KINEMATICS OF A PEDESTRIAN AND A TWO-WHEELER IMPACTED BY THE FRONT OF A CAR.

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1. Introduction

Progress made in the field of vehicle occupant protection and the resulting decrease in the number of casualties, emphasizes at the present time the relatively high number of people injured outside the vehicle. More than 50% of all people killed on the roads in Europe are on the outside of the vehicle (Japan : 63% - United States : 26% (1972)).

In France, road casualties on outside of vehicle, i.e. pedestrians and two-wheel riders, are the result, in 69% of cases for pedestrians (1968) and in 68% of cases for two-wheel riders (1974), of collisions with private cars (1).

Accidentology and experimental surveys of car-pedestrian collisions have shown that impacts of body segments with car fronts are the cause of the most frequent and serious injuries compared with injuries caused on the ground, and that the head-vehicle impact is the main cause of pedestrian deaths (2).

Collisions between private cars and two-wheelers are less well-known. Available date show however that, for two-wheeler riders as well as pedestrians, in the very large majority of cases, fatal injuries are located in the head area (60% - 80% (2)(3)), and that the most frequent accident is the head-on (car) - side (two-wheel) collision. The head-on collision, although generally more serious, is relatively less frequent (3) (4) (5). The analysis of 28,775 Peugeot-Renault private cars involved in accidents with two-wheelers showed front deformations.

These accidentology data have shown up how frequent collisions are between two-wheelers and pedestrians with private car fronts. In France, in more than 6 out of 10 pedestrian accidents of all types, and almost one out of two two-wheeler accidents of all types, the front of a car is involved.

The frequency and seriousness of head injuries to these road-users has led us to ask ourselves about the frequency of "head-car" impacts for pedestrians and two-wheel users in those collisions involving car fronts. The head of a pedestrian hit by a car front impacts the vehicle in more than 60% of cases (3) (6) (7). The head of a two-wheel user hit by a car front impacts the car a little less frequently (50% of cases in a sample of 33 collisions with mopeds (Renault-Peugeot Association) ; 63% of cases resulting in head injuries (3)).

It follows from these accidentology and statistical data that the "head-car frontal area" impact represents almost 40% of all types of pedestrian accidents and from 25 to 30% of all types of two-wheeler accidents.

Seeing the frequency of two-wheel and pedestrian accidents where the front of private cars is involved, and the importance of the head-vehicle impact, we would suggest that studies of car-two wheeler collisions be undertaken in conjunction with car-pedestrian collisions. Three experimental collisions between a two-wheeler and the front of a car are shown further on in conjunction with a car-pedestrian collision.

2. Kinematics of a dummy impacted by the front face of private car in different "two-wheeler" and "pedestrian" configurations.

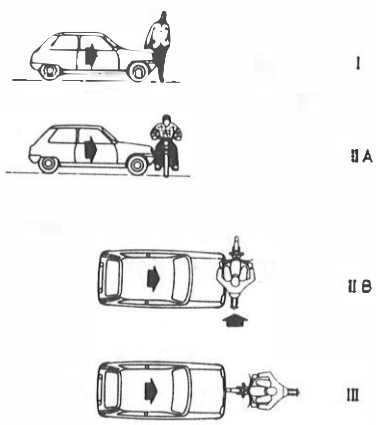

Fig. 1 - Test Configurations.

The dummy, (Sierra Stan 50° percentile) is impacted sideways by the front of a car (Renault 5) having a speed of from 29 to 36 km/h in car-pedestrian collision configuration (I) and car-moped, head-on/side collision at standstill (IIA) and then moving (IIB). A head-on collision was then simulated (Fig. 1). The moped is a two-wheeled vehicle with a 50 cc engine and having a mass of 40 kg ; the mopeds are involved, in France, in 70% of all types of two-wheeled vehicle accidents. Car braking is simulated in the different configuration as soon as collision starts.

2.1. Kinematics of an adult dummy impacted on side in a car-pedestrian collision (I).

The car-pedestrian collision is made up principally of three phases : the impacts of the pedestrian on the vehicle, sliding on the bonnet and projection to the ground. The parameters of the collision during the first phase are mainly, besides vehicle speed, the relative height of foremost edge of bonnet and the centre of gravity of pedestrian, as well as the distance of front face of vehicle from the windscreen. In the second and third phases, the time vehicle-pedestrian contact lasts, taken with braking intensity, bonnet length and, to a lesser degree, collision speed, determine for the main part the kinematics of the pedestrian, taking into account his position and speed at end of first phase.

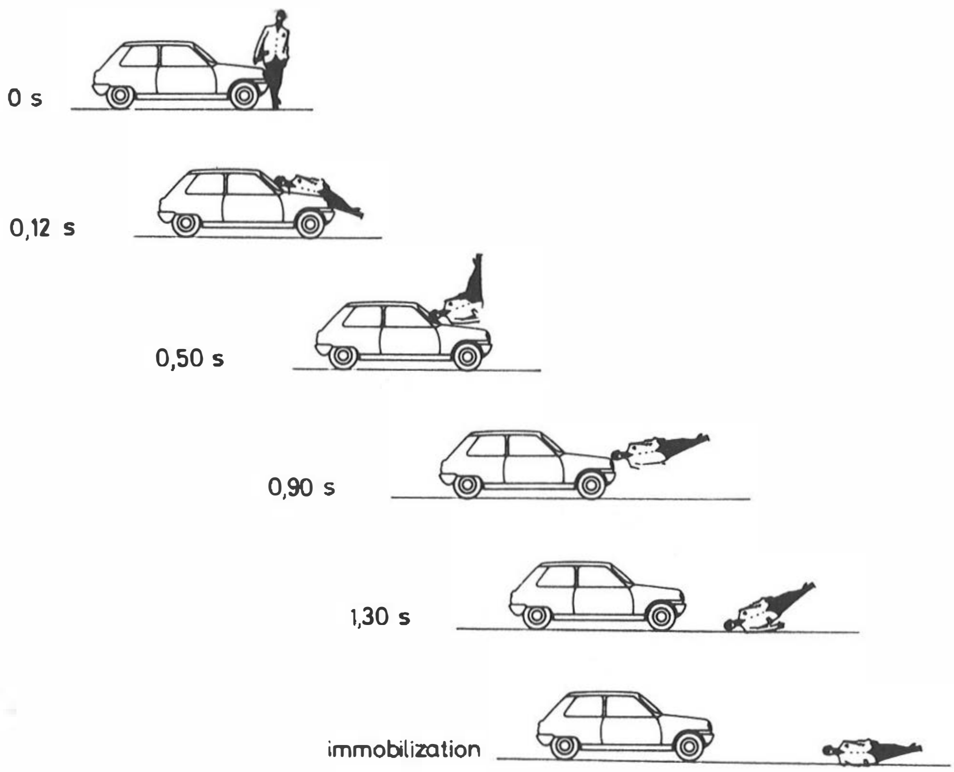

Fig. 2 - Car-dummy collision at 36 km/h (I).

The simulated collision is characterized by the collision speed (36 km/h, 10 m/s.), the position of pedestrian pelvis above the ground (90 cm), the height of foremost edge of car bonnet at moment of impact (75 cm), the distance of front face from lower windscreen opening (95 cm) and the average braking intensity of the car (6 ms^{-2}).

The dummy kinematics consist in tilting of the trunk in direction of the bonnet stopped by head impact on laminated windscreen (H.P.R.), followed by sliding on the bonnet and throwing to the ground (Fig. 2). The laminated windscreen is cracked, but the head does not go through it (HIC = 249). Throwing to the ground consists of being thrown through the air and impacting the ground (HIC = 963 at t = 130/100 s.). Dummy velocity at moment of loss of contact with the vehicle (t = 95/100 s.) is 6 m/s i.e. 60% of collision speed. (Table 1)

2.2. Kinematics of a moped at standstill impacted on side by a private car (IIA).

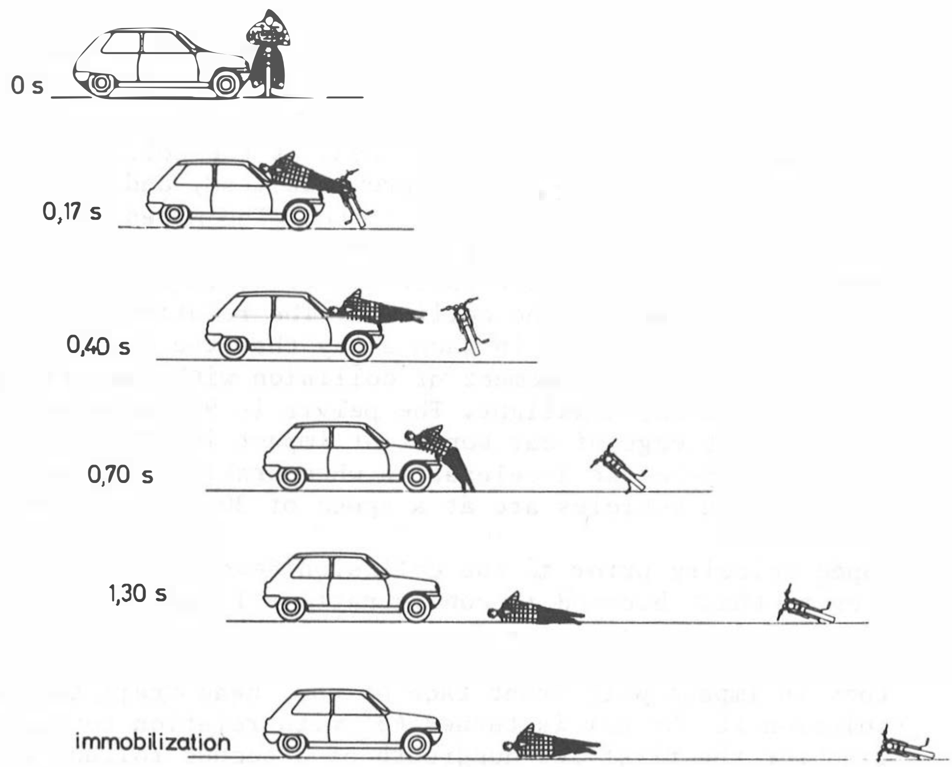

Fig. 3 - Car-two wheeler collision at 29 km/h (IIA)

The same dummy as previously used is placed on a moped at standstill. It is then impacted on the side by the same type of vehicle at a speed of 29 km/h (8.2 m/s.). Dummy's head is on vehicle centreline, with his foot on the impact side, on the moped footrest in the low position (15 cm above ground). Dummy pelvis is at the same height as in the previous test (90 cm), which corresponds to an average saddle height for moped users ($\simeq$ 85 cm). The foremost edge of car bonnet is at 75 cm at moment of impact, and average vehicle deceleration when braking is 8 ms^{-2} .

The dummy kinematics, as a whole, differs but little from the pedestrians' (Fig. 3). The same successive phases can be seen ; tilting of trunk, head-laminated windscreen impact cracked but not gone through (HIC = 206). The vehicle-dummy contact lasts 80/100 s. ; dummy projection velocity is 5 m/s., i.e. 65% of collision speed. Head-ground impact takes place at t = 133/100 s.; the corresponding severeness is small (HIC = 7) for previous impacting of lower members and pelvis on the ground slow down the head. The limited rotation of the lower members in comparison with the previous test could be due, besides to a lower collision speed, to interaction of dummy and moped during the first phase of collision (Table 1). There is no dummy-moped contact when first phase has ended, as the moped is projected in front of the car while dummy is in contact with the vehicle.

2.3. <u>Kinematics of a moped rider driving along at 30 km/h and impacted on side by a car at the same speed (IIB).</u>

The dummy is placed in the same position as before (IIA) on the same type of moped at the same speed as the colliding car, which is of the same type as in the previous test, and is driven in a perpendicular direction to the latter. The moped is fitted on a carriage which is stopped a few meters before the collision. The dummy and his vehicle are therefore released from the carriage a few moments before the collision. The relative chariot and car movements are adjusted in such a way that the dummy's head is on car centreline at moment of collision with the pelvis at that moment above car headlight. The pelvis is 90 cm above the ground, the foremost edge of car bonnet at impact is 80 cm above the ground. Average car deceleration when braking is 5 ms^{-2} . At impact, both vehicles are at a speed of 30 km/h (8.3 m/s).

Moped velocity prior to the collision develops different kinematics to that observed in configurations I and IIA (Fig. 4)

As dummy's head is deviated very little from its initial trajectory in impact with front face of car, head trajectory with relation to the car is turned 48° with relation to car centreline for the first few hundredth of a second following the moped-vehicle contact (Fig. 5).

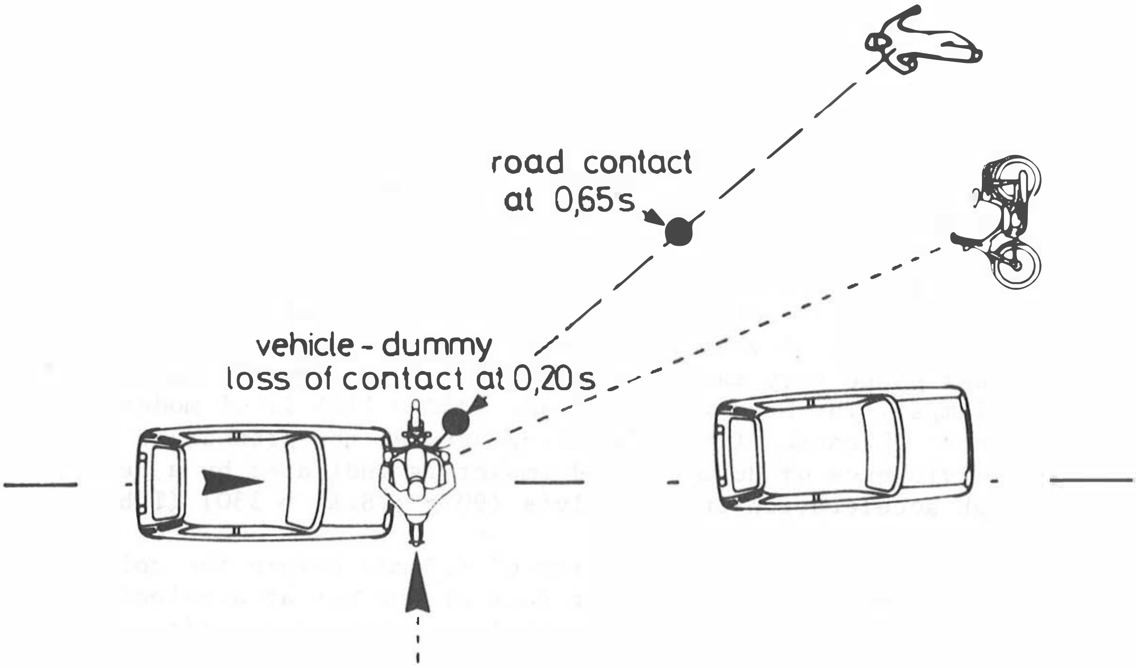

Fig. 4 - Car-two wheeler collision at 30x30 km/h (IIB).

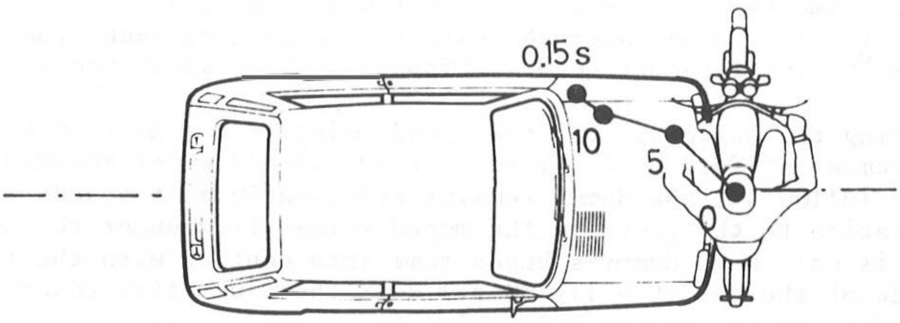

Fig. 5 - Head/vehicle kinematics in a car-two-wheeler collision at 30x30 km/h (IIB).

The head then loses velocity which leads to a curving of the trajectory towards the car. The movement is interrupted by dummy's arm impacting the bonnet of the car at t ≅ 10/100 s., thus appreciably modifying the trajectory of the head which misses the car along the side. Without this chance elbow impact, the head would probably have hit the lower windscreen opening at 50 to 60 cm from vehicle centreline near the base of the windscreen A pillar . The resulting head velocity with relation to the vehicle, which is the vectorial difference between the velocities of both vehicles when collision starts, then decreases until the head misses the car along the side.

Loss of contact between the car and dummy comes about very early (t = 20/100 s.). Dummy velocity is relatively high compared with the ground (10 m/s) and is turned by approx. 40° with relation to the car centreline. The dummy's pelvis with a velocity of 8.3 m/s prior to collision, loses contact with the vehicle at a velocity of 7 m/s in direction of initial movement, and gains approx. 7 m/s in direction of vehicle movement. Impact with the ground also takes place very early (t = 72/100 s.), and with a high velocity (11 m/s). The head-ground impact (HIC = 170) is of moderate severeness because of the arm being between the ground and the head. The violence of dummy ground impact is indicated by a relatively high acceleration on the pelvis (90 g ; S.I. = 330) (Table 1).

The moped which has a velocity of 8.3 m/s before the collision, loses contact with the front face of the car at a velocity of 3 m/s in the direction of initial movement, and 7 m/s in direction of car movement. Its trajectory is turned by approx. 20° with relation to the car centreline.

2.4. Kinematics of a stationary moped impacted from the front by a car having a velocity of 32 km/h (III).

The dummy is placed on the stationary moped on car centreline. The car, same type as previously, collides head-on at a velocity of 32 km/h (8.9 m/s). Average vehicle deceleration when braking is 6 ms^{-2} . The foremost edge at impact is 80 cm above the ground.

During the build-up of moped speed going with a maximum backward movement of fork of 10 cm (t = 6/100 s.) and wheel bursting at t = 10/100 s., the dummy remains practically at a standstill with relation to the ground : the moped slides from under the dummy. It is only when dummy's knees come into contact with the front face of the car (t = 11/100 s.) does the trunk tilt towards the bonnet and the pelvis rise (Fig. 6).

Then the thighs come into contact with the moped handlebars which are in contact with vehicle forward bonnet edge. The moped at this time is flat against the front face of vehicle. Head impact on lower car windscreen opening takes place at t = 29/100 s. from beginning of collision at a reduced velocity (V = 5.2 m/s : 0.6 times collision speed).

The dummy then slides along the bonnet and loses contact with the vehicle very late (t = 140/100 s.) at a reduced velocity V = 3 m/s (33% of collision speed). The dummy then comes back into contact with his moped which is pushed by the front face of the car, and then hits the ground at t = 168/100 s. (HIC = 427) (Table 1).

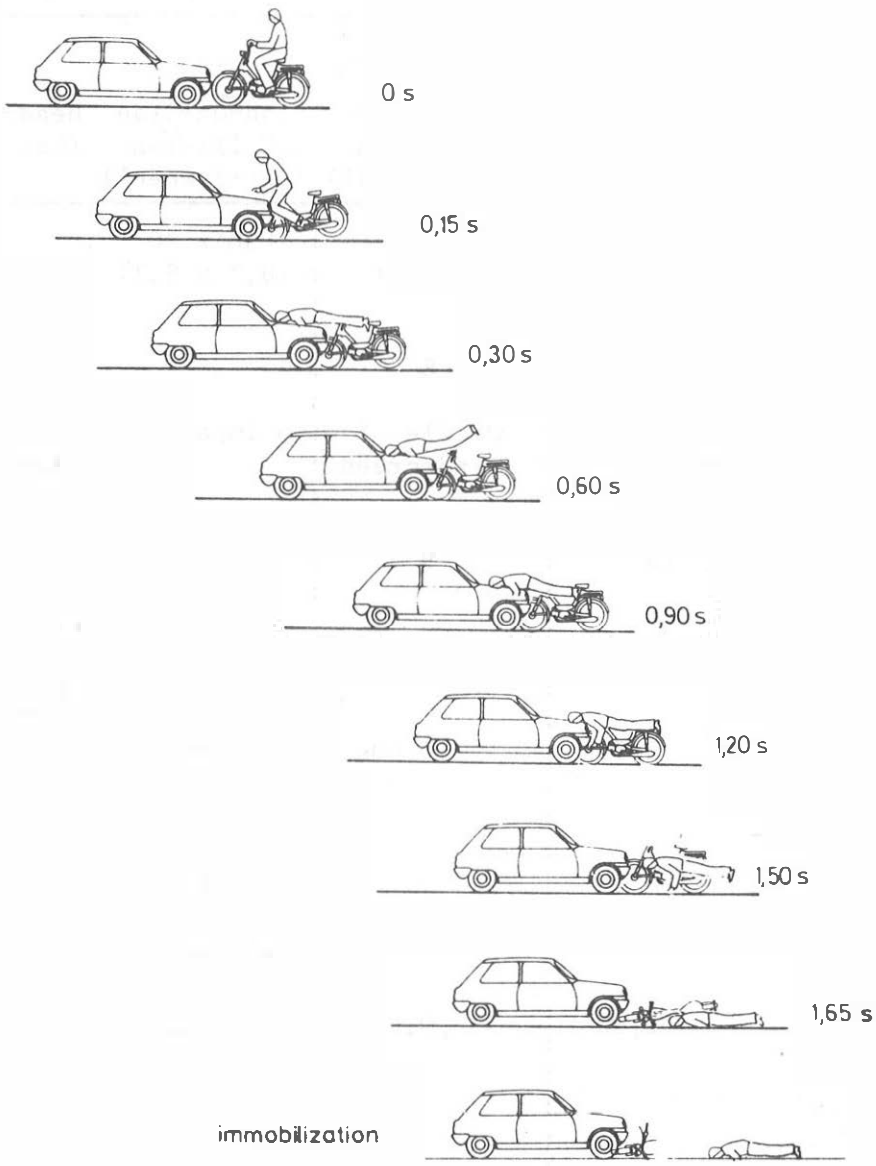

Fig. 6 - Car-two-wheeler head-on collision at 32 km/h (III).

3. Discussion

These four experimental collisions highlight a certain number of similar points as well as differences in the dummy's kinematics.

The similar points are mainly during the successive phases of the accident. It can be seen in the four configurations that the lower members impact the front face of vehicle, followed by the trunk tilting towards the bonnet, sliding along the bonnet and then being thrown to the ground. If configurations I and IIA give rise to kinematics which are difficult to differentiate, taking the difference between collision speeds into account (29 km/h and 36 km/h), configurations IIB and III give rise to very distinct kinematics.

Can be seen in configuration IIB :

- A head trajectory turned through 48° with relation to the vehicle centreline at beginning of collision, and then tilting towards the vehicle,

Table 1	I Car-Pedestrian Collision	IIa Head-on-Side Collision (Car-2-wheel)	IIb Head-on-Side Collision (Car-2-wheel)	III Head-on Collision (Car-Two-Wheel)
Collision speed kmh (m/s)	36 x 0 (10 x 0)	29 x 0 (8,2 x 0)	30 x 30 (8,3 x 8,3)	32 x 0 (8,9 x 0)
Car Deceleration (m/s^2)	6	8	5	6
Localisation of Head Impact	Middle of windscreen	Middle of windscreen	no impact	Windscreen lower frame
Head Car Impact Speed (m/s)	13	9,3	-	5,2
Head-Car Impact Severity (HIC)	249	206	-	129
Car-Dummy Loss of Contact Time (t*)	0,95s	0,80s	0,20s	1,40s
Dummy Projection Speed (at t *) (m/s)	6	5	7 10 7	3
Ratio of Dummy Projection Speed to Car Collision Speed	0,60	0,65	1,20	0,33
Dummy Speed at Ground Contact (m/s)	8 6 5	5,5 5 2	11 10 4	5 3 4

- Head passing along side of car,
- Dummy being projected at high velocity (10 m/s) and taking place very early (t = 20/100 s.),
- Dummy stopping on ground at 5.5 m from car centreline,

Can be seen in configuration III :

- A head vehicle impact taking place late (t = 29/100 s.) at a reduced velocity (V = 5.2 m/s) and located further forward on car,
- Dummy leaving the vehicle at a very reduced velocity (V = 3 m/s) and very late (t = 140/100 s.).

4. Conclusions.

- In France, over 60 % of pedestrian accidents and nearly 50 % of two-wheeled vehicle accidents of all types involve the front of a private car.
- In almost 40 % of pedestrian accidents of all types and 25 to 30 % of two-wheeled vehicle accidents of all types, the head strikes the front of a private car.
- The kinematics of a dummy struck laterally by a car in the configuration of a pedestrian accident differed only slightly from those of a halted moped rider struck laterally by the same car in the same speed range.
- A Simulated fronto-lateral collision between a car and a moped had resulted in different kinematics depending on whether the moped is halted or is moving. The movement of the moped results in the possibility of the head missing the vehicle with projection onto the ground occurring earlier at a higher speed and in a direction away from the trajectory of the vehicle.
- A fronto-frontal collision between car and halted moped at a relative speed of 32 km/hr was characterized by a head to vehicle impact occurring later, further forward on the vehicle and at a lower speed compared to a fronto(car)-lateral(halted moped) collision at the "same" speed. The projection of the dummy onto the ground also occured later and at a lower speed.
- The diversity of the car - two-wheeled vehicle collision configurations (relative speed vector, relative position of the vehicles at impact) and the various resulting kinematics justify the experimental simulation of a great number of collisions in order to interprete real accidents (collision speed, trajectory and location of the impact of the head).
- As might be expected from the accidentological data available, collisions between a car and a two-wheeled vehicle involve a risk of impact between the head and the vehicle which is higher in fronto-frontal collisions than in fronto-lateral collisions. Furthermore, they occur in zones of the vehicle which are also concerned by impact between the pedestrian's head and the car. In conjunction with the high impact frequency of the lower limbs of the pedestrian and the two-wheeled vehicle rider against the front face of the car, this remark would suggest that common benefit could be derived from possible modifications to the car designed for one or other of these two members of the traffic community.

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