Validation of an Economican Fast Method to Evaluate Situationspecific Parameters of Traffic Safety

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The need for efficient simulators for training and investigating complex and especially risky tasks is obvious. Accordingly simulators for as diverse tasks as flying a plane, driving a car, flight control and operating nuclear reactors have been developed. While the benefits of simulator training are easy to see, for instance, dangerous situations can be trained without any risk for personnel of machinery, the question how valid a simulation is, that is, how similar is the behavior in the simulator to the behavior in real-life situations quite often is left open or only answered by appealing to the obvious simularity in the layout of instruments plus the physical characteristics of controls and the realism of the depictured visual scene. Especially, the lacking degree of realism in computer generated visual scenes has been criticized: the lack of non-geometric perspective cues as haze or blue-shift, the unnatural regularity of buildings, the crispness of contures, and, in general, the lack of realistic clutter starting from pedestrians on seemingly random courses to debris and discolorations of the surfaces. This situation has led to the development of video-simulators (2D and 3D) at the Experimental Applied Psychology Unit at the University of Regensburg, among others (for an overview, especially for research in the US, see MacAdam, 1993); in this simulation methodology videos from real traffic scenes are used.

The simulator developed in the Experimental Applied Psychology Unit at the University in Regensburg consists of a BMW limousine, where all the controls and displays are linked to a computer, and a video projector producing for the driver a visual scene with a visual angle of about 45°. It is obvious, that such a kind of simulation is sensitive only to the skills on the basic level of Janssen´s (1979) hierarchy of the driving task (van der Molen & Bötticher, 1988): Subjects can accelerate and decelerate the speed of the video, and steering control can be simulated by keeping a target in the middle of the lane. Even on this level the task is not as interactive as in full fledged computer simulations because deceleration and acceleration influence not only the simulated car in relation to the stable environment but also influences all other moving objects in the video. Despite these draw-backs, the advantage of video simulation lies in the realism of the depicted scenes. In our experiments we were especially interested in drivers´ speeding behavior, for the adjusted speed is the main cause of traffic car accidents.

In order to determine the validity of this simulation technique the correspondences with real-life driving have been determined on three different levels corresponding to three separable research questions:

(i) Do individually different driving styles induce a corresponding regulation of velocity in the simulation and in the real-life driving?

(ii) Do different driving tasks (velocity maintenance vs. self paced driving) lead to the same effects in those situations? and

(iii) Do corresponding situations in the video and in the real world give rise to the same pattern of acceleration or deceleration?

Additionally, subjective evaluations of both tasks have been elicited with questionnaires in order to check if they are rated in such a different way that the experiences cannot be compared.

Method

The general experimental plan is shown in Table 1.

Table 1:

TASK	SEX	FIRST CONDITION
speed maintenance	female	real life driving style
		simulatordriving style
	male	real life driving style
		simulator driving style
free driving	female	real life driving style
		simulator driving style
	male	real life driving style
		simulator driving style

Additionally, in a questionnaire data about the subjects´ driving style were obtained. As in Assmann (1985) nearly all variance could be attributed to three factors, namely,

Factor 1: following the traffic flow,

Factor 2: attitudes towards car driving, and

Factor 3: judging once own driving ability.

Using factor scores to classify subjects it was possible to determine the influence of the driving style in the two experimental situations.

Table 2 gives an overview over the route used in the experiments; numbers indicate the corresponding situations. In order to determine if accidental influences in the real-life driving influence the choice of velocity any of the following observations were timecoded: oncoming traffic, following traffic, slow traffic ahead, passing or being passed, cyclists on the lane, pedestrians on the lane or immediately beside the lane, and children close to the road. The real-life driving was done in a BMW 730i with an automatic transmission. During the field experiment all the relevant driving parameters were entered into an on-board computer.

Table 2:

#	Traffic situation or road section respectively	Speed limit	Description
1	Segment of a county road	60 km/h	straight, flat
2	Entering a village with a reduced speed zone (Oberisling)	60 km/h 30 km/h	slightly curved, incline
3	Passage through a reduced speed zone (Oberisling)	30 km/h	slight decline, straight ahead
4	Leaving the reduced speed zone (Oberisling)	30 km/h 60 km/h	right turn, approximately 60°
5	Entering the reduced speed zone (Leoprechting)	60 km/h 30 km/h	straight ahead, flat
6	Leaving the reduced speed zone (Leoprechting)	30 km/h 60 km/h	straight ahead, flat
7	Entering the reduced speed zone (Graß)	60 km/h 30 km/h	straight ahead, priority of the turning road
8	First T-intersection in Graß (without traffic signs)	30 km/h	90°-turn to the right, with right of the way
9	Second T-intersection in Graß (Sign:“yield")	30 km/h	90°-turn to the right, while respecting the „yield“ sign
10	Free lane road	60 km/h 50 km/h	straight ahead, slight decline
11	„Sleeping policemen“ with following cross-walk for pedestrians	30 km/h	straight ahead, slight decline
12	„Sleeping policemen“	30 km/h	straight ahead, slight decline
13	Connecting road	30 km/h	straight ahead, slight decline

52 subjects participated in the experiment, 26 female and 26 male, in the age range from 19 to 26 years (mean 24,1 years). Subjects had their driving licences between 1.8 and 11.8 years (mean 6 years). 26 of the subjects were driving more than 10 000 km/year, 26 less. Half of the subjects have had experience with an automatic transmission. Subjects got a fee of 15 DM. Two subjects missed either the simulator or the real-life driving situation, therefore their data could not be used in the comparison of the corresponding behavior.

The simulator consists of a BMW 325i, where by means of the above-described projection technique driving can be simulated. Figure 1 shows what has been simulated for the speed regulation and what variables have been skipped.

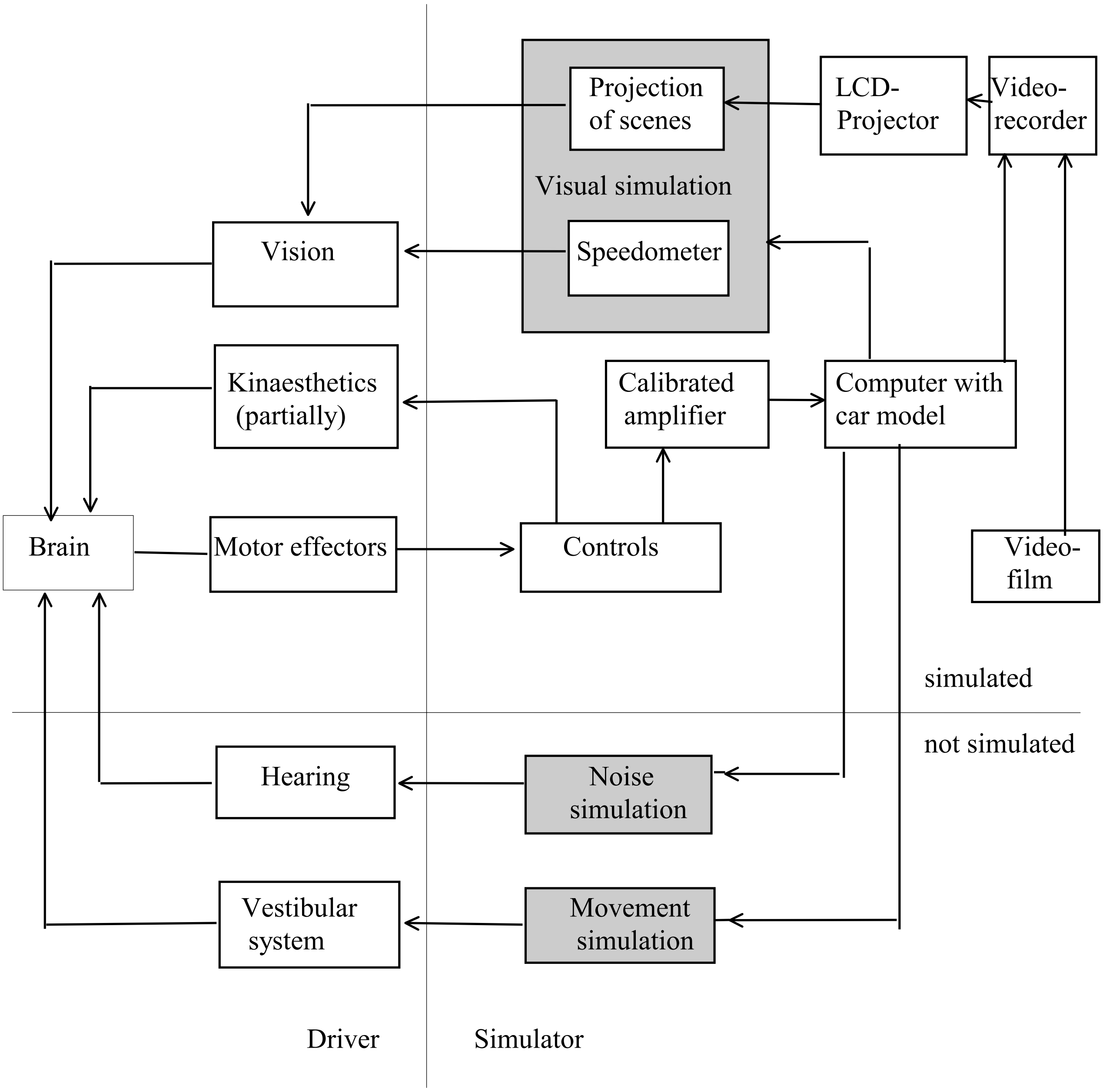

Figure 1: Influence diagram of the driver-simulator system

During simulation a virtual velocity is shown on the speedometer in the car. In order to influence the speed of the video realistically, the pressure on the effectors in the car (brakes and accelerator) are fed into a computer where by means of a formal car model the virtual speed is determined according to the following formula:

$$v_{psd} = \int_{t_0}^{t_f} (u^2 * (g - b/u) - u * v_{psd} * y) dt$$

u	=	$1 - (v_{psd} / v_{max})$	acceleration depending on the given velocity
g	=	$g_0 * 1{,}5$	pressure on the accelerator
b	=	$b_0 * 4{,}0$	pressure on the brake
y	=	$y_0 * 0{,}15 = 0{,}0\ 03$	rolling and air resistance

Due to the fact that the available videorecorder (Panasonic AG 7330) can not increase and decrease continually the following relation between the virtual velocity as shown on the speedometer and the projection velocity is as in Figure 2.

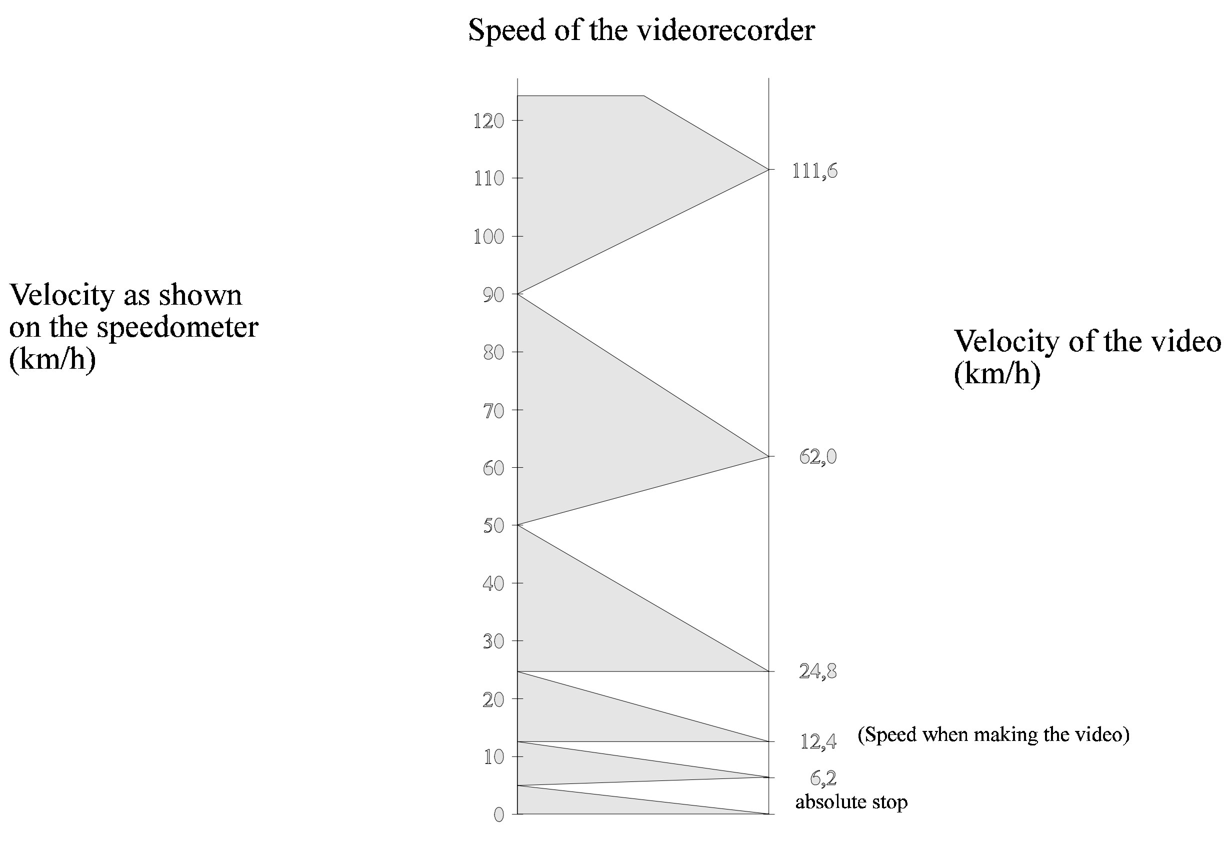

Figure 2: Relation between pseudospeed and recorder speed

Figure 3 shows the variability of velocity during one test drive.

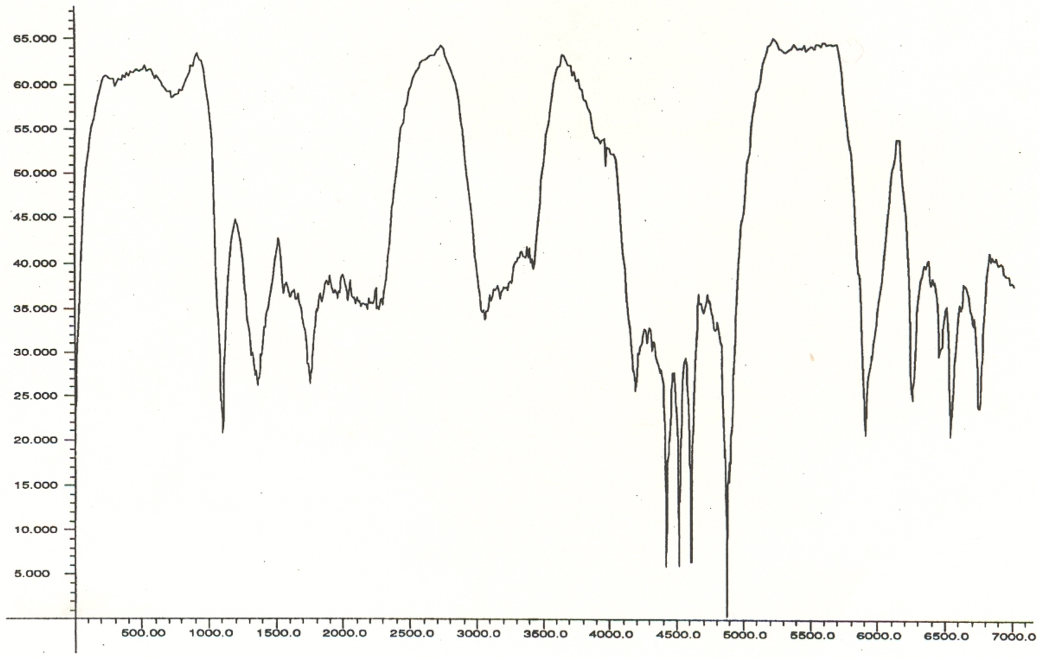

Figure 3: Curve of the driven speed in real-life driving (subject female, 21 years old with the task „speed maintenance") in relation to the position on the driving course.

Figure 4 shows the corresponding curve for the simulator condition.

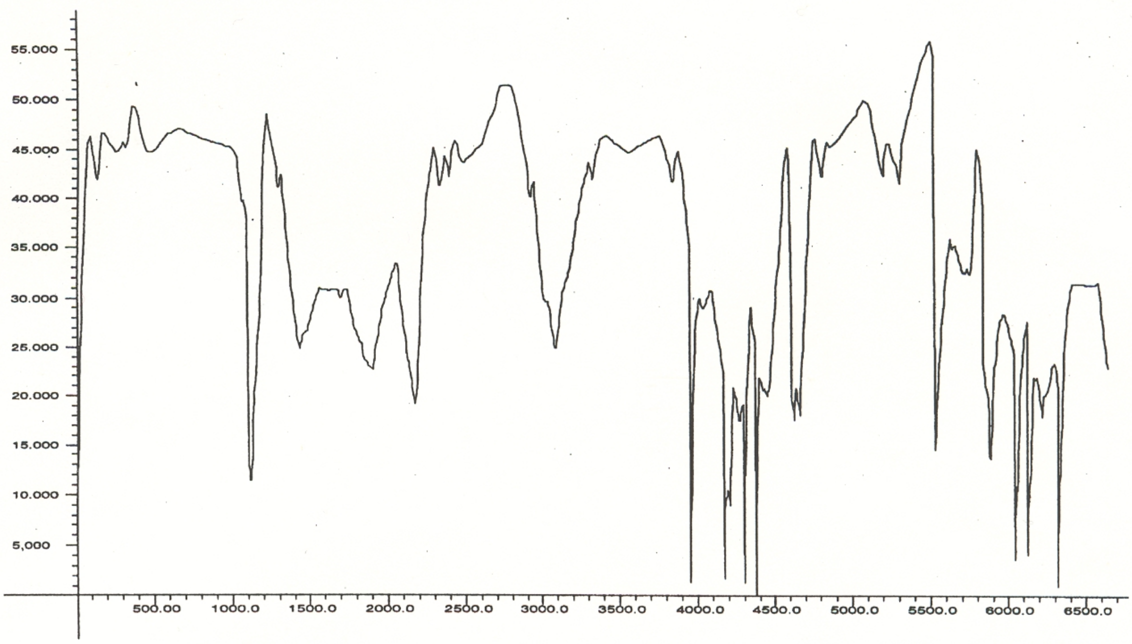

Figure 4: Curve of driven speed in the simulator in relation to the driven course.

Results

In general, subjects regard driving in real-life situations as easier (median answer: „easy") than in the simulator (median answer: „rather diffucult"). Furthermore, the simulator driving is regarded as needing more attention. Despite these differences, subjects when asked if the simulator influences their driving behavior, describe this influence as negligable (modal answer: „slightly if at all"). For this reason it can be assumed that the driving experience is comparable for both the field and the simulator.

Three analyses of variance regarding driving styles with the factor scores of the questionnaire on driving styles as the dependent variable, reveal no significant differences between real-life driving and simulator-driving with one exception: There is an interaction between the values of the factor 1 („going with the traffic flow") and the driving situation. The Scheffé-Test reveals that subjects who „go with the flow" increase the speed in the simulator in contrast to the subjects with negative factor scores who drive faster in the real-life situation.

An analysis of variance of the task („speed maintenance" vs. self-paced driving) shows significant main effects for the speed maxima and the average speed. The task „speed maintenance" induces slower driving (53,5 km/h) with less variance (1,62) than self-paced driving (67,8 km/h and 2,71 respectively) but no significant interaction with the driving situation (real-life vs. simulator). Furthermore, there is no significant influence of sex on the velocity regulation.

If one determines the average maximal velocity for the 13 situations (see Table 2) the following curves for real-life driving (upper curve) and simulator driving (lower curve) result (see Figure 5)

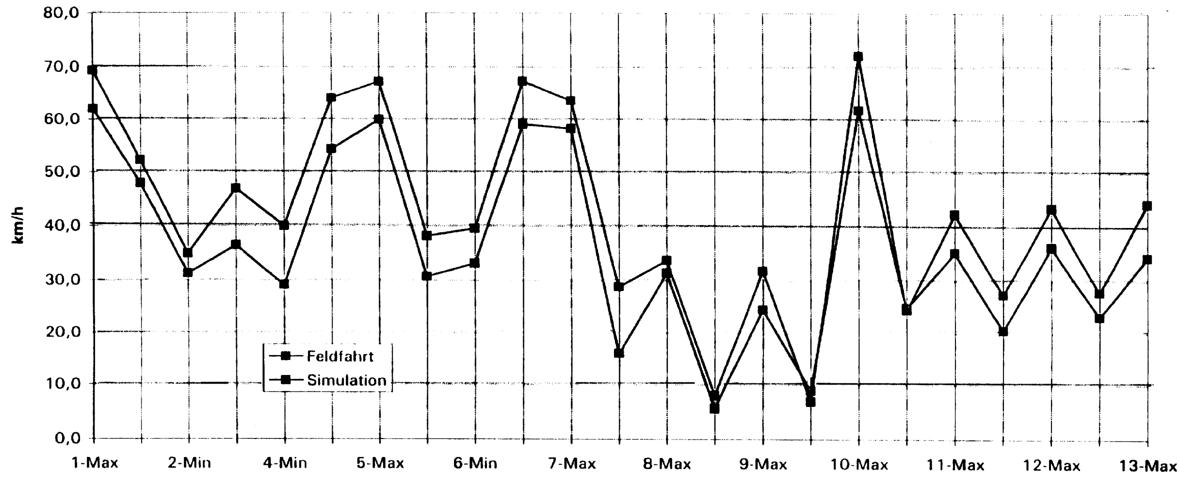

Figure 5: Mean values of the maximal velocities for the 13 situations

For all 13 situations (see Table 2) and all subjects the data for the real-life driving and for the simulator driving results of the scattergram in Figure 6.

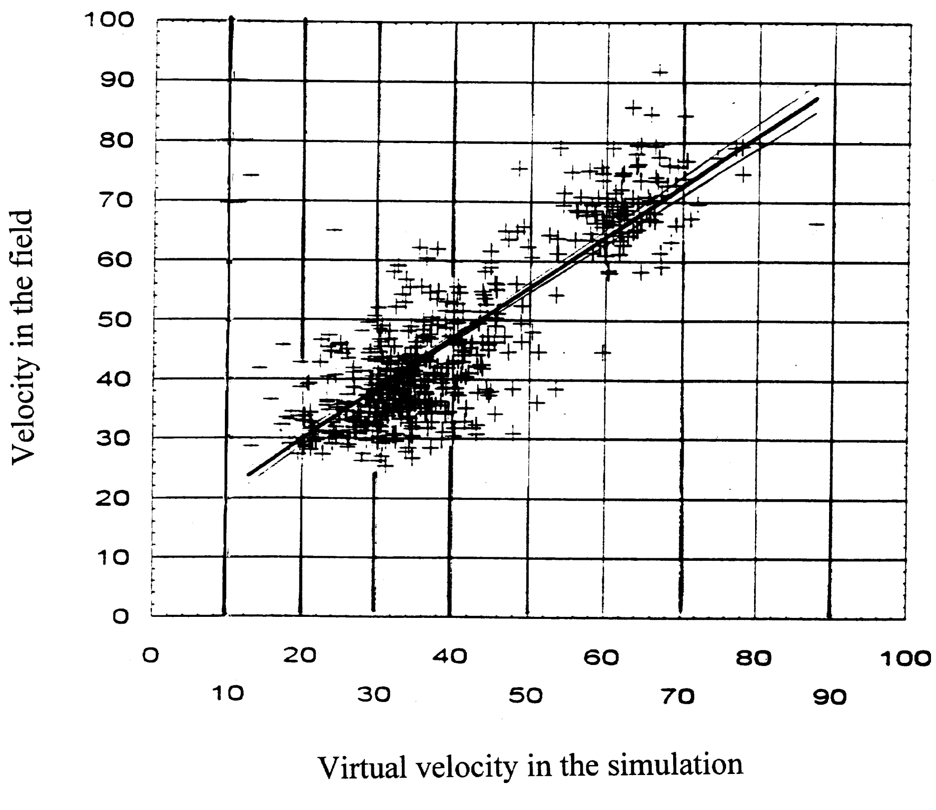

*Figure 6: Scattergram of driven velocities per situation in real-life driving and in simulator driving for all subjects (r = .7158; Regression (real-life) speed = 12.983 + .852 * simulatorspeed*

For all 13 situations (see Table 2) and all subjects the data for the real-life driving and for the simulator driving results of the scattergram in Figure 6.

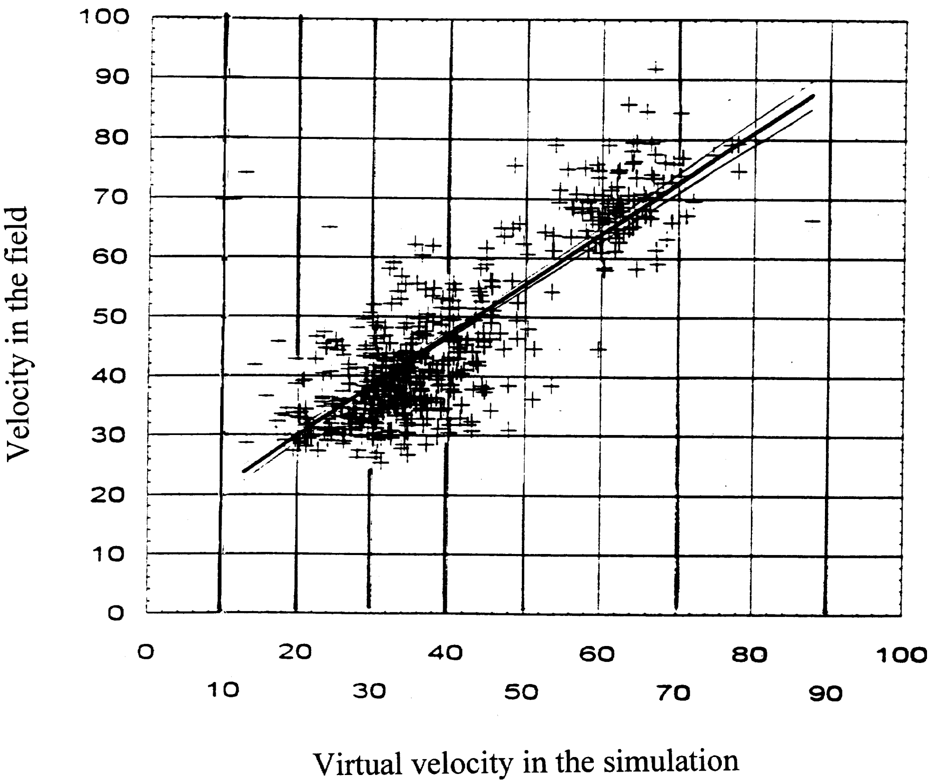

*Figure 6: Scattergram of driven velocities per situation in real-life driving and in simulator driving for all subjects (r = .7158; Regression (real-life) speed = 12.983 + .852 * simulatorspeed*

If one reduces the noise and uses only the mean velocities for the 13 situations the scattergram of Figure 7 results.

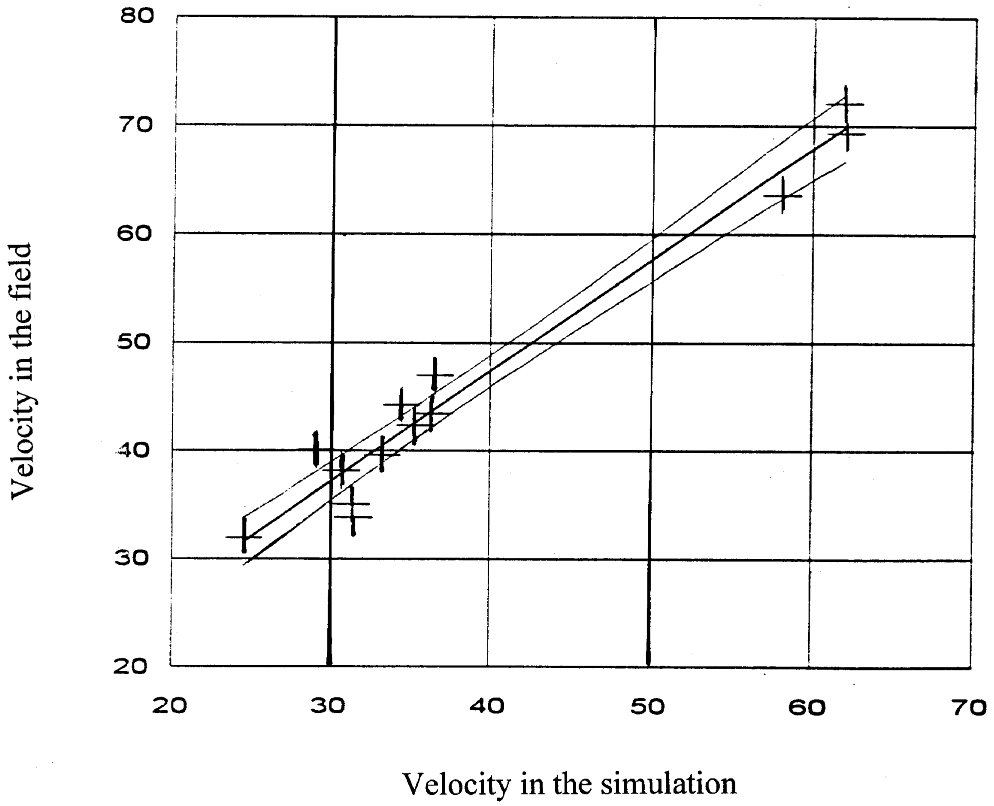

*Figure 7: Real-life driving velocities vs. simulator driving velocities (r = .982; Regression: (real-life) speed = 6.48 + 1.02 * simulatorspeed)*

Discussion

The data from the questionnaire where the subjects describe their experiences in the real-life driving situation and the simulator situation reveal that both situations are regarded as equally interesting and not influencing ones′ driving behavior. However, driving in the simulator is regarded as more difficult and requiring more attention. The reason for this might be that the simulator situation is novel and that the velocities in the simulator are not changed continuously but in steps. The fact that driving in the simulator is experienced as difficult and requiring special attention indicates that the motivation of the subjects is high even in the simulator situation. That is, when driving in the simulator subjects tried to exhibit „normal" driving behavior. This can be seen not only from the subjective reports but also from the fact that the observed driving style does not influence the driving in the two situations differently except for the interaction between „going with the flow" and average speed regulation, but also this influence is very slight. The conclusion can be drawn that in the two situations there is no differentiating influence of driving attituedes on the real-live vs. simulator driving.

Most important for the validation of the simulator are the situation dependent correlations of situation specific velocities in the simulator and in the real-life situation. Accelerating and decelerating behavior in real-life and simulator driving correspond nearly perfectly. The main influence on the driving behavior are the situational characteristics independently from the fact whether subjects experience real-life driving or simulator driving.

If one analyzes the individual correlations between the simulator data and the real-life data for the 13 situations, it turns out that only 4 subjects show correlations less than .5 but more than 75 % of the subjects show correlations above .85. The effect that the regression coefficient does not differ significantly from 1 shows that there is nearly a one-to-one correspondence between the driving behavior in real-life and in the simulator, only the additive constant of about 6 km/h shows the influence of a „tunnel effect“ in the simulator.

Conclusion

Standard approaches for estimating the validity of measures start from the theoretical assumption that the „true validity“ only depends on the correlation between the „true values“ in the measure and the „true values“ in the criterion. These „true values“ cannot be measured directly and are practically always confounded with the covariation of systematic errors. For these reasons the selection of situations, measures etc. has to be planned exactly: For instance, in the case of the evaluation of our video simulator it was not important that *individual* characteristics of drivers („speeding“ vs. „dawdling“ etc.) show in both situations but that the same *situational* factors elicit corresponding kinds of behavior, that is, for validating a simulator aimed at the improvement of traffic conditions the decisive carrier of information is not the *individual driver* but the *specific situation*. Generalizability of results therefore depends on the representativity of the situations. Insofar the video simulator can be regarded as a valid system for determinating situational characteristics of traffic safety.

Since finishing this field and simulator study the video simulator has been further improved, (i) it is now possible to increase and decrease the projection velocity continually, (ii) steering control can be simulated additionally by shifting the video picture to the left or right in accordance with a computerbased model of steering.

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