G Model
AAP-4234; No. of Pages 12

ARTICLE IN PRESS

Accident Analysis and Prevention xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Accident Analysis and Prevention

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

Learning game for training child bicyclists' situation awareness

Esko Lehtonen*, Heidi Sahlberg, Emilia Rovamo, Heikki Summala

Traffic Research Unit, Institute of Behavioural Sciences, University of Helsinki, Finland

ARTICLE INFO

Article history:
Received 15 December 2015
Received in revised form 21 June 2016
Accepted 26 July 2016
Available online xxx

Keywords:
Hazard perception
Anticipation
Situation awareness
Children
Serious game

ABSTRACT

Encouraging more children to bicycle would produce both environmental and health benefits, but bicycling accidents are a major source of injuries and fatalities among children. One reason for this may be children's less developed hazard perception skills. We assume that children's situation awareness could be trained with a computer based learning game, which should also improve their hazard perception skills. In this paper, we present a prototype for such a game and pilot it with 8–9 year old children.

The game consisted of videos filmed from a bicyclist's perspective. Using a touchscreen, the player's task was to point out targets early enough to gain points. The targets were either overt (other visible road users on a potentially conflicting course) or covert (occlusions, i.e. locations where other road users could suddenly emerge). If a target was missed or identified too late, the video was paused and feedback was given.

The game was tested with 49 children from the 2nd grade of primary school (aged 8–9). 31 young adults (aged 22–34) played the game for comparison. The effect of the game on situation awareness was assessed with situation awareness tests in a crossover design. Similar videos were used in the tests as in the game, but instead of pointing out the targets while watching, the video was suddenly masked and participants were asked to locate all targets which had been present just before the masking, choosing among several possible locations. Their performance was analyzed using Signal Detection Theory and answer latencies.

The game decreased answer latency and marginally changed response bias in a less conservative direction for both children and adults, but it did not significantly increase sensitivity for targets. Adults performed better in the tests and in the game, and it was possible to satisfactorily predict group membership based on the scores. Children found it especially difficult to find covert targets. Overall, the described version of the learning game cannot be regarded as an effective tool for situation awareness/hazard perception training, but ways to improve the game are discussed.

1. Introduction

Bicycling is a popular means of leisure, exercise and transport for children and youth around the world (Macarthur et al., 1998). All forms of active travelling, such as walking and biking to school, are seen as environmentally friendly and an easy and convenient way for children to improve their health (De Hartog et al., 2010; Stewart et al., 2012). However, bicycling related accidents are relatively common. In Finland, bicycling is the form of transport where most (40%) of children's traffic injuries happen (Liikenneturva, 2015a). In a study conducted by Thompson et al. (1990) in Seattle, Washington, overall bicycle-related injury rates were highest among 10- to 14-year-olds when adjusting the data for miles ridden. Bicycle-related head injury rates were highest for 5- to 9-year-olds. In Finland, child cyclists aged 10–14 have a risk of injury twice as high as the entire population (Liikenneturva, 2015b). Given child bicyclists' vulnerability due to their still developing physical and cognitive skills, it could be argued that it is important to develop methods to evaluate and improve their situation awareness and hazard perception skills.

1.1. Situation awareness and hazard perception

According to Endsley (1995a) situation awareness (SA) is defined as "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future". For acquir-

* Corresponding author at: Siltavuorenpenger 1 A, FIN-00014, University of Helsinki, Finland.
E-mail address: esko.lehtonen@helsinki.fi (E. Lehtonen).

http://dx.doi.org/10.1016/j.aap.2016.07.036

ing and maintaining SA, Endsley has drawn a careful distinction between three different levels of SA with higher levels depending on the success of lower levels (Wickens, 2008). The first level in SA is to *perceive* the status and attributes as well as the dynamics of relevant elements in the environment (Endsley, 1995a). At the second level, *comprehension* of the situation has been formed based on the elements and their relevance for the goals at hand. At the highest level of SA, a *prediction* of the future status and actions of the elements is present. In other words, SA is more than merely perceiving relevant information in the environment; it involves integration of information and its comprehension relative to the perceiver's goals and anticipation of future events.

Hazard perception (HP) has been defined as the process of detecting, evaluating and responding to dangerous situations in traffic, which have a high probability of leading to accidents or errors (Crundall et al., 2012). HP can be understood as SA for dangerous events in traffic settings, because the ability to use anticipatory cues to predict potential hazards is essential for HP (Horswill and McKenna, 2004; Crundall, 2016). Therefore, instead of HP, the term *hazard anticipation* would be also justified (e.g. Pradhan et al., 2009; McDonald et al., 2015).

In HP, not all hazards are equal. A distinction is typically made between *latent* and *acute* hazards. Latent hazard means that there are anticipatory cues which can be used to predict the occurrence the hazard (e.g. a ball rolls over the roadway, and after that a child comes running). Using these cues, the hazard can be avoided before it has materialized. In contrast, acute hazards are unpredictable hazards, without any forewarning cues (e.g. child running on the road behind parked cars). Therefore, it has been suggested that acute hazards should not be considered when investigating HP skills (Crundall et al., 2012).

Another distinction for latent hazard can be made according to the type of cues. Latent hazards can be either *overt* or *covert* (Vlakveld, 2014). Overt latent hazards are visible road users who start acting dangerously; covert latent hazards are road users who are hidden by an object (e.g. a house, parked cars) but can be on a collision course (Vlakveld, 2014). Corresponding terms according to Crundall et al. (2012) are *behavioural prediction* hazards and *environmental prediction* hazards, respectively. Behavioural prediction hazards or overt latent hazards require predicting the behaviour of the road user, e.g. a car signalling turning by blinking is likely to turn and thus might end up on a collision course. In environmental prediction hazards or covert latent hazards, prediction cannot be made and the driver needs to consider the probability of there being both an object that blocks the view and a road user on a collision course hidden behind the object (Crundall et al., 2012).

HP has typically been investigated using video clips taken from the driver's, motorcyclist's or bicyclist's perspective (Borowsky et al., 2010; Chapman et al., 2002; Crundall et al., 2012; Horswill and McKenna, 2004; Hosking et al., 2010; Lehtonen et al., 2015; Underwood et al., 2013). Each short clip contains one or more hazards and simple press-button responses to these events are often used as the measure of ability (Meyer et al., 2014).

Because good HP skills can result in more time to avoid a collision (Ahopalo et al., 1987; McKenna and Crick, 1994; Pelz and Krupat, 1974), it is not surprising that HP has been indicated to be an important factor in many traffic accidents (Horswill et al., 2015).

Multiple studies have reported differences in HP between inexperienced and experienced drivers and riders: novices respond to hazards more slowly and miss them more often (e.g. Horswill and McKenna, 2004; Hosking et al., 2010; Lehtonen et al., 2015; Underwood et al., 2005; Underwood et al., 2013). Novices also have difficulties identifying potential hazards, and they search and scan the roadway less, tending to focus on the road directly ahead of them compared with experienced drivers and riders (Underwood, 2007; Lehtonen et al., 2014). However, not all of these findings have been consistent, and a number of studies have failed to find the expected differences in HP ability as a function of experience and accident proneness (e.g. Crundall et al., 2002; Sagberg and Bjørnskau, 2006). Nevertheless, contradictory findings may be due to differences in HP tests (e.g. how hazardous situations are defined), in instructions given to participants, and in the criteria used in selecting novice and experienced drivers/riders (Borowsky et al., 2009; Crundall et al., 2012; Horswill and McKenna, 2004). It could be argued that a fundamental criterion for a test of HP or SA is that it is able to reflect the differences in the level of HP/SA skill between novice and experienced drivers/riders, or, as in this study, between children and adults.

1.2. Children in traffic

Riding a bicycle in traffic is a complicated task of combining motor (e.g. bicycle handling) and cognitive (e.g. attending and responding in traffic) skills or actions at the same time (Ellis, 2014). However, due to children's still developing physical, cognitive and psychosocial abilities, they may be especially vulnerable to traffic dangers (Barton and Morrongiello, 2011; Dye and Bavelier, 2010; Klenberg et al., 2001; Stewart et al., 2012). According to Liikenneturva (2015a) bicycling children are likely to be involved in crashes at intersections, for example where a bike lane and a roadway intersect. Ellis (2014) states that one of the reasons for these accidents is that the child most likely did not conduct a proper search of the traffic environment before crossing. Barton and Morrongiello (2011) furthermore discuss that cognitive processing and attentional demands of crossing a street are various and are not fully developed until the later primary school years. A study conducted by Schaefer et al. (2008) also suggests that children place priority on motor over cognitive task when engaging in both at the same time. An example of such prioritization might be observed in children when they are crossing a busy street intersection on a bicycle. This, of course, has implications for children's risk for injury while bicycling in traffic.

Studies of children's traffic behaviour have focused mostly on road crossing issues, such as finding a safe place to cross or judging safe gaps in traffic (Barton and Morrongiello, 2011; Chihak et al., 2010; Dunbar et al., 2001; Grechkin et al., 2013; Meir et al., 2013; Meyer et al., 2014; Plumert et al., 2004; Plumert et al., 2011). Studies have implied that children tend to have poor pedestrian skills and visual search strategies as well as other perceptual and cognitive limits that can interfere with their capabilities in safe traffic behaviour (e.g. Ellis, 2014; Barton and Morrongiello, 2011). However, children's ability to anticipate and perceive hazards could protect them from injury and also reduce the possibility of accidents, such as when crossing the road or while riding a bicycle (Meyer et al., 2014). Any rules or skills that children are taught with regard to safety in traffic are only of value if they are able to apply them to a wide variety of contexts after they have recognized a potential danger (Hill et al., 2000).

A study by Oron-Gilad et al. (2011) demonstrated that children under the age of 13 have significantly longer HP latencies as well as lower response rates to some traffic hazards compared with adults. It also showed that adult pedestrians were more sensitive to potential hazards. Hill et al. (2000) also contend that there is evidence that young children are poor at identifying unsafe and risky situations. However, Meir et al. (2013) note that skills required in safe traffic behaviour are not completely dependent upon maturation but that experience is an important factor as well. The result in their study indicated that as a pedestrian's age and experience increased, attentiveness towards potential hazards improved and their ability to anticipate events enhanced.

Previous research on children's traffic behaviour has also shown that child cyclists are less competent than adults at road crossing