Journal of Transport Geography 88 (2020) 102827

Contents lists available at ScienceDirect

Journal of Transport Geography

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

Wayfinding for cycle highways: Assessing e-bike users' experiences with wayfinding along a cycle highway in the Netherlands

D. van Lierop[a,*], J. Soemers[b], L. Hoeke[b], G. Liu[c], Z. Chen[a], D. Ettema[a], J. Kruijf[a]

[a] Human Geography and Spatial Planning, Utrecht University, Princetonlaan 8A, room 6.02, Utrecht 3584 CB, the Netherlands
[b] Built Environment and Logistics, Breda University of Applied Sciences, Mgr. Hopmanstraat 1, 4817JT, Breda, the Netherlands
[c] Department of the Built Environment, Eindhoven University of Technology, P.O. Box 513, Eindhoven 5600 MB, the Netherlands

ARTICLE INFO

Keywords:
Wayfinding
Cycle highways
E-bikes
Sustainable travel
Cycle-along
Semi-structured interviews

ABSTRACT

In many regions, governments are motivating increased bicycle ridership by designing new and improving existing bicycle infrastructure. Cycle highways are an effective and cost-efficient type of bicycle-specific infrastructure that are designed to provide a functional connection between places where people work, go to school and live. One important element of developing high quality cycle highways is the development of an effective wayfinding system which allows current, potential, and new users to clearly identify and navigate a bicycle network. The wayfinding design standards used for conventional bicycle infrastructure may not be compatible for cycle highways, which encourage cyclists to travel at relatively higher speeds. This may warrant introducing specific wayfinding signage compatible for this new type of bicycle infrastructure. This study uses qualitative analysis including field observations, ride-along videos, and semi-structured interviews, to assess electrically assisted pedal bicycle (e-bike) users' opinions and experiences with wayfinding signage along a pilot cycle highway route located between Tilburg and Waalwijk in the Netherlands. In the summer of 2018, base-line observations and interviews were administered with twelve e-bike users who were unfamiliar with the route to assess their experiences with conventional signage for cyclists before changes were made to the wayfinding system. Follow-up observations were held in the fall, after the installation of two new pilot wayfinding systems that were specifically designed to accommodate cycle highway users. Initial findings suggest that the changes made to the location, size and clarity of the signage improve cyclists' overall experiences, and that cyclists' perceptions of the built environment are important. Specifically, it became easier for users to navigate the route, their overall travel related stress decreased, and several participants perceived shorter travel times. Policy makers and transportation planners are likely to be interested in the results of this study as they reveal how specific improvements to wayfinding along cycle highways not only help improve navigation, but also positively influence cyclists' overall comfort and stress.

1. Introduction

In many regions, policies to promote sustainable travel are starting to positively influence the use of active transportation. One way that regional planning bodies are motivating increased bicycle ridership is by designing new and improving existing bicycle infrastructure. Cycle highways are an effective and cost-efficient type of bicycle-specific infrastructure that are designed to provide a functional connection between places where people work, go to school and live (Faber, 2016). While sometimes planned to support recreational cycling, cycle highways are often planned as the backbone of a cycle network specifically targeting commuters, students and other utilitarian cyclists who cycle for relatively longer distances. They are designed and built to be high quality infrastructure (for example, focusing on the connection to public transport networks, smooth and wide asphalt pavement, and being along a healthy and attractive landscape) in order to support fast, direct and attractive cycle experiences (Faber, 2016). Due to their potential benefits, regions around the world are building cycle highways to encourage sustainable inter-urban transport using conventional bicycles, electrically assisted pedal bicycles (e-bikes), and other forms of motorized two-wheelers. In Europe, examples of cycle highways can be found in Belgium (fietssnelwegen.be), the Netherlands (fietssnelwegen.nl; www.fietsfilevrij.nl), Denmark (supercykelstier.dk), and the United Kingdom (Transport for London, 2018). The focus on mid-range

* Corresponding author.
E-mail addresses: D.S.vanlierop@uu.nl (D. van Lierop), judith.soemers@gmail.com (J. Soemers), Hoeke.l@buas.nl (L. Hoeke), Y.Liu.5@tue.nl (G. Liu), Z.Chen1@uu.nl (Z. Chen), J.Kruijf@uu.nl (D. Ettema), D.F.Ettema@uu.nl (J. Kruijf).

https://doi.org/10.1016/j.jtrangeo.2020.102827
Received 13 February 2020; Received in revised form 17 July 2020; Accepted 5 August 2020
Available online 13 August 2020
0966-6923/

bicycle commuting infrastructure is now also becoming topical in many regions outside of Europe (Mason, Fulton, & McDonald, 2015).

1.1. Cycle highway outcomes

Similar to other bicycle infrastructure investments, cycle highways are expected to stimulate some car users to adopt (high speed) bicycles, including e-bikes, for commuting trips and thereby relieve automobile traffic congestion and decrease emissions (Buekers, Dons, Elen, & Int Panis, 2015; European Regional Development Fund, 2016). In regions with existing cycle highways, researchers have begun to assess potential modal-shift from cars to bicycles and the corresponding health impacts.

For example, to investigate the changes in bicycle mode share as well as cyclists' experiences and perceptions of cycling in the western suburbs of Copenhagen, Denmark, Skov-Petersen, Jacobsen, Vedel, Thomas Alexander, and Rask (2017) conducted a longitudinal survey before and one and two years after a route with traditional bicycle infrastructure was upgraded to a cycle highway. The results suggested an increase from 126 to 203 bicyclists per hour during daylight peak hours and from 89 to 154 during the darker peak hours on weekdays after the upgrade. The results also suggested that new users who previously would not have made the trip by bicycle accounted for 4–6% of users after the improvements. In Belgium, Buekers et al. (2015) evaluated the health impacts associated with a mode shift from car use to cycling or walking on two new cycle highways. These authors concluded that the benefits of increased physical activity outweighed the negative impacts of increased air pollution exposure during physical activity and crash risks.

1.2. Cycle highways and e-bikes

Cycle highways enable and encourage cyclists to ride at higher speeds and potentially travel relatively farther distances compared to those who travel on conventional bicycle infrastructure. *E*-bikes, as well as other highspeed bicycles, are therefore appropriate modes for this infrastructure type. Due to the relatively higher speeds associated with e-bikes, the average travel range of e-bikes has been found to be one and half times as far as that of a conventional pedal bicycle (Kennisinstituut voor Mobiliteitsbeleid, 2016), thereby becoming a viable travel mode for distances that for some individuals may be considered too far to travel by conventional bicycle. Accordingly, in many regions e-bike adoption is on the rise (Jones, Harms, & Heinen, 2016; Rose, 2012), and regional planning bodies are motivating the continued adoption of high-speed bicycles by designing policies and infrastructure (such as the development of cycle highways) that support the use of these sustainable travel modes. However, while e-bikes in Europe are pedal assisted bicycles with an auxiliary electric motor of less than 250 watts and with the output of the motor cutting off at 25 km an hour (Regulation, 2013), the design and usage of traditional bicycle infrastructure, often limits actual average speeds. For example, in the Netherlands, the average cycling speed for adults up to age 50 is 12.4 km per hour, which increases to 14.5 km per hour for e-bike users (Kennisinstituut voor Mobiliteitsbeleid, 2016). Therefore, to motivate sustainable mode switch and bicycle adoption for mid-range distances, cycle highways ideally possess high quality infrastructure which provide users with a fast, safe, and attractive cycling experience.

1.3. Bicycle wayfinding

One important element for developing high quality cycle highways is the presence of an effective wayfinding system which allows current, potential, and new users to clearly identify and navigate a bicycle network. Wayfinding systems help people orient themselves by providing information about how to navigate a specific area such as the geography of a region (Global Designing Cities Initiative, 2016). These systems can be both physical or digital, and in the context of this study we focus on physical wayfinding signage that is observed along cycle highways. Wayfinding is not only helpful for navigation but also essential for users of all modes to safely and efficiently move through and understand how space is intended to be shared amongst users of various modes. Therefore, in most cases, physical wayfinding signage is mode-specific, because the differences in average speeds, heights, and points of interest determine the ways that people interact with transport infrastructure. For example, wayfinding for pedestrians tends to be “human scale”, which concerns a match between the size and texture of physical elements and the size and proportion of a human being in urban design (Ewing & Handy, 2009). Since pedestrians navigate areas by foot, pedestrian-oriented wayfinding tends to be smaller, frequently distributed and placed at a height that an average sitting or standing person can read. However, for people viewing the city from the window of a fast-moving car, wayfinding signage along highways generally uses larger signs and fonts that are placed relatively higher from the ground, and are more spread-out. In other words, a scale that is appropriate for the size and speed of the car. Likewise, users of bicycle infrastructure interact with the environment by bicycle, and appropriate wayfinding systems should be optimized for bicycle use and designed to reflect “bicycle scale” – a scale that is distinct from those used to design for pedestrians or car drivers (Liu, te Brömmelstroet, Krishnamurthy, & van Wesemael, 2019). Moreover, the wayfinding needs of cycle highway users may be distinct from those using conventional bicycle infrastructure. Since cycle highways are a relatively new concept, and the adoption of higher speed bicycles such as e-bikes has only become more mainstream in recent years (Fishman & Cherry, 2016), the increased speeds and longer distances experienced by cycle highway users are a reason to assess users' specific wayfinding needs. Specifically, the wayfinding design standards used for conventional bicycle infrastructure may not be compatible for cycle highways. Accordingly, when incorporating a new kind of infrastructure such as a cycle highway as part of a region's transportation network, it is important to assess whether there is a need for new or updated wayfinding standards.

1.4. Cyclists' feelings and experiences with navigating and using cycle highways

While most of the current research on wayfinding design tends to focus on the material, size or shape of signs in relation to safety issues (e.g. Berces & Robertson, 2012; Hess & Peterson, 2015), little is known about how users experience and perceive different types of wayfinding while travelling on cycle highways. Previous research has suggested that an individual's interactions are embodied in their experiences of space and time, and that human emotion can influence or assist in forming a contextual understanding of the environment (Davidson & Milligan, 2004; Davidson, Smith, & Bondi, 2012). Emotions or feelings have been suggested to create, maintain or change the personal motivations underlying individuals' conscious or subconscious behavior (Davidson et al., 2012; Hallman & Benbow, 2007). Accordingly, it is critical to assess and understand cyclists' feelings and experiences with navigating and using cycle highways. The requirements of cycle infrastructure design are likely to vary for different users, and a better fit between design elements of cycle infrastructure and target users' needs (in this case high-speed cyclists such as e-bike users) is essential to ensure a positive cycling experience. Evidence based on conventional cyclists' experiences has previously suggested that the availability of high quality bicycle infrastructure is necessary to encourage cycling, and that the quality of bicycle infrastructure should be considered to avoid cyclists becoming frustrated with their cycling experiences (Mayers & Glover, 2019). While wayfinding is an element of bicycle infrastructure that influences the experience and behavior of cyclists (Hull & O'Holleran, 2014), it is unclear how the design of traditional bicycle wayfinding should evolve to accommodate the needs of cycle highway users. Yet, previous studies have suggested that individuals may perceive or understand identical wayfinding systems in different

Fig. 1. Original wayfinding signage for cyclists as experienced by participants in summer, 2018.

ways. For example, Lawton (2001) suggested that women rely more on the presence or absence of landmark cues than men, while men refer more to cardinal directions. Galea, Xie, and Lawrence (2014) found that only one third of people could "see" static emergency exit signage located in front of them, even when the signs were within their range of vision. Individuals' perceptions are thus a key aspect influencing the effectiveness of a wayfinding system. Therefore, additional knowledge is needed to better understand the preferences and experiences of cycle highway users.

The present study aims to assess what kind of wayfinding signage is the most effective for cycle highway users in the Netherlands. Using qualitative analysis including field observations and semi-structured interviews, the present study aims to better understand how to improve wayfinding on cycle highways by assessing e-bike users' opinions and experiences with the location and size of signage, as well as the color of the asphalt and on-road surface markings. To our knowledge this is the first study that assesses the specific signage and wayfinding needs of cycle highway users.

2. Context

In 2016 the European Regional Development Fund launched CHIPS (Cycle Highways Innovation for smarter People Transport and Spatial Planning) to *"develop and promote cycle highways as an effective and cost efficient low carbon solution for commuting towards and from urban employment poles"* (European Regional Development Fund, 2016). The initiative focused on the adoption of e-bikes and the associated need for cycle highway innovation. The project involved organizations and municipalities -from several countries in North-West Europe, and the planned cycle highway F261 between Tilburg and Waalwijk in the Netherlands was selected as a (national) pilot site for testing new approaches to wayfinding. This cycle highway is approximately 18-km, connecting Tilburg in the south, which has a population of approximately 200,000, and the smaller city of Waalwijk in the north which has a population of approximately 50,000. This site was selected due to the presence of inter-regional travel in the area (often related to employment) as well the presence of mostly uninterrupted bicycle infrastructure between the two cities. As of the first experiment in June 2018, the cycle route consisted of approximately 11 km of asphalt and 7 km of brick ground surfaces. Half of the bicycle infrastructure consisted of separated cycling lanes and routes, and the remaining 9 km was in mixed traffic. In addition, at least 7 km of the route was wide enough for cyclists to comfortably cycle side by side, and the full route included both dense urban regions as well as rural areas. Interactions with other modes and infrastructure types were also diverse due to variations in road width, asphalt and cobblestone quality, as well as the degree to which the bicycle path was separated from vehicular traffic at various speeds. The route has been slated to become a designated cycle highway with upgraded cycling infrastructure and backbone of the regional cycling network. Once the upgrades are complete, the trip is expected to take an average e-bike user just under 60 min from beginning to end.

2.1. Original wayfinding for cyclists in the Netherlands

The original wayfinding signage for cyclists used on the cycle highway meets the directives of national bicycle wayfinding signage in the Netherlands. Within these directives details about the height, position, text size, color and use of symbols are described (CROW, 2014). These regulations are obligatory for municipalities to use for bicycle wayfinding for utilitarian purposes in their region. The signs are positioned at specific decision points such as intersections and are required to be placed at a minimum height of 2.25 m (CROW, 2014). Since e-bikes are becoming a more popular commuting mode in the Netherlands and the government has starting to invest in the development of cycle highways, the usability of the current wayfinding signage for cycle highway users is being reviewed (European Regional Development Fund, 2016). Specifically, the height, font size, content, and location of decision points are being considered in order to increase safety and promote cyclist comfort (Fig. 1).

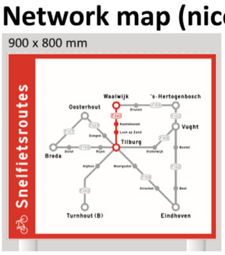
2.2. New wayfinding designs for cycle highways

In order to work towards more suitable wayfinding signage for cycle highways, regional (Noord-Brabant) and local (Tilburg) government officials mandated the design of two new concepts for wayfinding for cycle highways, designed by Mijksenaar Wayfinding specialists. Both designs are depicted in Table 1 and were required to include the color red as it is the standard color for Dutch cycling wayfinding signage.

The wayfinding concept *"Plus"* is based on the current national directives for bicycle wayfinding. While the signage was designed according to current bicycle signage regulations, it was tweaked and updated in order to meet the needs of cycle highway users travelling at relatively higher speeds. This concept included signage portraying arrows and information at eye-level, specialty ground markings, a network map and the design of advance notice signs placed before crucial decision moments such as intersections or forks in the road. This concept also included smaller confirmation signs which were placed at specific points along the route where people might require information to confirm the continued presence of the cycle highway route.

The wayfinding concept *"Snel"* was designed specifically for this study. The design of this concept was based on optimizing users' experiences and ease of use by going beyond the current bicycle signage regulations. While the concept is new, it still aims to be recognizable to

Table 1
Table 1: Comparing concept Plus and concept Snel. (For interpretation of the references to color in this table, the reader is referred to the web version of this article.)

<table>
<tr><th>Concept Plus</th><th>Concept Snel</th><th>Description of differences</th></tr>
<tr><td colspan="3">Route continuation sign (obligatory national wayfinding)</td></tr>
<tr><td></td><td></td><td>Shape: The Snel sign is arrow-shaped. When the route makes a turn, the sign is turned as well.
Content: The end destination is prominent in the Plus sign; The cycle highway name and logo are prominent in the Snel sign. Concept Snel also has a special sign for roundabouts to avoid any potential confusion.
Arrow: The Plus sign uses a closed arrow and the Snel sign uses an open arrow.
Colors: The Snel uses red, black and white to increase contrast. The Plus sign uses only red and white.</td></tr>
<tr><td colspan="3">Advance notice sign (obligatory national wayfinding)</td></tr>
<tr><td></td><td></td><td>Shape: The Snel sign is arrow-shaped and points in the direction of the route.
Content: The cycle highway name and logo are prominent in the Snel sign. The Plus signs have a red bar on both sides of the sign, whereas the Snel sign only uses red on the side of the arrow.
Arrow: The Plus sign uses a closed arrow and the Snel sign uses an open arrow.
Colors: The Snel uses red, black and white to increase contrast. The Plus sign uses only red and white.</td></tr>
<tr><td colspan="3">Network map (nice-to-have, but not officially part of national signage)</td></tr>
<tr><td></td><td></td><td>Both signs provide the location context for the cycle highway. The Snel sign also provides additional information about geographic context.</td></tr>
<tr><td colspan="3">Road surface markings (nice-to-have, but not officially part of national signage)</td></tr>
<tr><td></td><td></td><td>Arrow: The Plus sign uses a closed arrow and the Snel sign uses an open arrow.
Colors: The Snel uses red, black and white to increase contrast. The Plus sign uses only red and white.</td></tr>
</table>

Images from: Hoeke, de Kruijf, and Soemers (2019)

cyclists by using white and red coloring. In this scenario, there is a larger variety of signage with the goal of adequately informing cyclists about their position on the route and possible destinations. In addition to the red and white boards and signs, other changes included 1) the use of black text instead of red in order to improve the contrast and overall readability, 2) a cycle highway logo in combination with a cycle highway number, and 3) new shapes to enhance the recognition of a different type of cycle path, the cycle highway. Table 1 demonstrates the differences between the two concepts, and Fig. 2 shows how cyclists experienced the concepts while using the cycle highway.

In addition to the wayfinding concepts with signage and road surface markings, green colored lines were used on the cycle highway to enhance the recognizability and wayfinding. The experimental line and color was selected as it differs from the usual white lines that are used for cycle infrastructure and was intended to help users recognize and follow the route easily and comfortably (Fig. 3).

The new wayfinding signage, road surface markings and the green line were applied to the cycle highway between Tilburg and Waalwijk in August 2018. For this research the choice was made to apply the concept *"Plus"* on half of the cycle highway (Tilburg until Loon op

Fig. 2. Concepts “Plus” and “Snel” as experienced by cyclists in fall, 2018.

Zand) and concept *“Snel”* on the other half of the cycle highway (Loon op Zand to Waalwijk). The signage was designed and installed in two directions, and between the two wayfinding concepts several hundred meters were left without signage, as a buffer zone between the two concepts. Both wayfinding concepts were applied in urban and rural environments with different traffic situations and qualities of cycling infrastructure and paving. Fig. 4 demonstrates the geographic location of the two wayfinding concepts.

To visually demonstrate the differences between the original and new situations on the cycle highway, three examples are presented in Figs. 5-7. The first shows a situation where the cycle highway goes straight ahead but the infrastructural design, pedestrian crossing and location of nearby buildings might be confusing. The new arrow before the crossing improves the wayfinding to clarify that the cycle highway continues ahead. The second situation shows that cyclists should keep to the right in an otherwise potentially confusing fork in the road. Finally, the third situation shows the cycle highway where the direction changes. The improvement that is made with the new signage is that signs are placed before the crossing. In this way, cyclists are presented with navigational information about the direction before entering the crossing.

3. Method

3.1. Sample

Twelve participants took part in this study in the summer and the fall of 2018; six from a younger group were students between the ages of 19 and 23, and six from an older group were between the ages of 59 and 75. These two groups were selected in order to assess both younger and older cyclists' experiences. Eight men and four women participated in the cycle-alongs during each season, and eight cycled in pairs and four by themselves. All participants reported cycling weekly, with some cycling only for functional or recreational purposes, but most participated in both. On average the younger group cycled functionally three days a week, for an average of 20.4 min a day, and the older group cycled 2.5 days a week for an average of 22.6 min per day. None of the participants were familiar with the cycle-along route (cycle highway F261) and all participants were awarded a 50 Euro gift card for their participation.

3.2. Cycle-alongs

Using qualitative analysis including field observations, cycle-along videos, and semi-structured interviews, the present study assesses cyclists' opinions and experiences with cycle highway wayfinding signage in two phases. During the first experiment in June 2018, standard bicycle wayfinding signage was found along the route. Base-line video observations and interviews were administered with the twelve cyclists who were unfamiliar with the route to assess the experiences of the participants with conventional signage before changes were made to the wayfinding system. Participants cycled on the route between Tilburg and Waalwijk, and their assignment was to find the direction to Waalwijk (or Tilburg, depending on the participants' starting location).

Fig. 3. Green colored lines as experienced by cyclists in fall, 2018. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

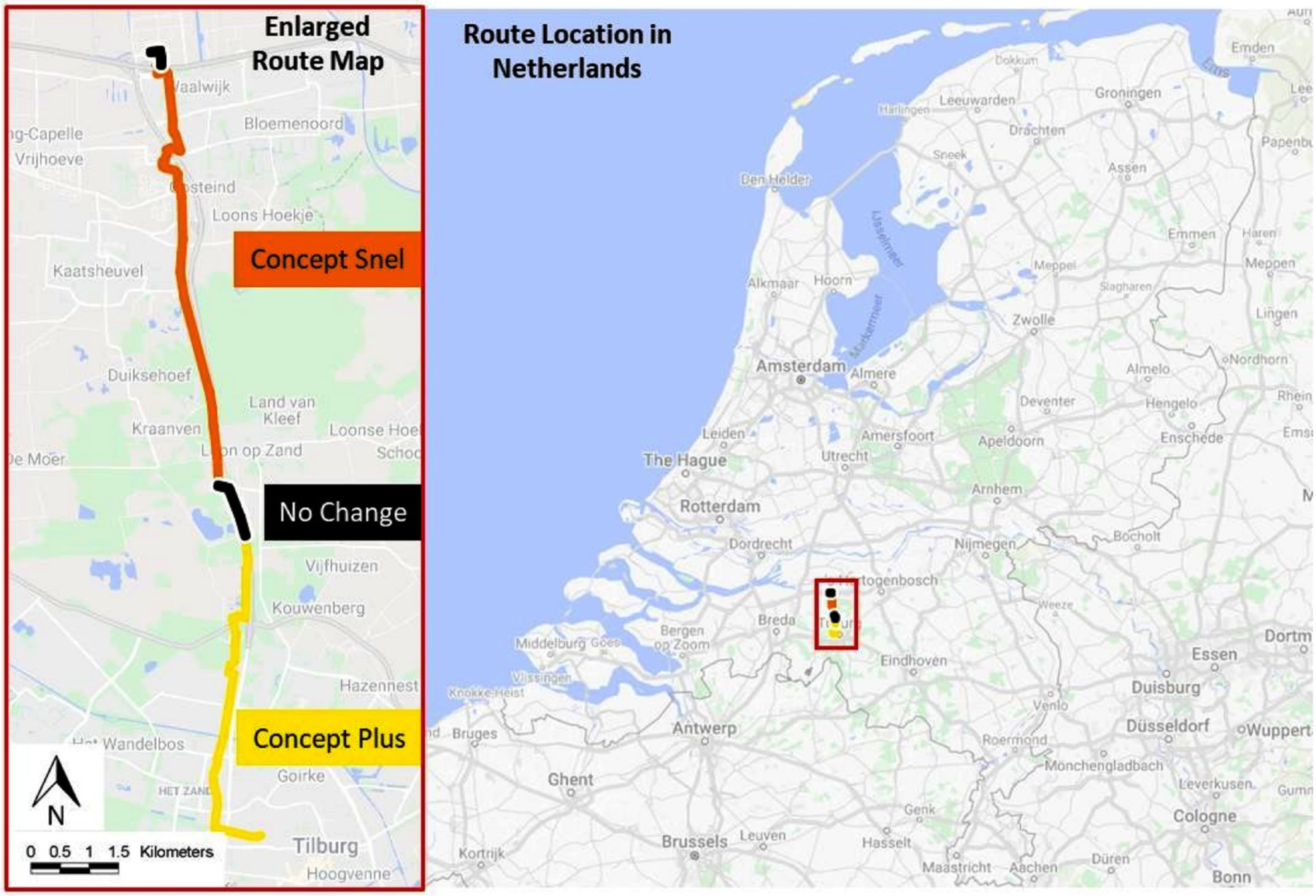


Fig. 4. Left: the wayfinding concepts where installed on the cycle highway, in two directions on a part of the cycle highway, each concept approximately 7–8 km long. Right: route to scale in context of the Netherlands. Map data ©2020 Google.

For this, they received a note with villages and places along the cycle highway so they could follow these destinations. Participants were not allowed to use their mobile phones or any other navigation systems to find the way. However, if the participants did get lost or needed to stop for any reason, they were instructed to stop at the side of the road and wave to the researchers, who followed at a distance behind them. Alternatively, when researchers observed cyclists going the wrong way for more than a few minutes, the researchers called out to the participants to help them correct their path. No other contact was had between participants and researchers during the cycle-alongs. During their cycle trips, a researcher cycled behind the participant(s) and observed using a GoPro camera mounted on the participant's handlebar and a 360-camera mounted on the researcher's bicycle. After the cycle trip, a semi-structured interview was conducted, and additional information concerning the interviews is described below.

In October 2018, follow-up observations were held after the

Fig. 5. Before (left) and after (right) placing the new signs before the crossing.

Fig. 6. Before (left) and after (right) placing round markings to avoid confusion at a fork in the road.

installation of two new pilot wayfinding scenarios that included signage and ground markings that were specifically designed to accommodate the relatively higher speeds of cycle highway users. Both new wayfinding options were planned and financed by the involved regional and local governments. During the second cycle-along, participants cycled in the opposite direction in order to rule out familiarization as best as possible. Interviews and video observations were again conducted as part of the second round of cycle-alongs, when participants navigated their way between the same two cities.

In both June and October, the cycle-alongs participants cycled either alone or in pairs and took place under normal, dry weather conditions. During this research, all participants used an e-bike with pedal assistance up to 25 km/h (when cyclists also pedal themselves). Three used their own e-bike, and the other participants used loaned *Gazelle*-brand e-bikes provided for the purposes of this study. All the e-bikes were in good condition, and no technical issues occurred during the cycle-alongs. All study participants were able to complete the ride and, depending on the participant, the bike ride lasted between one and one and half hours.

3.3. Review of video recordings

In addition to field notes taken during the cycle-alongs, video observations were reviewed by one researcher, not present during the ride-alongs, to systematically evaluate and quantify how many times participants had to stop due to unclear wayfinding scenarios. The advantage of the 360-degree video is that the video reviewer maintains the perspective of the field researcher. Simultaneously, the GoPro mounted on the participant's bicycle gives the participant's perspective of the route enabling the reviewer to judge the true distance to the signage. Given that we were able to replay the video multiple times to observe behavior, we trusted the video data if there was a discrepancy between the video observations and the field notes. The video data served two main functions. First, it allowed the researchers to track any temporary changes along the route, especially the few sections that were undergoing construction. Where participant behavior was caused directly by a temporary change, the videos allowed the researchers to exclude all data on that segment of the route. Second, the video data enabled the researchers to verify and reinterpret field notes that were taken during the ride-along and allowed re-coding of participant behavior during multiple iterations of our systematic video-coding framework. The video data, combined with the speed graph, enabled the researchers to consistently observe micro-behaviors such as participants turning their head or slowing down to read signage (Figs. 8 and 9).

3.4. Interviews

In the June 2018 data collection round, the researchers engaged the participants with semi-structured interviews once the cyclists arrived at their destination. During the October cycle-alongs, since participants experienced two wayfinding concepts during their cycle trips, interviews were held halfway, after experiencing each wayfinding concept. Accordingly, the initial interview focused on the experience of the first wayfinding concept, and in the second interview the researchers asked questions pertaining to the other wayfinding concept as well as the comparison of the two concepts.

When participants had cycled in pairs, the interviews were also held in pairs; for cyclists who cycled alone, interviews were conducted one-

Fig. 7. Before (left) and after (right) placing signs before an intersection.

Fig. 8. Still from 360-degree video attached to researcher.

on-one. On average, the interviews lasted approximately 40 min, and ranged from 35 to 50 min. The interviews were framed around gaining a better understanding of the cyclists' user experiences of the bicycle infrastructure and wayfinding system, and interviewees were asked specific questions regarding the social, spatial, and sensory factors that influenced how they perceived their cycling experience along the route.

All interviews were recorded and transcribed. As recommended by Prior (2014), content analysis was used to analyze the interview data and identify common sentiments, observations, opinions, remarks and thematic discussions. Since the existing theory and literature on wayfinding for cycle highways are limited, content analysis avoids using preconceived categories and alternatively allows themes to be derived and result from the analyzed data (Hsieh & Shannon, 2005). We examined the transcribed interview data in a systematic way using descriptive coding and later clustered information by theme (Saldaña, 2011). Two researchers independently coded the interview data using descriptive coding. Then, in a next step, the researchers compared and contrasted the themes that each researcher identified to test for consistency. One of these researchers had been present during the interviews, and to increase the robustness of the method, the other researcher only received access to the interview transcripts and never directly interacted with the participants during the study. The approach of independent researchers cross-referencing codes and themes is similar to that applied by Thomas and Harden (2008) in their thematic analysis of systematic reviews.

4. Results

4.1. Interviews

During the initial interviews in June, most participants' comments were regarding the legibility, visibility, and frequency of the signs. All twelve participants recognized the traditional red and white bicycle wayfinding signage. However, all participants mentioned that the height of the signage as well as the font sizes were a barrier to the legibility of the signs. Several participants also mentioned that the frequency of signage was too low during several sections of the cycle highway route and that additional signage would be helpful. Interesting, the older cyclists had fewer comments about the need for increased signage and mentioned that when there was no sign, they assumed they should continue straight ahead. However, the younger participants, who mentioned that they usually rely on Google Maps, had more doubts when they arrived at unmarked intersections, and often selected the path that appeared to have the best cycling infrastructure rather than continuing straight ahead. In the initial interviews, several participants also mentioned the dangers and tension that

Fig. 9. Still from GoPro video attached to participant with live telemetry: GPS, speed, heading, elevation, time and distance.

they experienced while cycling in mixed traffic at certain locations during their ride. They also mentioned lack of signage about having to give priority at roundabouts, which was unexpected and difficult to act on while travelling at the higher speed of the e-bike.

The post-cycle-along interviews in the fall revealed that the size, shape, color, height, and placement of the new cycle highway signage were important aspects of the identification and development of the cycle highway. When comparing the two proposed cycle highway concepts, many participants mentioned their preference for the *“Snel”* scenario. Most participants also mentioned that they expected a cycle highway to have consistent surface areas throughout the route, which at the moment of the cycle-alongs it did not. Specifically, while the wayfinding changed in the before and after scenarios, the paved surface areas were not changed, and remained being of inconsistent quality. However, even without upgrading the surface pavement, the results demonstrate that changes made to the wayfinding signage alone positively influenced the participants' navigation along the cycle highway.

In additional to navigational benefits, half of the participants stated that their cycling experience with the updated signs was more relaxing, and therefore less stressful, compared to their experience with the original signage. An important reason for this is that there was less need to pay close attention to the location and information provided on the signs. In both new concepts the signs were often clearly visible from a distance, which made the participants more confident that they were cycling the correct route and diminished the need for searching. Several participants also mentioned that the ride seemed to go by faster during the fall experiments, suggesting that there may be a relationship between wayfinding systems and perceived travel time.

Most participants preferred the design of the *“Snel”* scenario, which was thought to be very recognizable and was associated more strongly with a cycle highway than the *“Plus”* scenario. In comparison to the original signage, the *“Snel”* signage differed more in terms of shape and color than the *“Plus”* signage. In the fall interviews, one participant mentioned that the *“Snel”* signage was [1]:

Particularly the shape and the color red were mentioned as positive traits of the *“Snel”* scenario. The shape of the signs themselves provided information about the correct route by pointing in the right direction. Many participants reported that not necessarily having to read the signs in order to take in the information was a positive addition to the cycling experience. For example, one participant mentioned that (Fig. 10)[2]:

The red color of the signs and the black-on-white writing of the *“Snel”* scenario also helped participants see and identify the signs from a farther distance compared to the original signage. The ease of the visual information was reported as being a relaxing experience. One younger participant mentioned that[3]:

Many participants also mentioned that the consistency of the red color of the signs made it easier to identify the route as a cycle highway[4],[5]:

The height of the signage was also mentioned both in the summer and the fall interviews. For example, throughout the summer cycle-alongs, the participants had regularly trouble finding the signs on the route because of their height. A problem with these high signs, was that the cyclists had to slow down or even stop cycling to be able to find the signs and read the information. This difficulty persisted within the *“Plus”* scenario, which included several signs that were placed at the same height as the original signage. Even though the new design was implemented, the high signs were still difficult to see for the participants (Fig. 11)[6],[7].

During the fall interviews, many participants mentioned that the new signage was placed at a height that was more appropriate to the scale and size of a bicycle, suggesting that, similarly to the concept of “human scale”, the concept of “bicycle scale” should be taken into account and further considered (Fig. 12)[8].

The red, white, and black ground markings were also experienced as a positive change to the wayfinding experience when the infrastructure and/or the environment alone were not clear enough to follow the route (Fig. 13). Regarding these surface markings, one participant from the older group mentioned that[9]:

Finally, with regard to the green line surface markings, many participants did not recognize that this line was associated with the cycle highway. In addition, many participants also did not understand that the cycle highway name was “F261.” These findings suggest that it is essential to educate cyclists to be able to identify relevant cycle highway wayfinding elements.

Overall, during the interviews in both summer and fall, participants were asked to rank the quality of the route on a ten-point scale. During the fall interviews, all participants ranked the route as being at least as good or better than the score they assigned after the summer cycle-along. On average, the score increased from 6.5 (min = 5, max = 7.8, S.D. = 0.75) out of ten for the original route to 7.3 (min = 5, max = 9, S.D. = 1.1) for the concept *“Plus”* and 8.4 (min = 7, max = 9.5, S.D. = 0.73) for the concept *“Snel”*.

4.2. Video observations

The video analysis revealed that two types of severe faults occurred; the first type was when participants had to completely stop to either check a map, read a sign, or observe their environment for other wayfinding clues. The second type occurred when the researcher had to correct the participant after a significant deviation from the route, usually after ten seconds of cycling in the wrong direction. Before the implementation of the new wayfinding signage, 29 severe faults were observed amongst 11 participants. After the implementation of the new signage, only six severe faults were observed. Although the experiments took place four months apart and cyclists navigated the route in the opposite direction, the reduced navigation errors in the second round may in part be attributed to increased familiarity with the route. Fig. 14 demonstrates the results for both the summer and fall cycle-alongs. Due to an error in video recording, one set of observations was excluded in the fall video analysis due to missing video data, and accordingly the observations from the same participant in the summer ride-alongs were also removed from our analysis.

[1] “[The new signs are] clearer than the others because they are red. And the others are white. And these are red with a white bicycle and those other signs you have white signs with a red bicycle in the corner. And this is more striking, I thought.” – male participant (65), cycled alone.

[2] “What is positive is … that the shape of the signs is in an arrow, so that you are immediately clear on where you have to go.” – male participant (21), cycled alone.

[3] “Yes, yes, it felt a lot more relaxed. Because you were paying less attention because it was the visual stimulus of a red sign with an arrow and well, I'm still heading in the right direction or oh, I have to go right or left here.” – male participant (20), cycled in a pair.

[4] “They were newer signs for me. And I think, because they are slightly more red and slightly different than normal bicycle signs, I would also associate them more quickly with a cycle highway.” – male participant (23), cycled alone.

[5] “I find them clearly recognizable now. Because of that red background with a white bicycle on it.” – male participant (65), cycled alone.

[6] “They didn't stand out. But also, because they were hanging so high. Yes, they were really very high. You really had to look for it.” – male participant (22), cycled in a pair.

[7] “The white [signs] with the red letters, they are much higher and you have to try harder to keep following the route” – female participant (64), cycled in a pair.

[8] “Simply eye level. Yes, you just looked straight at it.” – female participant (20), cycled in a pair.

[9] “Those are super useful. I find them more useful than the signs, if I'm honest.” — female participant (64), cycled in a pair.

Fig. 10. Arrow-shaped Concept "Snel" located before the intersection.

Fig. 11. Concept "Plus" placed above traditional signage.

5. Discussion

To promote a modal shift towards environmentally sustainable modes, many regions are designing and building cycle highways which support the usage of high-speed bicycles such as e-bikes (Pucher & Buehler, 2017; Skov-Petersen et al., 2017). Along with the introduction of new cycle highway networks, the design of specialized wayfinding is being carefully considered. While research has been conducted on the effectiveness of various aspects of wayfinding in transportation (Delikostidis, van Elzakker, & Kraak, 2015), the influence that wayfinding has on how people experience cycle highways has not been fully explored. The present study assessed e-bike users' opinions and experiences with the location, size and design of two kinds of innovative and novel cycle highway wayfinding concepts *"Plus"* and *"Snel"*, as well as the color of the asphalt and on-road surface markings, in the Netherlands. All participants clearly reported that they preferred one of the two upgraded wayfinding concepts over the original wayfinding design. Systematic video observations also confirmed that participants made fewer stops (or direction errors) when they cycled under the new wayfinding conditions. Several important facets of cycle highway wayfinding design are discussed below.

5.1. Good wayfinding design for cycle highways should be at "bicycle-scale"

The design of the *"Snel"* scenario was rated higher by most participants in terms of clarity and ease of use. One reason that participants preferred the *"Snel"* scenario is because the arrow shape of the signs themselves provided information about the correct route by pointing cyclists in the right direction. This finding is in line with those of Bazire and Tijus (2009) who suggested that the shape of good signs should express the kind of action expected. The relatively larger size and red color of the arrow shaped sign also helped cyclists to see it from a distance. In addition, clear preference was given for the *"Snel"* scenario which made use of extreme color contrasts presenting black letters on a white background within the context of the overall red signage. The red color served to attract cyclists' attention, while the black-on-white information remained clearly visible and readable. This combination of colors matches what Smiley, Houghton, and Philp (2004) considered as effective coding and as having an "optimum background color and luminance contrast" (Smiley et al., 2004, p.5).

When directing individuals to use a path to reach a destination, directional signs were traditionally believed to be best placed at the decision points such as the nodes and intersections (Farr, Kleinschmidt, Yarlagadda, & Mengersen, 2012; Fewings, 2001). However, in the case of cycle highways, the traditional location of directional signs is ineffective as it can slow down a cyclist's speed and encourage unsafe cycling behavior. Smiley et al. (2004) put forward effective highway sign placement attributes for drivers, pointing out that decision points need to be placed in a location that allow drivers to have enough time to gain information from the signs and formulate a decision. These principles are aligned with the experiences of the e-bike users in this study, which clarify the need for relatively earlier sign placement, so that the signs are visible before a decision has to be made. In addition,

Fig. 12. Concept “Plus” (left) and “Snel” (right) placed at eye-level.

Fig. 13. Concept “Snel” ground markings.

an effective signage placement strategy for cycle highways should consider not only the location (before a decision point) but also the height of the signs. The signs should be placed at a height that is appropriate for the scale and size of a bicycle—at eye level for a cyclist. Our findings confirm the importance of designing “bicycle scale” wayfinding systems for cycle highways, consistent with Liu et al. (2019)’s suggestion that cycle highway design should be optimized to meet the unique requirements of cyclists.

5.2. Good wayfinding contributes to a cycle highway's recognizability

Our analysis suggests that a good signage system does not only work to improve navigation but also to identify a cycle highway. In the two updated scenarios *“Plus”* and *“Snel”*, the context map (which some participants described as being similar to a metro map) emphasized the location of the route relative to important landmarks and other connecting roads (Fig. 2, Table 1). Compared to the map showing the geographic route location and direction in real situations, participants found the information provided by the simpler, metro-style map easier to interpret, and therefore more useful. It is likely that participants' familiarity and previous experience with widely-used transit system maps influenced their preference.

In addition, the findings suggest that what has been reported in previous research concerning individual's preferences for consistent signage design in terms of size, color, texts and symbols (Farr et al., 2012; Fewings, 2001), is also relevant for bicycle-highway wayfinding design. According to Mitchell (2010), who assessed wayfinding for drivers, good signage design provides positive information and guidance in a standard way (e.g. same shape and color). Likewise, in the present study the standard red color for Dutch cycling wayfinding signage was continually used in the new concepts, and the red colored signs were described by participants as easily recognizable and as clearly belonging to the cycle highway network. Yet, although the color was consistent with the traditional signage, the new design, font, and sign shape differentiated the cycle highway signage from the regular bicycle lane network. The consistent sign colors and the repeating name, number and logo included in the design of the signage contributed to the identification of the route as a cycle highway.

The study respondents also mentioned that the consistent reappearance of the logo *“red background with a white bicycle on it”* in the *“Snel”* scenario made the route more recognizable. The repetition of the logo deepened cyclists' perceptions of connecting the logo with the cycle highway, resembling the familiar symbol of a transit system such as the London Underground which is very well known and widely recognizable (Farr et al., 2012).

5.3. Good wayfinding influences cyclists' perceived comfort and enjoyment

Previous studies have investigated the physical environment (such as the quality of cycling paths and green space) and the social environment (such as the social interaction during the trip) of cycling experiences (e.g. de Geus, De Bourdeaudhuij, Jannes, & Meeusen, 2008; Ettema, Friman, Gärling, & Olsson, 2016; Mayers & Glover, 2019; Van Cauwenberg et al., 2018). However, to the authors' knowledge, this study is the first to explore the role that wayfinding systems play in cycling experiences. Our analysis of cyclists' opinions and experiences with different signage systems has suggested that improved wayfinding along cycle highways not only helps improve navigation, but also positively influences cycle highway users' perceived comfort and enjoyment. The shape of the signs in scenario *“Snel”*, for example, can express simple information about navigation, thereby freeing cyclists from having to extract information from the texts on the signs. This approach

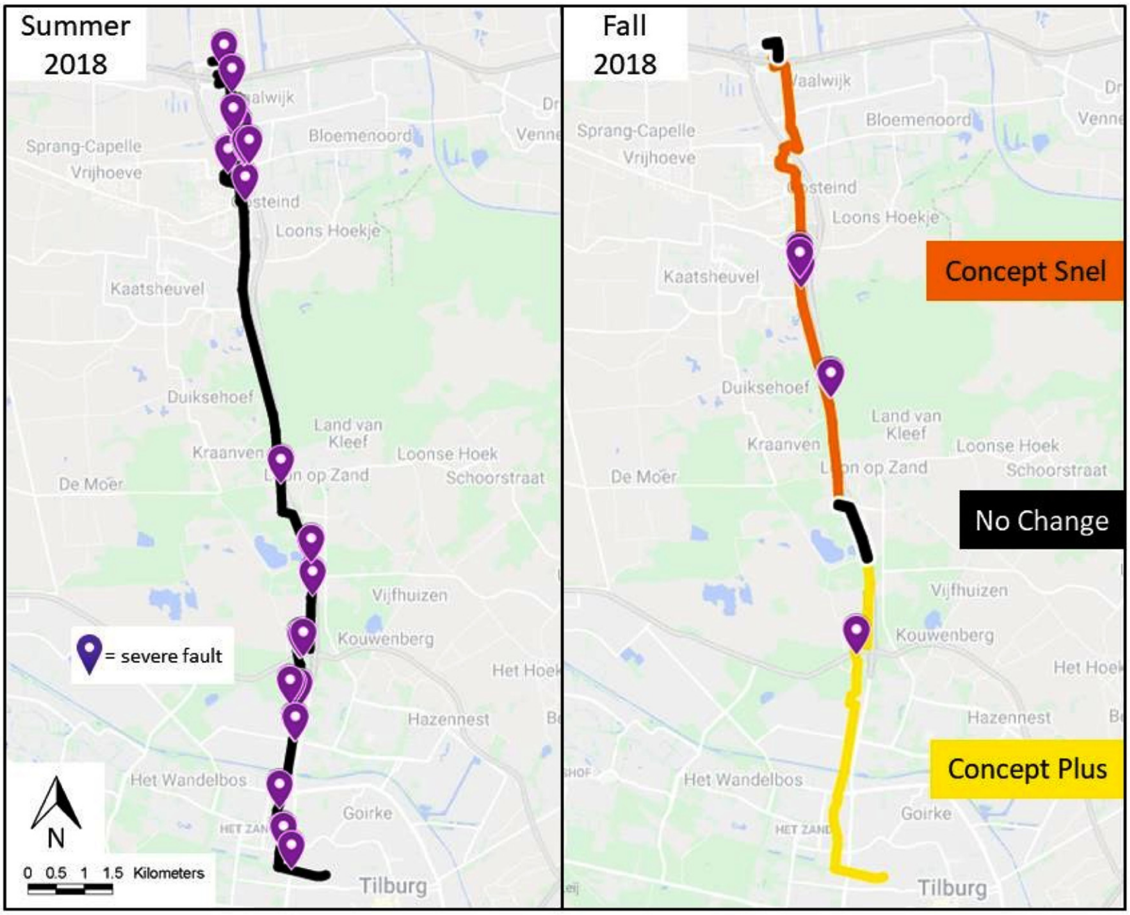


Fig. 14. Severe faults (lost or hesitation) of participants during cycle-along. Left the locations during summer 2018, right the locations during fall 2018. Map data ©2020 Google.

is perceived by many cyclists as a positive addition to the cycling experience. In addition, the placement of the signage at an appropriate distance from the decision point provides cyclists with more time between interpreting the information on the sign and making a navigational decision. This results in many cyclists feeling more relaxed as they can pay more attention to the traffic conditions thereby becoming more confident about their reactions at turning points and experience less stress, discomfort, and confusion. These wayfinding interventions improve cyclists' overall cycling experience and make travelling more relaxing and comfortable overall.

5.4. Limitations and future directions

While the study results strongly suggest that an effective cycle highway design should consider the wayfinding needs of high-speed cyclists, the study is also restricted by several limitations. First, even though the participants in this study were Dutch cyclists who were unfamiliar with the cycle highway route used for the purposes of this study, and the pre- and post- cycle-alongs took place four months apart, the reduced navigation errors in the second round may be in part attributed to increased familiarity with the route. To overcome this limitation, it would be ideal to also test wayfinding navigation in distinct, yet similar urban environments in future research. Second, although the video data analysis was performed in great detail by one researcher with clear criteria, a second non-informed video reviewer could have added objectivity to our results, thereby reducing this methodological limitation.

This research has also led to several interesting avenues for future studies. For example, while we observed the behavior of Dutch cyclists who were familiar with the design language of the cycling infrastructure in the Netherlands, the behavior of new cyclists, and cyclists in other contexts should also be assessed, preferably with larger sample sizes, to test whether the introduction of similar wayfinding would be appropriate in other geographic and cultural contexts. In addition, while this study focused on day-time wayfinding, night-time wayfinding should also be assessed as the findings from this study regarding the color and placement of the signs are likely to be experienced in a different way in low-light conditions. Finally, and although beyond the scope of the present study, an important focus of future research could be to explore the long-term relationship between wayfinding improvements and modal shift towards the use of the bicycle.

5.5. Conclusion

This study has identified several important features of a good wayfinding design for cycle highways, including the arrow shape, high-contrast colors, the larger font size, the placement (before the decision point) and height (eye level) of the signs. These specific design elements can be useful as a reference for planners in other regions to implement in their own systems. The context map, which had a similar aesthetic to a classic metro system map, was also found to be useful, suggesting that planners can build on people's previous experiences with wayfinding for other travel modes when designing new mobility infrastructures. In addition, practitioners should pay particular attention to the needs of targeted users by designing “bicycle friendly” wayfinding systems for cycle highways and apply the concept of “bicycle scale” to all types of infrastructure designed for bicycle use. This study revealed that for most of the participants, the clarity of the new signage improved their navigational confidence which resulted in a more relaxing cycle highway experience. Policy makers and transportation planners are likely to be interested in the results of this study as they reveal how specific improvements to wayfinding along cycle highways not only help improve navigation, but also positively influence users' perceived comfort and enjoyment.

Declaration of Competing Interest

None.

Acknowledgments

We would like to thank the participants who took part in the cycle-along interviews. We would also like to thank the Gazelle e-bike Experience Center for providing us with the e-bikes used in this study, as well as the City of Tilburg, Waalwijk and Loon op Zand, the province of Noord-Brabant, and the European Regional Development Fund for encouraging this research and for their financial support. Finally we wish to thank our CHIPS-project partners for their ongoing support. This research is part of a larger initiative on e-bikes supported by Eindhoven University of Technology and Breda University of Applied Sciences.

References

Bazire, M., Tijus, C., 2009. Understanding road signs. Saf. Sci. 47 (9), 1232–1240. https://doi.org/10.1016/j.ssci.2009.03.013.

Berces, A., Robertson, S., 2012. Keeping people safer through better visibility. In: Paper Presented at the Australasian Road Safety Research Policing Education Conference 2012.

Buekers, J., Dons, E., Elen, B., Int Panis, L., 2015. Health impact model for modal shift from car use to cycling or walking in Flanders: application to two bicycle highways. J. Transp. Health 2 (4), 549–562. https://doi.org/10.1016/j.jth.2015.08.003.

CROW, 2014. Richtlijn bewegwijzering 2014. CROW, Ede, Gelderland.

Davidson, J., Milligan, C., 2004. Embodying emotion sensing space: introducing emotional geographies. Soc. Cult. Geogr. 5 (4), 523–532. https://doi.org/10.1080/1464936042000317677.

Davidson, J., Smith, M.M., Bondi, L., 2012. Emotional Geographies. Ashgate Publishing, Ltd.

Delikostidis, I., van Elzakker, C.P.J.M., Kraak, M.-J., 2015. Overcoming challenges in developing more usable pedestrian navigation systems. Cartogr. Geogr. Inf. Sci. 43 (3), 189–207. https://doi.org/10.1080/15230406.2015.1031180.

Ettema, D., Friman, M., Gärling, T., Olsson, L.E., 2016. Travel Mode Use, Travel Mode Shift and Subjective Well-Being: Overview of Theories, Empirical Findings and Policy Implications.

European Regional Development Fund, 2016. CHIPS. Retrieved from. https://www.nweurope.eu/projects/project-search/cycle-highways-innovation-for-smarter-people-transport-and-spatial-planning/.

Ewing, R., Handy, S., 2009. Measuring the unmeasurable: Urban Design qualities related to walkability. J. Urban Des. 14 (1), 65–84. https://doi.org/10.1080/13574800802451155.

Faber, G. (2016, November 25). The Babylon Cycle Highway. European Cyclists Federation. Retrieved from https://ecf.com/news-and-events/news/babylon-cycle-highway.

Farr, A.C., Kleinschmidt, T., Yarlagadda, P., Mengersen, K., 2012. Wayfinding: a simple concept, a complex process. Transp. Rev. 32 (6), 715–743. https://doi.org/10.1080/01441647.2012.712555.

Fewings, R., 2001. Wayfinding and airport terminal design. J. Navig. 54 (2), 177–184. https://doi.org/10.1017/s0373463301001369.

Fishman, E., Cherry, C., 2016. E-bikes in the mainstream: reviewing a decade of research. Transp. Rev. 36 (1), 72–91.

Galea, E.R., Xie, H., Lawrence, P.J., 2014. Experimental and survey studies on the effectiveness of dynamic signage systems. Fire Saf. Sci. 11, 1129–1143.

de Geus, B., De Bourdeaudhuij, I., Jannes, C., Meeusen, R., 2008. Psychosocial and environmental factors associated with cycling for transport among a working population. Health Educ. Res. 23 (4), 697–708. https://doi.org/10.1093/her/cym055.

Global Designing Cities Initiative. (2016). Global Street Design Guide: Island Press.

Hallman, B.C., Benbow, S.M.P., 2007. Family leisure, family photography and zoos: exploring the emotional geographies of families. Soc. Cult. Geogr. 8 (6), 871–888.

Hess, G., Peterson, M.N., 2015. "bicycles may use full lane" signage communicates U.S. roadway rules and increases perception of safety. PLoS One 10 (8), e0136973. https://doi.org/10.1371/journal.pone.0136973.

Hoeke, L., de Kruijf, J., Soemers, J., 2019. Wayfinding op snelfietsroutes. (Retrieved from Breda, the Netherlands).

Hsieh, H.F., Shannon, S.E., 2005. Three approaches to qualitative content analysis. Qual. Health Res. 15 (9), 1277–1288. https://doi.org/10.1177/1049732305276687.

Hull, A., O'Holleran, C., 2014. Bicycle infrastructure: can good design encourage cycling? Urban Plann. Transp. Res. 2 (1), 369–406. https://doi.org/10.1080/21650020.2014.955210.

Jones, T., Harms, L., Heinen, E., 2016. Motives, perceptions and experiences of electric bicycle owners and implications for health, wellbeing and mobility. J. Transp. Geogr. 53, 41–49. https://doi.org/10.1016/j.jtrangeo.2016.04.006.

Lawton, C.A., 2001. Gender and regional differences in spatial referents used in direction giving. Sex Roles 44 (5–6), 321–337.

Liu, G., te Brömmelstroet, M., Krishnamurthy, S., van Wesemael, P., 2019. Practitioners' perspective on user experience and design of cycle highways. Transp. Res. Interdiscip. Perspect. 1, 100010. https://doi.org/10.1016/j.trip.2019.100010.

Mason, J., Fulton, L., McDonald, Z., 2015. A global high shift cycling scenario: The potential for dramatically increasing bicycle and e-bike use in cities around the world, with estimated energy, CO2, and cost impacts. Retrieved from Washington, DC, USA. https://www.itdp.org/wp-content/uploads/2015/11/A-Global-High-Shift-Cycling-Scenario_Nov-2015.pdf.

Mayers, R.F., Glover, T.D., 2019. Whose lane is it anyway? The experience of cycling in a mid-Sized City. Leis. Sci. 1–18. https://doi.org/10.1080/01490400.2018.1518174.

Mitchell, M., 2010. An analysis of road signage and advertising from a pragmatic visual communication perspective: case study of the M1 motorway between the Gold Coast and Brisbane. J. Aust. Coll. Road Saf. 21 (2), 55.

Kennisinstituut voor Mobiliteitsbeleid. (2016). Mobiliteitsbeeld 2016 Kennisinstituut voor Mobiliteitsbeleid. Retrieved from www.kimnet.nl.

Prior, L., 2014. Content analysis. In: Leavy, P. (Ed.), The Oxford Handbook of Qualitative Research. Oxford University Press, Oxford, pp. 359–379.

Pucher, J., Buehler, R., 2017. Cycling towards a more sustainable transport future. Transp. Rev. 37 (6), 689–694. https://doi.org/10.1080/01441647.2017.1340234.

Regulation, 2013. Regulation EU no 168/2013 of the European Parliament and of the council of 15 January 2013 on the approval and market surveillance of two- or three-wheel vehicles and quadricycle. Official J. Eur. Union 52–128 L60.

Rose, G., 2012. E-bikes and urban transportation: emerging issues and unresolved questions. Transportation 39 (1), 81–96. https://doi.org/10.1007/s11116-011-9328-y.

Saldaña, J., 2011. Fundamentals of qualitative research Series in understanding qualitative research, O. U. Press (Ed.). Retrieved from. http://www.myilibrary.com?id=300995.

Skov-Petersen, H., Jacobsen, J.B., Vedel, S.E., Thomas Alexander, S.N., Rask, S., 2017. Effects of upgrading to cycle highways - an analysis of demand induction, use patterns and satisfaction before and after. J. Transp. Geogr. 64, 203–210. https://doi.org/10.1016/j.jtrangeo.2017.09.011.

Smiley, A., Houghton, J., Philp, C., 2004. Highway signing for drivers' needs. In: Paper Presented at the Road Safety Engineering –New Developments and Initiatives Session of the 2004 Annual Conference of theTransportation Association of Canada, Quebec City, Quebec, . http://www.tacatc.ca/english/pdf/conf2004/haughton.pdf.

Thomas, J., Harden, A., 2008. Methods for the thematic synthesis of qualitative research in systematic reviews. BMC Med. Res. Methodol. 8 (1), 45.

Transport for London, 2018. Cycle Superhighways. Retrieved from. https://tfl.gov.uk/modes/cycling/routes-and-maps/cycle-superhighways.

Van Cauwenberg, J., Clarys, P., De Bourdeaudhuij, I., Ghekiere, A., de Geus, B., Owen, N., Deforche, B., 2018. Environmental influences on older adults' transportation cycling experiences: a study using bike-along interviews. Landsc. Urban Plan. 169, 37–46. https://doi.org/10.1016/j.landurbplan.2017.08.003.