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Using optical illusions in the shoulder of a cycle path to affect lateral position

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ABSTRACT

An important factor in single-sided accidents of older cyclists is that they ride off the cycle path onto the verge. Two experiments were performed to assess the feasibility of using virtual 3D objects in the verge to affect the lateral position of bicyclists. In the first experiment, different virtual objects were placed in the shoulder and 1150 passing bicyclists were observed using a fixed camera. The (standard deviation of the) lateral position and speed in four conditions with virtual objects differing in colour, structure, or 3D effect were compared with a control condition in which no virtual objects were applied. In a second experiment, the behaviour of 32 bicyclists aged 50 years or older was measured by mounting two digital action cameras with GPS on the participants' bicycles. The participants cycled a route of approximately 12 km in which several locations were passed, one of these contained 15 virtual objects similar to the ones used in the first experiment placed in the shoulder of the cycle path. Cyclist behaviour was compared with behaviour at a control location consisting of a solitary two-way cycle path with a grass shoulder. Results indicate that the virtual objects in the tested format had little overall effect on cyclists' behaviour. However, bicyclists were positioned closer to the virtual objects and the shoulder when they looked at the objects or when they reported that they saw them while cycling. This suggests that the overall visibility of the object design may have been too conservative.

1. Introduction

1.1. Cycling in the Netherlands

In the Netherlands cycling is a very popular mode of transportation. Estimations are that 26% of all journeys in the Netherlands are made by bicycle (Ministry of Transport, Public Works and Water Management, 2008). Cycling can be an effective mode of transportation and an important contributor to physical health and fitness (Oja et al., 2011) although cycling in traffic is not without risks. In 2012, 59% of all first aid treatments after traffic accidents in the Netherlands involved cyclists (Schepers, 2013).

Several factors influence cycling safety, such as adverse weather conditions, state of the pavement, other road users, defects of bicycles, alcohol or drug use, gender, helmet use, and bicycle use by two occupants (Juhra et al., 2012; Martínez-Ruiz et al., 2013, 2014). Common types of accidents are falls while getting on or off the bicycle and falls due to potholes or pavement irregularities, kerbstones, or similar (Scheiman, Moghaddas, Björnstig, Bylund, & Saveman, 2010).

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1.2. Older cyclists

As our society is ageing, bicycle use by older people is also increasing (Wegman, Zhang, & Dijkstra, 2012). This is a positive development as it contributes to independent mobility, which is an important factor for healthy ageing and quality of life (Fagerström & Borglin, 2010; Törnvall, Marcusson, & Wressle, 2016). However, increasing age is also related to a greater risk for being involved in a serious cycling accident (Martínez-Ruiz et al., 2014) and for sustaining severe injuries with poor outcome after a crash (Kaplan, Vavatsoulas, & Prato, 2014; Siman-Tov, Jaffe, Peleg, & Israel Trauma Group., 2012). In the Netherlands, 67% of all bicyclist fatalities were among cyclists aged 60 years or older. This is more than twice as much as fatally affected car drivers within the same age group (CBS, 2014).

The increased accident risk for older cyclists can be explained by both cognitive and physical decline (OECD, 2001). Cognitive factors such as a decrease in attention, working memory, and reaction capability can make many traffic situations a more mentally demanding task. Physical factors such as decreased balance, increased muscle stiffness, and bone fragility lead to more severe injuries after a collision or fall. These factors show the need to increase safety for older cyclists, which is currently one of the priorities within the Dutch cycling safety policy (Rijkswaterstaat, 2016).

1.3. Single-sided accidents

Older cyclists in the Netherlands are particularly at risk for single-sided accidents, which are accidents not involving other traffic participants (Schepers & Klein Wolt, 2012). Although minor cycling accidents in the Netherlands are underreported (Schepers & Klein Wolt, 2012; Wegman et al., 2012), estimations are that in more than 60% of all cyclist accidents leading to injuries no other traffic participants are involved (Schepers, 2013). In 50% of all single-sided accidents, infrastructural factors are of influence (Fabriek, De Waard, & Schepers, 2012; Schepers & den Brinker, 2011; Schepers & Klein Wolt, 2012) and 33% of these accidents happen on a cycle path (Schepers, 2008).

Westerhuis and De Waard (2016) studied the behaviour of older cyclists in a naturalistic cycling setting and identified behaviour potentially leading to an accident. They found that 20% of the cyclists accidently entered the verge once or more during a week of cycling. Although these events did not lead to any accidents in the observed cases, it is known that in 21% of all single-sided cycling accidents in the Netherlands cyclists end up riding off the road, either hitting a kerbstone or entering the verge (Schepers, 2013). Interacting with a cycling companion (45%), alcohol use (19%), not looking ahead (17%), moving out of the way for another road user or performing an overtaking manoeuvre (13%), or physical problems (12%) are important factors preceding these types of accidents (Schepers, 2008).

1.4. Safety measures

Current Dutch traffic policies are based on the evidence-based "Sustainable Safety" vision, in which several principles are applied to prevent accidents and limit injuries (Wegman, Aarts, & Bax, 2008). The current study is based on the principle of physical forgivingness, meaning that the infrastructure should be designed to prevent accidents or constrain negative outcome (Houtenbos, 2009). Examples of such safety measures are implementing a passable shoulder or reducing the number of objects on a cycle path. As a different form of physical forgivingness, the current study explores the use of optical illusions to influence the position of cyclists preventing them from riding off the road. As, currently, physical objects are mostly used to fence off roads or cycle paths (i.e. posts or bollards), these are objects cyclists can collide with potentially leading to a single-bicycle accident.

1.5. Optical illusions

As optical illusions are visual deceptions they are, in principle, undesirable in any traffic situation as they tend to misinform traffic participants (CREST., 2013). Remarkably, there are indications that they can be used to enhance traffic safety. For example, several studies have shown that the application of transverse delineation on roads can reduce driving speeds in motorised vehicles (CREST, 2013; Godley, Triggs, & Fildes, 2000; Wu, Hu, & Li, 2013). Furthermore, Wu et al. (2013) concluded that speed-reducing optical illusions also evoke a tendency in motorcyclists to maintain a more central lateral position, an effect they did not find in car drivers.

A more specific use of optical illusions in the traffic infrastructure is anamorphosis (CREST, 2013; Plankermann, 2013), which is purposefully distorting an image so that it can be seen from different perspectives, at greater distances, or at higher speeds. This paper describes a study in which anamorphic images placed in the cycle path shoulder might be used to affect the behaviour of cyclists. It was observed during a naturalistic cycling study that cyclists have a tendency to regularly move around objects, such as manhole covers, which may be a threat to balance (Westerhuis & De Waard, 2016). Therefore, it was hypothesised that creating virtual objects in the shoulder of a cycle path influences the lateral position of cyclists by provoking a natural reaction to avoid colliding with this object. As the object can be perceived either consciously or unconsciously through foveal vision or peripheral vision, respectively, lateral distance to these objects (and therefore the shoulder) should be increased. Furthermore, it was hypothesised that cyclists would lower their speed as an anticipatory reaction as they pass the objects.

The virtual objects were placed along the right-hand side of the cycle path so that they would be perceived in the peripheral visual field of passing cyclists and function as a subtle warning signal that the edge of a cycle path needs to be avoided.