Three-Dimensional Occupant Kinematics During Frontal, Lateral and Combined Emergency Maneuvers

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I. INTRODUCTION

Active human body models, i.e. numerical simulation models that not only allow predicting injury patterns during a vehicle crash, but are also capable of mimicing muscle-induced human movement during milder loading conditions, need realistic and reliable experimental data from volunteer tests for development and validation.

Typically volunteer experiments cover either lateral or frontal loading and fall into two groups, sled tests [1-10] and vehicle tests [11-15].

This work presents first results of 3D occupant kinematics from a vehicle-based study, where 6 female and 27 male passengers were subjected to braking and lane change maneuvers as well as combined frontal and lateral maneuvers with peak accelerations of around 1 g.

II. METHODS

Maneuvers were performed on a closed test track in a Mercedes-Benz S-500. A modified seat was used which included the original seat frame, but cushions were replaced with a single layer of foam applied on a wooden plate. Lateral support structures were added where the geometry was close to the geometry of the original seat. The standard three-point belt was used with the pre-tensioner disabled (see [16] for more detail).

Three types of maneuvers with an initial velocity of 50 km/h were analyzed in this study: (I) an emergency braking, induced by the driver with maximum effort, such that the brake-assist was enabled; (II) single lane change, performed to the left and right and at maximum effort (similar to [15]); and (III) a combined maneuver, where the driver turned the steering wheel at maximum effort (left or right) combined with an emergency braking. The test sequence for each subject started with a braking maneuver at 12 km/h [16], but then the maneuvers were performed in random order. More details are given in Table I[1].

In total 33 subjects (6 female, height: 169.0±4.1 cm, weight: 63.0±10.4 kg, age: 31.5±9.3 y and 27 male, 179.1±4.7 cm, weight: 77.8±8.4 kg, age: 25.4±9.6 y) were tested. Properties of the subgroups of the preliminary data sample are given in Table I.

Vehicle accelerations, steering wheel angle, angular velocity and brake status were recorded from the CAN bus using a Dewetron Dewe5000. For braking and combined maneuvers t=0 is defined by the brake status, while for lateral maneuvers t=0 is derived from the steering wheel angle [15].

TABLE I
PARAMETERS OF THE MANEUVER AND SUBJECT PROPERTIES

	peak acceleration [m/s^2]			*#subjects*			*height*		*weight*		*age*	
maneuver	*front.*	*lat.*	*total*	*total*	*fem.*	*male*	*[cm]*		*[kg]*		*[y]*	
Brake	-10.8	1.0	10.8	10	4	6	176.5	±5.9	76.5	±11.1	31.1	±8.4
Lane Chg.	1.1	10.0	10.1	5	3	2	175.2	±5.2	68.2	±9.1	29.0	±6.4
Combined	-10.7	8.3	10.8	4	1	3	178.8	±6.5	75.5	±8.0	28.8	±4.9

Kinematics of retro-reflective markers mounted to the subject was recorded at 100 Hz with eight Vicon M2 infrared cameras operated by a Vicon V612 data station. To ensure proper operation of the system the windshield and passenger side window and some material from the passenger side door were removed [15]. Before 3D reconstruction of marker trajectories a customized algorithm to account for camera motion [16] was

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[1] Additionally braking during a stationary circle maneuver and maneuvers in a handling and slalom parcours were recorded, but not included in this paper. For selected subjects additional electromyographic recordings of eight bilateral muscles were performed, which are also not included here.

applied. The coordinate system was chosen such that the H-point of the unmodified seat refers to the origin, the x-axis points towards the rear of the vehicle, the y-axis to the right and the z-axis up.

Eleven markers on the head and twelve markers on the torso were used to compute characteristic points of the head and upper torso segment in each video frame. These are referred to as center points, and displacements with respect to t=0 are reported. Maximum excursions are computed as maximum distance from the origin in the x-y plane.

I. INITIAL FINDINGS

In Figure I maximum excursions of head and torso center points are displayed in the x-y plane. The corresponding maximum distances are collected in Table II.

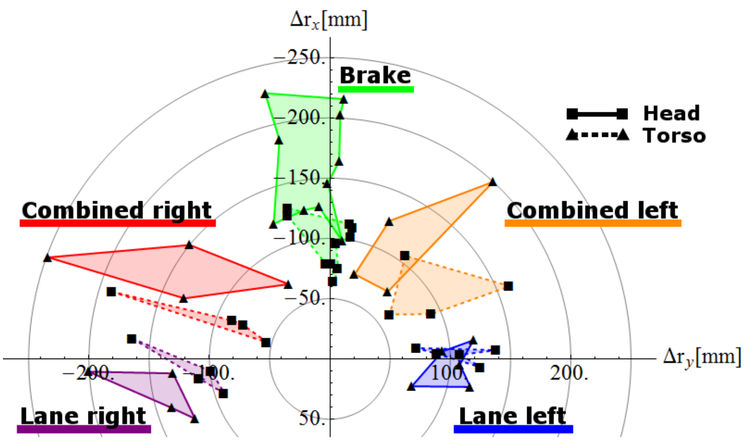

Figure I: Maximum excursion of head and torso during various maneuvers. Note that maneuvers to the left lead to an initial movement to the right. Values of associated body regions and maneuvers are connected to guide the eye.

TABLE II
Maximum Head and Torso Excursions

maneuver	*Δr^{Head} [mm]*		*Δr^{Torso} [mm]*	
Lane left	103	±20	107	±27
Combined left	118	±60	105	±42
Brake	161	±45	97	±22
Combined right	150	±74	102	±60
Lane right	148	±36	116	±33

II. DISCUSSION

To the authors' knowledge this study is the first one to include 3D kinematics of the occupant response to combined frontal and lateral loading in a vehicle. In combination with findings for other loading conditions with the same test setup and volunteer selection, the available validation basis for active human body models can be extended.

It is interesting to note that although the occupants were restrained with a three-point belt, large excursions and large inter-individual differences (164%-352%) in excursions in each maneuver were observed.

The missing windshield and subject preparation arguably lead to an explicit test situation, where behavior compared to a real-world traffic situation could be modified (expectation vs harmlessness of maneuvers).

In the next analysis phase the remaining kinematic data will be processed and statistical analysis will follow. Also correlation of kinematic data with data from electromyographic recordings is planned.

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