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Does the effect of traffic calming measures endure over time? – A simulator study on the influence of gates

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ABSTRACT

Accident statistics show that transitions from rural to urban areas are accident prone locations. Inappropriate speed and mental underload have been identified as important causal factors nearby such transitions. A variety of traffic calming measures (TCM) near rural–urban transitions has been tested in field experiments and driving simulator studies. Simulator experiments repeatedly exposing participants to the same treatment are scarce, hence it is unclear to what extent the effects of a TCM endure over time.

This is precisely the objective of the current study: to examine what happens with the behavior of drivers when they are exposed multiple times to the same treatment (in this case a gate construction located at a rural–urban transition). Over a period of five successive days, seventeen participants completed a 17 km test-drive on a driving simulator with two thoroughfare configurations (gates present or absent) in a within-subject design. Results indicate that gates induced a local speed reduction that sustained over this five-day period. Even though participants were inclined to accelerate again once passed by this gate configuration, they always kept driving at an appropriate speed. We did not find any negative side effects on SD of acceleration/deceleration or SDLP.

Overall we conclude that gate constructions have the potential to improve traffic safety in the direct vicinity of rural–urban transitions, even if drivers are repeatedly exposed. Notwithstanding, we advise policy makers to appropriately use this measure. Best is to always carefully consider the broader situational context (such as whether the road serves a traffic- rather than a residential function) of each particular location where the implementation of a gate construction is one of the options.

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1. Introduction

Experimental research shows that the transition from rural to urban areas is a serious problem in terms of traffic safety (Charlton, Alley, Baas, & Newman, 2002; Galante et al., 2010; Taylor & Wheeler, 2000). It is hypothesized that accidents near these transitions are largely caused by inappropriate speed (Charlton et al., 2002; Hallmark et al., 2007). Furthermore, mental underload and failure to maintain a proper lateral position are – besides many other – behavioral causative factors for accidents, especially in horizontal curves (Charlton, 2007). Insufficient driver alertness and the (unconscious) tendency to speed in turn, could be related to the combination of a changing road environment (the spatial and structural properties of rural areas are typically less complex than those of urban areas and probably generate less mental arousal) and a suddenly changing speed limit (i.e., typically from 70 kph to 50 kph) (Ariën et al., 2013; Forbes, 2011). Appropriately designed transition zones are therefore of crucial importance.

Previous field experiments and driving simulator studies examined the effect of a variety of traffic calming measures (TCM) on major cross-town roads. Forbes (2011) grouped the transition zone treatments into four categories: geometric design (e.g., chicanes or central islands), traffic control devices (e.g., variable message signs or speed cameras), surface treatments (e.g., speed humps or transverse rumble strips) and roadside features (e.g., as gateways or landscaping).

In general, the surrounding context and the type of measure have a large influence on the established results (Forbes, 2011). The County Surveyor's Society (1994) analyzed 24 village traffic calming schemes and obtained mean speed reductions between 2 kph and 16 kph, which resulted in a decrease of all injury accidents and fatal/serious injury accidents by about 25% and 50% respectively. The Federal Highway Administration (2009) reported speed reductions up to 24 kph in France, Denmark and the UK. However, speed reductions of 8–10 kph appear to be more typical (Department for Transport, 1993). Hallmark et al. (2007) examined seven low-cost TCMs in a before–after field experiment (data collection at 1-, 3-, 6-, 9- and 12-month intervals) and obtained changes in 85th percentile speed from −14 kph to +6 kph. However, a detailed look at the results showed that, while the speed reduction effect of some TCMs sustained over time or even increased, other speed reductions diminished under repeated exposure. This 'habituation' effect is also reported by Charlton et al. (2002, pp. 346).

Various driving simulator studies (e.g., Ariën et al., 2013; Dixon et al., 2008; Federal Highway Administration, 2010; Galante et al., 2010; Molino, Katz, & Hermosillo, 2010) reported speed reductions from 3 kph to 17 kph for TCMs in the transition zone. Important to notice is that the results of Dixon et al. (2008), Galante et al. (2010) and Ariën et al. (2013) all indicate that these speed reductions are limited in terms of distance. Generally, speed reductions stretch out from 97 m before to 400 m after the TCMs studied, thus covering not much more than the nearby vicinity. Overall, transition zone treatments complemented with measures further along the through route are most effective (Forbes, 2011; Harkey & Zegeer, 2004; Taylor & Wheeler, 2000).

Although the main purpose of a TCM is the reduction of driving speed, we aim to investigate both longitudinal and lateral driving parameters because we want to approach driving behavior as a multi-dimensional, rather than a single-dimensional concept (RISER, 2006; Rosey, Auberlet, Bertrand, & Plainchault, 2008). The way in which drivers manage their speed mostly applies to the longitudinal dimension. Mean speed is often used as a measure for safe driving because of its positive relation with crash risk and severity (Safetynet, 2009; European Commission, 1999; Shinar, 2007). The acceleration noise, defined as the standard deviation of longitudinal acceleration and deceleration (SDAD), is a good indicator for the degree to which drivers are able to keep speed fluctuations under control (Ko, Guensler, & Hunter, 2010) and gives an indication for the smoothness of the traffic flow (Tapani, 2012). An abrupt speed change might disrupt the traffic flow and decreases the time to anticipate and/or react, which might in turn result in an increased risk for rear-end collisions. af Wåhlberg (2000, 2004, 2006) found some support for a positive relation between driver acceleration behavior and accident rates. The lack of a harmonized horizontal position of the vehicle within the driving lane is one of the primary factors in single-vehicle run-off the road accidents and head-on collisions and refers thus to the lateral dimension of driving performance (Rosey et al., 2008; Verster & Roth, 2011). The standard deviation of the lateral position (SDLP) is often used as an indicator for lateral trajectory control or the amount of 'weaving' of the car (Verster & Roth, 2011).

The advantage of field experiments is that they collect speed measurements for a large number of vehicles over an extended period of time. However, they are costly and not without methodological constraints because there is no control over factors such as weather and traffic conditions. Different from that, driving simulators provide researchers with total control over the various driving conditions that matter. In addition, simulator experiments are safe and cost efficient and a variety of driving performance data can be collected at a continuous high rate (Nilsson, 1993; Rudin-Brown, Williamson, & Lenné, 2009). Notwithstanding, according to Jamson and Lai (2011) "the simulator community should – amongst the usual challenges of simulator validity, participant self-selection and simulator sickness – also consider the potential influence of novelty effects on driving performance data". As for the latter, Shinar (2007, p. 763) describes a novelty effect as the phenomenon where "people's reactions are more extreme to new systems than to existing ones".

Evidently, such novelty effects do not only apply to the simulator systems themselves, but also to the specific treatments (for instance TCMs) being tested. Interestingly however, most of the simulator experiments carried out exposed participants only once to the treatment under investigation. Authors often acknowledge this as an important limitation to their results since indeed, it remains unclear what would happen with the treatment effects found in case participants would be exposed repeatedly to the same treatment (e.g., Ariën et al., 2013; Charlton, 2007; Comte & Jamson, 2000; Jamson, Lai, & Jamson, 2010; Kircher, 2007). To the best of our knowledge, there is only a handful of simulator experiments exposing subjects multiple times to an identical treatment. Roughly, these can be subdivided into two groups.