HOW DRIVERS BEHAVE IN PRE-IMPACT EMERGENCY SITUATIONS

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ABSTRACT

Impacts in the real world differ from crash tests. Particularly, if the driver is trying to avoid an obstacle, decelerating sharply and/or rapidly changing trajectory, he may be dislocated from an optimal seat position for what concerns the interaction with restraint systems.

This paper evaluates the effects of full-force braking against an obstacle (rubber cones), of braking while trying to avoid the same obstacle (with and without ABS), and the consequences of a countersteering maneuver after losing adherence in a curve.

All tests have been performed with the collaboration of a safe-driving school, using a stock, middle-size sedan, and with the participation of volunteer drivers of both sexes, with ages from 18 and 45. The cars were equipped with a side-mounted VHS video recorder; appreciations and measures were taken directly on screen and compared.

The results show that the driver is almost never submitted, at test speed, at significant forward movement against the steering wheel, but however while trying to maintain control of the car he may expone hands and forearms in the proximity of an eventual airbag cover, with resulting non optimal performance of the restraint system. For what concern belts, in two cases the web went off the shoulder while operating the steering wheel and braking.

Some considerations upon refinement of smart restraints may be carried out, with reference to the behaviour of an active driver in a nearby accident.

BACKGROUND

STANDARD CRASH TESTS are conceived and performed as if a sudden crisis -the obstacle- would insorge abruptly while a car is normally travelling with unaffected speed and trajectory.

Practical investigations show that this regards only a minority of cases: in most of impacts, one or both drivers are conscious of the imminent danger of collision and try to adapt speed and direction of the car in order to avoid it.

Of course, this attempt will affect the position of both drivers and passenger, as forces are applied to bodies while decelerating or steering with energy.

This may significantly affect the body posture at the moment of the eventual impact, and therefore may affect the performance of restraint systems, and allow undesired contacts within the survival space.

It is well known in literature, as well as in laboratories, how the most important challenge to current airbag systems is given by out-of-position passengers in real world accidents. Nevertheless, it is extremely difficult to predict where and when the body of a car occupant will be positioned in the instant of the impact, that is at the time of the major deceleration peak.

Some intelligent works in literature deal how drivers sit in cars (Mackay, 1993); on the other side, there are no informations available about the way people modify their sitting in cars, under the menace of an impending collision.

Actually, if a crash is preceded by a panic maneuver or by a collision avoiding attempt, the body of the occupants may be displaced just before the activation of the airbags (Zuppichini, 1994; Bigi, 1996). The movements of a body in the pre-impact phase depend on many parameters; in our crash-reconstruction experience, however, most of the pre-impact configurations may be grouped in major families, such as blind braking, braking with change of trajectory, oversteering and attempt to recover, complete rotation of the car.

Objective of this work is to study the movement of volunteer drivers inside a car, in the following conditions: panic braking without steering; panic braking with obstacle avoidance maneuver; lose of control (oversteering) in a curve, with sideslipping and attempt to recover the trajectory; rotation of the car due to loss of adherence of two wheels of the same side.

To perform the "nearby-accident" tests, we used the vehicles and the experience of a safe driving school ("Centro Internazionale Guida Sicura", directed by former professional racing driver A. de Adamich), which routinely works out theoretical and practical courses to improve driving skills.

As this school usually teaches how to manage emergency conditions, we chose and refined some already existing exercises to be managed during an entire course of lessons, recording data both from a quantitative and a qualitative point of view.

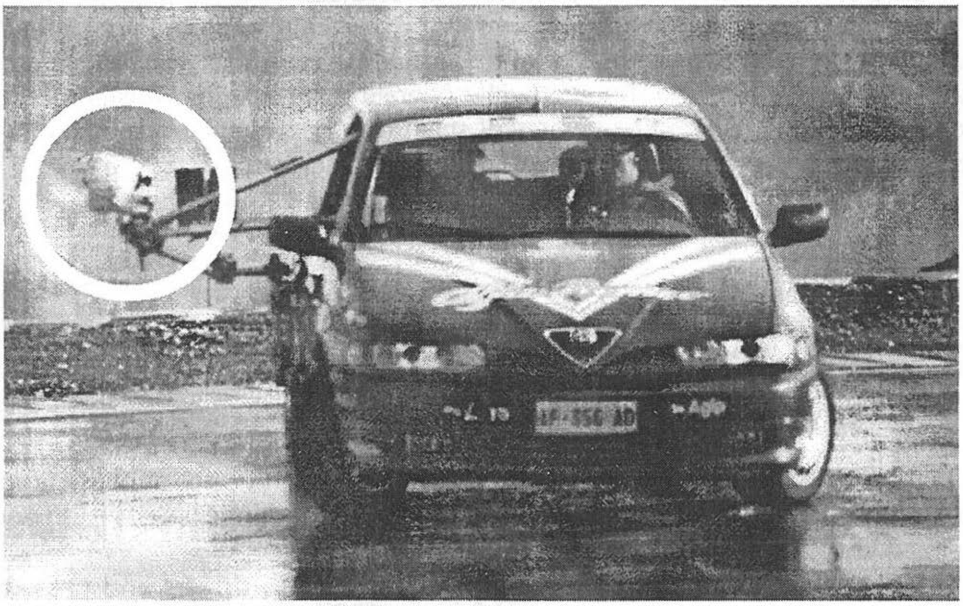

Fig. 1: Position of the recording VHS-camera outside the right door (test: braking in a curve, sideslipping and countersteering).

MATERIALS AND METHOD

We used a single car for all tests, a stock Alfa Romeo 145 1.7 sedan, with switchable ABS and supplemental safety devices, such as a roll-bar. All tests have been performed on the racing track "Riccardo Paletti" at Varano de' Melegari (Northern Italy), which is the permanent seat of the "Centro Internazionale Guida Sicura".

We chose a car without airbag and with the horn switch in the steering wheel centre, in order to add a "sounding" signal of contact of the upper limb with the region that would have hosted the airbag cover.

Outside the right door, a VHS-camera was installed, far enough not to alter the normal behaviour of car occupants (fig. 1); the visual field of the camera included the whole survival space of the driver, from the seat to the A-pillar. Later, we evaluated directly on a TV screen the behaviour of each driver, and we measured directly on-screen the movements, helped by a reference panel of white/black squares that was filmed inside the car before each group of tests.

All tests were performed at 65 km/h, with belted drivers; some tests were replied with unbelted drivers. Defective tests (i.e., too low speed, or too severe driving mistake, or however failure to reproduce the given exercise) were repeated until necessary.

The following tests were performed:

Test no. 1: Braking in front of an obstacle (row of rubber cones), without any attempt to change trajectory, with ABS switched off (fig. 2 A).

Test no. 2: Braking in front of the same obstacle, with emergency avoidance maneuver, with ABS switched off (fig. 2 B).

Test no. 3: Same as previous, with ABS activated (fig. 2 B).

Test no. 4: Excessive speed in a left curve, with braking, sideslipping, countersteering and attempt to recover the trajectory, without ABS (fig. 2 C).

Volunteers had ages between 18 and 45 and very different driving experience; a theoretical lesson always preceded the practical one, in order to shun dangers and to

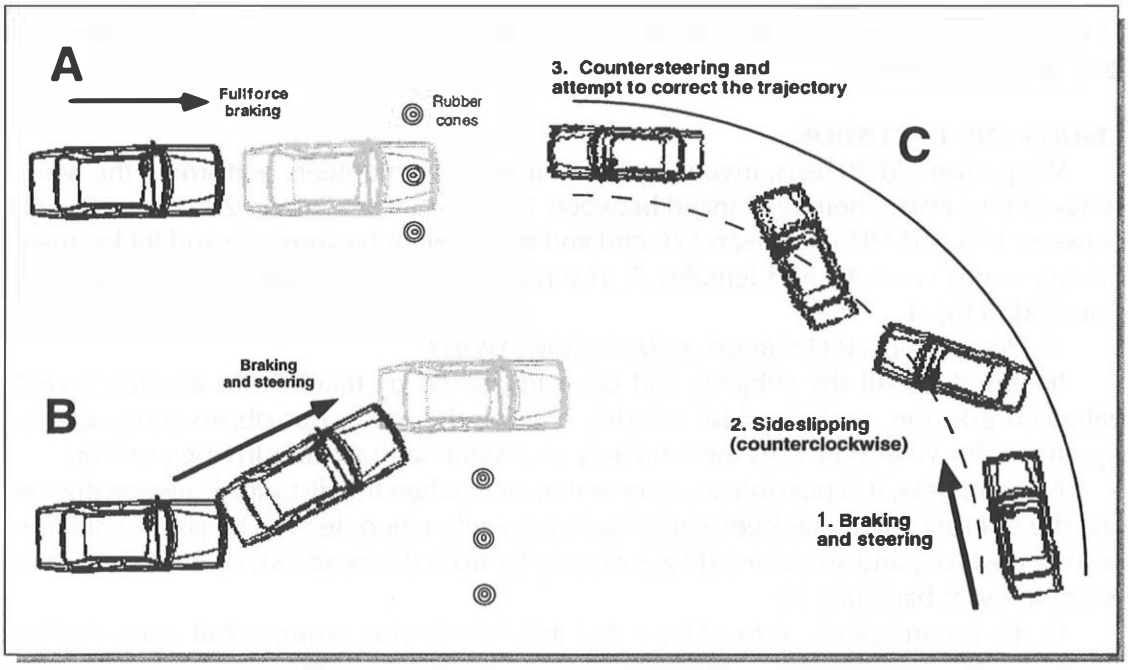

Fig. 2: Visual description of the performed emergency maneuvers (see description in text).

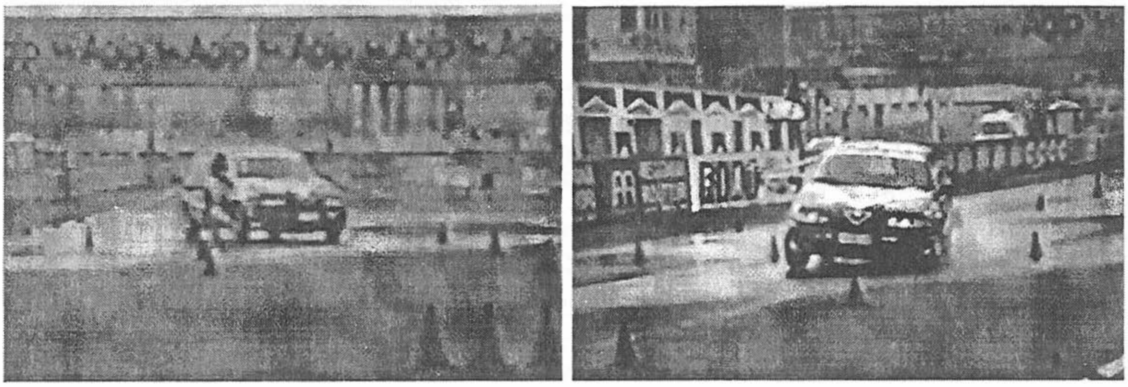

Fig. 3: Scene of the tests (obstacle avoidance, with or without ABS).

improve the performance. Before driving the car, each pupil tried the tests as a passenger, with a professional driver of the School showing the correct progression of maneuvers.

The normal sequence of the driving classroom was not manipulated, in order to interfere as little as possible with the normal behaviour of the volunteers. Instructions upon the behaviour to keep, the trajectory to maintain and the moment to brake or steer were given by radio in real time.

The scene of first three tests is reproduced in fig. 3, while fig. 1 reproduces one example of the fourth series of maneuvers.

It has to be noted that learners at the "Centro Internazionale Guida Sicura" are routinely filmed with an inside microcamera, just in order to review their mistakes or improvements and to provide them with a souvenir of the course. Our supplemental VHS-camera was simply fitted to the external of the car, while people were not explained in full detail about the characteristics of the study: they only knew that a further camera was filming them "in action", and agreed to participate to the study.

Moreover, drivers were so busy in trying to learn the maneuvers and keeping control of the vehicle that their attention was surely not reduced by the outside camera. Therefore, it is possible to assume only minimal or no bias at all vs. real on-the-road emergency conditions.

RESULTS AND DISCUSSION

We performed 90 tests, involving 49 volunteers; 9 volunteers performed the whole series of four tests. Their age ranged between 18 and 45 years (mean 29 y.), their height between 155 and 191 cm (mean 176 cm) and their weight between 49 and 94 kg (mean 72 kg); males were 42 and females 7. The main somatic data for each volunteer are resumed in fig. 4.

1. DISTANCE BETWEEN BODY AND STEERING WHEEL

In this study all the subjects had been instructed by teachers to assume a well-balanced position, optimized for steering control; therefore, our observations are not significant for what concerns the tendency to assume an habitual driving position.

Nevertheless, it is possible to observe that even when the distance between the seat and the steering wheel has been suggested by a teacher, people tend to assume different seating position, and some are always driving far from the headrest, or even not adherent to the seat back (fig. 5).

In the second place, it must be noted that safe driving requires full control of the steering wheel and the ability to firmly and vigorously rotate the wheel, which implies a more advanced seating position than usual.

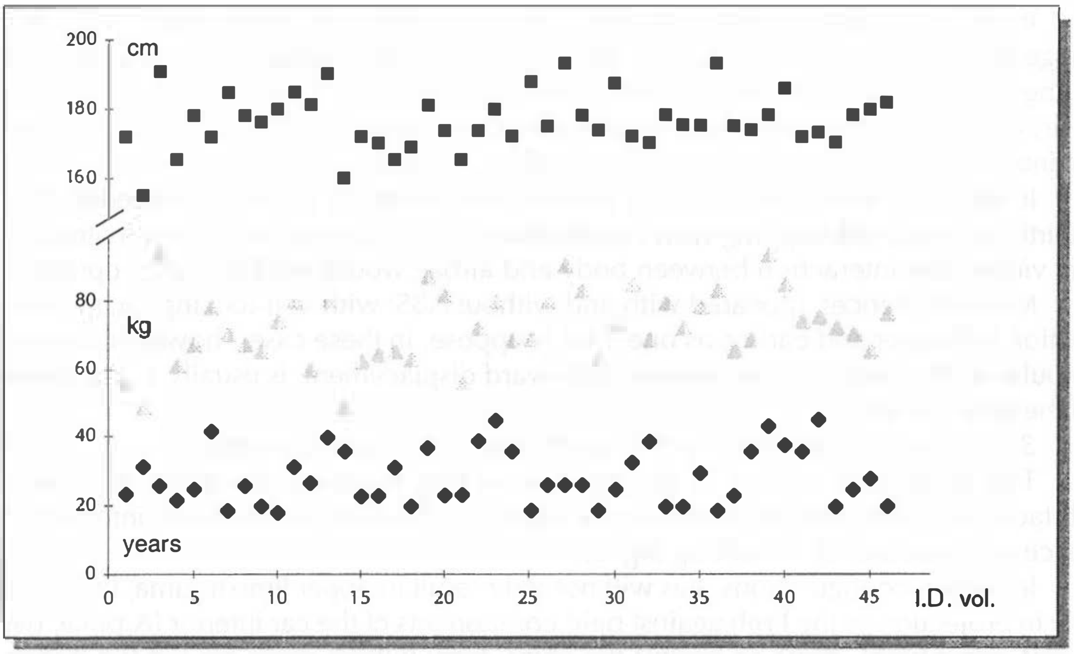

Fig. 4: Distribution of age, height (squares), and weight (triangles) among the drivers.

Almost all drivers had a clear demonstration that their usual driving position was too far from the steering wheel, in an amount quantified from 1 to 4 seat "adjustments marks" (most of cases, 2). These instructions are somehow opposite to current advises (mainly from magazines) to drive more "relaxed" and far from the steering wheel, in order to prevent airbag contact. In other words, choosing a driving position far from the airbag module may influence the quality of driving itself, and especially the ability to correctly perform an emergency maneuver.

2. FORWARD BODY MOVEMENTS DURING SHARP BRAKING OR COUNTERSTEERING

Drivers are by definition conscious of what is happening while they are braking. In our test, there was not any significant leaning forward of the torso and/or head in an emergency braking at 65 km/h, except for three drivers who were travelling with their back not fully adherent to the seat.

Fig. 5: Head forward movement at the end of a failed countersteering maneuver; the female driver has a seating position not fully adherent to the seat.

In all linear braking tests (first test), displacements were in the worst cases in the range of a few centimetres. Instead, some forward displacements were observed while trying to avoid an obstacle or countersteering: this effect may be due to the missed restraint by the arms, that are rotating the wheel and thus cannot help anymore in maintaining the posture, especially if the elbows are bent.

In the case shown in fig. 5 the forward movement of the head exceeded 20 cm (fourth test type, sideslipping with countersteering): had an obstacle been material and not virtual, the interaction between body and airbag would not have been optimal.

Main differences appeared with and without ABS: with anti-locking on, the deceleration is sharper and earlier, as one could suppose. In these cases, however, the wider impulse to the body, i.e. the maximum forward displacement, is usually at the moment of the final car stop.

3. INTERACTION BETWEEN UPPER LIMBS AND THE STEERING WHEEL

This appears to be one of the most interesting results: while trying to avoid the obstacle or to recover the trajectory, at least one forearm of the driver intersects the space of expansion of the airbag (fig. 6).

In certain configurations, this will not only result in upper limb trauma, but eventually in projection of the limb against rigid components of the car interior (A-pillar, dashboard, windshield, gear), or against the chest. Even if these cases are not life-threatening, we cannot forget that any anatomical damage to hands, wrists, forearms or elbows may result in severe permanent impairment after the accident, with very high social and insurance cost.

The most worrying configuration regards the "cross-arms" position, that could be due both to a driving mistake and to a deliberate maneuver in certain cases (fig. 7).

Of course, how much is needed to rotate the steering wheel in order to change trajectory is a function of the car geometry, and is a characteristic of each single model. In our test with the Alfa Romeo 145, the overlap between forearm and steering wheel occurs just when the car has invaded the opposite lane, that could be one of the most critical moments in a nearby accident, with immediate danger of frontal impact.

The analysis of our videos demonstrates that the overlap between forearm and steering wheel is a constant problem, with most drivers and while correctly operating the controls: at given moments, the forearms will alternatively travel just in proximity of the airbag cover.

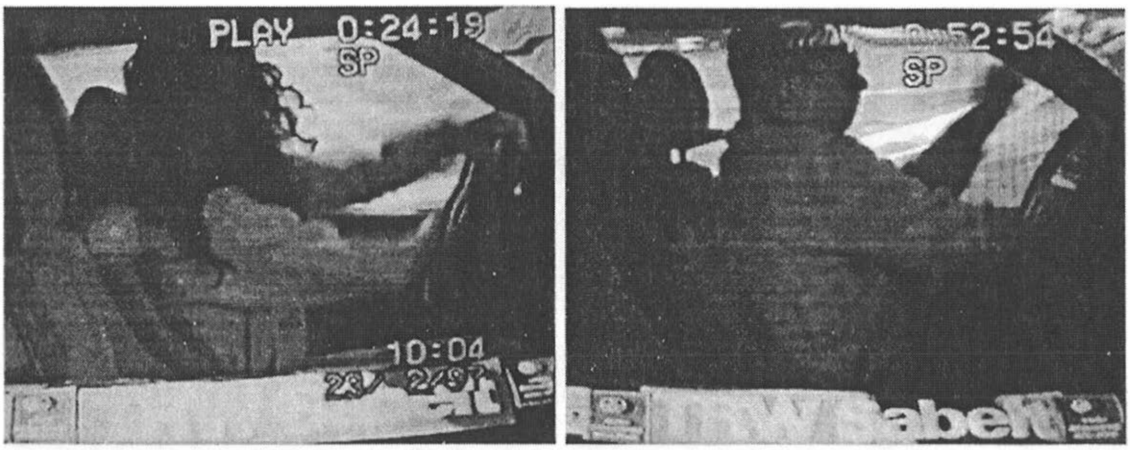

Fig. 6: Interaction between forearms and airbag expansion space during standard countersteering maneuvers.

Fig. 7: Different patterns of crossing arms while rapidly rotating the steering wheel, as result of panic maneuver while failing in countersteering (top left), of uncorrect technique in countersteering (top right), uncorrect technique in obstacle avoidance with too far seating position.

This seems to represent a challenge also for out-of-position sensors, that have been tailored to detect if a large mass (the chest) is too near or is approaching, but could be deceived by a rather thin body segment such as a forearm. This seems to suggest the need of sensors positioned in different locations in order to combine informations and distinguish between different scenarios.

The narrow contact of the forearm with the cover is emphasized by the accidental activation of the horn in six cases, which gives a sure information upon pressure directly in the middle of the steering wheel (fig. 8).

4. IMPLICATIONS FOR RESTRAINT AND SEAT DESIGN

In two of our tests the belts fell off the shoulder of the driver while energically countersteering in the curve test. The Alfa 145 is a two-door sedan, with long excursion of the web between B-pillar and seat: in our conditions, the geometry of the system reached its limit.

For what concerns airbag systems, it must be noted that a driver normally assumes an "airbag friendly" posture, so that an expanding bag would be embraced without violent contacts (fig. 9 left), filling the natural gap delimited by the two arms and the chest. This is obviously no more true if there is an attempt to change or correct the car trajectory with the steering wheel (fig. 9 right). In this situation, if an impact occurs during the emergency maneuver, the airbag will exert pressure on the upper limb (or limbs) during its inflation process.

Even if an airbag provides globally a higher safety level in a frontal impact, injuries to forearms may lead to undesired and expensive permanent impairment: preventing such injuries, that are therefore not closely related to out-of-position situations, will be a challenging task for smart bags in the near future.

Fig. 8: Contact between right forearm and the centre of the steering wheel, with enough pressure to activate the horn. Note also the head forward movement (over 10 cm) resulting from sideslipping, failure in countersteering and complete loss of control of the vehicle.

We had strong suggestions that the rather good anatomical conformation of the Alfa Romeo 145 seats, together with the good adherence of the fabric surface, has prevented lateral displacement of the driver while countersteering (fourth test) and sometimes in the braking test with obstacle avoidance (second and third tests). We tried the same maneuvers with an Alfa Romeo 164 with leather seats, finding actually a worse adherence to the seat and a more sensible side and frontal displacement.

This aspect is interesting indeed but beyond the purposes of this paper. However, our impression from the tests is that the interaction between dressing and seat texture is perhaps underevaluated in preventing movements of the occupant's hip in the braking or skidding deceleration phase just before a collision.

CONCLUSIONS

For what concerns axial deceleration in emergency maneuvers, our tests at middle-range speed (65 km/h) show that this depends mainly on the adherence between body and seat. Even unbelted occupants do not suffer large displacements in linear braking, if correctly positioned in a correctly designed seat.

The problem is however related not only to the prevention of airbag contacts, but also to optimizing the survival space and providing seat belts with optimized parameters in yielding or not under stress (Bigi, 1996).

More dangerous is surely the chance for the driver to overlap the airbag cover with his upper limb; in some crash and avoidance maneuver configuration, the forearm will not be driven off from the airbag deployment scene, but will be pushed against the chest, with possible thoracic injuries. While rapidly rotating the steering wheel, the forearm is so close to the centre that sometimes the horn is activated during an emergency maneuver. Some studies already reported upper limb lesions, usually by violent displacement and contact with rigid components, while other studies simulated this situation in order to assess the injury potential and define countermeasures (Huelke, 1994; Johnston, 1997; Kuppa, 1997).

Some findings of our tests have implications upon airbag deployment: particularly, it seems challenging for a "smart" module to recognize a forearm in rapid movement. Nevertheless, an interaction between the cover and an overlapping limb seems dangerous and could usher in undesired side effects, also in panic reactions with bare braking and horning, if the horn switch is in the middle of the steering wheel.

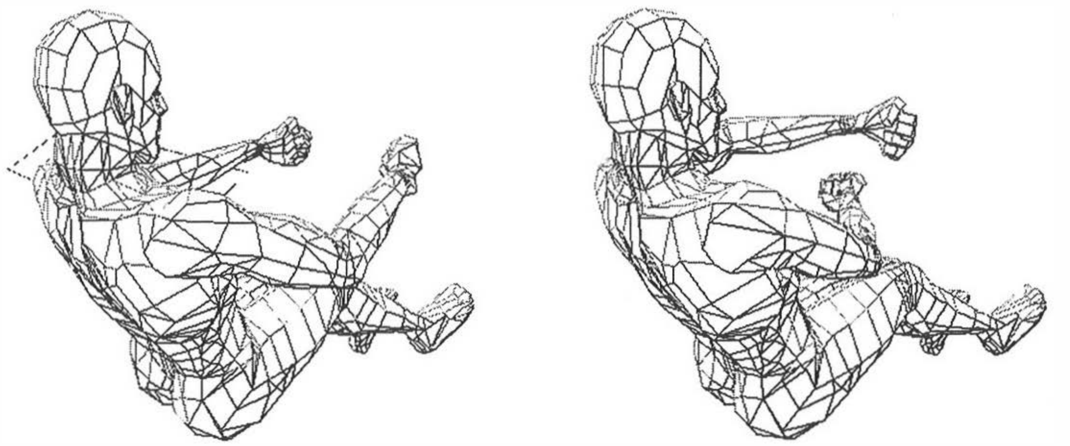

Fig. 9: "Airbag friendly" posture of a driver in straight driving (left), compared to overlapping of forearms and airbag cover region in an emergency maneuver (right).

Our tests were part of a series of lessons and therefore generally lack the "surprise and fear" factor: other configurations could be possible, such as for instance completely leaving the controls and protecting the face. We intended to study only the behaviour of a conscious, alert, cold-blooded driver in common emergency maneuvers and its patterns of movement with regard to out-of-position situations.

Actually, car occupants are never out of their position: at any given time, they are occupying their physical space inside the car and performing tasks allowed or imposed them by the car project itself. Rather, car occupants may assume a position not desired or not foreseen by designers and testers; to understand as far as possible the whole range of body positions with reference to what is happening in the real world requires a better understanding of the events that may precede an impact and the sudden reactions of the driver to the sudden traffic crisis and the menace of a crash.

The definition of "out-of-position" itself seems too strictly related with concepts derived from simulation and laboratory tests, and with abstract geometries that are seldom found in reality. Men are not dummies, and real impacts are not crash tests.

Drivers' attempts to resolve a nearby accident and avoid a crash may therefore result in body movements, especially at upper limb level, thus altering the normal posture at the driving seat: knowing the variables of this rapidly changing posture in the imminence of an impact may further enhance the effectiveness of restraint systems and lower their side effects.

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