Transportation Research Part F 58 (2018) 292–301

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

Where do people direct their attention while cycling? A comparison of adults and children

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ARTICLE INFO

Article history:
Received 9 August 2017
Received in revised form 25 May 2018
Accepted 15 June 2018

Keywords:
Situation awareness
Hazard perception
Children
Cycling
Safety

ABSTRACT

Cycling in urban environments requires the ability to distinguish between relevant and irrelevant targets quickly and reliably, so that potential hazards can be anticipated and avoided. In two experiments, we investigated where adults and children direct their attention when viewing videos filmed from a cyclist's perspective. We wanted to see if there were any differences in the responses given by experienced adult cyclists, inexperienced adult cyclists, and child cyclists.

In Experiment 1, 16 adults (19–33 years) were asked to watch ten videos and to point out things they would pay attention to by tapping a touchscreen (pointed out locations). Afterwards, they were asked to explain their answers. In Experiment 2, 17 adults (19–34 years) and 17 children (11–12 years) performed the same task with the same ten videos, but they were not asked to explain their answers afterwards. The data sets from these two experiments were pooled, creating three groups: ten experienced adult cyclists, 23 inexperienced adult cyclists and 17 children. A total of 23 clearly visible, traffic-relevant targets (pre-specified targets) had previously been identified in the videos. We investigated whether the participants' pointed-out locations matched these targets (and if so, how fast they responded in pointing them out). We also investigated the number and vertical/horizontal dispersion of these pointed-out locations on the touchscreen.

Adults pointed out more locations than children, especially pedestrians and cyclists. This result suggests that, while children focussed as well as adults on cars (arguably the most salient hazard), they were less able to identify other hazards (such as pedestrians or other cyclists). The children had also a larger vertical dispersion and a larger between-participant variation than the adults. Adults were faster at tapping the pre-specified targets and they missed them less often. Overall, the results suggest that 11–12 year old-cyclists have worse situation awareness in traffic than adults.

1. Introduction

Cycling has been linked to longer and healthier lives due to the physical activity it entails (Celis-Morales et al., 2017; Oja et al., 2011). However, cycling-related injuries incur substantial costs for the individual and society (Scholten, Polinder, Panneman, Van Beeck, & Haagsma, 2015). Measures to improve cycling safety are sorely needed. While helmet use has been

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https://doi.org/10.1016/j.trf.2018.06.017
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demonstrated to be an effective countermeasure for head injuries (Olivier & Creighton, 2016), it is important to understand why crashes occur in the first place in order to further reduce the risks to cyclists. Crashes and injuries may decrease the popularity of cycling if cycling is perceived as dangerous (Backer-Grøndahl, Fyhri, Ulleberg, & Amundsen, 2009; Noland, 1995). Specifically, parents' conception of the safety of cycling may affect their decision to let children cycle to school (Panter, Jones, van Sluijs, Simon, & Griffin, 2010).

In Finland between 2012 and 2014 there were on average 860 cycling injuries and 19 fatalities every year, constituting 12% of all traffic accidents and 7% of all accident-related deaths (Liikenneturva, 2015). Among 10–14 year olds, the risk of a cycling injury was twice that of the overall population (Liikenneturva, 2015).

Children's bicycle crashes most often happen when they are entering the roadway or crossing it mid-block (Ellis, 2014). This suggests they may have failed to anticipate and look for approaching cars. Appropriate expectations in this situation help predict what will happen next and thus focus the visual search (Räsänen & Summala, 1998; Underwood, 2007). The ability to accurately assess visual cues that indicate a situation with a high probability of leading to a crash is called hazard perception (e.g. Crundall et al., 2012).

Typical hazard perception tests measure reaction times to a set of hazards which have been predefined to discriminate between novice drivers and safer, more experienced ones (Horswill & McKenna, 2004). However, hazard perception can be conceptualized more generally as situation awareness in hazardous situations (Endsley, 1995; Horswill & Mckenna, 2004). With this perspective, hazard perception tests have been expanded to probe for participants' awareness of relevant elements, their interpretation of the situations, and their predictions for what will happen next (Crundall, 2016; Jackson, Chapman, & Crundall, 2009; Lehtonen, Airaksinen, et al., 2017). Significantly, hazard prediction appears to be robust against variation in the participant's response criteria; that is, it is not affected by the person's assessment of the level of hazard/risk (Lim, Sheppard, & Crundall, 2014).

Hazard perception studies among car drivers suggest that more experienced drivers scan relevant areas in the traffic environment for potential hazards more extensively than novices do, and they identify hazards earlier (Borowsky, Shinar, & Oron-Gilad, 2010; Crundall et al., 2012; Pradhan et al., 2005). However, few comparable studies have been done among cyclists. Lehtonen, Havia, Kovanen, Leminen, and Saure (2016) asked adults to assess how much 'caution' the situation required when they viewed videos from the cyclist's perspective. More experienced cyclists reported increased caution more often than less experienced cyclists, a result which can be interpreted to mean that they detected more potential hazards. On the other hand, another study with similar video material and criteria for cycling experience failed to find a difference as a function of cycling experience among adults (Lehtonen, Airaksinen, et al., 2017). However, that study probed for the presence of hazards in a predefined set of locations, instead of asking the participants to point out all the locations, as in the current study. We were interested to see if experienced cyclists would point out more locations than inexperienced ones and if their locations would be more spread out horizontally, suggesting wider scanning for potential hazards.

Studies comparing children and adults have often found that children identify fewer hazards than adults and react to them more slowly (Lehtonen, Airaksinen, et al., 2017; Lehtonen, Sahlberg, Rovamo, & Summala, 2017; Meir, Parmet, & Oron-Gilad, 2013; Meyer, Sagberg, & Torquato, 2014; Zeuwts, Vansteenkiste, Deconinck, Cardon, & Lenoir, 2016). Typically, it is more challenging for children to detect covert hazards, where the road users causing the hazards are occluded (e.g. a pedestrian stepping behind a parked van) than overt hazards (e.g. a clearly visible approaching car) (Meir et al. 2013; Zeuwts et al., 2016; Lehtonen, Sahlberg, et al., 2017 but see Lehtonen, Airaksinen, et al., 2017). Consequently, we expected that adults would point out more hazards, especially covert hazards, than children.

The purpose of the current study was to explore what cycling-relevant locations the adult and child cyclists would direct attention to when watching videos recorded from a cyclist's perspective. The research questions were the following:

Q1: What elements did the participants point out in the videos (pointed-out locations)? The reported locations, at least, were part of their situation awareness—even though we would not suggest that these were the only elements that made up the participants' situation awareness.

Q2: Are there differences in the number or horizontal and vertical dispersion of the pointed-out locations for the different groups (children, inexperienced adult cyclists, and experienced adult cyclists)?

Q3: How do the pointed-out locations match against the set of targets previously classified as potential hazards (pre-specified targets)? How fast did participants respond to them and how many of the latter did they miss?

2. Methods

2.1. Task

For this paper, we performed two different experiments (Experiment 1 and Experiment 2). The first task was similar in both experiments. All participants were asked to imagine being the cyclist in a video played on a touchscreen and tap any locations in the videos that they felt they should pay attention to if they were in traffic. The location was then highlighted with a red circle. These pointed-out locations on the screen were not prespecified.

The second task was presented only in Experiment 1: participants were shown the videos again and this time they were able to see what they had tapped. At the moment of each tap, the video stopped and the target they had tapped was once again highlighted with a red circle, for 250 ms. After that the video stopped and the screen went blank. The participant was

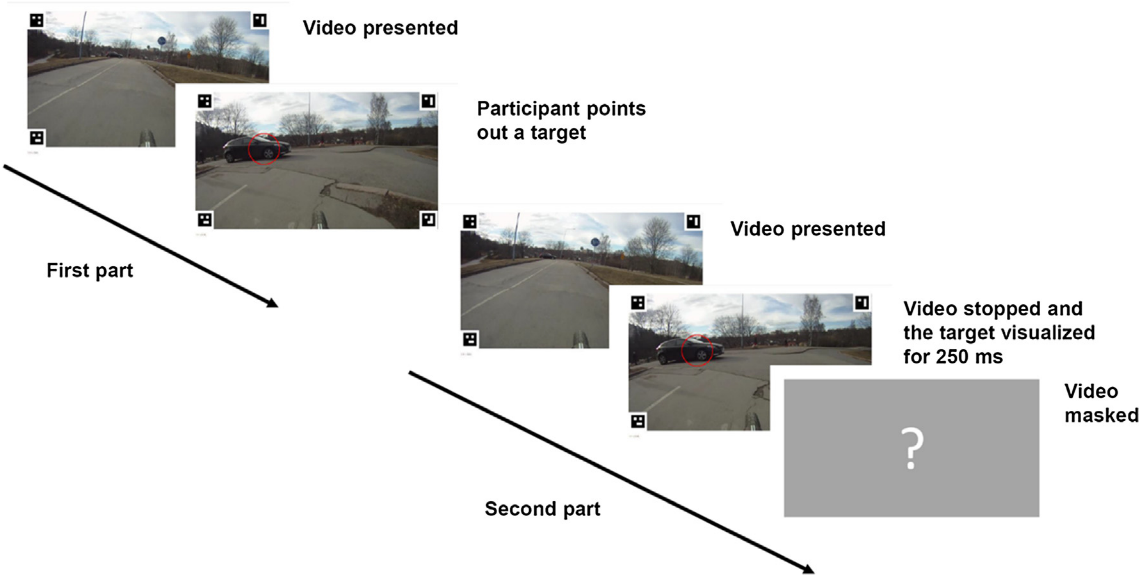

Fig. 1. In the first part of Experiment 1, the participants watched videos and tapped on locations as the video was running. When a location was tapped on, it was highlighted with a red circle. In the second part of Experiment 1, the videos were presented again. For each previously tapped-on location, the video was stopped and the target was once again highlighted with a similar red circle. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

asked to explain what they had tapped and why. The screen was blank so that they could not create an explanation based on the inspection of a still image; thus, their answers should have been based on the original situation, when the decision to tap was made while watching the running video. Participants did this for all the locations they had tapped, allowing us to study what people consider potentially relevant by collecting data on the visual elements that have drawn their attention (see Fig. 1).

2.2. Videos

Experiment 1 consisted of 11 video clips (of which one was a practice clip). Experiment 2 consisted of the same video clips and 21 additional clips, but these additional clips were not analyzed for this study. The video clips showed different traffic situations from a bicyclist's perspective. The videos were filmed with a camera (GoPro Hero HD1) that was attached to the head tube of the bicycle, approximately 90 cm from the ground. Because the head tube is part of the bicycle frame, the video did not record information on the rider's head movements or steering. Filming was done in the city of Helsinki, Finland, during spring and summer 2014 in clear weather. The cyclist in the videos cycled on combined bike/pedestrian paths, which are either shared with pedestrians or separated from the pedestrian walkway with a painted line. On these kinds of bike paths there is always the possibility of pedestrians walking on the bike path or bikes crossing car lanes.

2.3. Equipment

The task was presented with a Firefox web browser (version 45.0.1). The operating system was Ubuntu Linux (14.04 LTS) running on an HP EliteBook 850 G2 computer. The touch screen was an Acer 23″ T232HL with a resolution of 1980 × 1080 px. Participants were seated in front of the screen, with the distance from the screen adjusted to ensure that they were able to see the whole screen without turning their heads. A head-mounted monocular Pupil Labs camera was used as an eye tracker, but the eye-tracking data is not reported here due to technical difficulties which made the collected data too unreliable to use.

2.4. Experiment 1

2.4.1. Participants

There were 16 participants, 19–39 years of age; 12 had a driver's license. They were divided into two groups: experienced cyclists (n = 6) and inexperienced cyclists (n = 10).

The following criteria were used to classify a cyclist as experienced:

- Riding at least three days a week during one's cycling season.
- Riding regularly after the age of 18 for at least five years.
- Riding in urban areas, not only in the countryside.

The inexperienced group consisted of participants who have not cycled regularly since the age of 18. All the participants, experienced and inexperienced, were regular commuters. The difference between the groups was based on their weekly cycling activity. A benchmark of 18 years of age was set because in Finland one is considered to be a legal adult and allowed to have a driving license at that age.

2.4.2. Procedure

The experiments were conducted in a laboratory of the University of Helsinki. As an incentive, the participants were given either a movie ticket or a note certifying experiment participation for a course. First, the participants provided their informed consent. They were asked about their use of glasses or contact lenses to ensure satisfactory eyesight. They were also asked about any tendency to motion sickness, as watching videos filmed from a cyclist's perspective may cause nausea. (None of the participants reported feeling sick while watching the videos.) All the participants got written and oral instructions. They also practiced with the first video before starting the task. Finally, the participants were asked to fill a background information sheet which consisted of questions concerning their cycling and driving history.

2.5. Experiment 2

2.5.1. Participants

Participants in Experiment 2 consisted of adults (n = 17) and children (n = 17). The adults, 19–34 years old, were students of University of Helsinki who had answered an invitation sent out using mailing lists. Four were classified as experienced cyclists and 13 were classified as inexperienced (using the same criteria as in Experiment 1). Nineteen 11–12-year-old children also participated in the study. They were all pupils in an elementary school in Helsinki and all of them could cycle. Two of the children in the original sample were excluded from the analysis because they attended a special education class.

2.5.2. Procedure

The same procedure was used as in the first part of Experiment 1, but the second part (participants' explanation) was not performed. Children were given the same instruction as adults. Experiments with the children were conducted in a temporary laboratory set up in a vacant classroom of their school. Informed consent was obtained from their parents. Because the study included children, it had to be approved by the University of Helsinki Ethical Review Board in Humanities and Social and Behavioural Sciences.

2.6. Analyses

For analyses, the data from both studies were combined. The combined data was obtained from 50 participants (ten experienced adults, 23 inexperienced adults, and 17 children). Adults were between 19 and 39 years old and the children were between 11 and 12 years old (Table 1).

First, the explanations given in Experiment 1 were categorized according to the element the participant had targeted (based on the explanation they had given). The categories were pedestrians, cars, cyclists, animals, traffic signs, environment (all road infrastructure except traffic signs), and other. The data from Experiment 1 were used to categorize the answers given in Experiment 2. The differences across categories were analyzed using the Mann-Whitney test.

Second, the number of pointed-out locations and their horizontal and vertical distributions, as a function of experience and age group, were analyzed using logistic regressions.

Finally, these pointed-out locations were matched against the set of 23 pre-specified targets. These targets were elements which could be clearly classified as potential or latent hazards (e.g. a road user on an intersecting path with the cyclist). Targets were identified by consensus among the researchers. Pre-specified targets were defined spatially as occupying 1/10 of the video screen, and temporally as existing from their first appearance until they were in front of the camera or passed out of view. We examined how many of these pre-specified targets the participants pointed out and when they first did so. The

Table 1
Combined data from Experiments 1 and 2.

	Adults			Children
	Experienced	Inexperienced	Total	
Male (n)	4	20	24	10
Female (n)	6	3	9	7
Age in years (mean, sd)	28.4 (5.4)	23.2 (3.3)	24.8 (4.6)	11.2 (0.4)

latency of first tap was defined as the time it took for the participant to point out the target after it first appeared. The percentage of missed targets and the average latency of the first tap were calculated for each participant. Logistic regressions were used to compare the participant groups. A significance level of $\alpha = 0.05$ was used to reject the null hypothesis. All statistical tests were two-sided.

3. Results

3.1. Pointed-out locations

In Experiment 1, the adult participants were asked to name the locations they had pointed out. Their answers were then categorized. The most frequent targets were pedestrians, followed by cars (Table 2).

The categorized pointed-out locations from Experiment 1 identify what elements adults deemed relevant in the videos, but naturally the data do not objectively tell how many targets there were in the videos (i.e. how many targets were 'tapped' or 'missed'). However, the data can be used to contrast the answers given by children and adults. In order to do that, we categorized all pointed-out locations (Experiments 1 and 2 combined) by calculating how often the different adult groups and children tap close to the same locations as the adults in Experiment 1. The answers of the adults in Experiment 1 were compared only to all other adults in Experiment 1.

A location was classified as *close* if it was spatially within 1/10 of the video width and temporally less than 1 s before or after a categorized location given in Experiment 1 (Table 3). The percentages sum up to more than 100%, because a location was counted once for every location in Experiment 1 that it was close to, and some were close to more than one. Similarly, if a given location did not match any location in Experiment 1, it was not counted at all. When tested with the Mann-Whitney test, the children had lower percentages (hit rate) compared to all adults in pedestrian, cyclist, environment, and animals categories ($p < .05$). In contrast, the locations with cars were tapped by children and adults equally often ($p = .12$).

3.2. Number and dispersion of locations between groups

The average differences in the number of pointed-out locations as well as horizontal and vertical dispersion are illustrated in Figs. 2–4. Horizontal and vertical dispersions have been standardized (z-score) so that it is easier to interpret the differences between the groups.

The first logistic regression analysis compared the differences between the groups (all adults vs. children and comparisons between experienced cyclists, inexperienced cyclists, and children) (Table 4). Gender was controlled in all analyses. Adults pointed out significantly more locations than children ($p < .05$).

There were no statistically significant differences between the groups regarding the horizontal dispersion. However, the difference in the horizontal dispersion between the experienced and inexperienced cyclists was close to significant ($p = .07$). Regarding the vertical dispersion, we found significant differences between all adults and children and between inexperienced cyclists and children. Surprisingly, there was no difference in the vertical dispersion between experienced adults and children. In other words, children's vertical dispersion was closer to that of the experienced adults than that of the inexperienced adults.

Table 2
Mean frequencies of categorized pointed-out locations in Experiment 1. Standard deviations in parentheses.

Group	Total	Pedestrians	Cars	Cyclists	Environment	Traffic signs	Animals	Other
All	31.8	14.0	10.2	2.3	2.1	2.0	1.1	0.1
	(17.1)	(8.5)	(3.3)	(1.2)	(3.2)	(5.2)	(0.9)	(0.2)
Experienced	31.8	12.7	11.2	2.5	2.7	1.5	1.3	0.0
	(17.8)	(8.6)	(4.5)	(1.4)	(4.2)	(1.4)	(0.8)	(0.0)
Inexperienced	31.7	14.8	9.7	2.2	1.7	2.3	0.9	0.1
	(17.6)	(8.8)	(2.3)	(1.1)	(2.6)	(6.6)	(0.9)	(0.3)

Table 3
Average percentage of pointed-out locations which coincide with the ones given in Experiment 1. Adults from Experiment 1 and 2 are combined. Standard deviations are given within the parentheses.

Group	Pedestrians	Cyclists	Cars	Traffic signs	Environment	Animals	Other
Exp. adults	43 (9)	11 (7)	39 (10)	7 (4)	9 (4)	4 (3)	0 (0)
Inexp. adults	48 (9)	12 (7)	42 (12)	6 (6)	8 (6)	3 (3)	0 (0)
All adults	46 (9)	12 (7)	41 (11)	6 (5)	9 (6)	4 (3)	0 (0)
Children	29 (15)*	4 (5)*	45 (20)	4 (5)*	3 (4)*	1 (2)*	0 (0)

* The differences between children and all adults are statistically significant ($p < .05$)

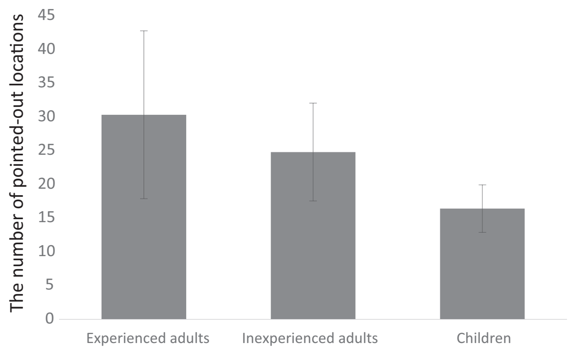

Fig. 2. The number of targets pointed out (means with 95% CI).

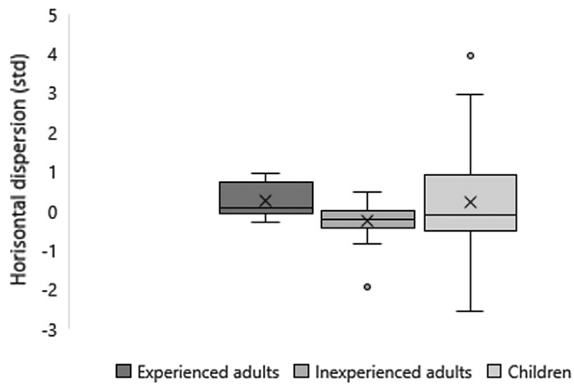

Fig. 3. Boxplots of the standardized horizontal dispersion.

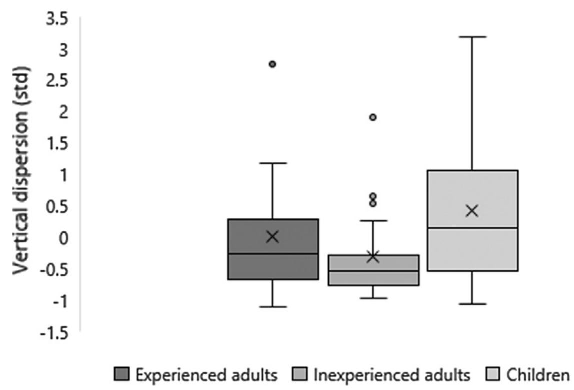

Fig. 4. Boxplots of the standardized vertical dispersion.

3.3. Pre-specified targets

Missed pre-specified targets had a significant positive correlation with the latency of the first tap (Table 5); therefore, separate logistic regression analyses were performed. Gender was controlled in both analyses. The percentage of missed pre-specified targets per group is illustrated in Fig. 5. The average time of the first tap on pre-specified targets is illustrated on Fig. 6.

Logistic regression analysis indicated that adults (both experienced and inexperienced) were faster at pointing out pre-specified targets and missed fewer targets than children (Table 6). There were no differences in the latency of the first tap or the amount of missed pre-specified targets between experienced cyclists and inexperienced cyclists.

Table 4
Results of logistic regression analysis: comparing group differences in the number of pointed-out locations and horizontal and vertical dispersion.

Groups	Variable	B	OR	95% Cl	p
Adults – Children[a]	**The number of pointed-out locations**	**0.08**	**1.09**	**1.01–1.17**	**.04**[*]
	The horizontal dispersion of pointed-out locations (std)	−0.36	0.70	0.34–1.47	.35
	The vertical dispersion of pointed-out locations (std)	**−0.77**	**0.46**	**0.22–0.99**	**.05**[*]
Experienced – Inexperienced[a]	The number of pointed-out locations	−0.01	0.99	0.93–1.06	.83
	The horizontal dispersion of pointed-out locations (std)	3.17	23.71	0.80–704.28	.07
	The vertical dispersion of pointed-out locations (std)	0.89	2.44	0.50–11.83	.27
Experienced – Children[a]	**The number of pointed-out locations**	**0.11**	**1.12**	**1.01–1.24**	**.04**[*]
	The horizontal dispersion of pointed-out locations (std)	−0.36	0.70	0.32–1.52	.36
	The vertical dispersion of pointed-out locations (std)	−0.03	0.97	0.43–2.98	.95
Inexperienced – Children[a]	**The number of pointed-out locations**	**0.10**	**1.10**	**1.01–1.20**	**.03**[*]
	The horizontal dispersion of pointed-out locations (std)	−0.82	0.44	0.10–1.98	.29
	The vertical dispersion of pointed-out locations (std)	**−1.83**	**0.16**	**0.04–0.70**	**.02**[*]

[a] = Reference group, Cl = Confidence level.
[*] = Statistically significant (p < .05) coefficient in the model comparing the specified groups.

Table 5
Means (standard deviations) and correlations of the main variables.

Variable	Mean (sd)	1	2	3	4
1. Number of pointed-out locations	23.04 (15.00)	1.00			
2. First tap at pre-specified target (s)	3.32 (0.93)	**−.78**[**]	1.00		
3. Missed pre-specified targets (%)	45.64 (22.32)	**−.66**[**]	**.77**[**]	1.00	
4. Horizontal dispersion (std)	−(1.00)	.13	−.05	−.09	1.00
5. Vertical dispersion (std)	−(1.00)	.05	.10	**.44**[**]	.03

[**] = Statistically significant p < .01.

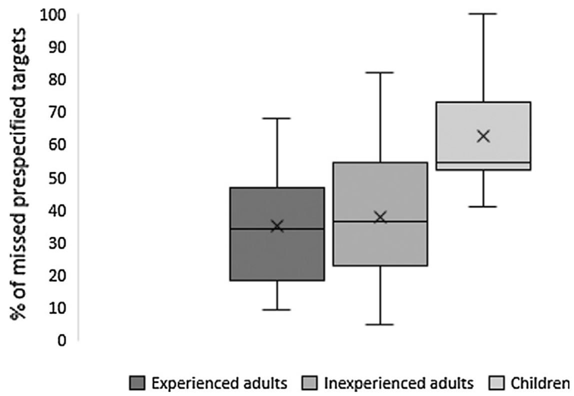

Fig. 5. Boxplots of the percentage of missed pre-specified targets.

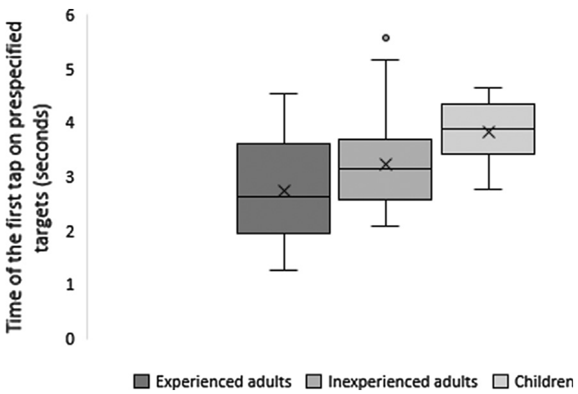

Fig. 6. Boxplots of the average latencies of first taps to the pre-specified targets.

Table 6
Results of logistic regression analyses: comparing group differences for the percent of missed pre-specified targets and latency of the first tap to the pre-specified targets.

Variable	Groups	B	OR	95% CI	p
Missed targets					
	Adults – Children[a]	**−7.29**	**0.00**	**0.00–0.60**	**<.01[**]**
	Experienced – Inexperienced[a]	−0.52	0.60	0.01–54.93	.82
	Experienced – Children[a]	**−13.01**	**0.00**	**0.00–0.08**	**.02[*]**
	Inexperienced – Children[a]	**−6.99**	**0.00**	**0.00–0.10**	**<.01[**]**
Latency of the first tap					
	Adults – Children[a]	**−1.08**	**0.34**	**0.15–0.78**	**.01[*]**
	Experienced – Inexperienced[a]	−0.43	0.65	0.25–1.69	.38
	Experienced – Children[a]	**−1.71**	**0.18**	**0.04–0.76**	**.02[*]**
	Inexperienced – Children[a]	**−1.01**	**0.37**	**0.14–0.97**	**.04[*]**

[a] = Reference group, CI = Confidence level.
[*] = Statistically significant ($p < .05$) coefficient in the model comparing the specified groups.
[**] = Statistically significant ($p < .01$) coefficient in the model comparing the specified groups.

4. Discussion

The purpose of this study was to investigate (1) what elements adults and children pay attention to when viewing videos filmed from a cyclist's perspective, (2) are there differences in the number or dispersion of these pointed-out locations, (3) and how these pointed out locations match against a set of pre-specified, traffic-relevant targets.

The adult cyclists in Experiment 1 pointed out mostly other road users (cars, cyclists, and pedestrians). Children targeted as many cars as the adults did, but did not point out as many pedestrians, cyclists, or environmental objects. This result is in line with the results of Meyer et al. (2014), which found that in a hazard perception test designed for car drivers, children did relatively well at spotting hazards related to motorized vehicles.

It is noteworthy that even the adults did not target many elements related to the road environment. This finding was surprising, since studies of naturalistic cycling data suggest that road surface conditions, pedestrians, and other cyclists are common causes of critical events and crashes in cycling (Dozza & Werneke, 2014; Dozza, Bianchi Piccinini, & Werneke, 2016). The reason for the relatively low number of pointed-out locations related to the environment could be that participants in the study did not have to control the bicycle, so they may not have paid as much attention to the road surface in the video as they would have if they were cycling themselves. Furthermore, the quality of the video image may not be good enough for spotting possible hazards, e.g., loose gravel on asphalt.

Adults pointed out more locations than children. In this respect, a clear difference between children and adults emerged. The experienced adults did not point out more locations than the inexperienced ones, contrary to our expectations. It is possible that the situations in the videos were not complex enough to capture the relevant aspects of situation awareness, or that there is no large effect of cycling experience (cf. Lehtonen, Airaksinen, et al., 2017). Inexperienced adults had only a marginally smaller horizontal dispersion than experienced adults, and there was no difference between adults and children. The vertical dispersion, however, was larger with children compared to all adults or to inexperienced adults. This indicates that children focus on information which the adults do not deem relevant.

Regarding the pre-specified targets, both adult groups missed fewer of them and were faster to point them out compared to children. These results are in line with previous studies comparing children and adult cyclists (Lehtonen, Airaksinen, et al., 2017; Lehtonen, Sahlberg, et al., 2017; Zeuwts et al., 2016).

Previous studies suggest that children have worse situation awareness/hazard perception skills than adults (Ellis, 2014; Lehtonen, Airaksinen, et al., 2017; Lehtonen, Sahlberg, et al., 2017; Meir et al., 2013; Meyer et al., 2014; Zeuwts et al., 2016). The current results can be interpreted to corroborate these results. Likely explanations for the differences between adults and children are in cognitive development or in the lack of latter's experience. The frontal lobe, which is essential for memory and attention, is one of the last brain areas to fully develop (Casey, Giedd, & Thomas, 2000). For this reason, children might not have the ability to divide and maintain attention as well as adults (Wierda & Brookhuis, 1991). Children are also less experienced, so they may understand less about what is relevant in traffic and thus target fewer potential hazards.

Naturally, some caution is needed when drawing conclusions regarding situation awareness based on the current data. The locations the participants pointed out in the videos were targets they chose deliberately to point out. Such responses depend not only on detection but on the judgement of what is considered worth reporting as a target. For example, it is possible that participants noted a pre-specified target but did not consider it worth pressing. Situation awareness may also contain a lot of information which is not readily expressed with deliberate responses, but which could still affect real-life behavior. The challenge of accessing this information could be addressed in future studies. For example, behavioral reactions – like braking in response to a conflict situation – could be measured in naturalistic research settings. It might also be useful to examine eye-tracking data or some other physical measurements to reveal reactions to different stimuli in the environment.

4.1. Limitations

The participants were given the task of watching videos from a cyclist's point of view and pointing out when they saw something they would pay attention to. The results, of course, only partially reflect a cyclist's situation awareness. In real-life situations, the participants may pay attention to much different things than they would while watching videos. Studies indicate that watching videos without actually controlling a vehicle may make hazard perception easier, because dual tasking in driving/cycling (steering and observing) may have a negative influence on reaction times (Mackenzie & Harris, 2015; Wierda & Brookhuis, 1991). It is possible that the differences between adults and children would have been larger if the setup had required both cycling and observing. On the other hand, real-life drivers and cyclists are sometimes distracted by non-driving/cycling related tasks, which was not the case in a more controlled laboratory setting. The participants were able to devote all their attention to the task without real-world distractions.

The sample size of this study was relatively small, so it is possible that the power of the statistical analyses was not sufficient to bring out all the group differences. With a bigger sample size we might find more differences between experienced and inexperienced adult cyclists, in particular. In addition, adults' additional experience (e.g., driving a car) may affect the results, but it was not controlled for in the current study. We were not able to find enough inexperienced and experienced cyclists with matching car-driving histories or enough people without a driver's license. These limitations need to be considered when interpreting the results and will, ideally, be addressed in future studies.

5. Conclusion

In summary, the results suggest that children may focus on different—possibly less relevant—targets, compared to adults. The results also suggest that children may not pay as much attention to the hazards created by the environment. Thus, children's cycling safety could be improved by designing and maintaining infrastructure in a way, which take these limitations into account. Also educational interventions to improve children's situation awareness should be considered (e.g. Meir, Oron-Gilad, & Parmet, 2015; Lehtonen, Airaksinen, et al., 2017; Zeuwts, Vansteenkiste, Deconinck, Cardon, & Lenoir, 2017).

Acknowledgements

We thank Marko Tikka for filming the videos used in the experiments, Hans Hoffmann who participated in the realization of Experiment 1, and Katja Elo and Vilma Kinnunen who participated in the realization of Experiment 2. We also want to thank the staff, pupils, and parents of the school from which the children were recruited. Jari Lipsanen gave very helpful statistical consultation for the analyses. We thank Kristina Mayberry for linguistic revision.

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