<arttitle> Testing a new intervention to enhance road safety

<aug> Rainer Spiegel[1], Roger Kalla[1], Frank Spiegel[2], Michael Strupp[1]

<aff> [1]Department of Neurology, Ludwig-Maximilians University, Munich, Germany

[2]Faculty of Business Sciences, Technische Universität München, Munich, Germany

<abs> By 2020, it is estimated that road accidents will have moved from ninth to third in the worldwide ranking of burden of disease, as assessed in the disability adjusted life years (DALY)[1, 2]. Therefore, it is vital to find effective methods to enhance road safety. Speed limits and traffic calming have the potential to reduce injuries due to road accidents[3,4]. Many drivers, however, do not adhere to speed limits[1-7]. Several studies have shown that adherence to speed limits can be explained by the theory of planned behaviour[5-7] and that it is possible to focus on drivers' intentions via self-report questionnaires. It is often difficult, however, to reach the majority of drivers on accident-prone locations with self-report questionnaires. This paper demonstrates an intervention that can be interpreted in the light of two of the theory's key variables[8]. It also has the potential to reach a large number of drivers on such locations. It is a speed-displaying device mounted next to the road (especially in villages). It tells drivers their actual speed (which is publicly visible). The measurement takes place continuously, giving the driver the chance to adjust speed and see the new speed shortly thereafter. The results show that the feedback about the current speed is associated with a significant speed reduction relative to a Control condition.

<p> In various areas around Munich (Germany), communities have placed speed-displaying devices on locations where it is considered particularly important for people's safety that speed-limits are adhered to. Whilst speed cameras have been

considered effective devices for the prevention of road accidents[4], it might be too expensive to install a permanent camera at every location where a speed-limit is critical (e.g. near every school, playground, elderly home etc.). The cameras need an electricity supply and the photos need to be taken and analysed. An alternative way to support the adherence to speed limits might be solar-driven speed-displaying devices (mounted next to the road), informing drivers and the surrounding public about the driver's present speed. If the speed limit is 50 kilometers per hour and the motorist drives faster (e.g. 63 km/h), the device displays the 63 kilometers in bright red colour (see Fig. 1a). If the driver slows down or speeds up, s/he and the surrounding public can view the new average speed shortly thereafter. Speed is displayed until approx. 10 meters before the driver reaches the device. If the speed changes towards a speed equal to or slower than the speed limit, the colour changes from bright-red to yellow (see Fig. 1a for bright red display and Figure 1b for yellow display).

a

b

<LEGEND> **Figure 1** The solar-driven device displaying speed in km/h. **a**, the driver is faster than the speed limit of 50 km/h. Hence the speed is displayed in red numbers. **b**, the driver adheres to the speed-limit, so the speed is displayed in yellow numbers.

<p> Effective speed management leads to a reduction in road accidents[3,4], which are on the rise and cause enormous difficulties to both individuals and society[1,2]. According to the disability adjusted life years (DALYs), for example, where one DALY represents the loss of one year of equivalent full health[9], the consequences of road accidents will have moved from ninth to third place in the worldwide burden of disease by 2020[1,2]. As speed-displaying devices are specifically made for the purpose to enhance road safety, we tested how effective these devices are at reaching a significant speed reduction. From a theoretical point of view, there is reason to believe that these devices are effective. Although the actual aim of this paper is not to test the Theory of Planned Behavior (which is supported by a wide range of studies on human behaviour[5-7, 10-12]), nor does literature relate present theories to these devices (a literature search including PubMed or PsychIndex did not reveal any literature mentioning or citing studies on speed-monitoring devices other than speed cameras), there are at least two variables from the Theory of Planned Behavior that would make speed reduction with these devices likely: actual behavioural control as well as normative beliefs/subjective norm. First, it is likely that these devices enhance control over the driver's own behaviour, because they make it possible to have an eye on the road as well as on the device right next to it. Second, normative beliefs referring to behavioural expectations (e.g. expectations to avoid putting others or oneself at risk) and the subjective norm referring to the perceived social pressure to drive carefully at critical locations (e.g. at an entrance to a village) are likely to remind drivers of the need to slow down. Perceived social pressure is probably enhanced by the fact that the speed of the driver is also visible to pedestrians.

<p> This study therefore compared motorists in the presence of the device (=Experimental condition) at the entrance to a village with drivers at an equivalent location where no such device was mounted (=Control condition).

<meth1ttl> Methods

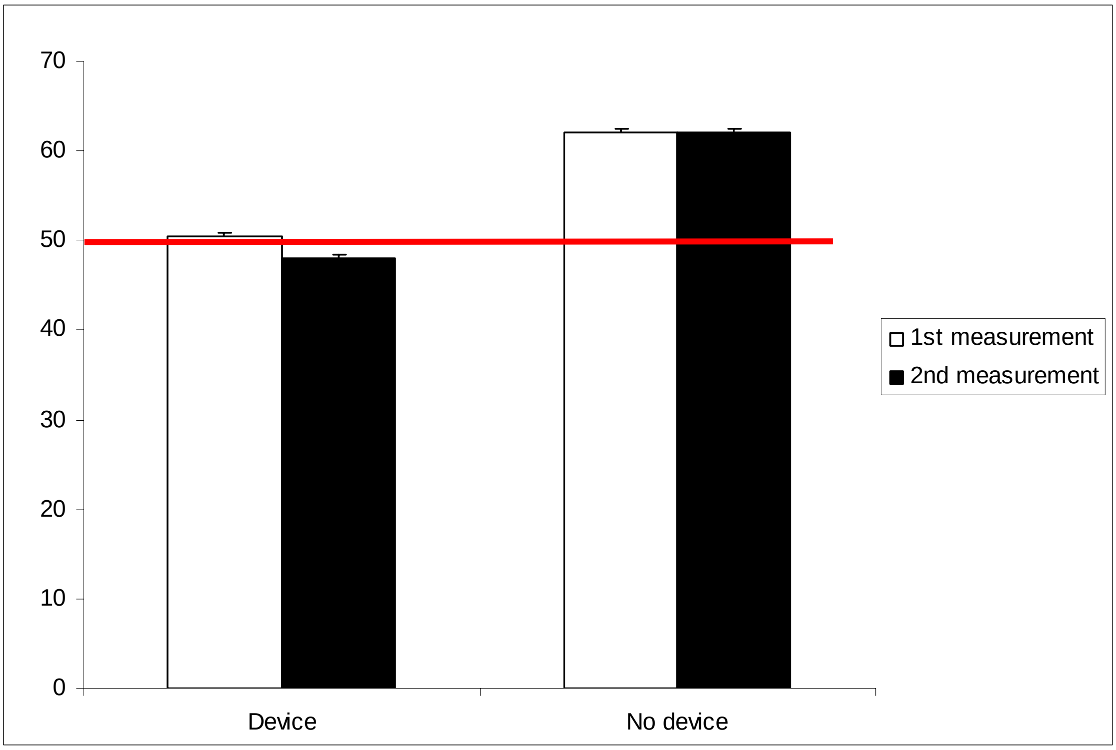
<meth1hd> The devices are mounted next to the road and give feedback about the motorist's average speed, which is assessed via radar (see supplementary material S1 for further details). The monitoring device used in this experiment displayed the average speed from a distance of approx. 55 meters until approx. 10 meters before the device was reached, i.e. the first display can show the average speed from Measure Point 1 to Measure Point 2 and lies at a distance of approx. 55 meters from the device. The second display can show the average speed of the next 45 meters (displayed at a distance of 10 meters prior to reaching the device), see Fig. 2 for an illustration.

<LEGEND> **Figure 2** An illustration of a car driving in the direction of a device, where the driver can see the present speed being displayed. The first measurement starts at measure point 1 (100 meters from the device). The average speed between 100 meters and 55 meters is displayed at measure point 2 (55 meters from the device). The average speed between 55 meters and 10 meters is displayed at measure point 3 (10 meters from the device). Consequently, the first measurement spans measure points 1 and 2, whilst the second measurement spans measure points 2 and 3. In this example, the average speed for Display points 1 and 2 are calculated over a distance of 45 meters each.

<meth1hd> Monitoring was done in kilometres per hour. Speed limits (50km/h) on both roads (the one with the device and the one acting as Control condition) were the same. For the Control condition, it would clearly have been easiest to measure after removing or disabling the device at the original location. This would have been unethical, though, as removing or switching off a device which is likely to enhance safety could have enhanced risk and would have been unacceptable to the local community. The measurement took place during daylight under clear sight, where it is likely to find children playing near the road. The study was not immediately carried out after the devices were introduced to its present location in March 2006, but 2 years later because otherwise it would be hard to say whether they have a stable effect on people's driving behaviour, for drivers may show habituating effects and simply ignore these devices after a while. The speed (first measurement vs. second measurement) of 120 motorists passing the device (Experimental condition) or 120 motorists passing invisible measurement points (Control condition) was measured. In both conditions, it took approximately 120 minutes until the vehicles had passed the device (approx. 1 vehicle per minute), refer to supplementary material S2 for details about speed assessment in both groups.

<p> **Results** In the Experimental condition, the average speed was 50.51 km/h (SE: 0.42) at the first measurement compared to 48.07 km/h (SE: 0.46) at the second measurement. The average speed reduction between the first and the second measurement was statistically significant, $t(119)=7.06$, $p<.001$. In the Control condition, the average speed of the first measurement was 62.13 km/h (SE: 0.69) compared to 62.04 km/h (SE: 0.7) at the second measurement. For the Control condition, there was no statistically significant difference between the two calculated speeds, $t(119)=0.36$, $p=.72$. Comparing the two conditions at the last measure point 3 (which is the one closest to the device in the Experimental condition), there is clear evidence that drivers are significantly slower in the presence of the device, $F(1, 238)=278.96$, $p<.001$,

$M_{Experimental\ condition}$=48.07 km/h ($SE_{Experimental\ condition}$: 0.46) vs. $M_{Control\ condition}$=62.04 km/h ($SE_{Control\ condition}$: 0.7). The results are displayed in Fig. 3. The presence of the device also seems to have an effect on how drivers approach the device, because the average speed between measure points 1 and 2 is already lower in the Experimental condition $M_{Experimental\ condition}$=50.51 km/h ($SE_{Experimental\ condition}$: 0.42) than in the Control condition $M_{Control\ condition}$=62.13 km/h ($SE_{Control\ condition}$: 0.69), $F(1,238)= 207.91$, $p<.001$ (Fig. 3).



<LEGEND> **Figure 3** The average speed of 120 motorists each (= 240 cars in total) in both Experimental and Control conditions (i.e. in the presence versus absence of the speed displaying device). The red line indicates the speed limit of 50 km/h. In the presence of the device, drivers reduce their speed to a speed within the limit (difference between first and second measurement). When no device was present, there was hardly a trend towards speed reduction between the two measurements, which were both clearly above limit.

<p> Looking at speed changes of individual vehicles, 90 motorists slowed down in the presence of the device, 23 kept constant speed, 7 became faster. 60 out of 120 motorists were above speed limit at the first display (between measure points 1 and 2), whilst only 35 were above speed limit at the second display. With no device present (=Control condition), 40 motorists slowed down, 39 kept constant speed and 41 became faster. 116 out of 120 motorists were above limit between measure points 1 and 2 and 116 were above speed limit between measure points 2 and 3 (in 114 cases it were the same drivers being above limit).

<p> **Discussion** In order to have an equivalent comparison between both conditions, one could ask for the same average speed to start with (otherwise it is difficult to argue that Experimental and Control condition were at comparable locations). This was indeed something we considered when carrying out our pilot work. In our 3 pilot experiments with 60 motorists per condition (which took place at different locations), the first average speed was already significantly higher in the Control condition than in the condition where a device had been present. There is at least one reason why the same speed cannot be expected. If these devices impact on people, it is likely that they approach them with a slower speed in the first place, for drivers might know the location of the device already. Consequently, these devices seem to have two effects: that people generally drive slower in the presence of them and that they reduce their speed. In spite of the fact that these devices do not cause penalty fares, there are several ways to explain this behaviour. It can be taken for granted that drivers know about the risk of speeding. Likewise, drivers know that other people know that speeding is wrong (e.g. pedestrians). One important observation during the study was a group of children standing on the sidewalk and yelling at a speeding motorist. Consequently, the behaviour of the motorists might be explained by normative beliefs as well as enhanced control over their own behaviour. Trying to shift the warning from red letters indicating

speeding to yellow letters might also have rewarding properties. Taken together, articles on road safety have been in the focus of scientific research for more than half a century[13-19]. These results provide a new and alternative way to reach speed reduction.

<bibcit>

1. Bunn, F., Collier, T., Frost, C., Ker, K., Roberts, I. & Wentz, R. Area-wide traffic calming for preventing traffic related injuries. *Cochrane Database Syst. Rev*. **1**, CD003110 (2003).

2. Wilson, C., Willis, C., Hendrikz, J.K. & Bellamy, N. Speed enforcement detection devices for preventing road traffic injuries. *Cochrane Database Syst. Rev*. **2,** CD004607 (2006).

3. Bunn, F., Collier, T., Frost, C., Ker, K., Roberts, I. & Wentz, R. Traffic calming for the prevention of road traffic injuries: systematic review and meta-analysis. *Inj. Prev*. **9**, 200-4 (2003).

4. Aeron-Thomas, A.S. & Hess, S. Red-light cameras for the prevention of road traffic crashes. *Cochrane Database Syst. Rev*. **2**, CD003862 (2005).

5. Elliott, M.A., Armitage, C.J. & Baughan, C.J. Using the theory of planned behaviour to predict observed driving behaviour. *Br. J. Soc. Psychol.* **46**, 69-90 (2007).

6. Elliott, M.A. & Armitage, C.J. Effects of implementation intentions on the self-reported frequency of drivers' compliance with speed limits. *J. Exp. Psychol. Appl.* **12**, 108-17 (2006).

7. Elliott, M.A., Armitage, C.J. & Baughan, C.J. Drivers' compliance with speed limits: an application of the theory of planned behavior. *J. Appl. Psychol.* **88**, 964-72, (2003).

8. Ajzen, I. The theory of planned behaviour. *Organizational Behavior and Human Decision Processes* **50**, 179-211 (1991).

9. http://www.who.int/healthinfo/boddaly/en/

10. Albarracin, D., Johnson, B.T., Fishbein, M. & Muellerleile, P.A. Theories of reasoned action and planned behavior as models of condom use: a meta-analysis. *Psychological Bulletin* **127**, 142-161 (2001).

11. Armitage, C.J. & Conner, M. Efficacy of the theory of planned behaviour: a meta-analytic review. *British Journal of Social Psychology* **40**, 471-499 (2001).

12. Hagger, M.S., Chatzisarantis, N.L.D. & Biddle, S.J.H. A meta-analytic review of the theories of reasoned action and planned behaviour in physical activity: predictive validity and the contribution of additional variables. *Journal of Sport and Exercise Psychology* **24**, 3-32 (2002).

13. Probst, T., Krafczyk, S, Brandt, T & Wist E.R. Interaction between perceived self-motion and object-motion impairs vehicle guidance. *Science* **225**, 536-538 (1984).

14. Charlton, T.M. Research on roads in Britain. *Nature* **180**, 588-589 (1957).

15. Frankl, E.K. A century of developments in Engineering. *Nature* **168**, 237-239 (1951).

16. Jeffcoate, G.O. Effect of motor patrols on accidents. *Nature* **166**, 639-640 (1950).

17. Davies, W.W. Road accidents and road structure. *Nature* **153**, 330-333 (1944).

18. o'Gorman, M. Research and road traffic. *Nature* **134**, 310-312 (1934).

19. Reichhardt, T. Car-safety lobby on collision course with researchers. *Nature* **423**, 675 (2003).

<supp> Style tag for supplementary information line '**Supplementary Information** accompanies the paper on **www.nature.com/nature**.'

<ack> There are no competing interests. The authors assure that they have no connections to any manufacturer or distributor of the devices mentioned in this article. The authors were entirely independent in terms of carrying out the study. The authors have received no funding from any manufacturer or distributor of speed monitoring devices, nor are they involved doing business with any individual, manufacturer or any company that holds business relations with the manufacturers/distributors. The authors thank the community of Oberhaching (a local community south of Munich) and the local police P31 for permitting them to carry out the study in their community and for their advice in terms of the measurement.

<corr> Correspondence and requests for materials should be addressed to R.S, Dept. of Neurology, Klinikum Grosshadern, Ludwig-Maximilian University, D-81377 Munich, Germany, E-mail: rainer.spiegel@campus.lmu.de.