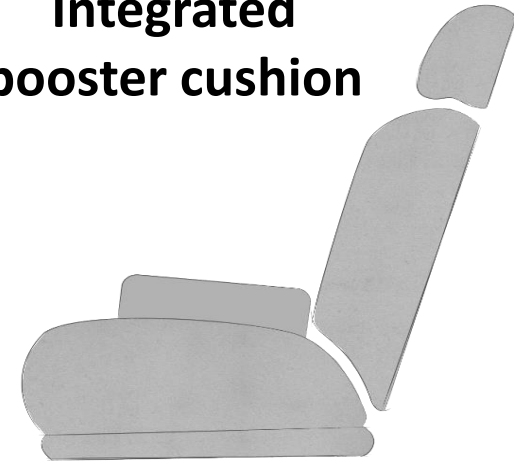
High back booster



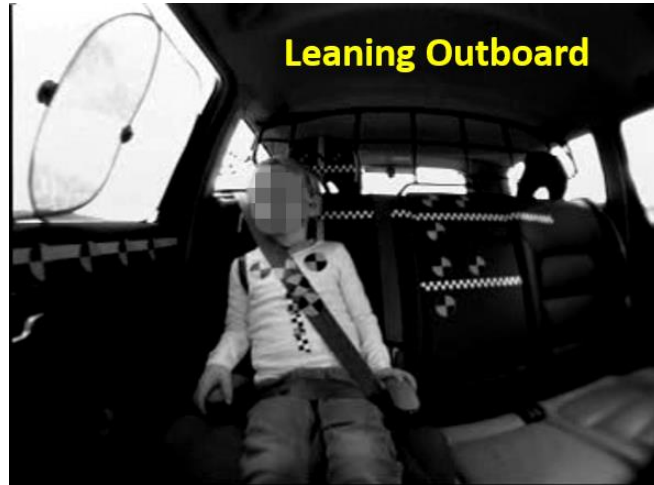
Booster cushion



Integrated booster cushion



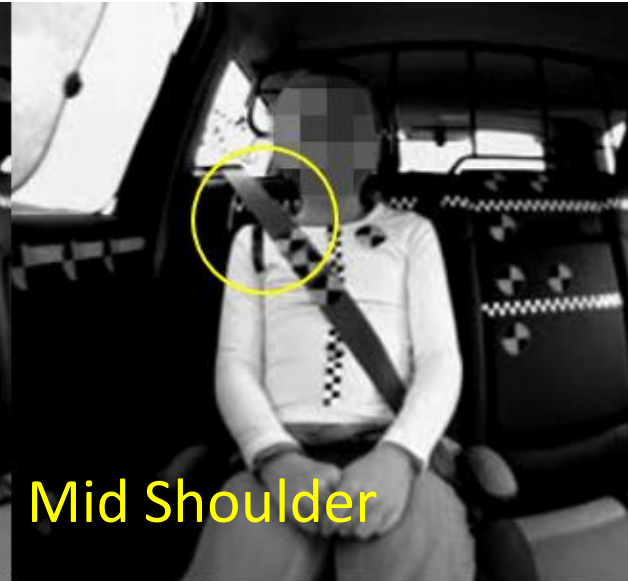
Initial Sitting Position



Initial Seatbelt Fit



Close to Neck



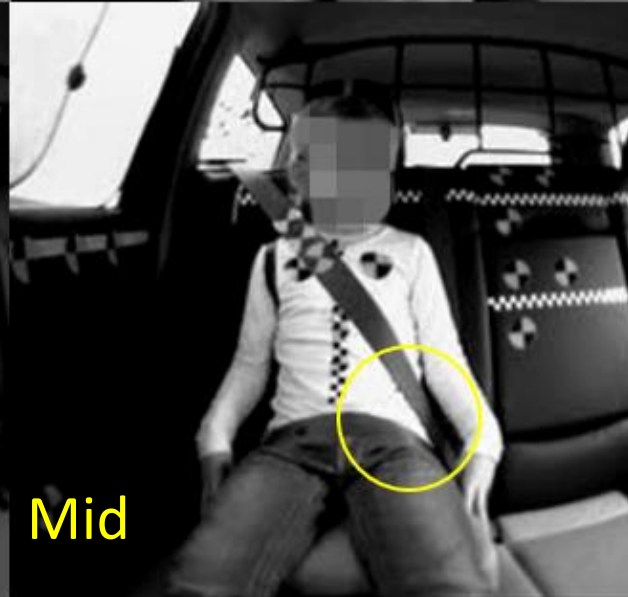
Mid Shoulder



Far Out



Low

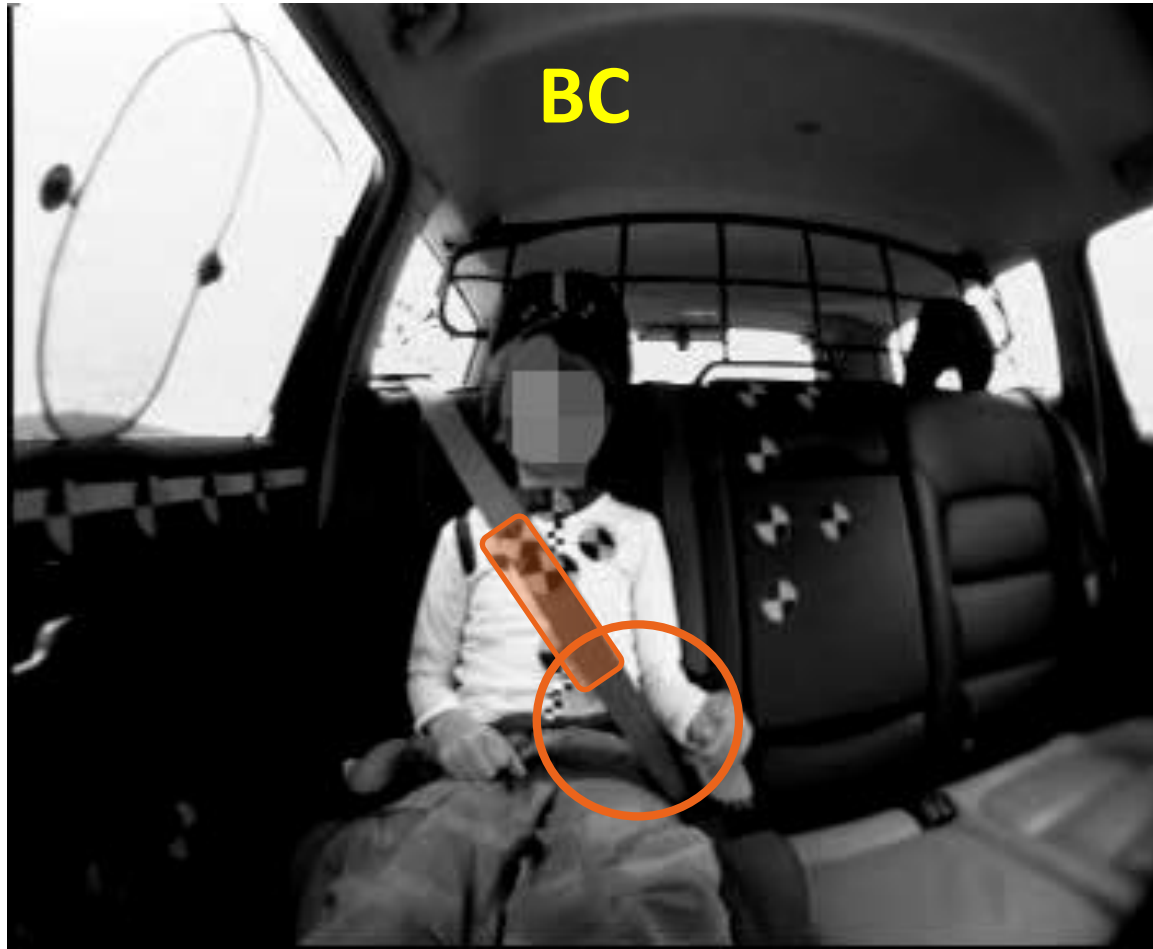


Mid



High

Shoulder Belt Contact with Torso



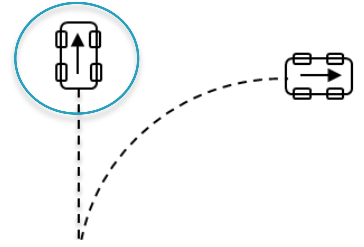
Shorter Child

Shoulder Belt Contact with Torso



Taller Child

Emergency Braking



Shorter Child

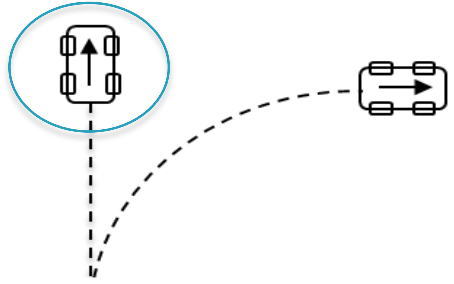


Taller Child



Playback speed 0.5*normal speed

Braking Maneuvers



**Shorter
BC**



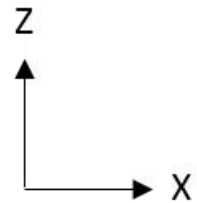
**Shorter
IBC**

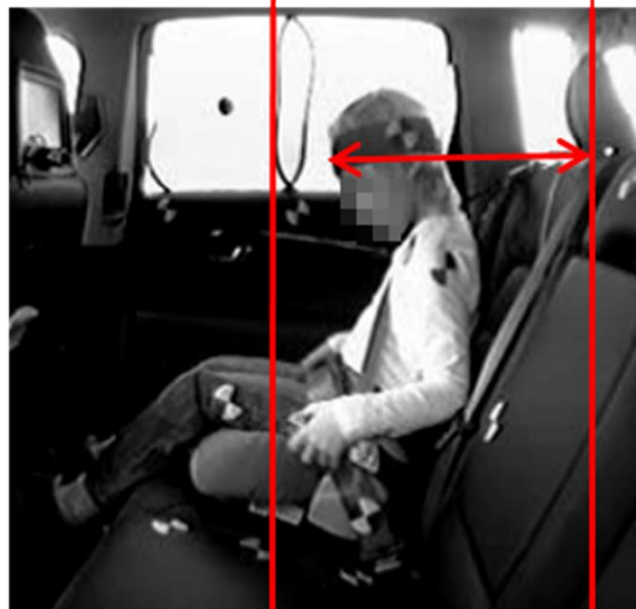
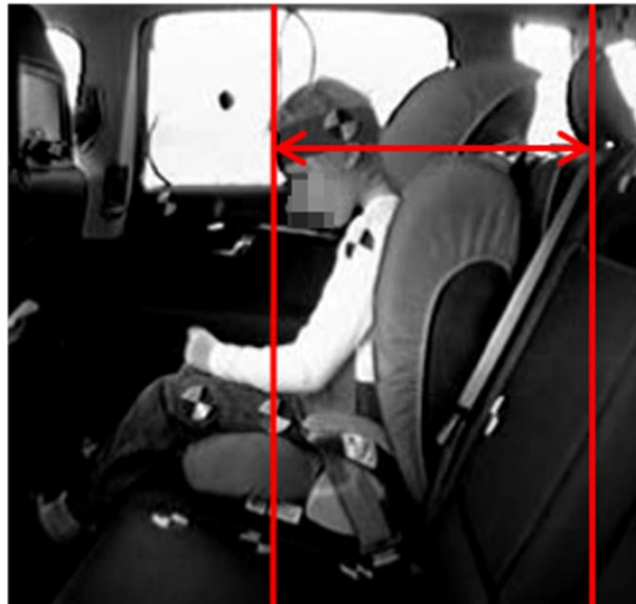
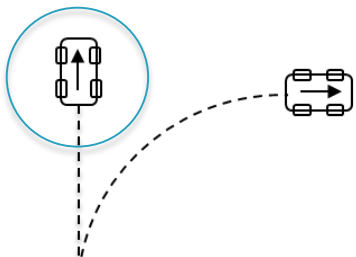


**Taller
BC**

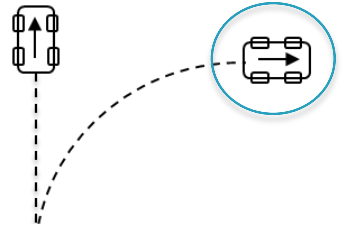


**Taller
IBC**





Evasive Steering



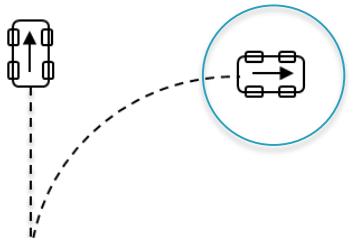
Shorter Child



Taller Child

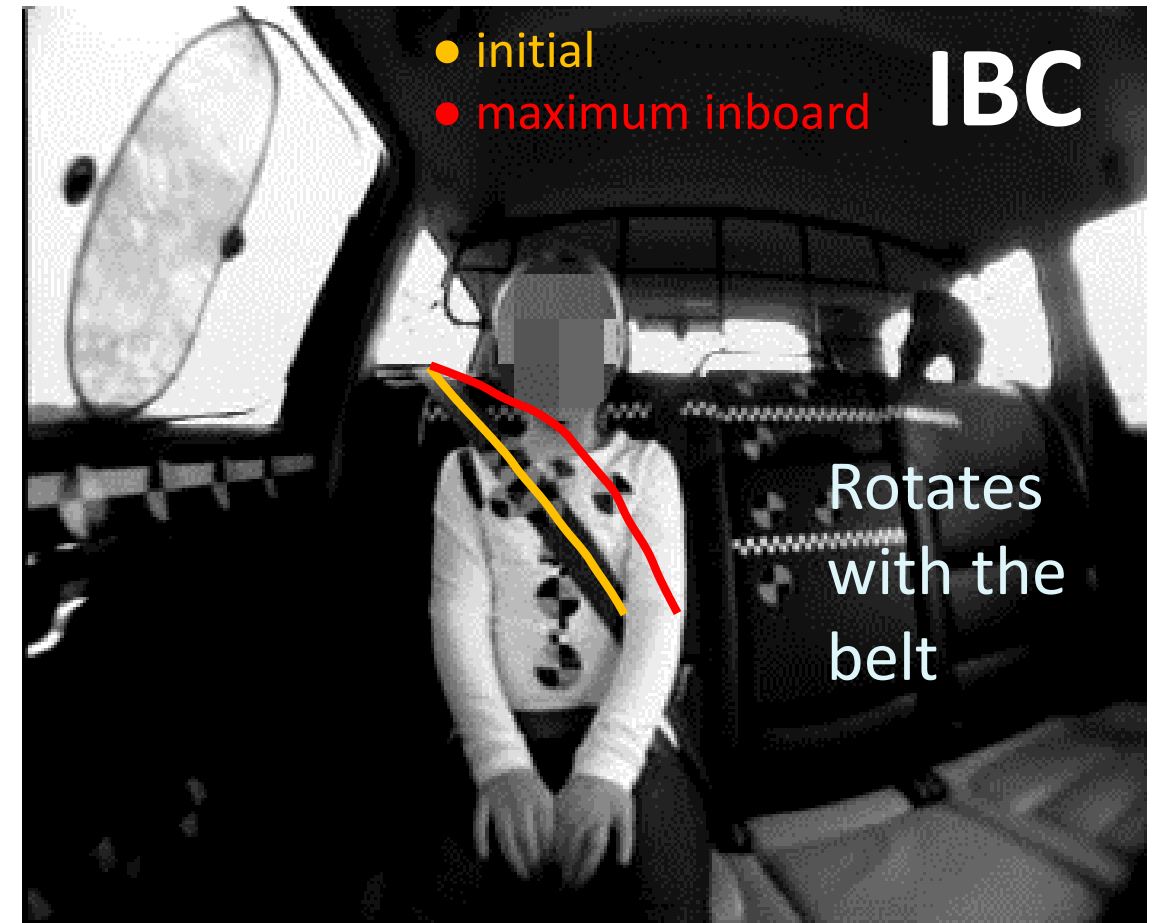
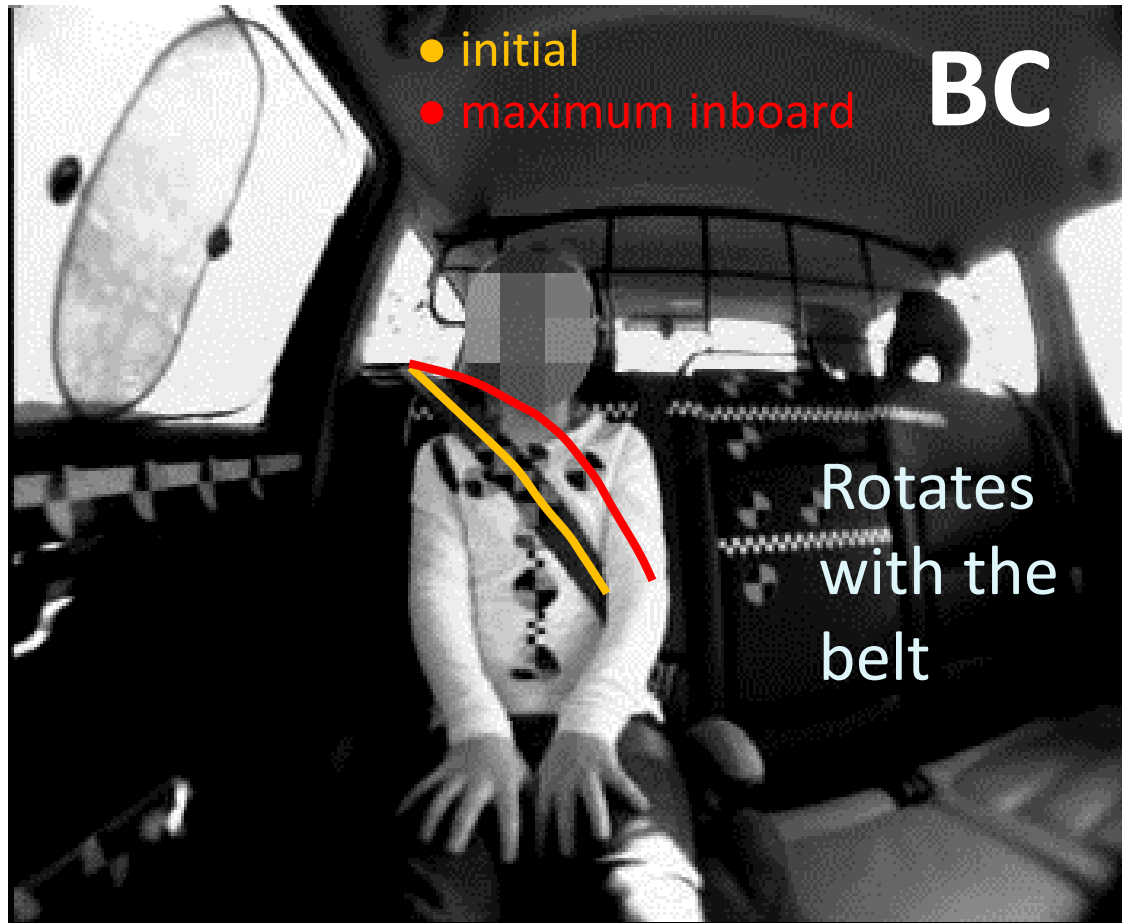


Shoulder belt position



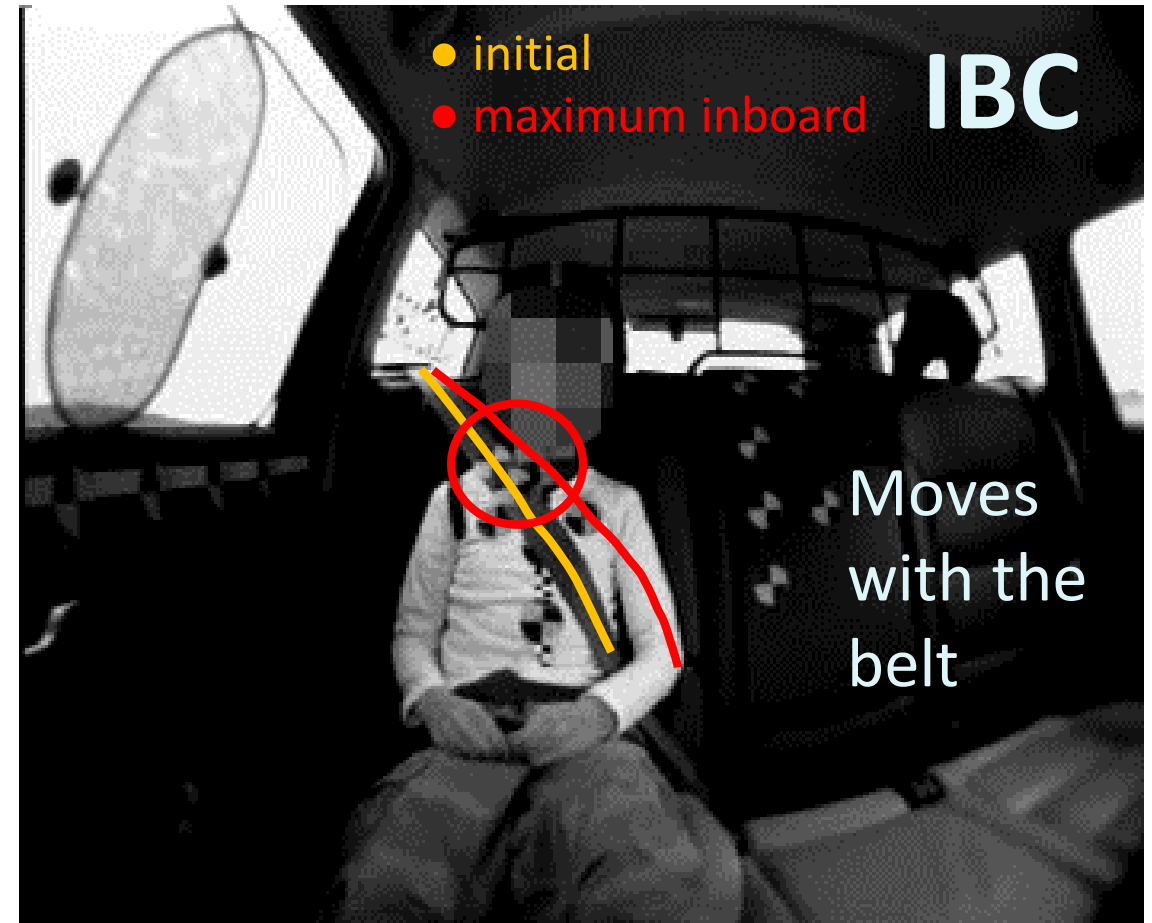
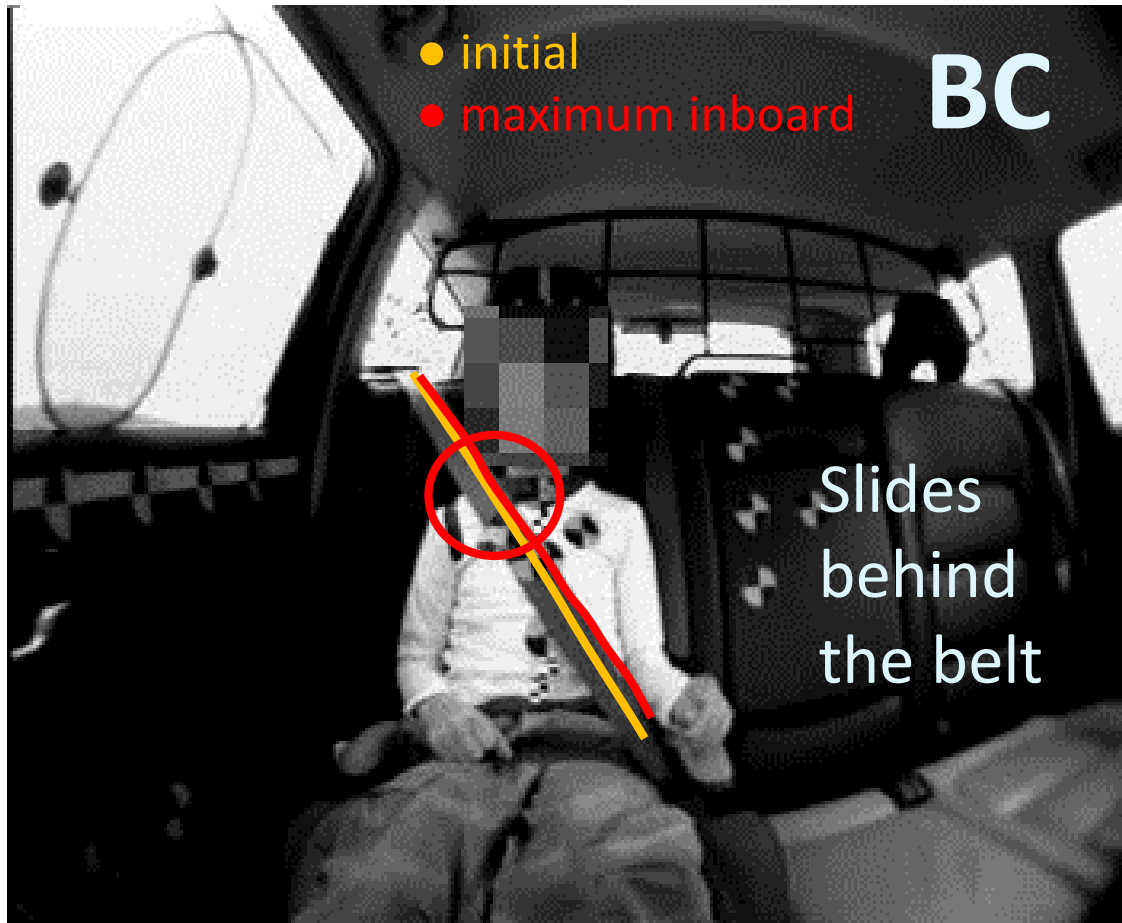
Shoulder Belt Engagement

Taller Child

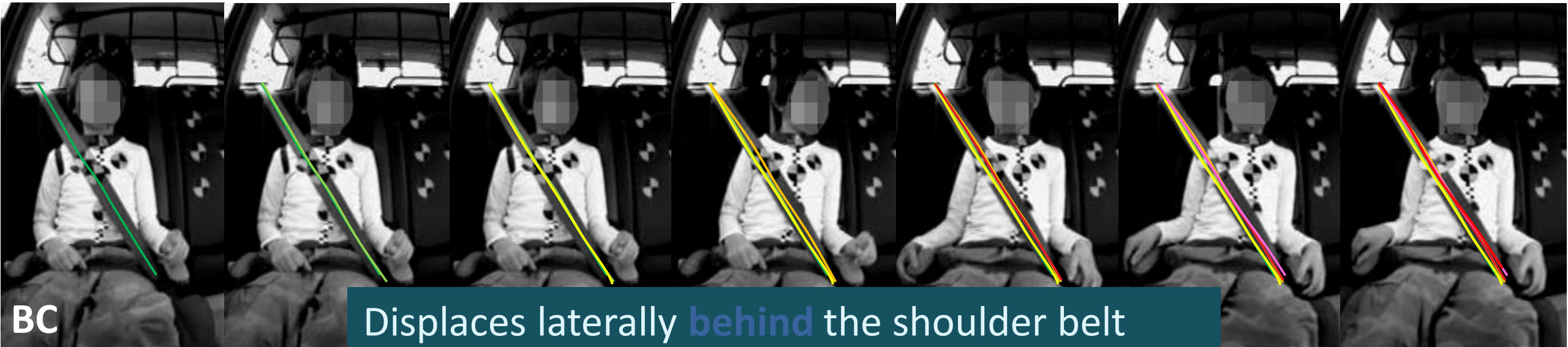


Shoulder Belt Engagement

Shorter Child



Two types of Shoulder Belt Engagement



0.00 s

1.00 s

2.00 s

3.00 s

4.00 s

5.00 s

6.00 s

Implications for Child Safety

Evasive maneuvers → forward and inboard positions closer to vehicle surfaces

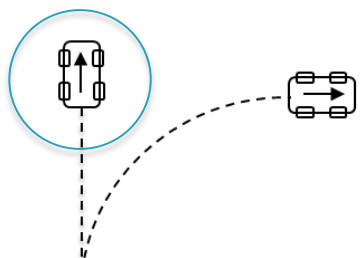
- Impact in the case of a subsequent crash
- Possibility increasing the likelihood of sustaining (head) injuries

Evasive maneuvers → shoulder belt far out or slipped-off

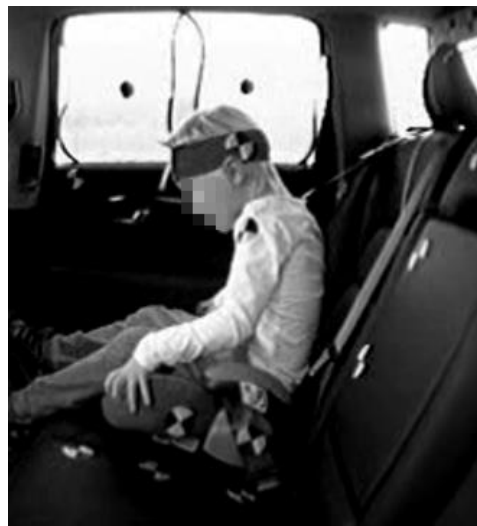
- Not engaging with the shoulder belt during maneuvers (prior to crash)
- Potential unstable conditions in case of subsequent crash

Initial seatbelt engagement → motion types, displacement, final restraint scenarios

- Booster design and anthropometry (seated height, chest depth, etc.)
- Pre-maneuver voluntary motions → shifted and/or tilted postures, grabbing, leaning forward, or supporting with the feet

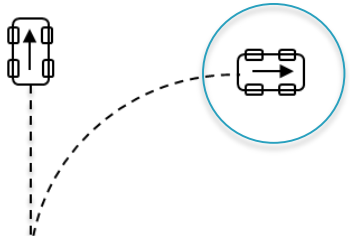


Children



Crash test dummies





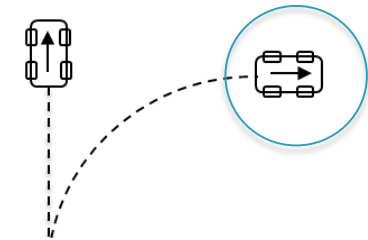
Dummies limited due to rigid spine

Unstable results when out of the restraint zone

Loading device when inside the restraint zone

Countermeasure – pre-pretensioner

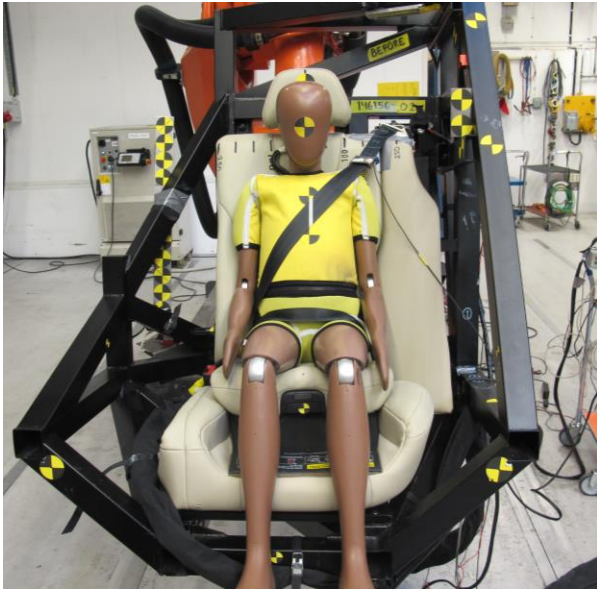
- Method 1 – Rig test
- Method 2 – In-vehicle test
- Method 3 – Steering maneuver with passenger car



Method 1 – Rig test

Rear seat (Volvo XC60) mounted on a multi-axial robot.

- Q6 and Q10 using integrated booster.
- HIII 5%-ile female direct on seat.
- 2 different pre-pretensioner force levels + inactivated.



Recreating a vehicle drifting into a ditch.



Method 2 – In vehicle test

Volvo XC60 with robot driving device.

- Q6 and Q10 using integrated booster.
- HIII 5%-ile female direct on seat.
- 2 different pre-pretensioner force levels + inactivated.



Driving in the ditch and driving up from the ditch.



Method 3 – Steering maneuver with passenger car

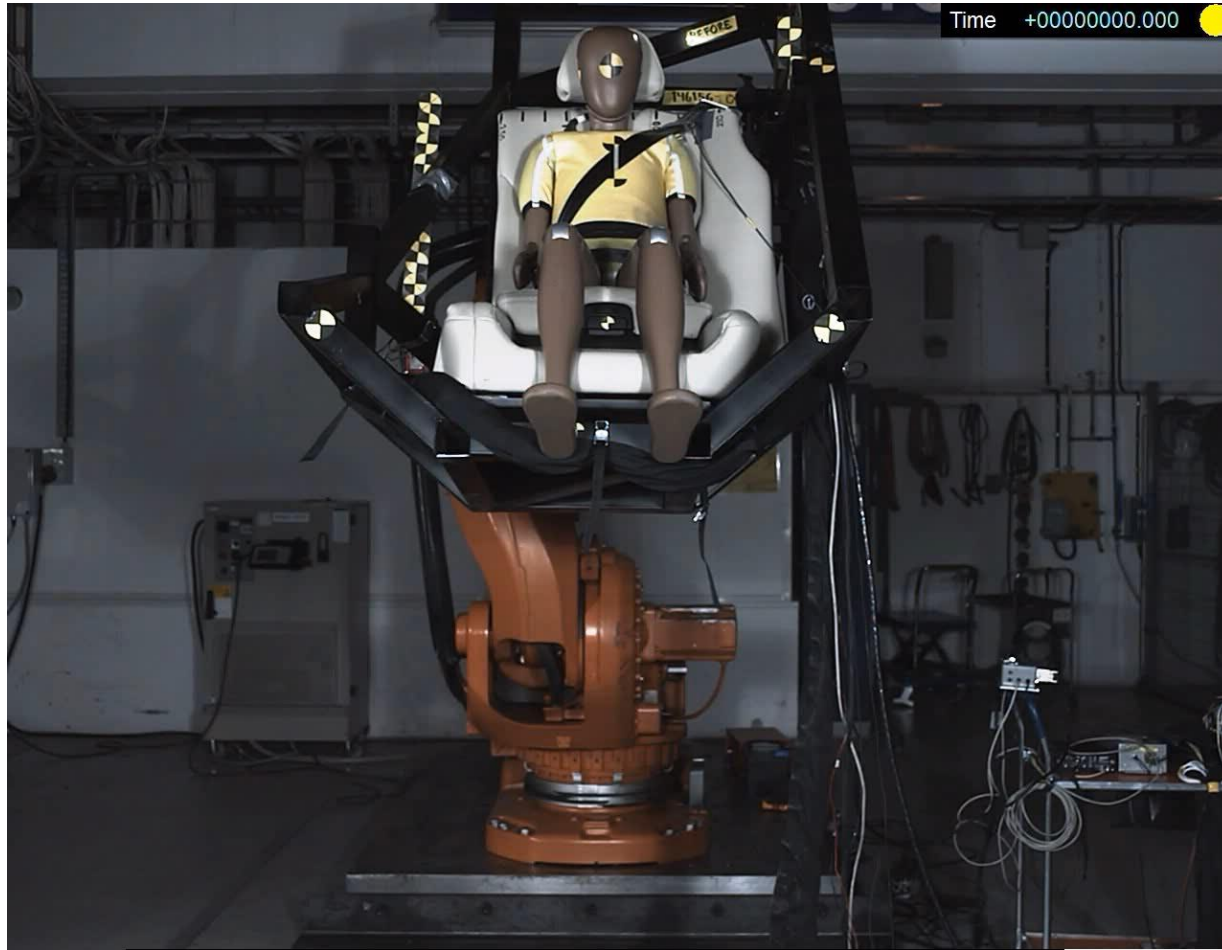
Volvo XC60 with robot driving device.

- Q6 and Q10 using integrated booster.
- HIII 5%-ile female direct on seat.
- 2 different pre-pretensioner force levels + inactivated.

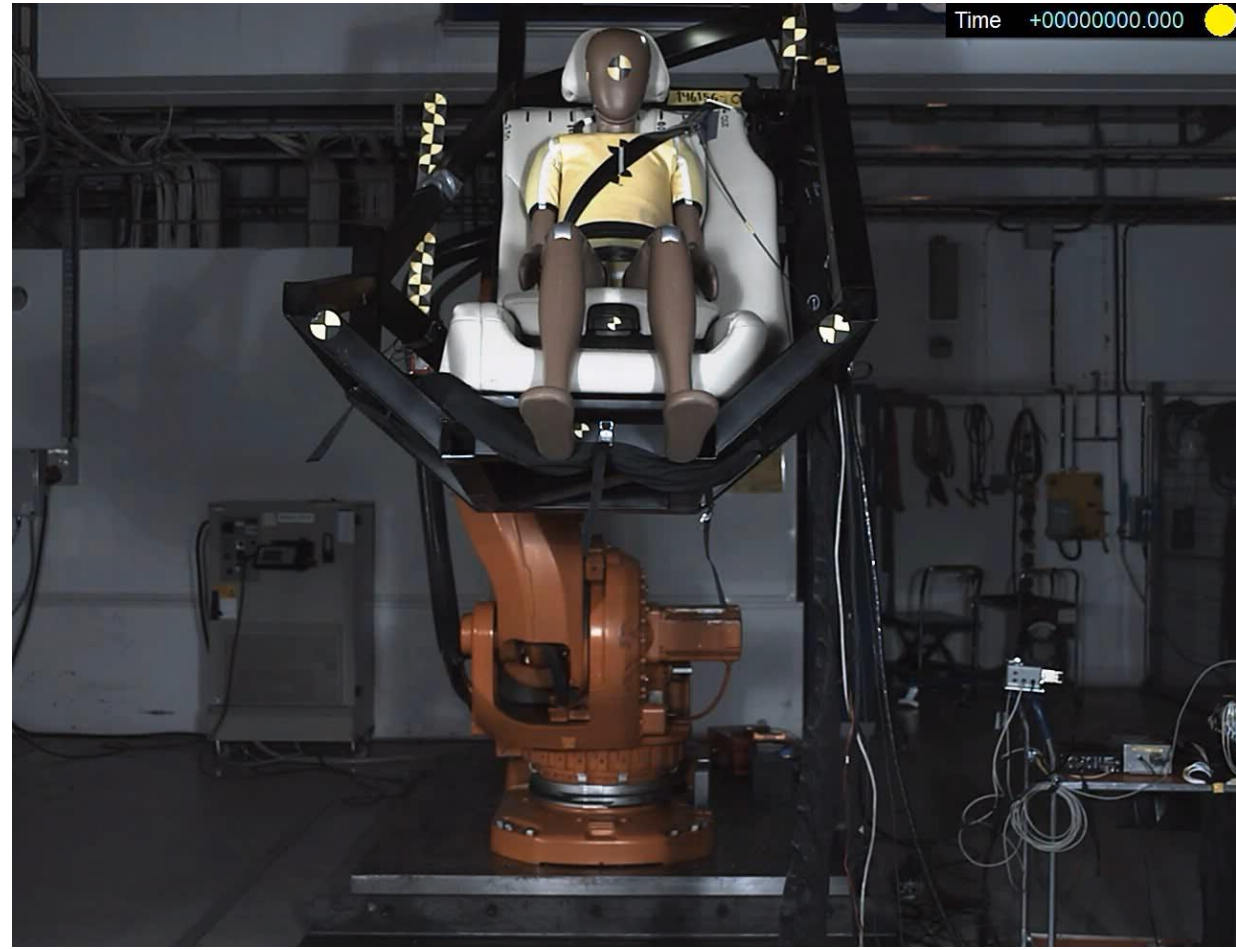
40 km/h – left turns, lateral acceleration of 0.8g

Rig test

No pre-pretensioner



Pre-pretensioner



Results - Rig test

- Restricts lateral motion
- Shoulder belt stays on shoulder



Results – In vehicle test



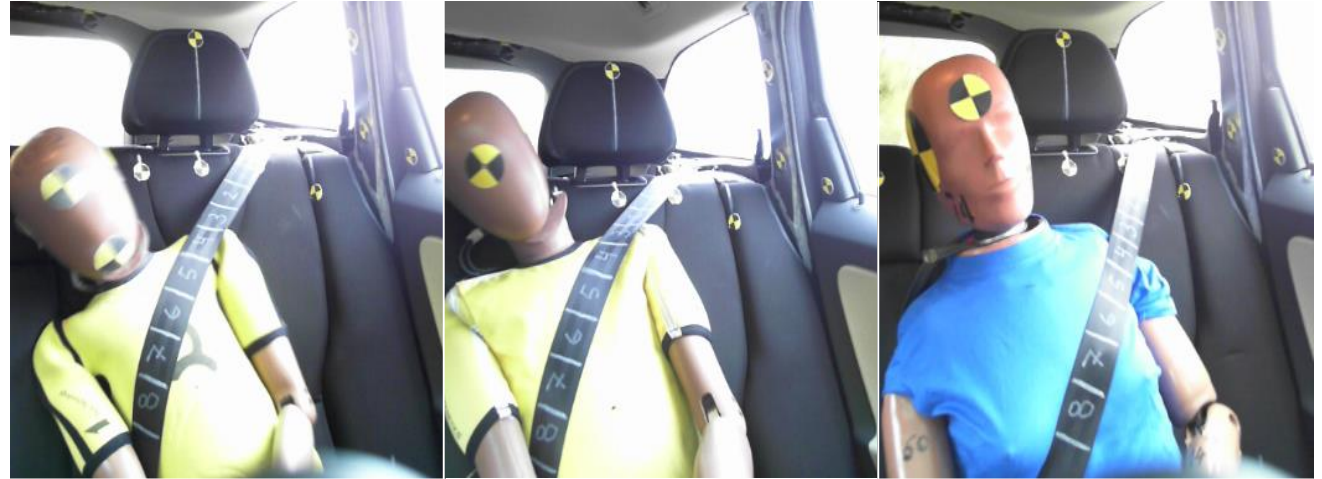
No pre-pretensioner



Pre-pretensioner

Results – In vehicle test

No pre-pretensioner



Pre-pretensioner



Results – Steering maneuver with passenger car

No pre-pretensioner



Pre-pretensioner



Child kinematics

- a braking event places the child's head in a forward position
- a steering event places the shoulder belt far out on the shoulder or completely off

Kinematic response of crash test dummies

- capable as a loading device in the restraint zone
- limited in capturing realistic child response

Pre-pretensioner

- help restrict lateral motion
- help shoulder belt to stay on shoulder

Ensure that the upper torso remains restrained
despite a preceding emergency event

References

Baker G, Stockman I, Bohman K, Jakobsson L, Svensson M, Osvalder A-L, Wimmerstedt M. **Kinematics and shoulder belt engagement of children on belt-positioning boosters during emergency braking events.** *Ircobi Conf.*, 2017

Baker G, Stockman I, Bohman K, Jakobsson L, Osvalder A-L, Svensson M, Wimmerstedt M. **Kinematics and shoulder belt engagement of children on belt-position boosters during evasive steering maneuvers.** *AAAM*, 2017

Bohman K, Stockman I, Jakobsson L, Osvalder AL, Bostrom O, Arbogast KB, **Kinematics and shoulder belt position of child rear seat passengers during vehicle maneuvers.** *AAAM*, 2011

Bohman K, Jakobsson L, Stockman I. **Retention of rear seat occupants during evasive steering maneuver – effect of seatbelt pre-pretensioner.** *14th Int. Conf. Prot. of Children in Cars*, 2016

Stockman I, Bohman K, Jakobsson L, Brolin K. **Kinematics of child volunteers and child anthropomorphic test devices during emergency braking events in real car environment,** *Traffic Inj Prev* 14:1, 2013

Stockman I, Bohman K, Jakobsson L. **Kinematics and shoulder belt position of child anthropomorphic test devices during steering manoeuvres,** *Traffic Inj Prev*, 14:8, 2013

Stockman I, Bohman K, Jakobsson L. **Pre-pretensioner effect on child sized dummies during run-off road events,** *Traffic Inj Prev*, 18:sup1 (ESV), 2017