THE SPEED BEHAVIOR OF CZECH PROFESSIONAL DRIVERS ACCORDING TO ORDINARY VS. VARIABLE SPEED LIMIT SIGNS: AN ON-ROAD AND DRIVING SIMULATION-BASED COMPARISON

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Summary: Using the speed of professional truck drivers, the effectiveness of speed limit signs was compared for 1) a temporary variable-message sign that uses LED technology and displays the current speed limit (hereinafter "VSL sign") and 2) a normal vertical road sign with retroreflective sheeting (hereinafter "ordinary sign"). Measurements were made at two locations in the Czech Republic. Each location provided a different scenario with a different displayed speed limit on both types of signs (60 kph or 80kph). Similar measurements were made in a driving simulation. Drivers were more likely to slow down in the presence of a VSL sign than in the presence of an ordinary sign on a real road, however, no differences were found in the driving simulation. The overall results indicate that VSL signs seem to be respected more than ordinary signs in reducing professional truck drivers' speed. Therefore, VSL signs may be beneficial as a part of a telematic system and in places with high accident risk.

Keywords: Professional drivers, trucks, large vehicles, variable speed limit signs, speed reduction, LED traffic signs, traffic safety.

INTRODUCTION

The question of how to encourage drivers to decrease their vehicle speed when required or beneficial is an important one for increasing traffic safety for a number of reasons. For instance, speeding is one of the leading traffic violations resulting in numerous accidents (1). Generally, speeding less is linked with a decreased probability of being involved in a traffic accident (2), lower average speed leads to lower likelihood of being involved in a traffic accident (3), and, typically, lower speeds of vehicles in an accident situation mean less damage and reduction in the accident risks and costs (4,5). Sullman et al. (6) found that the violations factor in a driver behavior questionnaire (7), which mainly concerns disregarding the speed limit, significantly predicted the number of truck accidents in New Zealand.

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One way to reduce vehicle speed is to post traffic signs, however, drivers do not always slow down in the presence of traffic signs with speed limits, rather, they often tend to change their speed according to the credibility of the speed limit posted on such traffic signs (8). Different traffic sign settings can lead to differential effects of conveying their speed limiting message – for instance, Rahman and Strawderman (9) showed that a higher density of school zone traffic signs in a school zone leads to a lower average speed in the zone. Jongen et al. (10) found that drivers reduce their speed more at the end of the reduced speed section when the speed limit sign is repeated after every intersection and there is not only a speed limit zone sign used. Guan et al. (11) found that the earlier a traffic sign is placed before a curve, the earlier drivers start to reduce their speed.

Speed reduction is also dependent on the information written on the traffic sign – Bham and Leu (12) found that the most effective way to make drivers reduce speed is to display "stopped traffic ahead". Gregory et al. (13) researched which kind of traffic signs would reduce the speed difference between traffic-lights-stopped and non-stopped cars. When they put either text "Check speed" or flashing lights 70 meters after the intersection, the difference between stopped and non-stopped cars still existed. However, when they used both the text and flashing lights, the differences disappeared.

Instead of ordinary signs, variable speed limit (VSL) signs can be used. VSL signs help decrease the speed of cars in problematic parts of roads (14), and can help streamline traffic flow in work zones or places with a reduction in traffic flow (15; 16). Lee et al. (17) report that VSL signs are able to reduce the accident potential of cars in risky traffic conditions by 17 %. Moreover, VSL signs help improve the traffic flow by reducing speed variations in problematic parts of the road (18), or help reduce skids on a slippery road by showing a slippery-road image (19).

Thus, is it more effective to use a VSL sign or a different method to reduce drivers' speed? Rämä (20) put VSL signs on a highway and concluded that, in comparison with not using the variable signs, the average traffic speed was slower by 3-5 kph. Interestingly, variance can be found within different types of VSL signs with respect to their effect on speed reduction. Luoma and Rämä (21) compared two types of VSL signs - a fiber optic sign and an electromechanical sign – and found that using the former resulted in lower average speed of passing drivers. Possibly, the difference in speed was influenced by the driver's ability to detect the sign: the electromechanical signs were harder to recall later than were the fiber optic signs.

Our study concerns whether an ordinary sign or an VSL sign is more effective for reducing drivers' speed. We assessed driver speed in the presence of ordinary signs and in the presence of VSL signs in both real and simulated environments to answer this question. We employed truck driving simulator in the study design and therefore decided to study professional drivers also on the road. It is important to note that professionals drive differently

from those for whom driving is not their occupation – above all, they drive more safely. For instance, professional truck drivers are less often considered responsible for accidents in which they are involved than non-professional drivers (22). Häkkänen and Summala (23) report the causes of accidents of truck drivers in Finland. Half of the accidents where the truck driver was found to be responsible were caused by the driver's inattention or lack of anticipation. The driver's ability to anticipate could be improved by driving slower (23). Professional drivers tend to keep smaller distances to cars in front of them relative to non-professional drivers (24).

The speeding offenses of professional heavy-vehicle drivers correlate with their aggressive and thrill-seeking behavior, and professional drivers who commit speeding offenses more often are also more often engaged in traffic accidents (25). The speeding offenses of professional truck drivers are also influenced by fatigue, age, and education. The older and the less educated the driver, the more speeding offenses. Speeding offenses are more often committed by drivers who drive late at night and have a poor quality of sleep (26). The tendency to speed is also related to demographic variables – men tend to speed more often (27). Stavrinos et al. (28) found in a sample of American truck drivers that the more confidence the driver has about his driving skills, the more speeding violations he commits.

1. STUDY 1

In Study 1 we compared professional truck drivers' speed after they passed ordinary and VSL traffic signs on three different roads in the Czech Republic.

1.1 Materials and methods

We placed either an ordinary sign or a VSL sign in two different locations with different speed limits. We used LED sign as a VSL sign. The measurement spots were selected to fit the situation in the respective locations.

The first test location (road 1) was an inner city highway (GPS: 49.2205428N, 16.6171731E) with a speed limit of 60 kph since, at the time, it was an active work zone. Vehicle speed was measured at the sign (location A) and 100 meters past the sign (location B). There was a digressive road between the sign and the measurement at 100 meters past the sign, so some cars measured at the first spot might leave the road before the second measurement spot. First, the VSL sign was placed at the location for 24 hours (from 2 PM, 22.3.2017, to 2 PM, 23.3.2017), then an ordinary sign was placed at the location for the same period the following week (from 2 PM, 29.3.2017, to 2 PM, 30.3.2017).

The second test location (road 2) was another section of the same highway (GPS: 49.2200556N, 16.6108392E) with a speed limit of 80 kph (the speed limit before the sign was

also 80 kph, so in this case it was a repeated speed limit sign). Vehicle speed was measured 25 meters past the sign (location C) and 90 meters past the sign (location D). There was a road joining the current road between these two measurements, thus, some cars which were not measured at the first spot were measured at the second spot. First, an LED sign was placed at the location for approximately four days (from 3PM, 6.4.2017, to 6 PM, 10.4.2017), then an ordinary sign was placed at the location for the same period three days after (from 3 PM, 13.4.2017, to 6 PM, 17.4.2017).

Measurements were performed using Wavetronix, SmartSensor 125 HD. We only worked with measurements on trucks, buses, and other large vehicles. Prior to data collection, we observed cars on the highway road for one hour and compared our observations with radar observations. Trucks and other vehicles which require a professional driving license were found to be longer than 8.1 meters. Therefore, vehicles longer than 8.1 meters are considered a truck in the current research.

1.2 Results

We used the Mann-Whitney U test in the following analyses, because the assumption of normality was violated. Overall, trucks drove slower in the presence of an LED sign than in the presence of an ordinary sign. This difference was consistent across all four measured locations ($p < 0.001$). See Table 1 for details.

Tab. 1 - Speed per type of sign, Study 1

		Ordinary sign			VSL sign					
Road	Location	Mean speed (kph)	SD	N	Mean speed (kph)	SD	N	u-test	p	Cohen's d
1	A	74.04	10.20	2620	66.77	9.73	2796	-26.94	0.001	0.73
	B	76.56	10.49	1615	69.76	10.77	1960	-18.65	0.001	0.64
2	C	80.92	10.60	3085	77.40	10.06	8327	-16.86	0.001	0.34
	D	82.86	9.92	4007	79.46	10.13	7947	-17.33	0.001	0.34

Source: Authors

2. STUDY 2

In study 1, we have shown that truck drivers drive slower past a VSL sign than past an ordinary speed limit sign. Additionally, we wanted to compare the observations with those in a simulated environment, in an attempt to cross-validate the findings and contribute to the field-

wide effort of comparing data from simulated environments with those from real-road environments (29). Thus, we conducted second study where professional drivers drove in a driving simulator in environments similar to those in Study 1.

2.1 Participants

The participants were 41 professional drivers with a truck driver's license, recruited through advertisements in cargo companies, on the internet, and through word-of-mouth. Each participant received 1,000 CZK (approximately 46 USD) as a reward for their participation. All the participants were male with a mean age of 40.4 years (SD = 10.1). One participant did not finish the procedure because of simulator sickness. The procedure was described to participants prior to their participation and participants gave written consent regarding their research participation. As this research was conducted at a governmental institution, participants might have been worried about punishment for their driving mistakes during data collection. As such, they were assured that the collected data will be kept confidential.

2.2 Materials and methods

The participants undertook seven scenarios in the Autosim AS 1600 driving simulator. Autosim AS 1600 is a truck driving simulator with a truck cabin on a movable platform and three large screens in front and on both sides. Two scenarios were made to resemble the real locations where measurement was done in the first study. The first scenario was a 15-minute highway drive, which was only used to familiarize the drivers with the driving simulator. After the warm-up drive, the other four scenarios followed – all aimed to resemble the observed environments in Study 1. Scenario 1 was simulating a highway environment within city limits with a 60 kph speed limit sign, and vehicle speed was measured right at the sign (location A) and 100 meters past the sign (location B), much like at the Road 1 location in Study 1. Scenario 2 was identical to the first one, only there was a 80 kph speed limit sign and vehicle speed was measured at 25 meters (location C) and 90 meters (location D) past the sign, much like at the Road 2 location in Study 1. Both scenarios were administered twice, once with an ordinary sign and once with a VSL sign denoting the speed limit. Drivers drove through all scenarios in a random order.

2.3 Results

We used the Wilcoxon test to compare data in most cases, because the assumption of normality was violated. Only in a single case (location A) the test used was a paired t-test, as denoted in Table 2. There was no significant difference in vehicle speed with respect to sign type, and all the calculated effect sizes were rather small. See Table 2 for details.

Tab. 2 - Speed per type of sign, Study 2

		Ordinary sign			VSL sign					
Scenario		Mean speed (kph)	SD	n	Mean speed (kph)	SD	N	W	p	Cohen's d
1	A	70.524	9.216	40	69.336	8.676	40	0.847 (t)	0.402	0.13
	B	63.9	8.172	40	61.956	5.004	40	-1.485	0.137	0.29
2	C	78.48	5.4	40	78.984	3.096	40	-0.349	0.727	-0.12
	D	78.48	3.96	40	78.516	2.952	40	-0.639	0.523	-0.01

Source: Authors

3. DISCUSSION AND CONCLUSION

The first study conducted on real roads showed that drivers drive slower in the presence of a VSL sign than in the presence of an ordinary sign. This difference seems to be larger on a highway than on a country road, where the effect size very small (and likely without practical significance). The difference between the two types of signs, though, was not supported in the simulator study, where all calculated effect sizes were minimal. Naturally, the Study 2 participants might have not believed our confidentiality and might have been afraid to break traffic rules while participating in research being conducted by a governmental institution. This might have forced them to maintain their speed limit at both types of traffic signs, while in real circumstances they might not do so. However, a more plausible interpretation is that VSL signs are not used very often in Czech environment and, as such, represent a novelty. Novelty itself might be the reason why drivers are slower in real environment after seeing a VSL sign. On the other hand, the simulated environment is novel in its entirety, and participants might not react differentially to VSL signs precisely because such signs do no longer "stand out" as something unusual within the simulated environment. For these reasons, the conclusions based on data from real roads seem to have stronger validity. The overall results of our research support the idea that VSL signs are more effective than ordinary signs in making professional drivers slow down, however, this effect was not present in the simulated environment.

A VSL sign might be used to effectively reduce a driver's speed (14). How drivers respect the meaning of the traffic sign depends on how its message is presented (12); therefore, changing the type of traffic sign might help drivers follow it. Luoma and Rämä (21) and Rämä (20) found that if the correct VSL is chosen, it might reduce the automobile speed by 3 kph in comparison with other signs. Similarly, we found that using a VSL sign instead of an ordinary

one might reduce the average speed of professional drivers on a highway by 7 kph if it is the first speed limit sign and by 3 kph if it is a speed limit sign which repeats an already set speed limit. On a country road a VSL sign reduces the average speed by 2 kph in comparison with an ordinary sign.

Slowing down allows for better driver anticipation (23), which, in turn, should improve traffic safety. Therefore, a VSL sign might be a beneficial part of a telematic system or could, for instance, be planted in sites with a high accident risk, such as dangerous highway exit ramps, work zones, intersections, and so forth (Khorashadi et al., 2005). Further research could focus on how professional drivers decrease their speed past ordinary and VSL signs in these types of places.

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