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Visual guidance during bicycle steering through narrow lanes: A study in children

Pieter Vansteenkiste*, Greet Cardon, Matthieu Lenoir

Department of Movement and Sports Sciences, Ghent University, Belgium

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ABSTRACT

Recently, Vansteenkiste et al. (2013) explored how visual behaviour guides bicycle steering when cycling at different speeds through 15 m long lanes of 10, 25 and 40 cm wide. Participants were found to shift their gaze direction towards the end of the lanes at higher speeds, towards the near pathway on narrow lanes and more towards irrelevant areas on wider lanes. To investigate to what extent young learner bicyclists adapt their visual behaviour in a similar way as adults, the experiment was repeated with seven eight-year-old children, and results were compared to the adult data. Children were found to cycle slower through narrow lanes than adults. However, with increasing lane width and cycling speed, children made the same shifts of visual gaze direction as the adults. These results suggest that for a simple precision steering task, children are able to adopt a similar visual-motor strategy as adults, provided that they cycle at their own pace.

1. Introduction

Although bicyclists of all age groups can be considered vulnerable road users, accident analyses have shown that children under the age of 15 and elder people over 65 are particularly at risk (Carpentier and Nuyttens, 2013; DEKRA Automobil GmbH, 2011). The higher accident proneness of children has been linked to the fact that they are still developing the motor and cognitive skills essential for safe traffic participation. Regarding the motor skills required for safe cycling, multiple studies have documented the development of cycling skills, and the effects of cycling skills training programs (Ducheyne et al., 2013; Macarthur et al., 1998; Zeuwts et al., 2015). The development of cognitive skills in traffic safety such as visual attention, judgement and decision making however, has mostly been described in pedestrians and car drivers (Land and Horwood, 1995; Mcknight, 2003; Oxley et al., 2005; Salvucci and Gray, 2004; Underwood et al., 2007).

For example, pedestrians should be able to detect the presence of traffic, make judgements about it, and co-ordinate their actions to it, to safely cross a street (Geruschat et al., 2003; Whitebread and Neilson, 2000). Studies have showed that children younger than ten have problems with all three of these actions. They adopt different visual search strategies, featured by a limited use of peripheral vision, watching irrelevant areas in their field of view, and less switching between relevant cues compared to adults. As a result, they need more time to make decisions and have difficulties in synchronizing themselves with moving objects (Ampofo-Boateng and Thomson, 1991; Chihak et al., 2010; Franchak and Adolph, 2010; Plumert et al., 2007; Thomson et al., 1996; Whitebread and Neilson, 2000). In contrast to the relatively well documented visual behaviour in young pedestrians, it remains unclear to what extent these less developed cognitive skills affect the cycling behaviour of learner cyclists.

Recently, Vansteenkiste et al. explored how visual behaviour guides bicycle steering in a simple bicycling tasks (Vansteenkiste et al., 2013). In this experiment, adults were asked to steer at three different speeds through 15 m long narrow straight lanes of different widths. The results showed that although there were considerable individual differences in where participants looked, participants shifted their gaze direction towards the end of the lanes at higher speeds, towards the near pathway on narrow lanes and more towards irrelevant areas on wider lanes. However, while this task-specificity of gaze behaviour seems obvious for adults, and has been described in many other visual-motor tasks (Land and Hayhoe, 2001; Land, 2006; Pelz and Rothkopf, 2007; Vaeyens et al., 2007; Vansteenkiste et al., 2014; Yarbus, 1967), it is not known whether children exhibit the same task-specific adaptations in visual behaviour.

* Corresponding author at: Ghent University, Department of Movement and Sports Sciences, Watersportlaan 2, 9000 Ghent, Belgium. Tel.: +32 9 264 63 63.
E-mail addresses: pieter.vansteenkiste@ugent.be (P. Vansteenkiste), greet.cardon@ugent.be (G. Cardon), matthieu.lenoir@ugent.be (M. Lenoir).

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To investigate if young learner bicyclists adapt their visual behaviour in a similar way to adults, the experiment of Vansteenkiste et al. (2013) was repeated with eight-year-old children, and compared to the adult data. Taking into account the differences in visual behaviour between adults and children, we expected that children would spend more time watching irrelevant areas (Whitebread and Neilson, 2000) and focus less on the goal region than adults (Franchak and Adolph, 2010; see also Vansteenkiste et al., 2013, and the Section 2.4 of current paper').

2. Materials and methods

2.1. Subjects

Seventeen children were recruited by disseminating a request for volunteers via elementary schools in the neighbourhood of Ghent University. All children who participated were accompanied by at least one of their parents, who read and signed the informed consent. With the approval of the parents, all children received a small incentive (i.e., a toy of approximately €5) after the experiment. Similar to the previous study, participants were only included in the analysis if they had a Tracking Ratio (TR = percentage of time that direction of gaze could be determined relative to the duration of trial) of at least 85% and good pre and post calibration. Eye tracking data for seven children met these criteria. These children (3♂, 4♀) were 8.29 ± 0.95 year old and had a TR of $95 \pm 3\%$. According to parental report, the children could already cycle without side wheels for 3.43 ± 1.37 years but had little to no experience in cycling independently in traffic. All children had normal or corrected-to-normal vision.

2.2. Apparatus

Eye movements were recorded using the Head mounted Eye tracking Device (HED, SensoMotoric Instruments, Teltow GER). The system consists of an infra red eye camera that recorded the left eye movements at 50 Hz, and a scene camera that recorded the viewpoint of the participant at 25 Hz. Both cameras were mounted on a baseball cap and connected to a notebook (Lenovo X201; 1.4 kg, Lenovo Group Ltd., Beijing, China) which was worn in a backpack. Eye tracking data and video data of the scene camera were saved using SMI's software iViewX. The system was calibrated using a five-point calibration and has an accuracy of 1° (SensoMotoric Instruments, 2012).

2.3. Set up and procedure

The experimental set up and the data procedure were identical to the first study (Vansteenkiste et al., 2013). In a gymnasium with a parquet floor, cycling lanes of 10 cm (Narrow), 25 cm (Middle) and 40 cm (Wide) of width and 15 m of length were marked on the floor with a white tape, and a starting line was marked 15 m before the start of the lanes (see Fig 1). Two mechanical gates were placed at the start and at the end of the lane and gave a visual signal when the cyclist passed through. This signal and the participants cycling performance were filmed by an overview camera (25 Hz, Full HD), which stood four metre behind the second gate.

The children were asked to bring their own bicycle, and if necessary the saddle was adjusted to the participant's height. Each participant was then given one familiarization trial for each lane. For the calibration of the eye tracker, participants were asked to sit down and look subsequently to five reference points without moving their head. Since children often had troubles holding still, an experimenter helped them by supporting their heads. When the eye-tracker was calibrated and the recording unit was put in the backpack, the participants were positioned at the start line for the actual experiment.

One of the experimenters (A on Fig. 1) instructed the participant to cycle through one of the lanes at low, preferred or high speed without crossing the edge lines. A start signal was given by a second experimenter using a clapperboard (B on Fig. 1). This signal was also used for synchronizing eye tracking data with the video images of the overview camera. Nine conditions (3 lanes × 3 speed) were carried out in a randomized order and after the last condition a calibration check was done.

2.4. Data analysis

The data of the adults in the first study were used to compare with the data of the children in the current study. The data analysis of the children was identical to that of the adults in the first study (Vansteenkiste et al., 2013).

Using the signals from the mechanical gates, the average cycling speed (km/h) on the 15 m lane was calculated. Steering precision was expressed as the percentage of time the participant cycled inside the edge lines and was visually obtained from the overview camera at the end of the lane. To analyze gaze behaviour, the video data with overlay gaze cursor were exported from BeGaze for each trial. These videos were then analyzed frame by frame in Kinovea to measure fixation duration, fixation type, and fixation location. A fixation was defined when the cursor was steady for at least three consecutive frames (120 ms) and ended when a saccade was initiated. This "direct inspection" method has been reported to be time-consuming but very effective for head mounted eye trackers (Duchowski, 2007; p138).

Four 'types' of fixations were distinguished. Travel fixations were defined when "gaze was stabilized at a constant distance in front of the participants' body and moved in the same direction and at the same speed" (Hollands et al., 2002; Patla and Vickers, 1997). The other fixations, which were directed to an object or specific location, were categorized according to the fixation location: fixations on the cycling path (Path), on the final metre of the cycling lane (Goal) and on areas outside of the travel path (External). A total fixation percentage (TotFix%) was calculated by

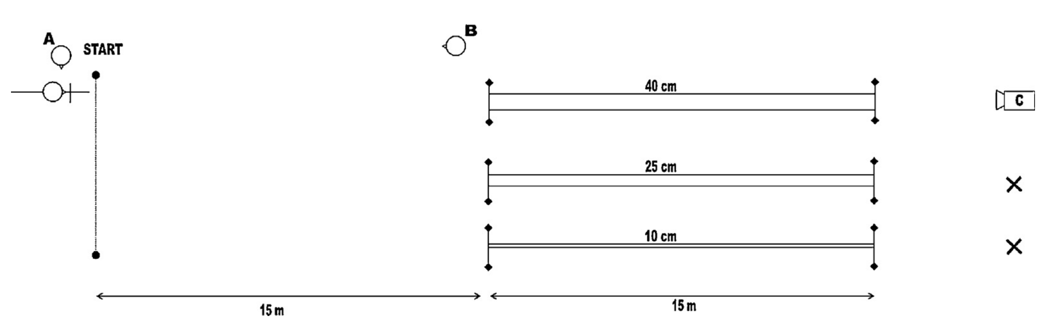

Fig. 1. Experimental set-up. (A) Experimenter who gives instructions to the participant; (B) experimenter with clapperboard, (C) and (X) places of overview camera.