Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 14 (2016) 4277 – 4285

Transportation Research Procedia

www.elsevier.com/locate/procedia

6th Transport Research Arena April 18-21, 2016

Gantries or cantilevers for route guidance on a reorganized arterial road? A before study of route choice effectiveness using a traffic sign simulator (case study)

Kristof Mollu [a,*], Joris Cornu [a], Kris Brijs [a,b], Max Van Der Linden [c], Jaap de Boer [d], Tom Brijs[a]

[a]*Transportation Research Institute (Hasselt University), Wetenschapspark 5 bus 6, B-3590 Diepenbeek, Belgium*
[b]*Faculty of Applied Engineering Sciences: Road design (Hasselt University) Agoralaan Building H, B-3590 Diepenbeek, Belgium*
[b]*Connect Belgium, Maastrichterstraat 71, B-3500 Hasselt, Belgium*
[d]*iNFRANEA Belgium, Klokstraat 12, B-2600 Antwerpen, Belgium*

Abstract

This study evaluates ex-ante which of two signalization concepts is most effective at a reorganized arterial road in Hasselt (Flanders; Belgium): a gantry (advance direction sign above the road) or a cantilever (advance direction sign alongside the road). Over a distance of 500 meters, three intersections will be replaced by five intersections with traffic lights and the number of sorting lanes will be increased. The complexity of the situation poses a challenge as to how most optimally signalize route guidance.
Twenty-two participants drove seven different routes in a medium fidelity fixed-base simulator with a mock-up in front of a single projection screen. Participants were exposed to an animated graphic road environment that integrated a full HD video recording of the actual real life road environment and a virtually developed scenery. The video contained 3D animations of the foreseen geometric road realignments. We used a within-subject design with origin, destination, and signalization concept (gantry vs. cantilever) as the manipulated conditions in a randomized order. Participants were able to control the rendering of the video simulation by means of the gas pedal, mimicking speed. The direction indicator was used to signal lane switches and route-related decisions at a number of predefined locations. In addition, we recorded eye tracking data by means of a combined FaceLab-EyeWorks system. For each drive, we instructed participants to head for one of the destinations. In the analysis, reaching the destination (outcome of a decision) was less important as the performance at a decision point (optimal or suboptimal). Performance

* Corresponding author. Tel.: +32-(0)11-269-142 ; fax: +32-(0)11-269-199.
E-*mail* address: kristof.mollu@uhasselt.be

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)
doi:10.1016/j.trpro.2016.05.399

was measured in terms of capacity gains (correct car in the correct lane) and less weaving behavior (as a surrogate of traffic safety). At the end of the experiment the participants completed a short questionnaire.
Test scenarios with gantries resulted in more optimal decisions compared to scenarios with cantilevers and participants needed less attempts to reach the correct destination. Compared to the cantilevers, participants had more but equally long eye fixations on the gantries, resulting in a higher total fixation duration time for the latter. The questionnaire showed that 73% of the participants preferred the gantries over the cantilevers. Based on the simulator study gantries can be considered as more effective in terms of route guidance than cantilevers because they induce the lowest number of maneuvers. Consequently, the recommendation was to equip the reorganized arterial with gantries.

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

Keywords: Ex-ante evaluation; traffic signs; gantry; cantilever; Traffic Sign Simulator; road infrastructure; case study

1. Introduction

Signalization is an important aspect of a road. A first distinction which should be made in signposts is the difference between advance direction signs (placed before the junction and giving route information in respect of a junction ahead), direction signs (placed at a junction and pointing along specific routes) and finally route confirmation signs (placed after a junction and giving confirmation). According to the Traffic Signs Manual of the United Kingdom (Department for Transport, Department for Regional Development (Northern Ireland), Scottish Government, & Welsh Government, 2013)) there are two types of advance directional signs, gantries and cantilevers. This paper examines the difference between gantries and cantilevers (Fig. 1). Gantry mounted signs are placed above the road and give the direction for each lane or for a number of lanes. Cantilevers, or post mounted signs, are placed alongside the road. This study uses gantries which indicate for each lane the direction without arrows and uses a stack-type for the cantilevers. According to the Belgian legislation, the straight ahead direction must be at the top of the sign, the left-hand direction must be at the middle of the sign and the right-hand direction at the bottom (OCW, 2014).

A large part of the information required for driving is visual by nature thus traffic signs play an important role in driving behavior. Shinar (2007) cites several studies which argue that visual information is up to 90% in the driving task. Previous experiences built up by the driver give rise to expectations regarding the placement of traffic signs. This expectation helps the driver to pay attention to places where he assumes that information can be found (= top-down processing). According to Weller, Schlag, Gatti, Jorna, & van de Leur (2006) driving is a self-paced task and perception can be seen as part of the information-processing (chain) which consists of selection of relevant information, processing this information and the execution of the appropriate action. The effectiveness of signalization depends on some sequential user oriented criteria which result in the action of the driver (Lay, 2004). (a) The position of the sign relative to the road, the color, the contrast, etc. influences the *detection of a sign*. (b) The *sign readability* is influenced by the size of the letters, the amount of information units of the message, the position of the message field relative to the road, etc. (c) Drivers should readily understand a sign's intended message (*sign comprehension*).

Taking an intersection is a high demanding task for road users (visual search, gap estimation and decision-making). The turning movement involves different actions: *controlling* the vehicle at the desired speed and heading within the lane; *guiding* because there are numerous conflicts at an intersection; and *navigating* from origin to destination by reading signs (AASHTO, 2010). Furthermore, lane changing is the most critical facet in weaving (Transportation Research Board (TRB), 2010). Thus, at complicated intersection with multiple presorting lanes, such as the intersection in Hasselt, it is advisable that road users are in the correct lane before they enter the intersection. Consequently, the lane change maneuver is preferably done before the road user enters the intersection. A clear signalization which is processed early, shall result in an early presorting maneuver and less lane changes nearby the intersection.

This paper presents the results of a driving simulator study combined with an eye movement study regarding the signalization at the reorganization of an arterial road in Hasselt (Flanders; Belgium). Over a distance of 500 meters, three intersections will be replaced by five intersections with traffic lights with an increased number of sorting lanes (Fig. 1). The complexity of the situation poses a challenge as to how most optimally signalize route guidance. The present study investigates ex-ante the effectiveness of both signalization concepts with respect to traffic safety and accurate route guidance. The outcome of the present study will have significant impact on the design process of the reorganized arterial road by the Flemish Road Administration.

The main objective of this study is to perform a proactive evaluation of the signalization scheme of the reorganization of the road and, more in general, to compare the behavior towards gantries and cantilevers. This results in the following research question: *Which signalization concept (gantry or cantilever), in terms of capacity gains and less weaving behavior, is best for route guidance?*

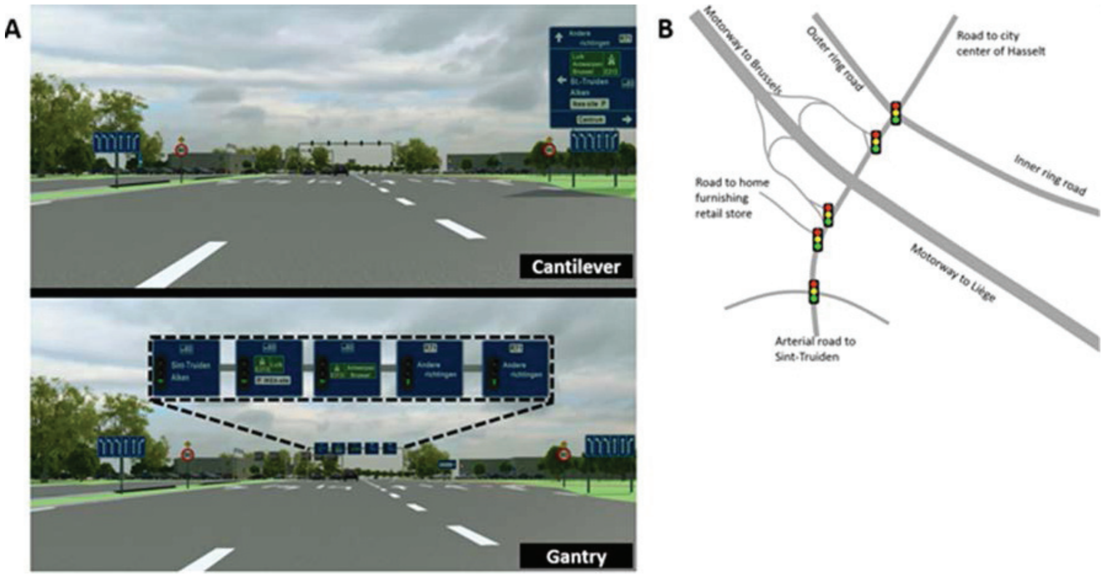

Fig. 1 (a) Two signalization concepts for advance directional signs: cantilever versus gantry (+ zoom on gantry); (b) Conceptual location of the reorganization.

2. Methods and Materials

2.1. Participants

In this study, a varied sample in terms of age and driving experience from the local area (i.e. Limburg region) was recruited. In total, 22 volunteers participated in the simulator study and all gave informed consent. None of the participants suffered from simulator sickness. Thus, 22 participants (ages 22 to 55; mean age = 35.6; SD = 9.5; 8 females) drove all the trips in the simulator. All had a car driving license for an average of 16.4 years (range 3 to 36 years; SD = 9.6). 63% Of the participants drove more than 15,000 km a year while the average in Belgium for 2013 was 15,284 km (Kwanten, 2014). All had normal (40%) or corrected-to-normal vision (60%) during the experiment. Six participants were excluded for the eye movement study because they had a bad calibration thus the analysis of the eye tracking data was based on 16 participants.

The current study was approved by the ethical committee of Hasselt University. Participants received a gift voucher from a bookstore (€20) as a reward for their participation.

2.2. Driving simulator

An important advantage of driving simulations is the possibility to drive in a virtually created environment so ex-ante evaluation can be done in a cost-effective way before important road design decisions are made. A proactive evaluation of (the quality of) the road design elements will help to improve the safety performance of roadways. Since experiments are conducted in a virtual environment and the simulation can be controlled, only hypothetical accidents can happen and the experiment can be kept under control. This way, confounding factors can be controlled. According to De Ceunynck et al. (2015) two types of driving simulator studies can be distinguished for evaluating traffic signs: either a virtually simulated road environment, or real-life video footage. Several studies used these kind of simulations for experiments regarding signs but none of them combined (eg. Ariën et al., 2013; Dutta, Fisher, & Noyce, 2004; Jongen, Brijs, Mollu, Brijs, & Wets, 2011).

The experiment was conducted on the fixed-base Traffic Sign Simulator (SignSim) of Hasselt University which, for first, combined a virtual environment and real-life video footage. The SignSim is an innovative research tool created by Hasselt University, Connect and iNFRANEA. Normally it only uses real-life images and implements signs. For this study, the tool was used to study road users' comprehension of traffic signs, the influence on lane choice and to collect suggestions for improvements to the signs. The mock-up consisted of a simple driving cab with a steering wheel, direction indicators, brake pedal, accelerator, clutch, and manual transmission. The visual virtual environment was presented on a 1.80 m by 1.06 m seamless flat screen by means of a high definition projector.

Participants were able to control the rendering of the video simulation by means of the gas pedal as a way to mimic acceleration/deceleration. When participants pressed/released the gas pedal, the video accelerated/decelerated. The direction indicator was used to signal lane switches and route-related decisions at a number of predefined decision points. These predefined locations were presented to the participant in combination with a decision time frame, i.e. a red bar which filled the bottom of the screen (Fig. 2). The decisional time frame was made dependent upon the driving speed, but on average the time to reach a decision was 4 to 5 seconds. When the direction indicator was used when the bar was completely full, the participants changed one lane to left or right or made a turn at an intersection. Use of the direction indicator was monitored by the experimenter and stored by the computer running the simulation.

2.3. Eye Tracking

An eye tracking system, FaceLAB 5.0 (Seeing Machines), was used to record eye movements. The eye tracker was installed at the dashboard of the driving cab and tracked eye movements via the relationship between the pupil and the reflection of the infrared light on the cornea. A sampling rate of 60 Hz at an accuracy of approximately 0.5 ° of visual angle (~1 ° at the periphery) was used. The system could accommodate head rotations of +/-45 ° and gaze rotations of +/-22 ° around horizontal-axis, allowing participants to have large freedom of movement. An overlay between the scenario video and the logged eye tracking was used afterwards to derive parameters which are related to the detection of the traffic signs, such as the number of glances at a certain traffic sign per participant or the duration of each glance. EyeWorksTM software (EyeTracking, Inc) was used to carry out these analyses.

Besides the eye tracker, a webcam monitored the participants to have full body picture.

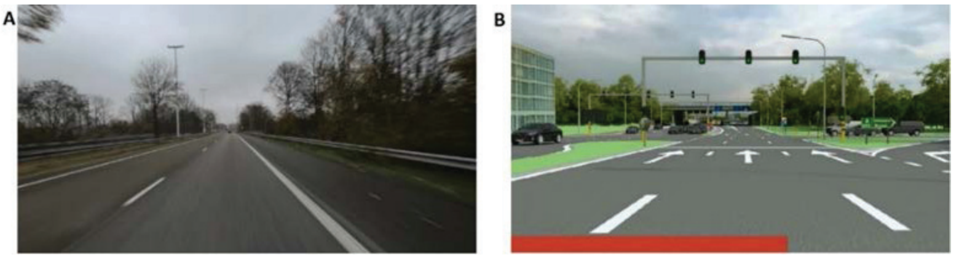

Fig. 2 (a) Real-life footage; (b) Simulated 3d world with red decision bar.

2.4. Scenario production

The *real-life routes* of interest were recorded using a high-resolution RED-cam camera with a wide angle lens which allowed to collect video footage in full-HD resolution (4096x2304 pixels in 16:9 aspect ratio). The camera was mounted on the hood of a minivan, so the footage was filmed from the viewpoint of a normal car driver. The minivan drove as much as possible at a constant driving speed. In case the driving speed during recording was lower than the customary driving speed on the route, the number of frames per distance was improved; the camera filmed at a rate of

2k 60 frames per second (also to reduce motion blur), but the distance which was traveled per frame by the camera was reduced by recording at a lower speed, which improved the quality of the final scenario film. In each route there was a transition from the real-life images to a simulated *3D environment*. This 3D world consisted of the 'to-be-foreseen' lay-out of the intersection and roads and included different 'to-be-foreseen' signs. It was not possible to work only with a real-life footage because not all the future road infrastructure was present in the current situation. At the beginning of each route we used the real-life footages to create a recognizable environment for the participants. Additionally, in the 3D world, we implemented recognizable landmarks as much as possible. Fig. 2 gives an illustration of both types of footage.

2.5. Procedure and scenarios

After the introduction of the experiment by the researcher and completion of the informed consent and a questionnaire related to some demographic questions, the researcher explained the working of the simulator. He explained the working of the lane changes at the decision points and the participant's influence on speed control. A practice session took place to acquaint drivers with the driving simulator and to let them practice the lane changes and the speed of the simulation. Hereafter, the eye-tracking equipment was custom calibrated by means of the software of FaceLAB and EyeWorksTM .

The experiment consisted of a within-subject design with origin (inner ring road vs. outer ring road vs. the arterial road), destination (city of Sint-Truiden vs. home furnishing retail store vs. motorway entry to Liège), and signalization concept (gantry vs. cantilever) as the manipulated conditions. Each participant drove 7 experimental trips of each approximately 2 km in a randomized order to cancel out order and potential learning effects. For each drive, we instructed participants to head for one of the three destinations. During the trips, the researcher did not influence the participants and noted all the verbal comments and lane choices of the driver. Table 1ffi presents an overview of the experimental design.

After the experiment in the simulator, the participant answered a questionnaire regarding the trips and their preference for one of the signalization concepts.

2.6. Outcome measures

Participants' route choice was monitored at each decision point while navigating through the different scenarios. Each lane switch or direction-related decision at a decision point was qualified by the researchers in terms of capacity and traffic safety gains. There were three performance levels:

- Optimal: The decision was done in a desirable way which means the participant used the predefined lane for his destination (capacity gain) so less weaving maneuvers needed to be done to reach the destination (traffic safety gain);
- Suboptimal: The decision was not done in a desirable way which means the participant did not use the predefined lane for his destination (capacity loss) so more weaving maneuvers needed to be done to reach the destination (traffic safety loss);
- Incorrect: The participant made an incorrect decision so he could not reach the destination.

During the test drives, participants' visual scanning and driving behavior were saved in an overlay video. A recording screen of the eye movements was merged with a simultaneous recording screen of the test drives. The average amount of fixations for each traffic sign and the average fixation time per fixation were calculated.

Table 1. Experimental design.

Origin	Destination		
	City of Sint-Truiden	**Home furnishing retail store**	**Motorway entry to Liège**
Inner ring road	Route 1 (cantilever)	Route 2 (gantry)	n/a
Outer ring road	Route 3 (gantry)	Route 4 (cantilever)	n/a
Arterial road	n/a	Route 5 (cantilever) & Route 7 (gantry)	Route 6 (gantry)

Table 2. Results at each decision point for each route.

		Optimal	Suboptimal	Incorrect
Route 1 (cantilever)	Inner ring > Sint-Truiden: decision A	9 out of 22 (41%)	13 out of 22 (59%)	N/A
Route 2 (gantry)	Inner ring > Home furnishing: decision A	15 out of 22 (68%)	3 out of 22 (14%)	4 out of 22 (18%)
	Inner ring > Home furnishing: decision B	6 out of 7 (86%)	1 out of 7 (14%)	N/A
Route 3 (gantry)	Outer ring > Sint-Truiden: decision C	7 out of 22 (32%)	15 out of 22 (68%)	N/A
	Outer ring > Sint-Truiden: decision B	13 out of 15 (87%)	2 out of 15 (13%)	N/A
Route 4 (cantilever)	Outer ring > Home furnishing: decision C	3 out of 22 (14%)	19 out of 22 (86%)	N/A
Route 5 (cantilever)	Arterial road > Home furnishing: decision D	15 out of 22 (68%)	N/A	7 out of 22 (32%)
	Arterial road > Home furnishing: decision E	14 out of 15 (93%)	N/A	1 out of 15 (7%)
Route 6 (gantry)	Arterial road > Motorway entry: decision E	16 out of 22 (73%)	N/A	6 out of 22 (27%)
Route 7 (gantry)	Arterial road > Home furnishing: decision D	22 out of 22 (100%)	N/A	0 (0%)
	Arterial road > Home furnishing: decision E	22 out of 22 (100%)	N/A	0 (0%)

**N/A: This performance level was not possible*

3. Results

3.1. Route choice

For neither of the two signalization concepts, gantries and cantilevers, did all participants reach the destination. The only difference between route 5 and route 7 was the signalization concept (both had the same origin (Arterial road) and the same destination (Home furnishing store)). When these two routes were compared with each other, 36% did not reach the home furnishing store in route 5 (cantilevers) while this was 18% for route 7 (gantries).

Table 2 shows for each route the results for each lane choice at the decision points. Participants choose a more optimal lane when a gantry was used (range from 32% to 100%) instead of a cantilever (range from 14% to 41%). This means a gain in capacity (the right car is in the right lane) and a gain in safety (less weaving maneuvers. The difference between both signalization concepts is most explicit in the comparison of decision point D (Table 2) between route 5 and route 7. The only difference between both routes was the signalization concept. At precisely the same location (point D), an identical choice needed to be made and the gantry (100% made the optimal choice) resulted in a more optimal lane choice than the cantilever (68% made the optimal choice). Furthermore, in route 5 at the cantilever at point D, 7 out of 22 participants made an incorrect lane choice so it was no longer possible to reach the destination while none of the participants made this error at the gantry in route 7.

The gantry in route 3 at decision point C was less effective than the other gantries (the lowest percentage of optimal choice; 32%). In this route, there were two gantries present and the results show that participants corrected their suboptimal behavior when they reached the second gantry. 13 of the 15 participants who first were not in an optimal lane (after decision point C) corrected their behavior at decision point B.

The questionnaire after the trips revealed that 73% of the participants preferred gantries above cantilevers.

3.2. Visual behavior

For visual behavior, the routes with the same origin were compared with each other. By doing this, the same kind of content on the direction sign and the same environment of the sign was compared with each other. For each pair of origin (route 1 vs. route 2; route 3 vs. route 4; route 5 vs. route 6 and 7), the average amount of fixations was higher for a gantry compared to a cantilever (1.4 to 3.0 times higher) and the average fixation time per fixation was the same. This resulted in a higher total fixation time on gantries.

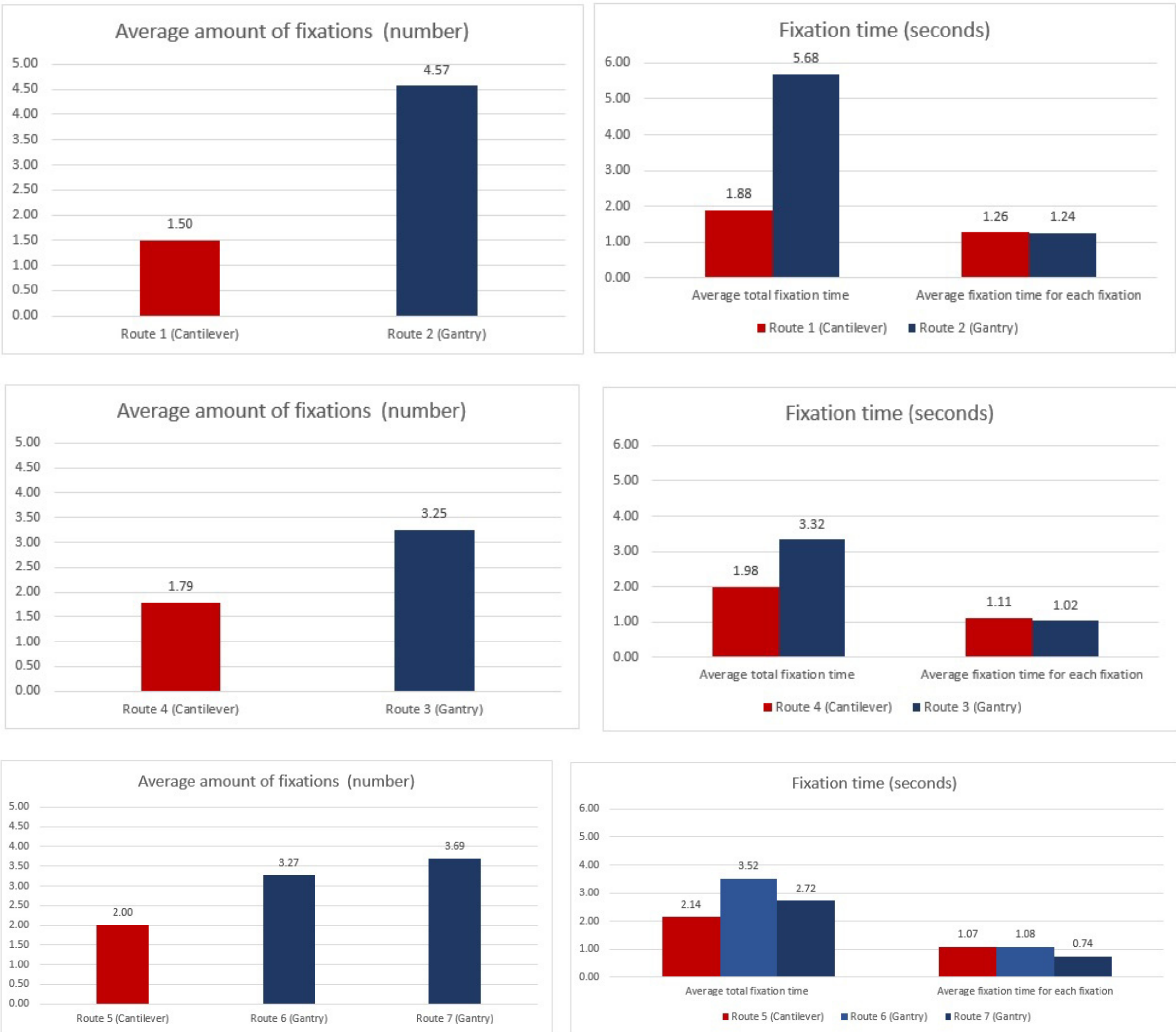

Fig. 3. Results of visual behavior of each route.

4. Discussion

This study at an intersection in Belgium indicates that gantries are more effective than cantilevers to obtain an optimal lane choice. This seems to be logical because a gantry can give specific route guidance information for each lane separately, while a cantilever only can give more general information related to route guidance. Nevertheless, participants did not always follow the gantry in an optimal way. This can be explained as follows:

- Road users regularly travelling through the environment knew which lanes could be used to reach the destination and did not follow the lane indicated by the gantry. This could somehow be related to the "three-term contingency model of behavior theory" (Fuller, 2004). According to this theory, the effectiveness of a traffic sign can be explained and predicted. The contingent relation between behavior and consequence is influenced by an antecedent event. This means, behavior followed by a rewarding consequence is strengthened, and behavior followed by an averse consequence is weakened. Or in this case, not following the optimal lane, has no aversive consequence or otherwise, following the optimal lane has no rewarding consequence.
- The legislation in Belgium obliges road users to drive at the most right lane when this is possible. Because there were several presorting lanes (up to 3 lanes) the most right lane was not always the optimal one.
- There were no white arrows on the gantries (while a white arrow was present on the cantilevers) but in the gantry the arrows were integrated in the traffic lights (green arrow in the simulation; see Fig. 1). The questionnaire revealed that 68% of the participants did not notice the traffic light in the gantry and thus neither the arrows. This could be attributed to the fact that the integration of a traffic light in a gantry is very new in Belgium and Flanders or to the limitations of the traffic simulator. Because not noticing the integrated traffic lights in the gantry could raise direct traffic safety problems, a limited qualitative field experiment with 15 participants was conducted. It has been proven that the traffic lights were well noticed.

An eye fixation towards a traffic sign could mean the driver does not pay attention to the road. However, brief glances (less than 2 seconds) away from the forward roadway for the purpose of scanning the driving environment are safe (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006). The average time per fixation was for both signalization concepts less than 2 seconds, thus it can be concluded that both signalization concepts are safe in relation to looking behavior. The higher total amount of fixations for gantries can be explained according to findings by Crundall, Van Loon, & Underwood (2006). They conclude that an object above the road attracts more attention because this is central in the field of view. Consequently, drivers do not have to move their head or eyes to see the information (Sanders, 1970).

In addition to the positive evaluation in the SignSim data regarding gantries, the questionnaire after the trips revealed that 73% of the participants preferred gantries above cantilevers. Reasons were: obvious to interpret at a distance, less distraction, more readable.

5. Conclusion

This virtual approach, based on a driving simulation, is very useful to evaluate a road design ex-ante. It can be conducted more frequently as it gives an useful feedback and helps understanding drivers' behaviour.

Based on the simulator study gantries can be considered as more effective in terms of route guidance than cantilevers because (1) they induce the lowest number of maneuvers, (2) the highest number of correct direction-related decisions, and (3) require an equally long total fixation duration time in order to be visually processed. This recommendation is justifiable because the road administrator can enforce, or at least, suggest a lane choice. By doing this, the capacity of the lanes can be influenced in a positive manner so lanes can be devoted to specific directions and there will be less weaving behavior. Consequently, this has a positive influence on traffic safety. This is related to other research (Martens, Brouwer, & Hoedemaeker, 2008) which advised to present important information such as advance direction signs central in the field of view and other information outside this functional field of view.

The Flemish Road Administration has followed the recommendations of this study and the reorganization of the arterial road in Hasselt is equipped with gantries. However it is not studied, we have received positive signs that the reorganization with gantries works well in real life and the traffic flows smoothly.

Acknowledgements

Part of this research was funded by grants from the Flemish Road Administration (Province of Limburg) and by the European Regional Development Fund. The authors thank Marc Geraerts and Daniël Purwin for technical assistance. The content of this paper is the sole responsibility of the authors.

References

AASHTO. (2010). *Highway Safety Manual* (1st ed.). Washington D.C., USA: American Association of State Highway and Transportation Officials (AASHTO).

Ariën, C., Cornu, J., Brijs, K., Brijs, T., Vanroelen, G., Jongen, E. M. M., Wets, G. (2013). Measuring the impact of digital information displays on speed: a driving simulator study (p. 17). Presented at the Transportation Research Board 92nd Annual Meeting, Washington DC, United States.

Crundall, D., Van Loon, E., & Underwood, G. (2006). Attraction and distraction of attention with roadside advertisements. *Accident Analysis & Prevention*, 38(4), 671–677.

De Ceunynck, T., Ariën, C., Brijs, K., Brijs, T., Van Vlierden, K., Kuppens, J., Wets, G. (2015). Proactive Evaluation of Traffic Signs Using a Traffic Sign Simulator. *European Journal of Transport and Infrastructure Research*, 15(2), 184–204.

Department for Transport, Department for Regional Development (Northern Ireland), Scottish Government & Welsh Government. (2013). *Traffic Signs Manual - Chapter 7: The Design of Traffic Signs* (4th ed.). London, United Kingdom: Crown.

Dutta, A., Fisher, D. L., & Noyce, D. A. (2004). Use of a driving simulator to evaluate and optimize factors affecting understandability of variable message signs. *Transportation Research Part F: Traffic Psychology and Behaviour*, 7(4–5), 209–227. http://doi.org/10.1016/j.trf.2004.09.001

Fuller, R. (2004). Motivational Aspects of Traffic Signs. In C. Castro & T. Horberry (Eds.), *The human factors of transport signs* (pp. 135–154). Boca Raton, USA: CRC Press.

Jongen, E. M. M., Brijs, K., Mollu, K., Brijs, T., & Wets, G. (2011). 70 km/h Speed Limits on Former 90 km/h Roads: Effects of Sign Repetition and Distraction on Speed. *Human Factors*, 53(6), 771–785. http://doi.org/10.1177/0018720811419848

Kwanten, M. (2014). *Kilometers afgelegd door Belgische voertuigen in het jaar 2013* (p. 53). Brussels, Belgium: Federale Overheidsdienst Mobiliteit en Vervoer - Directoraat-generaal Duurzame Mobiliteit en Spoorbeleid - Directie Mobiliteit.

Lay, M. G. (2004). Design of Traffic Signs. In C. Castro & T. Horberry (Eds.), *The human factors of transport signs* (pp. 25–48). Boca Raton, USA: CRC Press.

Martens, M. H., Brouwer, R. F., & Hoedemaeker, D. M. (2008). *Het Preview Project: Praktische vragen van wegbeheerders en antwoorden op basis van bestaande kennis* (No. TNO-report TNO-DV 2008 C101). Soesterberg, the Netherlands: TNO Defensie en Veiligheid.

OCW. (2014). Geïllustreerd reglement voor de wegbeheerder - Versie 21/01/2014. Opzoekingscentrum voor de Wegenbouw (OCW), Brussels.

Sanders, A. F. (1970). Some aspects of the selective process in the functional visual field. *Ergonomics*, 13(1), 101–117.

Shinar, D. (2007). *Traffic safety and human behavior* (Vol. 5620). Elsevier.

Transportation Research Board (TRB). (2010). *Highway Capacity Manual* (HCM). Washington DC, United States: Transportation Research Board - National Research Council.

Weller, G., Schlag, B., Gatti, G., Jorna, R., & van de Leur, M. (2006). Human Factors in Road Design. State of the art and empirical evidence. *Road Infrastructure Safety Protection–Core Research and Development for Road Safety in Europe.*