

How Do eHMIs Affect Pedestrians' Crossing Behavior? A Study Using a Head-Mounted Display Combined with a Motion Suit

Lars Kooijman ¹, Riender Happee ^{2,3} and Joost C.F. de Winter ^{2,*}

¹ Department of BioMechanical Engineering, Delft University of Technology, Mekelweg 2, CD Delft 2628, The Netherlands; L.Kooijman-1@tudelft.nl

² Department of Cognitive Robotics, Delft University of Technology, Mekelweg 2, CD Delft 2628, The Netherlands; R.Happee@tudelft.nl

³ Department of Transport & Planning, Delft University of Technology, Mekelweg 2, CD Delft 2628, The Netherlands

* Correspondence: j.c.f.dewinter@tudelft.nl

Received: 23 October 2019; Accepted: 26 November 2019; Published: 6 December 2019

Supplementary material

A video showing two trials can be found here:

<https://doi.org/10.4121/uuid:45378b74-4dab-465d-97dd-e593972d6125>

Figures S1-S4 and Tables S1-S2 show the results of signed-rank tests and paired-sample t-tests.

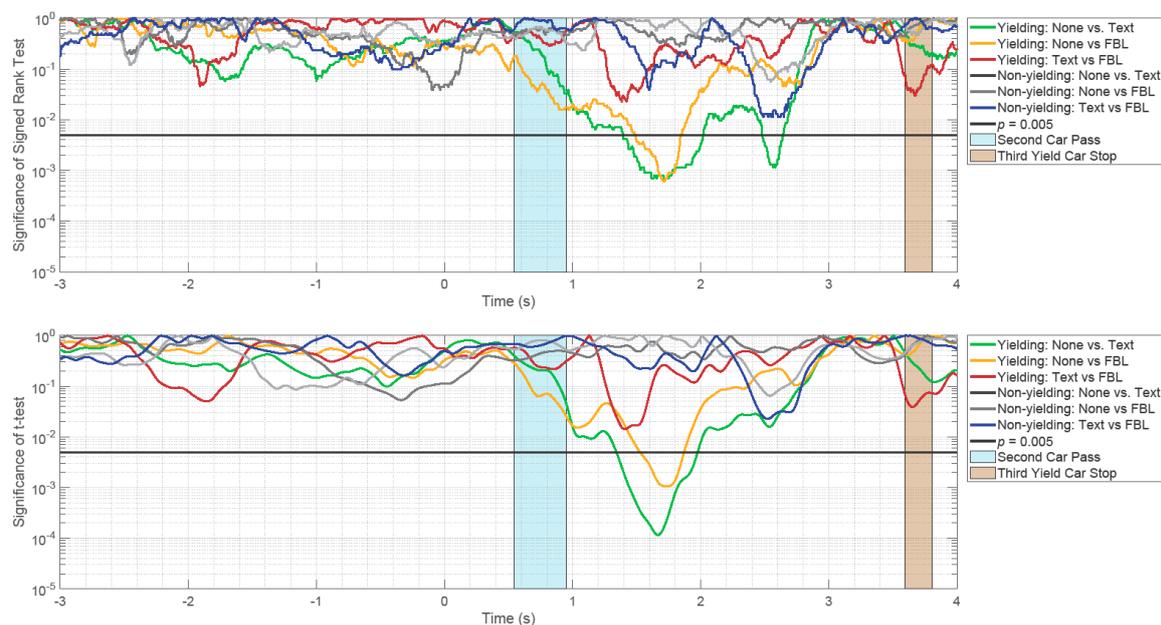


Figure S1. Results of signed-rank tests (top graph) and *t*-tests (bottom graph) of the forward gait velocities of participants during the conditions '20 meters, yielding' and '20 meters, nonyielding'. None = No eHMI, Text = Text eHMI, FBL = Front Brake Lights. *t* = 0 is the moment when the third vehicle in the platoon started braking.

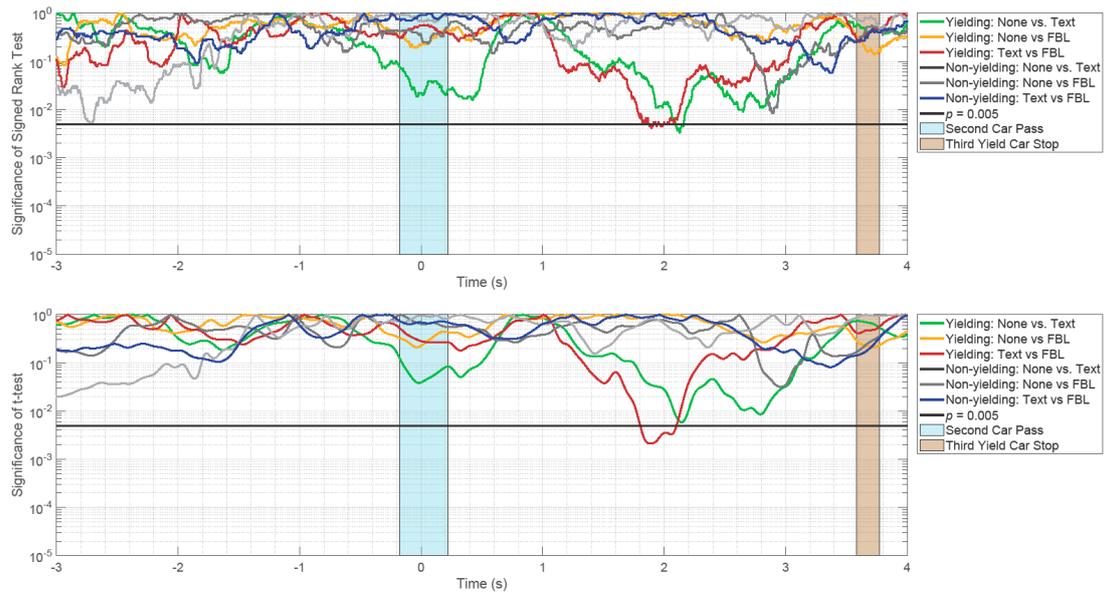


Figure S2. Results of signed-rank tests (top graph) and t -tests (bottom graph) of the forward gait velocities of participants during the conditions '30 meters, yielding' '30 meters, nonyielding'. None = No eHMI, Text = Text eHMI, FBL = Front Brake Lights. $t = 0$ is the moment when the third vehicle in the platoon started braking.

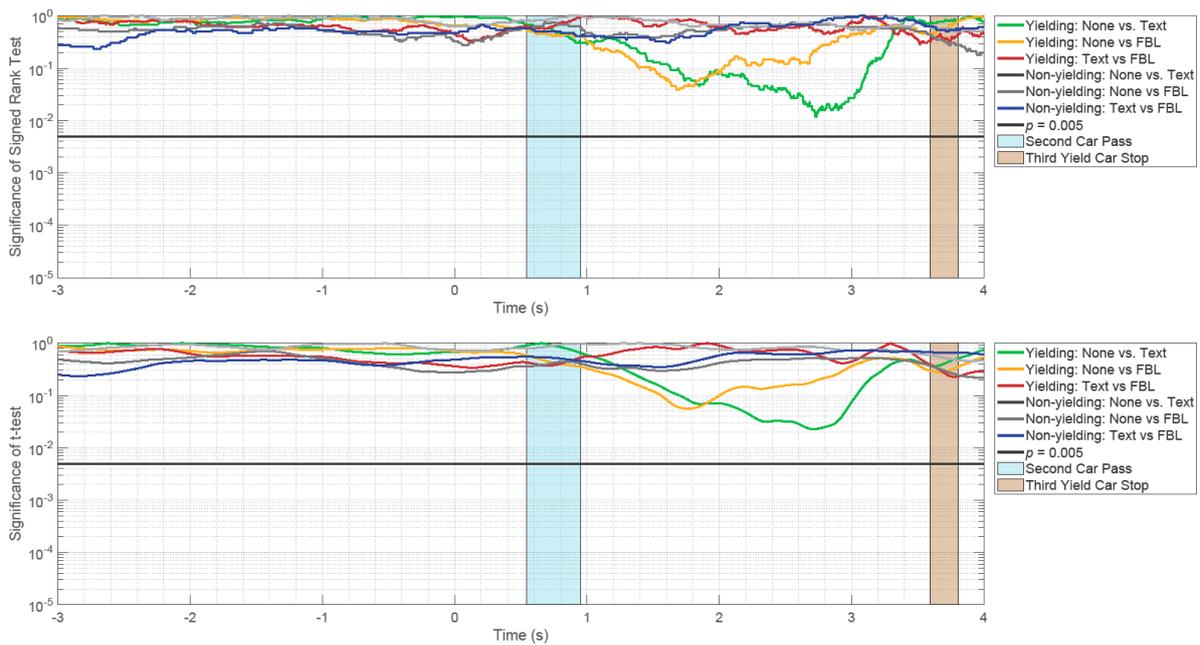


Figure S3. Results of signed-rank tests (top graph) and t -tests (bottom graph) of the thorax angles of participants during the conditions '20 meters, yielding' and '20 meters, nonyielding'. None = No eHMI, Text = Text eHMI, FBL = Front Brake Lights. $t = 0$ is the moment when the third vehicle in the platoon started braking.

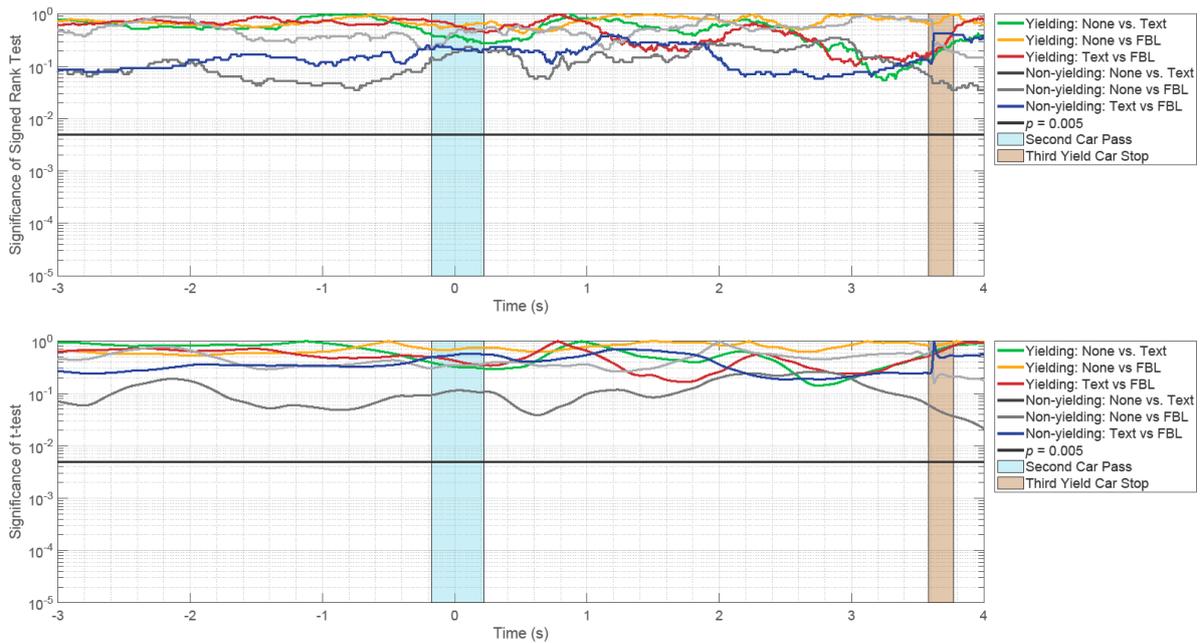


Figure S4. Results of signed-rank tests (top graph) and *t*-tests (bottom graph) of the thorax angles of participants during the conditions '30 meters, yielding' and '30 meters, nonyielding'. None = No eHMI, Text = Text eHMI, FBL = Front Brake Lights. $t = 0$ is the moment when the third vehicle in the platoon started braking.

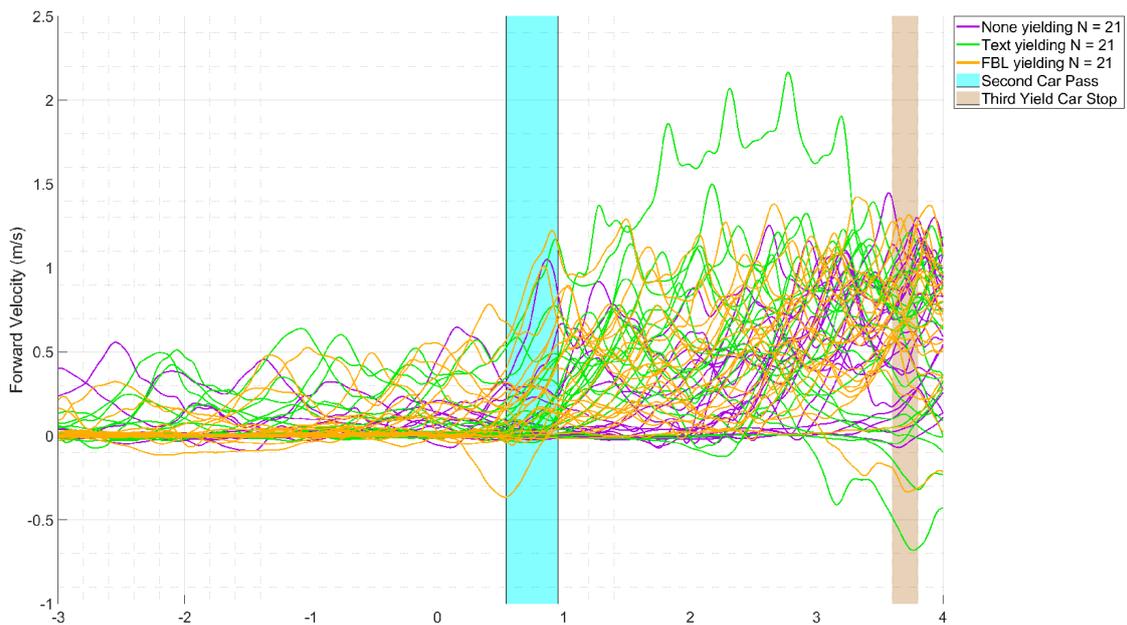


Figure S5. Forward gait velocities of participants during the condition '20 meters, yielding'. None = No eHMI, Text = Text eHMI, FBL = Front Brake Lights. $t = 0$ is the moment when the third vehicle in the platoon started braking.

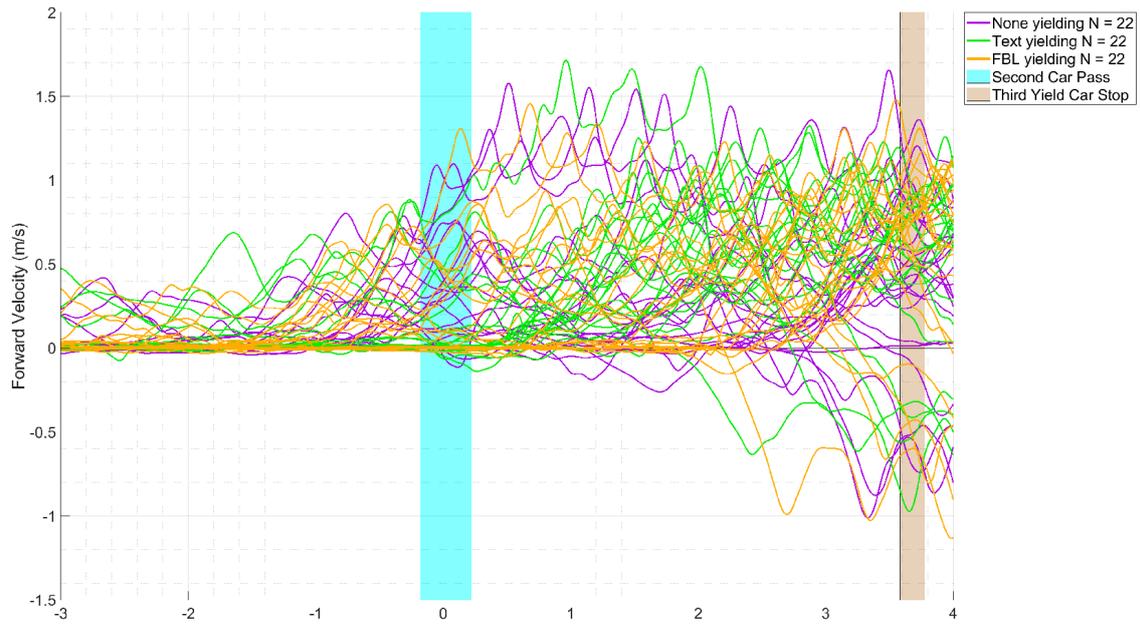


Figure S6. Forward gait velocities of participants during the condition ‘30 meters, yielding’. None = No eHMI, Text = Text eHMI, FBL = Front Brake Lights. $t = 0$ is the moment when the third vehicle in the platoon started braking.

Table S1. Descriptive statistics and results of signed-rank tests for the Moment of Leaving Curb (in seconds).

	None	Text	Front Brake Lights
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
20 meters yielding	3.67 (0.99)	2.75 (1.25)	2.97 (1.21)
30 meters yielding	2.94 (1.71)	2.28 (1.02)	2.59 (1.67)
20 meters yielding	None – Text	$Z = 3.48, p < .001$	
20 meters yielding	None – FBL	$Z = 3.25, p = .001$	
20 meters yielding	Text – FBL	$Z = -1.48, p = .140$	
30 meters yielding	None – Text	$Z = 2.06, p = .040$	
30 meters yielding	None – FBL	$Z = 0.70, p = .485$	
30 meters yielding	Text – FBL	$Z = -1.22, p = .224$	

Note. None = No eHMI, Text = Text eHMI, FBL = Front Brake Lights. Significant differences ($p < 0.017$) are indicated in boldface.

Table S2. Descriptive statistics and results of signed-rank tests of the comparison between the subjective responses of participants' difficulty to predict the behaviour of oncoming vehicles when an eHMI was either present or absent.

	None	Text	Front Brake Lights
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
20 meters yielding	4.48 (2.18)	2.43 (1.33)	3.43 (2.23)
20 meters nonyielding	3.63 (2.42)	2.25 (1.53)	3.88 (2.09)
30 meters yielding	4.36 (2.56)	2.91 (1.97)	4.00 (2.51)
30 meters nonyielding	4.28 (2.65)	2.89 (2.22)	4.06 (2.21)
20 meters yielding	None vs. Text	$Z = 3.09, p = .002$	
20 meters yielding	None vs. FBL	$Z = 2.40, p = .016$	
20 meters yielding	Text vs. FBL	$Z = -1.65, p = .099$	
20 meters nonyielding	None vs. Text	$Z = 2.21, p = .027$	
20 meters nonyielding	None vs. FBL	$Z = -0.83, p = .406$	
20 meters nonyielding	Text vs. FBL	$Z = -2.77, p = .006$	
30 meters yielding	None vs. Text	$Z = 2.31, p = .021$	
30 meters yielding	None vs. FBL	$Z = 1.13, p = .261$	
30 meters yielding	Text vs. FBL	$Z = -1.89, p = .059$	
30 meters nonyielding	None vs. Text	$Z = 2.54, p = .011$	
30 meters nonyielding	None vs. FBL	$Z = 0.72, p = .470$	
30 meters nonyielding	Text vs. FBL	$Z = -2.45, p = .014$	

Note. None = No eHMI, Text = Text eHMI, FBL = Front Brake Lights. Significant differences ($p < 0.017$) are indicated in boldface.

Table S3. Results from the 22-item presence questionnaire on a 7-point Likert scale ($N = 24$). Results are sorted on the mean response, from high to low.

Item number and question	Lowest label (1)	Highest label (7)	Factor	<i>M</i>	<i>SD</i>
18. How quickly did you adjust to the virtual environment experience?	Not at all	Less than one minute	Adaptation	5.88	1.19
19. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?	Not proficient	Very proficient	Adaptation	5.83	0.70
10. How completely were you able to actively survey or search the environment using vision?	Not at all	Completely	Involvement	5.63	1.10
16. How involved were you in the virtual environment experience?	Not involved	Completely engrossed	Involvement	5.63	1.01
13. How compelling was your sense of moving around inside the virtual environment?	Not compelling	Very compelling	Involvement	5.58	0.93
17. How much delay did you experience between your actions and expected outcomes?*	Long delays	No delays	Interface Quality	5.58	1.32
11. How well could you identify sounds?	Not at all	Completely	Sensor Fidelity	5.54	1.47
22. How well could you concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities?	Not at all	Completely	Adaptation	5.54	1.35

6. How natural was the mechanism which controlled movement through the environment?	Extremely artificial	Completely natural	Involvement	5.25	1.15
7. How compelling was your sense of objects moving through space?	Not at all	Very compelling	Involvement	5.25	0.68
3. How natural did your interactions with the environment seem?	Extremely artificial	Completely natural	Involvement	5.17	0.92
9. Were you able to anticipate what would happen next in response to the actions that you performed?	Not at all	Completely	Adaptation	5.00	1.06
12. How well could you localize sounds?	Not at all	Completely	Sensor Fidelity	5.00	1.50
4. How much did the visual aspects of the environment involve you?	Not at all	Completely	Involvement	4.92	1.25
8. How much did your experiences in the virtual environment seem consistent with your real world experiences?	Not consistent	Very consistent	Involvement	4.88	1.26
2. How responsive was the environment to actions that you initiated (or performed)?	Not responsive	Completely responsive	Involvement	4.63	1.74
15. How well could you examine objects from multiple viewpoints?	Not at all	Extensively	Sensor Fidelity	4.63	1.17
21. How much did the control devices interfere with the performance of assigned tasks or with other activities?*	Interfered greatly	Not at all	Interface Quality	4.54	1.74
14. How closely were you able to examine objects?	Not at all	Very closely	Sensor Fidelity	4.42	1.35
5. How much did the auditory aspects of the environment involve you?	Not at all	Completely	Sensor Fidelity	4.38	1.53
20. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?*	Prevented task performance	Not at all	Interface Quality	4.29	1.57
1. How much were you able to control events?	Not at all	Completely	Involvement	4.08	1.86

*These three items, which comprise the 'Interface Quality', have been reversed (8 minus the item score in the original questionnaire) for better interpretability. That is, in this table, a higher score reflects higher Interface Quality. In Table 4 of the paper, a higher score on the 'Interface Quality' scale reflects lower Interface Quality.