University of Groningen

The acceptance of a prototype rear-view assistant for older cyclists: two modalities of warnings compared

Engbers, Carola; Dubbeldam, Rosemary; Buurke, Jaap H.; Schaake, Leendert; de Goede, Maartje; Rietman, J.S.; de Waard, Dick

Published in:

International Journal of Human Factors and Ergonomics

DOI:

[10.1504/IJHFE.2016.083520](https://doi.org/10.1504/IJHFE.2016.083520)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version

Publisher's PDF, also known as Version of record

Publication date:

2017

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Engbers, C., Dubbeldam, R., Buurke, J. H., Schaake, L., de Goede, M., Rietman, J. S., & de Waard, D. (2017). The acceptance of a prototype rear-view assistant for older cyclists: two modalities of warnings compared. *International Journal of Human Factors and Ergonomics*, 4(3/4), 264-281.
<https://doi.org/10.1504/IJHFE.2016.083520>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

The acceptance of a prototype rear-view assistant for older cyclists: two modalities of warnings compared

C. Engbers* and R. Dubbeldam

Roessingh Research and Development,
Roessinghsbleekweg 33,
Enschede 7522 AH,
The Netherlands

and

Faculty of Engineering Technology,
Department of Biomechanical Engineering,
University of Twente,
P.O. Box 217,
Enschede 7500 AE,
The Netherlands
Email: c.engbers@rrd.nl
Email: r.dubbeldam@rrd.nl
*Corresponding author

J.H. Buurke

Roessingh Research and Development,
Roessinghsbleekweg 33,
Enschede 7522 AH,
The Netherlands

and

Faculty of Biomedical Signals and Systems,
University of Twente,
P.O. Box 217,
Enschede 7500 AE,
The Netherlands
Email: j.buurke@rrd.nl

L. Schaake

Roessingh Research and Development,
Roessinghsbleekweg 33,
Enschede 7522 AH,
The Netherlands
Email: l.schaake@rrd.nl

M. de Goede

Department of Earth, Life and Social Sciences,
TNO Soesterberg, Postbus 23,
Soesterberg 3769 ZG, The Netherlands
Email: maartje.degoede@tno.nl

J.S. Rietman

Roessingh Research and Development,
Roessinghsbleekweg 33,
Enschede 7522 AH, The Netherlands

and

Faculty of Engineering Technology,
Department of Biomechanical Engineering,
University of Twente,
PO Box 217, Enschede 7500 AE,
The Netherlands
Email: j.s.rietman@rrd.nl

D. de Waard

Faculty of Behavioural and Social Sciences,
Neuropsychology/Traffic Psychology,
University of Groningen,
Grote Kruisstraat 2/1,
Groningen, 9712 TS, The Netherlands
Email: d.de.waard@rug.nl

Abstract: The aim of this study was to evaluate the effects on behaviour, mental effort and acceptance of a simple prototype of an electronic rear-view assistance system designed for older cyclists that are at risk of falls. The prototype was incorporated into a simple cycling simulator and provided information about traffic from behind in two modalities: visual and haptic. Twenty-one older participants (>64 years) completed three conditions: warnings in two modalities and a control condition without warnings. Mental effort and acceptance were assessed using subjective rating scales and by monitoring changes in cycling speed. Less mental effort was reported when using the rear-view assistant. Significantly more correct decisions regarding a safe left turn were made with system advice. No significant speed differences were found between the two modality conditions. It is concluded that the electronic rear-view assistance system can potentially support the older cyclist successfully by warning for traffic coming from behind.

Keywords: acceptance; cycling speed; ergonomics; evaluation; human factors; mental effort; Netherlands; older cyclists; rear-view assistant; subjective rating; technological support; warning modalities comparison.

Reference to this paper should be made as follows: Engbers, C., Dubbeldam, R., Buurke, J.H., Schaake, L., de Goede, M., Rietman, J.S. and de Waard, D. (2016) 'The acceptance of a prototype rear-view assistant for older cyclists: two modalities of warnings compared', *Int. J. Human Factors and Ergonomics*, Vol. 4, Nos. 3/4, pp.264–281.

Biographical notes: Carola Engbers was born on May 22, 1988 in Enschede, The Netherlands. She performed her bachelors in Psychology in Enschede and graduated in Psychology in Groningen in 2012. She began working at Roessingh Research and Development in 2012 as a PhD student, which is about supporting the older cyclists in traffic. After graduation from Delft University (MSc Aerospace Engineering, 1996).

Rosemary Dubbeldam worked at Delphi Automotive Systems in Wuppertal, Germany, developing airbags for the automotive industry and lower extremity computer models (1997–2003). In 2005, she started as part-time Researcher at Roessingh Research and Development and assessed foot and ankle motion during gait of patients with rheumatoid arthritis. The data were eventually formed the basis for her PhD thesis (Twente University, 2012). Currently, as Senior Research Engineer, her projects include measurements and analysis of foot and ankle motion of patients with plantar fasciitis or equinovarus foot deformity after stroke; biomechanics of bicycle and cyclist; and the development of technological support for cyclists. Furthermore, as Physiotherapist (Van der Laan, 2007), she treats patients with foot and ankle problems.

Jaap Buurke, PT, PhD, received his PhD in 2005 from the University of Twente for his work on recovery of gait after stroke. He is track coordinator (Principal Investigator) of the Rehabilitation Technology Research cluster at Roessingh Research and Development, adjunct professor at Northwestern University, Chicago, USA, senior researcher at Roessingh Rehabilitation Centre, and he is affiliated to the biomedical signals and systems group of the University of Twente. He is specialised on human movement analysis. He is actively involved in a diversity of (inter)national projects focusing on motor control, movement analysis, rehabilitation robotics and active assistive devices.

Leendert Schaake received a B.Sc. degree (with honours) in biomedical engineering in 1992 and a B.Sc. degree in Telematics in 1993, both from the Hogeschool Enschede (the Netherlands). Since 1993, he works as laboratory manager and biomedical engineer at Roessingh Research and Development (the Netherlands). He has a special interest in movement analysis, biomechanics, the use of surface EMG and the use of telematics in combination with ambulatory measurement systems for the use of the remote monitoring of outpatients. He (co-)developed multiple measurement systems and proof of concept systems.

Maartje de Goede (1976) has been working as a researcher and consultant at the Traffic Behaviour Research Group at TNO Human Factors in Soesterberg, the Netherlands since 2009. She obtained a master's degree in Psychology and Cognitive Neuroscience (cum laude) at the Utrecht University. In 2009, she got her PhD at the department of Experimental Psychology of the Utrecht University on the subject: 'gender differences in spatial cognition'. Her main expertise is human factors in road design, traffic safety and vulnerable road users. She has been involved in several projects on safe road design, walking and cycling behaviour, traffic conflict analyses and road user interaction, in terms of perception, information processing capacities, comfort and acceptance. In 2014, she worked as a visiting scholar at the Research Institute for Transport Economics (TOI) in Norway on a Scandinavian cycling safety research project ('Safety in Numbers').

Prof. J.S. (Hans) Rietman, MD, PhD is physiatrist and professor in Rehabilitation Medicine and Technology at the University of Twente. He performs his clinical work as a rehabilitation physician at Roessingh Center for Rehabilitation. He is also appointed at the research institute Roessingh Research and Development and adjunct professor at Northwestern University, Chicago, USA. His research focuses on the clinical use of technology in restoration of functions in patients with neurological disorders and patients with amputations of upper and lower extremities. He is coeditor of the Dutch book of Rehabilitation Medicine for adults and the Dutch book of Amputation and Prosthetics of the lower extremities and (co)author of more than 80 Pubmed cited articles.

Dick de Waard is an Associate Professor of Traffic Psychology and the Retention of Mobility in the Department of Psychology at the University of Groningen. He received his PhD in Psychology from the University of Groningen in 1996.

1 Introduction

People in the Netherlands have a strong cycling ethos. Thanks to the introduction of the electric bicycle, older cyclists (65 years and older) typically continue cycling for more years than previously. However, older cyclists are at increased risk of injury (van Boggelen et al., 2005; Ekman et al., 2001; Oxley et al., 2004). Cyclists have a mortality rate eight times as high as that of car occupants (CEC, 2000; Ekman et al., 2001). Besides that, the risk of older cyclists being injured in a cycling accident in the Netherlands is on average 3.2× higher than for younger cyclists (Zeegers, 2010). Also injury severity increases with age (Oxley et al., 2004; Twisk et al., 2013). Even more important is that older cyclists are overrepresented in the group of seriously injured cyclists involved in single-sided accidents (Berveling and Derriks, 2012); accidents in which there is no other party directly involved (Weseman and Weijermans, 2011).

Turning left on a crossing is in particular considered as a problem by older cyclists in right-hand drive countries (Goldenbeld, 1992; SWOV, 2013). Older cyclists may have difficulty looking over their shoulder due to stiffness of the neck. In such cases, older cyclists often use the strategy of dismounting their bicycle (Bernhoft and Carstensen, 2011). However, dismounting is a potential risk to fall for older cyclists since many accidents occur while mounting or dismounting their bicycle (Hagemeister and Tegen-Klebingat, 2012). Another strategy can be to turn left in two steps, that is first cross one street and then the other (Hagemeister and Tegen-Klebingat, 2011). Or, as a compensatory strategy, many older cyclists rely on their hearing ability when turning left (Goldenbeld, 1992). However, it is dangerous to rely entirely on auditory information for several reasons. First, for older cyclists, hearing abilities reduce with age (Gordon-Salant, 2005). Second, the increasing amount of silent motorised traffic (electric and hybrid cars and motorbikes) is a complicating factor (Schoon and Huijskens, 2011). Another way to handle the complex situation of deciding whether it is safe to turn, may be to reduce cycling speed and hence increase the time available to process traffic information. However, it can be questioned whether slowing down is the best strategy. With reducing speed, a bicycle becomes less stable, and therefore the risk of balance problems and

consequently falling increases (Hubbard et al., 2011; Moore et al., 2011; Schwab et al., 2012).

Information about traffic approaching from behind could be made available to the cyclists in a straightforward way by adding a rear-view mirror to the bicycle. However, older cyclists often choose not to use a mirror as it confronts them with their limitations and makes this visible to others. Besides that, disabilities generally increase gradually and people like to hold on to old habits and behaviours (Berveling and Derriks, 2012). Furthermore, good mirrors in which traffic from behind is always visible are difficult to find (Fietsberaad, 2012). To increase the opportunity for older cyclists to continue cycling safely for as long as possible, a solution other than a mirror that can inform about traffic approaching from behind is therefore to be considered.

One possible way of making cycling for the elderly safer is to provide them with information about traffic approaching from behind. A so-called rear-view cycling assistance system could eliminate the need to look over one's shoulder or in a mirror. Although an actual rear-view cycling assistant or a working warning prototype is not available yet, in this study, such a system has been simulated to see how cyclists respond to it. This kind of technology is comparable to advanced driver assistance systems (ADAS), in-vehicle information systems and intelligence transport systems, such as collision avoidance systems in cars. ADAS can provide personal assistance in a traffic environment (Davidse, 2007). Several studies have suggested that ADAS may be able to provide tailored assistance for older drivers (Bekiaris, 1999; Dotzauer et al., 2015; Färber, 2000; Mitchell and Suen, 1997). However, handing over control to a device and automated functions are evaluated as negative aspects of assistance systems (Hoedemaeker, 1996; Hoedemaeker and Brookhuis, 1998). Therefore, during the design process of an assistance system, one has to take into account that end-user acceptance is an important prerequisite for implementation success (Brookhuis and van Driel, 2008; Van der Laan et al., 1997). In this sense, a rear-view cycling assistant system requires a design that is acceptable to its potential users in our case of older cyclists, and provides the optimal desired support.

A second issue that has to be considered when introducing ADAS is their impact on mental workload: the amount of information processing capacity that is used for task performance (Brookhuis and de Waard, 1993; 2000; de Waard, 1996). There is evidence that traffic communication and information systems can lead to an increased mental workload (Jahn et al., 2005), which might have a negative effect on safety (Verwey et al., 1996). Nevertheless, many positive examples of introducing ADAS in cars have been reported. Davidse (2007) concluded that information systems in cars can make the driving task easier without negative effects on workload. Brookhuis et al. (2008) stated that driving with a traffic-congestion assistant in cars potentially leads to decreased driver mental workload and acceptance is generally high after experiencing the system.

So far, no studies have evaluated the usage of traffic information systems on bicycles, hence we do not know if such a system would be accepted by older cyclists nor if such a system would have the potential to enhance cycling safety. Therefore, the aim of this study was to evaluate the acceptance of a prototype rear-view assistance for older cyclists by comparing two warning modalities (visual-light, haptic-vibration) for traffic from behind, compared to a control condition. The two warning types were compared with regard to acceptance, effects on mental effort and cycling speed. Also the extent to which cyclists follow the advice (whether it is safe or not to cross an intersection) which is

related to acceptance of the system was assessed. We focused on the effects of rear-view assistance on mental effort and acceptance of the system by older cyclists, because these two factors are crucial for the successful implementation of any new system. To analyse the safety potential of the system, cyclists' decisions to follow the advice of the system or not were related to whether it actually was safe or not to cross the intersection. Cycling speeds both before and after a warning for traffic from behind were compared to assess behavioural adaptation to these warnings. It was expected that taking the decision on whether it was safe or not to cross would be mentally demanding and accordingly respondents might compensate by slowing down.

2 Method

2.1 Participants

In total, 21 cyclists participated in this study. Participants were included if they were older than 64 years and cycled frequently (weekly) on a conventional or an electric bicycle. The included participants were between 64 and 78 years old and their average age was 69.8 years (SD: 4.4). Ten female participants and eleven males took part. Participants were recruited through a local newspaper advert and by the word of mouth. The participants were fully informed in advance and gave informed written consent to participate in the test. The test design, protocol and used equipment were approved by the regional Medical Ethics Research Committee. The participants were asked if they had difficulty looking at traffic approaching from behind when cycling.

2.2 Material

A simple and safe, cycling-in-traffic simulator was developed at Roessingh Research and Development that consisted of an instrumented bicycle, positioned on a cycle training stand (TACX T2650BluematicCycletrainer). The bicycle stayed firmly on the ground in the laboratory environment, but the front wheel was able to move. This setting was considered necessary to ensure sufficient safety during this stage of the design process. Furthermore, when cycling straight, the cycling motions are very limited (Moore et al., 2011). A fixed resistance was set up on the bicycle to simulate a natural cycling resistance. The instrumentation of the bicycle consisted of speed sensors built into the rear wheel of the bicycle. The rear-view assistant's feedback was evaluated in two modalities:

- 1 haptic vibration actuators (eccentric rotating mass pager motors) mounted in the handles
- 2 a visual LED display containing two red and two green LEDs mounted on the handle bar.

The bicycle was positioned in front of a large TV screen (65 inch) on which a video was shown. Two-and-a half metre behind the bicycle, a 71-inch screen was placed, on which a still picture of traffic from behind was shown. This set-up was chosen because, when normally cycling and looking over one's shoulder, there is only limited time, which is

comparable to a still view. The participants had to anticipate for traffic coming from behind when turning left. The screen was placed under the angle of 67.5° from the bicycle. Together, the screens displayed a typical cycling environment (Figure 1). No traffic sound was available.

Figure 1 Experimental set-up. On the left a schematic overview, and on the right a close up of the vibrating handles and the LED display (see online version for colours)

The software for the bicycle simulator was written in Python 2.6. The software controlled the display of the video in front of the bicycle and of the still image of the traffic situation behind the bicycle. The display speed of the video was matched to the cycling speed of the participant, so the video started when pedalling started. Steering did not affect the images displayed. Signals from the sensors from the instrumented bicycle were sampled at 1000 Hz using a NI USB-6008 12-bit multifunction DAQ (National Instruments, Austin, USA). The actuators were controlled by digital and analogue signals generated via the NI USB-6008 DAQ mentioned earlier.

2.3 Measures

2.3.1 Rating scale mental effort

The Rating Scale Mental Effort (RSME, Zijlstra, 1993) was used to assess mental effort, which was based on the cyclist's subjective rating of invested effort. The RSME is a unidimensional rating scale consisting a line with a length of 150 mm marked with nine anchor point, each accompanied by a descriptive label indication a degree of effort, ranging from 'no effort-some effort' (score 2/38) to 'extreme effort' (score 112, max score 150). The RSME has proven to be good self-report measure of mental workload (Zijlstra, 1993; Widyanti et al., 2013) and correlates well with other subjective methods to assess mental workload, such as the NASA TLX (Veltman and Gaillard, 1996).

2.3.2 Acceptance scale

Acceptance of the system was assessed using an acceptance scale (Van der Laan et al., 1997) after each test condition (vibration, light and control condition). This scale includes the following opposing items: 'useful-useless', 'pleasant-unpleasant', 'bad-good', 'nice-annoying', 'effective-superfluous', 'irritating-likeable', 'assisting-worthless',

‘undesirable-desirable’ and ‘alertness increasing-sleep-inducing’. Each set of opposite items was scored using a semantically differential 5-point Likert scale. The scale results consist of two subscales that reflect acceptance in two dimensions: usefulness and satisfaction.

2.3.3 Cycling speed

A movement sensor in the rear wheel sampled the position of the wheel at 1000 Hz. Cycling speed was derived from this signal and expressed in metres per second (m/s).

2.4 Procedure

The experiments were carried out in a laboratory setting on the cycling-in-traffic simulator at Roessingh Research and Development in Enschede, the Netherlands. The video started when the participant started pedalling. The video showed the cyclist on a street approaching a non-priority intersection, meaning that priority should be given to traffic approaching from the right. At a predefined moment, the participants were asked whether it would be safe to either ‘cross the intersection’, ‘turn left’, or ‘turn right’. The participants were asked to just reply with ‘yes’ or ‘no’ and the experiment leader pressed a button when the answer was given. There were three conditions assigned in random order to each participant. Each condition was practised at least four times before the actual experiment started.

- 1 Light warning condition: the cyclist was warned about traffic from behind by LED lights on the handlebar (red: traffic from behind, green: no traffic behind). The warning signal only turned green or red in the vicinity of the intersection.
- 2 Vibration warning condition: the participant was warned for traffic from behind by vibrating handles. If there was no traffic behind, the situation was considered safe and no warning was given.
- 3 Control condition: no information was given and therefore the participant did not receive any warning.

In each condition, the participant could look over his or her shoulder to check the rear-screen to see if there was traffic approaching from behind. Within each condition, 14 different traffic situations were randomly assigned to the participants: eight of them were about turning left, four about going straight on and two about turning right. Each of the 14 videos lasted approximately 40 s and each condition lasted approximately 10 min. In both experimental conditions - light and vibration - participants received a warning of traffic approaching from behind in six of the scenarios. The warning (haptic or visual) was given based on the traffic situation that was behind them, independently of the turn instructions. Thus, if participants were asked whether they could turn right and there was traffic from behind, they were accordingly informed visually or haptically in both experimental conditions, but not in the control condition.

After each experimental condition, participants were asked to complete the RSME and the Acceptance Scale, with regard to acceptance of the rear-view assistant and the invested mental effort. Invested mental effort was also rated after the control condition. In total, the experiment lasted approximately one hour to one hour and a half.

2.4.1 Instructions

Before the experiment, it was explained that the experiment was about a simple rear-view assistance prototype. The participants were asked to mount the bicycle and there was time to get used to the bicycle and the situation. Before the start of every condition four example videos were played. The participants were informed that they would approach and cross an intersection and needed to answer the question whether it was safe to turn right, to turn left or to go straight. The participants were asked to reply with a simple 'yes' or 'no'. It was stressed that they needed to answer whether they experienced the manoeuvre to be safe or unsafe to actually perform. The participants were asked to make a similar decision as they would when cycling in the real world. Although we tried to make the simulation as realistic as possible, there was no possibility to merge to the centre of the road in this simulator and this was explained to them. The approached intersection in the simulator was a junction where priority should be given to traffic approaching from the right. The video stopped just after crossing the intersection.

2.5 Dependent variables and analysis

The four main outcome parameters were:

- 1 Subjective effort as assessed using the RSME.
- 2 Acceptance as assessed using the Acceptance scale (usefulness, satisfying).
- 3 Cycling speed, assessed as change in cycle speed from before to until 3 s after the question was asked.
- 4 Correctness of the decision on the question whether it was safe to cross the intersection, turn right or turn left ('safe-crossing question').

This is a measure of the extent to which cyclists use the information of the system. These four main outcome parameters were analysed in the following way:

- 1 The effects of the three test conditions on the scores of the RSME were analysed with a repeated measures generalised linear model, after the data were visually checked for normality. Sidak post-hoc tests were used to identify between which conditions significant differences existed.
- 2 The results of acceptance of the rear-view assistance system concern the scores on the two acceptance subscales, namely usefulness and satisfaction, obtained by implementing the procedure described in Van der Laan et al. (1997). Subscale averages were calculated for the two warning conditions. It was checked that there was not a period-effect in the data, meaning the order of the conditions did not lead to variability in the results. The data of the acceptance scale were not normally distributed; therefore a Wilcoxon ranked test was used to test for statistical differences.
- 3 *Cycling speed.* Baseline cycling speed was determined at 1 s before the 'safe-crossing question' was asked. One second was chosen as baseline speed in order to give participants enough time to reach a constant speed after a new scenario was started. We performed repeated measures analysis according to mixed model methods, during which we averaged baseline cycling speed per condition (average of

14 scenarios) comparing average cycling baseline speed per condition over all respondents. Cycling speed 3 s after the 'safe-crossing question' was determined and compared to baseline speed to assess the effect of the 'safe-crossing question' on cycling speed. Three seconds was chosen because this point is *after* the warning for traffic from behind (if applicable) and (usually) *before* answering the 'safe-crossing question'. It was expected that this moment would be mentally demanding and respondents might compensate by slowing down if mental workload was high. The difference in cycling speed 1 s before and 3 s after the 'safe-crossing question' was analysed with a 'Mixed Model' for a repeated measurement with baseline speed taken into account.

- 4 The experiment leader scored the answers to the question 'is it safe to turn left, turn right or go straight'. This can be used as the extent to which cyclists use the information of the system. The decision (on the 'safe-crossing question') was scored 'correct' or 'incorrect', which was judged on the traffic situation in which the participant was cycling and on behaviour that is considered to be appropriate in the Netherlands, like following the traffic rules. It was expected that more correct decisions would be made in the warning conditions compared to the control condition. The percentage of correct decisions (excluding missing answers) for the three corresponding scenarios was compared based on descriptive statistics. All data were analysed using IBM SPSS 19.0 Statistics.

3 Results

3.1 Participants

All participants ($n = 21$) finished the two experimental conditions, one participant did not complete the control condition because of dizziness. Eleven participants reported that they were able to look over their shoulder, nine reported having difficulties looking over their shoulder and one reported not being able to look over the shoulder at all.

3.2 Rating scale mental effort

In Table 1, an overview of the mean scores (range 0–150) on the RSME is given. A higher score on the RSME corresponds to higher experienced effort. 'Mixed Model' analysis displayed a significant difference between the three conditions ($F(2, 20.077) = 4.437, p = 0.025$).

Table 1 Overview of the results from the rating scale mental effort (RSME), mean and standard deviation (SD)

Condition	RSME mean score (0–150) (SD)	δ^a
Control	36.2 (5.3)	
Haptic warning: vibration	24.0 (3.4)	0.50
Visual warning: light	24.9 (3.8)	0.46

^aEffect size compared to control condition

Additionally, Sidak post-hoc tests were performed to identify conditions between which significant differences existed. The control condition without warning took significantly more effort than the light condition ($\Delta 11.3$; 95% CI: 1.3–21.3, $p = 0.024$). The control condition compared to the vibration condition did not reach the 5% level of statistical significance ($\Delta 12.2$; 95% CI: –1.5 to 26.0, $p = 0.092$). No differences were found between the two types of warning conditions.

3.3 Acceptance scale

Acceptance of the rear-view assistance systems was assessed with a simple acceptance scale that consists of two subscales; usefulness and satisfaction (Van der Laan et al., 1997). In general, the participants were very positive about the rear-view assistance system, both in terms of usefulness and satisfaction (scale range –2 to +2) and in both conditions (light and vibration); see Table 2.

Table 2 Median and interquartile ranges (ICR) for the van der Laan subscales (usefulness, satisfaction) (scale range –2 tot +2) and the results of the Wilcoxon ranked test

	<i>Light</i>	<i>Vibration</i>	<i>Z</i>	<i>p</i>
Usefulness median (IQR)	1.4 (0.6–1.9)	1.8 (0.8–2.0)	–1.616	0.11
Satisfying median (IQR)	1.25 (0.4–2.0)	1.25 (0.6–1.9)	–0.141	0.88

As can be seen in Table 2, no significant difference was found between the two versions of the rear-view assistant regarding the two subscales of usefulness and satisfaction, tested with a Wilcoxon ranked test. However, most participants reported that they appreciated the rear-view assistant and preferred the vibration over the light signal.

3.4 Cycling speed

3.4.1 Baseline speed

The average speed 1 s before the ‘safe-crossing question’ was used as the cycling baseline speed. During this stage, the participants did not receive a warning. Repeated measures analysis demonstrated there was no significant difference between the three conditions in baseline speed (Table 3).

Table 3 Baseline cycling speed in meters per seconds (m/s): cycling speed 1 s before the question was asked

<i>Condition</i>	<i>Avg. baseline speed (SD) (m/s)</i>	<i>Avg. speed after warning</i>	<i>δ^a</i>
Control	2.88 (0.10)	2.83 (0.09)	
Light	2.79 (0.08)	2.75 (0.07)	–0.02
Vibration	2.75 (0.10)	2.83 (0.08)	0.21

^aEffect size compared to control condition

No difference between conditions in change in cycling speed was found between the three different conditions ($F(2,20) = 1.636$, $p = 0.220$). So cycling speed did not differ between the different conditions after the respondents received a warning when there was traffic approaching from behind in the experimental conditions.

3.4.2 Correct decision on the 'safe-crossing' question

The experiment leader scored the answers to the question 'is it safe to turn left, turn right or go straight?' The answer in the experimental conditions reflects whether they used the information of the system. To analyse the answers given, the scenarios were grouped based on traffic coming from behind (safe-unsafe) and the decision of the turn (left, right, straight). In the end, we only analysed two situations:

- 1 the turn left-unsafe situation
- 2 the turn right-unsafe situation.

Other situations could not be evaluated, because the scenarios did not correspond to each other, because there was too much difference in terms of risk and danger. In these cases, the situations were more ambiguous, so the researchers could not easily tell whether it was actually safe or unsafe to cross the intersection. For example, it depended on many other factors, such as a personal preference to let other traffic pass. In these situations, a decision could not be classified as 'correct' or 'incorrect'.

To determine if the rear-view assistant is helpful in taking the correct safety decision for the left-unsafe conditions, the percentage of correct decisions for the three corresponding scenarios was averaged and compared (Table 4). In all three reported scenarios for all conditions, there was traffic approaching from behind. Scenarios 1 and 2 were very similar to each other, both with an unsafe situation in front and behind of the cyclists, with traffic (different cars) approaching from both sides, which would make it unsafe to turn left, according to the traffic rules. The difference between the scenarios consisted of different types and colours of cars or another bicycle or motor driver. This set-up was chosen to obtain data for a critical situation with different traffic users. By using different types and colours of cars the respondents could not so easily recognise the situation as being the same.

Table 4 Percentages of the correct decisions for the 'left-unsafe' (traffic approaching from behind) scenarios in each condition

Scenario			Results		
			Control	Vibration	Light
Video	Front	Behind	Correct decision (%)	Correct decision(%)	Correct decision(%)
1. Is it safe to turn left?	Unsafe	Unsafe	61.9	85.7	89.5**
2. Is it safe to turn left?	Unsafe	Unsafe	57.1	71.4	89.5**
3. Is it safe to turn left?	Safe	Unsafe	45.0	95.2*	78.9**
Average			54.7	84.1	86.0

*Control vs. vibration scenario 3: ($\chi^2(1) = 12.489$, $p < 0.001$, $\Phi = 0.77$); **Control vs. light scenario 1 ($\chi^2(1) = 4.043$, $p < 0.05$, $\Phi = 0.44$), scenario 2 ($\chi^2(1) = 5.230$, $p < 0.05$) and scenario 3 ($\chi^2(1) = 4.744$, $p < 0.05$, $\Phi = 0.48$)

Note: The video in front of the participants and the picture behind the participants were judged separately on safety for the 'crossing-left-situation'. Correct answer is always 'no'

As shown in Table 4, the participants more often gave correct answers in the warning light conditions (significant for scenarios 1, 2 and 3) and vibration conditions (significant for scenario 3) compared to the control condition.

The 'turn right-unsafe situation' is only represented by one scenario. In this situation, the participants received a warning because there was traffic approaching from behind, so in principle, 'unsafe' for the system. However, when turning right it should not matter whether there is traffic approaching from behind or not, as a safe turn to the right does not depend on whether or not traffic is approaching from behind. Therefore, the warning signal for traffic from behind is actually distracting and should be suppressed. Hence, the percentage of correct decisions represents possible distraction.

More correct decisions (to the question: 'Is it safe to turn right?') were given in the vibration (100%) and light (90.0%) condition in comparison with the control condition (73.7%). In this condition, there was traffic approaching from behind, so they received a warning. A significant difference was found between the vibration and the control condition ($\chi^2(1) = 6.316, p < 0.05, \Phi = 0.55$).

4 Conclusion

The aim of this study was to evaluate effects on behaviour, mental effort and acceptance of a prototype rear-view assistance system for older cyclists that gave warnings in two modalities for traffic approaching from behind. The two types, providing the cyclists with, respectively, haptic and visual warnings, were compared to each other and to a control condition for their effects on mental effort, acceptance and behaviour.

The subjective effort ratings showed that cyclists invested less mental effort with the rear-view assistant than without the assistant. It also turns out that they did not experience the rear-view assistant system's warnings as mentally demanding, but merely as a device giving decision support. The cycling speed results confirm this subjective evaluation, reflected by no significant difference in cycling speed between the three different conditions. Cyclists were probably cycling at a preferred speed in all conditions, and did not have to protect performance by increased effort investment (Hockey, 1997). Subjective mental effort in the assist conditions was lower, not higher than in the control condition, thus not necessitating reducing mental workload by reducing speed. Nevertheless, it has to be mentioned that a few participants experienced the whole experiment as strenuous. Since we made no distinction in analysing the three different 'safe-crossing questions' (straight on, turn left, turn right) regarding the required level of effort, it may be possible that the rear-view system is less strenuous in situations where the support is needed (looking behind when turning left), but mentally disturbing in situations where it is not necessary, such as turning right. No distinctions were made because a real-life system cannot sense in which direction the cyclist is heading and will also always warn for traffic from behind. However, when participants received a warning when it was distracting and should be ignored (when turning right) this did not lead to more wrong decisions regarding to the 'safe-crossing' question. This is an indication that irrelevant information by the system is not disturbing in the decision-making process.

In general, the rear-view assistance was experienced as both very useful and satisfying as measured by the two subscales from the user acceptance scale. The participants were very positive about both types of feedback, with a slight preference for the vibration feedback. In general, the participants reported that they appreciated the rear-

view assistant and in particular the vibration signal since that did not require looking at the display. The participants who were still able to look over their shoulder were less positive with regard to the usefulness and satisfaction subscales, which may be because they did not need this warning.

With regard to follow-up decisions (on the safe-crossing question), participants gave more correct decisions in the two assisted conditions (80 and 84% correct follow-up answers) compared to the control condition (55%). It seems that the rear-view assistant is of added value in helping to make a safe decision, most importantly in the “left-unsafe” condition. In this case, important information was presented to the cyclists; information they might not have noticed without a warning. This was also demonstrated in the study of Schepers and den Brinker (2011) who studied what cyclists need to see to avoid single-bicycle crashes. Although Schepers and Den Brinker focus on the role of visual features of the infrastructure, their study indicates that an important condition for safe cycling is the visibility of critical information in the peripheral field. Even when the participants received a warning which was not relevant for that specific situation (when turning right), they were able to not follow up the advice given from the system in the experimental conditions. It can be tentatively concluded that the rear-view assistant can be ignored in situations where participants should not be distracted by it, namely when the warning is not relevant (e.g. when turning right). Long-term complacency and potential negative generalisation effects (ignoring all warnings), however, need to be studied in future research.

Some respondents mentioned they would have preferred to receive the warning earlier, since in real-life cycling they would look over their shoulder earlier. This is also important to take into account in future systems. In this experiment, we chose to ask the ‘safe-crossing question’ and give the warning at a fixed time that was the same for each trial. In real life, the moment of warning depends on the distance and the speed of the traffic approaching from behind. However, this was not possible in a simulated cycling environment.

5 Discussion

The present study has some limitations. Some participants cycled at very low speed. Cycling outside the lab at a similar speed would probably impede balance. However, when questioned, the participants reported acting the same in this simulated situation as they would do when cycling outside. For example, some of them always stopped to let other traffic pass, some stood on the pedals so they could better look behind them and some indicated a change of direction with a hand signal, as one officially should. The overall impression is that, despite the simple set-up, the participants performed in a natural way. However, this experimental set-up, in which the participants’ movement was restrained as the bicycle could not move side-ways, did not allow the participants to move freely. This could have had an impact on their evaluation. A second limitation is that the participants in this study were first-time users, practice time was essential and the participants indicated that they needed time to get used to the rear-view assistant. Experience might change with repeated and longer usage. Further, although most respondents mentioned that they favoured the vibration warning, the participants only received information when there was traffic approaching. An advantage of the light warning is that participants also receive information, namely, a green light, when there

was no traffic approaching. The light warning thus always gives feedback about the fact that the system is functioning. Finally, the average age of the participants in this study was almost 70, and therefore participants in this study can be considered 'young elderly'. In future research, participants of higher age could be incorporated as the 'older elderly' may perceive this kind of traffic support as more strenuous, or on the other hand perhaps as more helpful.

Additional limitations from this simulation cycling environment were the lack of noise and a static screen behind the participants, which may have led to participants missing clues to judge speed. Furthermore, the participants could not merge to the centre of the road before turning. A cycling simulator with more advanced functions could provide these options and cover more complex dynamic situations.

No study has yet been done with an intelligent transport system on a bicycle, but the results are in line with studies on ADAS in cars driven by older people. In those studies, it was mentioned that ADAS may be able to provide useful personalised assistance for older drivers (Bekiaris, 1999; Davidse, 2006; Färber, 2000; Mitchell and Suen, 1997; Shaheen and Niemeier, 2001). Resistance by older adults against technological innovations in vehicles has been reported (Hancock and Parasuraman, 1993), although the general consensus is that driver assistance systems have the potential to keep older drivers mobile for longer (Davidse, 2007) and that older drivers are more positive with regard to in-vehicle devices in comparison to younger drivers (Yannis et al., 2009). Although older people have a higher risk of getting injured in traffic, it is still important to keep the older people mobile, because poor mobility has negative consequences on the elderly, their environment and society (Oxley and Whelan, 2008).

In previous research it has been proposed that one has to be aware that information systems may increase mental effort (Jahn et al., 2005) and as a consequence have a negative effect on safety (Verwey et al., 1996). Davidse (2007) concluded that information systems in cars made the driving task easier and no effects on effort were found, which is in line with the results from our cycling study. Brookhuis et al. (2008) stated that acceptance is generally high after experiencing a traffic-congestion assistant for cars, and this high acceptance for a new type of technology is in line with the results of this study.

This study demonstrated the effect of rear-view assistance on mental effort, acceptance and cycling speed in a simple experimental set-up. Testing immediately in real life might have been dangerous because the effects of the rear-view assistance system on cycling performance were not yet well understood. Based on the current study, the next step - actually developing a more advanced rear-view assistant - could prove beneficial. Such a product should be evaluated in real traffic situations. As a consequence of the simulated environment, there was no danger, since the participants were not actually moving. Therefore, testing the rear-view assistant in real life remains important as there are factors that may influence perception of the signals of the rear-view assistant such as sunlight, environmental noise that causes distraction or non-level roads that induce steering vibration. Only in real life it can be judged and evaluated how the algorithm used in the rear-view assistant copes with unexpected, not previously simulated situations.

In conclusion, this study gives a first indication of use and acceptance of a rear-view assistant system that supports older cyclists in detecting traffic from behind. The results indicate that such a system can support the older cyclist successfully without increasing their mental effort. Further research in real traffic situations is needed to optimise the

rear-view assistant in terms of timing of warnings, intensity of warnings and long-term and real-life effects.

Acknowledgements

This work was supported by the Dutch Ministry of Infrastructure and Environment under agreement no. 31080043. The authors would like to thank Elise Bolding and Krista Endema for helping with the data collection.

References

- Bekiaris, E. (1999) 'New driving assistance technologies for elderly drivers.' in *JIDITVA '98 International days of Road Safety, Brussels, Belgium*, 26–28 October 1998. (Theme B: driving license), InstitutBelge Pour la Sécurité Routière IBSR, Brussels.
- Bernhoft, I.M. and Carstensen, G. (2011) 'Preferences and behaviour of pedestrians and cyclists by age and gender', *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 11, No. 2, pp.83–95.
- Berveling, J. and Derriks, H. (2012) '*Opstappen als het Kan, Afstappen als het Moet*' (mounting if possible, dismounting if necessary), Netherlands Institute for Transport Policy Analysis, Den Haag.
- Brookhuis, K.A. and De Waard, D. (1993) 'The use of psychophysiology to assess driver status', *Ergonomics*, Vol. 36, No. 9, pp.1099–1110.
- Brookhuis, K.A. and De Waard, D. (2000) 'Assessment of drivers' workload: performance, subjective and physiological indices', in Hancock, P.A. and Desmond, P.A. (Eds.): *Stress, Workload and Fatigue*, Lawrence Erlbaum, New Jersey, pp.321–333.
- Brookhuis, K.A., van Driel, C.J., Hof, T., van Arem, B. and Hoedemaeker, M. (2008) 'Driving with a congestion assistant; mental workload and acceptance', *Applied Ergonomics*, Vol. 40, No. 6, pp.1019–1025.
- CEC (2000) '*Priorities in EU Road Safety: Progress Report and Ranking of Actions*.' Commission of the European Communities, Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, Brussels, Belgium.
- Davidse, R.J. (2006) 'Older drivers and ADAS: which systems improve road safety?', *LATSS Research*, Vol. 30, No. 1, pp.6–20.
- Davidse, R.J. (2007) *Assisting the Older Driver: Intersection Design and In-car Devices to Improve the Safety of the Older Driver*, PhD Thesis, University of Groningen.
- De Waard, D. (1996) *The Measurement of Drivers' Mental Workload*, PhD thesis, University of Groningen, The Netherlands.
- Dotzauer, M., De Waard, D., Caljouw, S. R., Pöhler, G. and Brouwer, W.H. (2015) 'Behavioral adaptation of young and older drivers to an intersection crossing advisory system', *Accident Analysis & Prevention*, Vol. 74, pp.24–32.
- Ekman, R., Welander, G., Svanström, L., Schelp, L. and Santesson, P. (2001) 'Bicycle-related injuries among the elderly—a new epidemic?', *Public Health*, Vol. 115, No. 1, pp.38–43.
- Färber, B. (2000) 'Neue Fahrzeugtechnologien zur Unterstützung der Mobilität Älterer', *Zeitschrift für Gerontologie und Geriatrie*, Vol. 33, pp.179–185.
- Fietsberaad (2012) *Gat in de markt voor veilige producten fietsende senioren*. [online]. Available at: <http://fietsberaad.org/index.cfm?lang=nl&repository=Gat+in+de+markt+voor+veilige+producten+fietsende+senioren#Comments> (access 4 October 2016).

- Goldenbeld, C. (1992) *Ongevallen van oudere fietsers in 1991 (Crashes with older cyclists)*, Institute for Road Safety Research, Leidschendam.
- Gordon-Salant, S. (2005) 'Hearing loss and aging: new research findings and clinical implications', *Journal of Rehabilitation Research and Development*, Vol. 42, No. 4, p.9.
- Hagemeister, C. and Tegen-Klebingatm, A. (2011) *Fahrgewohnheiten älterer Radfahrerinnen und Radfahrer*, TUV Media GmbH, Köln.
- Hagemeister, C. and Tegen-Klebingat, A. (2012) 'Cycling habits and accident risk of older cyclists in Germany', *Proceedings of the International Cycling Safety Conference*, 20–21 November, Helmond, The Netherlands.
- Hancock, P.A. and Parasuraman, R. (1993) 'Human factors and safety in the design of intelligent vehicle-highway systems (IVHS)', *Journal of Safety Research*, Vol. 23, No. 4, pp.181–198.
- Hockey, G.R.J. (1997) 'Compensatory control in the regulation of human performance under stress and high workload: a cognitive-energetical framework', *Biological Psychology*, Vol. 45, pp.73–93.
- Hoedemaeker, M. (1996) *Behoeften, rijstijlen en meningen ten aanzien van Automatische Voertuig Besturing (Needs, driving styles and opinions towards Automated Driving)*. Technical University Delft, Delft, The Netherlands. Report.
- Hoedemaeker, M. and Brookhuis, K.A. (1998) 'Behavioural adaptation to driving with an adaptive cruise control (ACC)', *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 1, No. 2, pp.95–106.
- Hubbard, M., Hess, R., Moore, J.K. and Peterson, D.L. (2011) 'Human control of bicycle dynamics with experimental validation and implications for bike handling and design', *Proceedings of 2011 NSF Engineering Research and Innovation Conference*, Atlanta, GA, USA.
- Jahn, G., Oehme, A., Krems, J.F. and Gelau, C. (2005) 'Peripheral detection as a workload measure in driving: Effects of traffic complexity and route guidance system use in a driving study', *Transportation Research Part F: Traffic Psychology and Behaviour*, Vol. 8, No. 3, pp.255–275.
- Mitchell, C.G.B. and Suen, S.L. (1997) 'ITS impact on elderly drivers', *Proceedings of the 13th International Road Federation IRF World Meeting, Toronto, Ontario, Canada*, June 16–20, 1997 [CD-ROM], International Road Federation IRF, Genève, Switzerland.
- Moore, J.K., Kooijman, J.D.G., Schwab, A.L. and Hubbard, M. (2011) 'Rider motion identification during normal bicycling by means of principle component analysis', *Multibody System Dynamics*, Vol. 25, pp.225–244.
- Oxley, J., Corben, B., Fildes, B., O'Hare, M. and Rothengatter, T. (2004) 'Older vulnerable road users- measures to reduce crash and injury risk', *Monash University Accident Research Centre Reports*, pp.1–164.
- Oxley, J. and Whelan, M. (2008) 'It cannot be all about safety: the benefits of prolonged mobility', *Traffic Injury Prevention*, Vol. 9, No. 4, pp.367–378.
- Schepers, P. and den Brinker, B. (2011) 'What do cyclists need to see to avoid single-bicycle crashes?', *Ergonomics*, Vol. 54, No. 4, pp.315–327.
- Schoon, C.C. and Huijskens, C. (2011) *Traffic Safety Consequences of Electrically Powered Vehicles: A Preliminary Survey*, Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV.
- Schwab, A.L., Meijaard, J.P. and Kooijman, J.D.G. (2012) 'Lateral dynamics of a bicycle with a passive rider model: stability and controllability', *Vehicle System Dynamics*, Vol. 50, pp.1209–1222.
- Shaheen, S.A. and Niemeier, D.A. (2001) 'Integrating vehicle design and human factors: minimizing elderly driving constraints', *Transportation Research Part C: Emerging Technologies*, Vol. 9, No. 3, pp.155–174.
- SWOV (2013) Factsheet Senior Cyclists. [online]. Available at: https://www.swov.nl/rapport/Factsheets/UK/FS_Senior_cyclists.pdf (access 4 October 2016).

- Twisk, D., Vlakveld, W., Dijkstra, A., Reurings, M. and Wijnen, W. (2013) *From Bicycle Crashes to Measures*, SWOV Institute for Road Safety Research, Leidschendam.
- Van Boggelen, O., Janssen, R. and Everaars, E. (2005) *Effect toename fietsaandeel op de verkeersveiligheid*. Adviesdienst Verkeer en Vervoer, Rotterdam, the Netherlands.
- Van der Laan, J.D., Heino, A. and De Waard, D. (1997) 'A simple procedure for the assessment of acceptance of advanced transport telematics', *Transportation Research Part C*, Vol. 5, No. 1, pp.1–10.
- Veltman, J.A. and Gaillard, A.W.K. (1996) 'Pilot workload evaluated with subjective and physiological measures', in Brookhuis, K.A., Weikert, C., Moraal, J. and De Waard, D. (Eds.): *Aging and Human Factors. Proceedings of the Europe Chapter of the Human Factors and Ergonomics Society Annual Meeting 1993*, University of Groningen, Traffic Research Centre, Haren, pp.107–128. Retrieved from: <http://www.hfes-europe.org/largefiles/Veltman.pdf>.
- Verwey, W.B., Brookhuis, K.A. and Janssen, W.H. (1996) *Safety Effects of In-vehicle Information Systems*. (report TM-96-C002), TNO Human Factors Research Institute, Soesterberg, The Netherlands.
- Weseman and Weijermans (2011) *Verkeersveiligheidsverkenning 2020*, Stichting Wetenschappelijk Onderzoek Verkeersveiligheid, Leidschendam.
- Widyanti, A., Johnson, A. and De Waard, D. (2013) 'Adaptation of the rating scale mental effort (RSME) for use in Indonesia', *International Journal of Industrial Ergonomics*, Vol. 43, pp.70–76.
- Yannis, G., Antoniou, C., Vardaki, S. and Kanellaidis, G. (2009) 'Older drivers' perception and acceptance of in-vehicle devices for traffic safety and traffic efficiency', *Journal of Transportation Engineering*, Vol. 136, No. 5, pp.472–479.
- Zeegers, T. (2010) *Ongevallen met oudere fietsers*, Fietzersbond, Utrecht.
- Zijlstra, F.R.H. (1993) *Efficiency in Work Behavior: A Design Approach for Modern Tools*, Phd Thesis, Delft University of Technology, Delft University Press, Delft, The Netherlands.