Decreasing the likelihood of cycling accidents by signalling intentions to other road users through a lighting system: A feasibility study

Master Thesis

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Abstract

A new intelligent lighting system for on a bicycle was designed so that road-users can easily interpret a cyclist's intentions and behaviour. The system conveys speed, breaking- and turning intentions to other road users through different lighting signals. The effect the system has on other cyclists' behaviour needs to be explored, but no general guidelines for setting up a test like this exist. For this reason, an exploratory feasibility study is carried out. This study aims to answer whether the distance between cyclists can be reliably measured, whether time-to-collision(TTC) is a useful indicator for cycling safety, and whether the System usability Scale (SUS) can be used for systems with less (complex) functions. Results show that participants were generally positive about the lighting system, mostly about the turning- and breaking signal. The distance between two cyclists can be measured reliably, but speed cannot. Therefore TTC is not as useful an indicator as following distance. The SUS can be used for systems with less (complex) functions as well. Other recommendations to improve the validity of a follow-up study were made. Finally, it is recommended that feasibility studies in general are conducted and reported on more often, so that the exploratory nature of research is stressed more clearly.

Introduction

While the amount of car accidents have steadily decreased over the past ten years, the number of lethal cycling accidents have increased. This is discounting the fact that the number of non-fatal cycling accidents also increased the last few years, especially compared to automotive accidents (VeiligheidNL, 2014). Especially cyclists who are 60 years or older more often get into (fatal) accidents (CBS, 2017). This is increasingly problematic, since people generally get older than ever before while also remaining more physically active (Arias, 2014; Gerland, Raftery, Ševčíková, Li, Gu, Spoorenberg, Alkema, Fosdick, Chunn, Lalic, Bay, Buettner, Heilig & Wilmoth, 2014). A lot of literature can be found that focuses on improving safety for car drivers, but little literature focuses on improving traffic safety for cyclists. Possibly because the number of lethal car accidents is still greater than the number of lethal cycling accidents (CBS, 2017). Even though this problem is more common in the Netherlands, because people use their bicycle more (Pucher & Dijkstra, 2003; Pucher & Buehler, 2008), increasing cyclists' safety has worldwide applications. The current problem is that there is no existing literature that focuses on how to execute tests that try to measure safer cycling behaviour, even though there are several papers that focus on the cultural and environmental aspects of cycling (e.g. Taylor & Davis, 1999; Pucher & Dijkstra, 2003; Habib, Mann, Mahmoud & Weiss, 2014). Roessingh Research & Development (RRD), INDES and Rijksuniversiteit Groningen (RUG) have spent the last few years working on a system that improves communication between cyclists to potentially decrease the number of accidents. The goal of the current study is explore what measurements and tools can best be used to study cyclists' traffic behaviour. Specific recommendations for a follow-up study will be given. Some recommendations might also be useful for studies in the same domain.

A new intelligent lighting system

The system RRD, INDES and RUG have developed is a lighting system, integrated with a speed indicator, breaking signal and turning signal. The difference between this new lighting system and conventional lighting system is the fact that the new system communicates intentions to other road users through the use of lighting signals (Kamphuis, 2017). Speed is indicated by 16 bars around the base light. The faster someone cycles, the more bars are gradually shown. Breaking is communicated through a large red ring around the speed indicator, which will turn red if someone's speed drops. Turning is communicated through blinking arrows at the side of the system as well as a light in the end of both handlebars. A more comprehensive explanation of the system is given in the methods section, for now it is important to remember that the systems conveys speed, breaking and turning through different lighting signals.

This product was designed by incorporating cyclists and other road-users in each step of the design process, asking them what their problems in traffic were, whether a proposed solution would truly solve their problem, whether they thought the system was intuitive, next to other user related issues. Because of this, the current system has already gone through several iterations, each time changing the product to the wishes of the end user (Kamphuis, 2017). This is typical for User-Centered Design (UCD); A way of designing where you incorporate your end users in the design of a product as much as possible, so that the eventual product fits the user's actual needs (Abras, Maloney-Krichmar, & Preece, 2004; Endsley, 2016). Almost all feedback given by the intended end users was incorporated into this final prototype.

Deteriorating cognitive- and motoric skills in elderly

The reason that the target group, people of age 65 and over, get into more (lethal) cycling accidents compared to other age groups is because of deteriorating motoric and cognitive skills (Mori and Mizuhata, 1995; Tacken, 1998; Horswill, Marrington, McCullough, Wood, Pachana, McWilliam & Raikos, 2008). Decreased motor skills cause them to respond more slowly on changes (Davidse, van Duijvenvoorde, Boele & Doumen, 2015), while decreased cognitive skills make it harder for elderly to adequately respond to all stimuli. Adequately responding to everything you perceive becomes increasingly difficult if the number of stimuli increases (Kahneman, 1973). After a certain number of stimuli, a person's mental resources are all in use. A practical example of this would be an elderly cyclist cycling towards an intersection, seeing someone further away cycling towards him while also having to keep track of the things directly around him. He then doubts whether he can cross the intersection in time, fails to maintain enough speed and falls over. This is an example of a one-sided accident, an accident where another road user is not directly involved (Ormel, Wolt & den Hertog, 2009). Even though this was a one-sided accident, interaction between cyclists was still an important aspect.

The problem in this example was that the user could not quickly obtain sufficient information. This is likely because it takes more effort to register and decode novel information, whether it be conscious or unconscious, compared to familiar information (Kahneman, 1973, p54). Currently, cyclists have to obtain information from other road users through different channels of nonverbal communication, such as swaying, hand gestures and eye contact. If the process of retrieving certain information would be standardized or automated, less mental resources would be needed for that specific task. In turn, these resources can be used to put more effort in registering and decoding other stimuli. The effectiveness of assistive tools to reduce workload is already proven in the automotive industry (Parasuraman, Sheridan & Wickens, 2000). However, they also mention that some systems and designs actually increase workload.

Comparing cycling- to automotive research

Effectiveness of certain tools in the automotive industry can usually easily be tested, since there is a lot of literature on what aspects need to be tested and when a product can be considered a success (e.g. Hounsell, Shrestha, Piao & McDonald, 2009; Takai, Harada, Andoh, Yasutomi, Kagawa & Kawahito, 2014). A guideline for testing products in the automotive industry is to not only look at whether the system improves the concept you are interested in, but also whether people are interested in using the system (Caird, 2004; Bengler, Dietmayer, Farber, Maurer, Stiller & Winner, 2014). An example of a concept that is used in the automotive industry as an indicator of safer driving is time-to-collision (TTC). Time-to-collision is the time it takes for a vehicle to hit another vehicle, assuming they both maintain the same course and speed. It is expected that TTC a good indicator of safer cycling, because of the effectiveness of this indicator in automotive research, and bicycles and cars usually use comparable roads. However, no papers exist on this subject, so this study tries to find whether it is indeed possible to use as an indicator, and whether it is a better indicator than following distance. It has to be kept in mind however, that safer cycling is a broad and vague term, so the results of this study will only practically be able to show whether people keep more distance or have a higher TTC when using the system. It can be assumed that this constitutes safer cycling, but they are not proven to be linked. The best method of collecting data such as speed and distance between bicycles is also explored in this study, since these processes are usually automated in automotive systems and tests thereof.

Feasibility studies

When you are unsure whether your outcome variables measure the concept you are interested in, it is important to first do a feasibility study (Arain, Campbell, Cooper & Lancaster, 2010). Especially when these tests are carried out in a field- instead of a lab-setting (Kaikkonen, Kekäläinen, Cankar, Kallio & Kankainen, 2005). For this reason, this paper will be a feasibility study preparing for a test planned by RRD later this year. The goal of the project team (RRD, INDES, RUG) for that planned test is to find out whether elderly actually cycle more safely, defined by how much distance a cyclists keeps in respect to another, when using the system and whether people are interested in using the system. To ensure the validity of that test, as well as keeping time- and cost investment low, this feasibility study is conducted.

Since no paper specifically focuses on feasibility testing in bicycle studies, studies from other domains were used to follow general feasibility study guidelines (e.g. Kearney, Kidd, Miller, Sage, Khorrami, McGee, Cassidy, Niven, & Gray, 2006; Thielen, Lorenz, Hannibal, Köster, & Plättner, 2012; Kiryu, & Minagawa, 2013; van Lier et al., 2016). These general guidelines were not specifically mentioned, but rather a common theme in all papers. The three most important finding were that (1) participant should use the product, but also comment on their perception and acceptance of it, (2) it is usually best to try several forms of data measurement, rather than just trying one and not having found a good solution at the end of a paper and (3) results are not conclusive but rather serve as a stepping stone for further research.

The fact that participants also should be asked about their opinion is comparable to what Caird (2004) mentioned about asking end-users whether they would like to use a certain system. The reason results are not conclusive comes from the fact that feasibility studies usually have less participants than other studies, generally around 10 or 20. For feasibility studies this is enough, since you are interested in optimizing data measurement or finding whether a concept can be accurately measured. Most problems (94%) can usually be found with just ten participants, while 15 participants usually find 97% of all usability problems. Having more than 15 participants is unlikely to yield much more unfound problems (Faulkner, 2003).

The current study

This study tests on both younger and older participants, to see whether there are differences in the results between age categories. According to Hakamies-Blomqvist (2004), plans that improve safety for elderly in traffic will benefit all drivers. It is tested whether this is indeed the case. For this feasibility study it was chosen to test with 12 participants. This is because an even number of participants in both age categories is needed, to be able to properly compare both age categories.

This study explores two different aspects: Whether the system actually improves traffic safety and whether people would like to use this system. As mentioned before, it can only be assumed that TTC and following distance indicate safer cycling behaviour, as this link was never proven. Even though these statements cannot be conclusively answered because of the small sample size and the fact that this is an exploratory feasibility study, these questions are answered as best as possible at the end of the paper. The results that are actually most important are how 'safer cycling' and 'prefer to use' can be measured. For safer cycling, it is assumed assume that TTC is a good indicator, as that is used in the automotive industry (but again, only as an indicator). To test whether people think the system is useful, two standardized questionnaires are used, namely the System Usability Scale (SUS) by Brooke (1996) and the acceptance scale by van der Laan, Heino and de Waard (1997). Brooke (1996) defines usability as "a general quality of the appropriateness to a purpose of any particular artefact" and mentions context being an important factor.

Because TTC has not been used in bicycle research before, it is explored whether it would be a good fit here. This is done by comparing the difference between following distance (FD) and TTC. This will, however, only be done if the measured TTC's are below 5 seconds for each participant. If the TTC is higher than that, which is possible because speed differences are lower compared to cars, then TTC is considered to not be a good fit for this type of research, because more than 5 seconds is almost always enough to properly react on a situation. Following distance will be measured by letting participants cycle behind someone who is using the new lighting system with either the system turned off (control condition) or on (experimental condition). TTC can be calculated from the following distance over several moments to determine someone's speed. If the TTC shows a distinctive difference between conditions compared to FD, then TTC is assumed to be the better fit, because TTC is often a better indicator of safety (Vogel, 2013). If both FD and TTC show around the same difference between conditions, FD is assumed to be the better choice because it saves time measuring. Different ways of measuring following distance will also be looked at, of which pros and cons will be discussed.

The acceptance scale by van der Laan, Heino and de Waard (1997) was used to determine the acceptance of new technology for drivers, so it is assumed that it also properly measures the acceptance of new technology for cyclists. But the SUS is usually used for different types of research, often systems that have more, and more complex, functions. It will be tested whether the SUS is a good tool for assessing usability for this kind of, relatively simple, system. This will be done by letting participants comment on the questionnaire itself when filling it in. If at least 10 out of 12 participants did not have the feeling they wanted to say anything else about the tested system after filling in the questionnaire, then it is considered a useful tool.

The goal of this study is to improve the validity of the tests planned by RRD later this year, since that will save time and money. The main questions this paper tries to answer are whether TTC and the SUS are good indicators of their respective points of interest. Participants' opinion on the system, their preferred ways of real-life testing as well as the distance they hold in respect to the bicycle equipped with the intelligent lighting system will also be looked at. It is expected that both TTC and the SUS are useful tools. It is also expected that older cyclists will like the prototype, while the younger cyclists have no preferences. No expectations about the preferred ways of measurement can be given. Finally, it is expected that the distance participants keep in respect to the bicycle equipped with the intelligent lighting system will differ when the system is either turned on or off, but it is unclear whether the difference will be greater or smaller.

Method

Participants

Twelve people participated in this research, split into two difference age groups. One group from age 18-30 and one from age 65 and over. These groups will be referred to as the younger and older group respectively. All participants had to be at least 160cm in height, since the frame height was 56cm, and should be cycling at least once a week. Someone could not participate if he had uncorrected sight problems, since that might influence behaviour in traffic. Four out of six elderly participant signed up to participate in this research when they got a small demonstration on how the bicycle worked at RRD. The other two as well as all the participant in the younger group were gathered using convenience sampling.

The younger age group had 2 male and 4 female participants with an average age of 23.76 (sd = 2.81). The older age group had 5 male 1 and 1 female participant with an average age of 73.67 (sd = 5.54). All participants signed two informed consent forms before participating; one to take home and one for RRD. This study was approved by the Ethical Committee of the University of Twente.

Apparatus & Materials

The apparatus used in this studywere the new (intelligent) lighting system, a control panel for the signalling device, an integrated battery and operating system (OS) pack, an odometer and two cameras. Some descriptions are purposefully vague because of ongoing patents from INDES, the technological developer. Other materials that are used are two grips for positioning the cameras on a bicycle, the bicycle itself, two 1.25m wooden beams taped in with red and white tape every 25cm, the Kinovea (v0.8.25) program (Charmant, 2016), the System Usability Scale by Brooke (1996), the acceptance scale by van der Laan, Heino and de Waard (1997) and two self-constructed questionnaires for measuring overall opinion of the lighting system and real-life testing recommendations.

Intelligent Lighting system

The intelligent lighting system is mounted on a Batavus Diva bicycle, with a frame height of 56cm and the saddle and steering wheel in the lowest possible configuration. The actions the lighting system communicates are speed, braking and turning. The prototype can be seen in Figure 1 and 2. Speed is conveyed through 16 blocks on the side of the base light that gradually increase if someone cycles faster. The front light has a yellow to blue hue while the rear light has an orange-red to dark-red hue. Braking is communicated through a large red ring on the outer side that brightens up when difference in speed within a specific timeframe goes below a threshold. The harder someone breaks, the brighter it shines. Turning is signalled by a blinking orange arrow to the left or right of the light and by an orange light in both ends of the handlebar. Currently, people still have to manually press a button on their steering wheel to activate the turning signal. A sensor that measures the x-, y- and z-axis of the bicycle turns the turning signal off automatically if it registers someone cycling straight again. The current lighting system is 9 cm in height, 13 cm in width and 4.5cm thick.

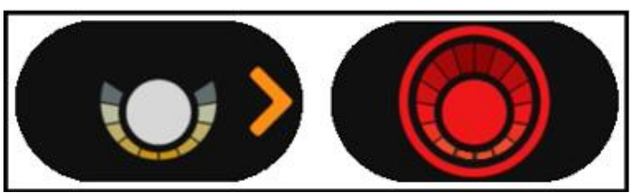

Figure 1, front light(l) with the turning signal and rear light(r) with the break signal activated

Figure 2, Pictures of the physical prototype (l=front, r=rear)

Extensions

The turning operator (TO) is a small device located on the left side of the steering wheel used to activate the turning signal in the front and rear light, as well as a light integrated in steering wheel. The device is mounted in such a way that it is slightly bent towards the left hand of the user so that clicking is takes little effort. The device was part of the IGGI Signal Pod set and was restructured and rewired by INDES to work with the new lighting system. The device has three buttons. The left button activates the left turning signal and the right button the right turning signal. The middle button originally activated a white warning light on the front wheel, but that functionality has been removed because people commented that they did not find it necessary in previous iterations. A small LED-light is located above the left and the right button that blinks in concurrence with the turning signal in the lighting system, so that the user can immediately see if the system is turned on or off. The turning operator, as well as the integrated lighting in the steering wheel, can be found in figure 3.

Figure 3, The turning operator and integrated lighting(currently turned off)

The operating system (OS) and battery pack are located in a small pouch mounted on the front of the steering wheel. The OS is connected to the turning operator, as well as the two lighting systems, the lights at the side of the steering wheel, a sensor in the front wheel that calculates speed and a sensor to the right side of the front fork that registers brightness. This OS translates button presses on the turning operator to the front- and rear lights as well as the lights on the side of the steering wheel. It also translates speed, through three small magnets on the spokes that pass a sensor on the front fork of the bicycle, into a number of blocks in the speed indicator of the light. These magnets and sensor are also used to trigger the breaking light, if someone goes below a certain speed threshold within a certain time. To be able to cycle a consistent speed, an Action store brand odometer was located on the steering wheel of the bicycle equipped with the new lighting system.

Measurement

To measure the longitudinal and lateral distance between the bicycle of the participant and the bicycle equipped with the new lighting system, four GoPro Hero 2 cameras were used. One camera was mounted on the right side of the carrier, pointing backwards, to determine following distance. The other camera was mounted on the left side of the steering wheel, pointing downwards, to film the road to the side of the bicycle. Both cameras were originally mounted with an Arkon camera bike handlebar mount, but the weight of a GoPro camera seemed to be too much for the one located on the steering wheel, because it was bent downwards. That mount got replaced with a GoPro jaws clamp mount after three participants.

Video images were analyzed in Kinovea. In this program, you can load a video and then lay a grid of any size within the video. Then real-life measurements taken beforehand can be used to calibrate the size of that grid, so that any distance within that grid can be measured by drawing lines. Lines drawn just outside the grid have been proven to be reliable (a measurement error of below 2%) in (still unpublished) research that was worked on concurrently. The real life-measurements were taken beforehand by laying down two 1.25 meter long wooden beams, alternating with red and white tape every 25cm, inside the camera’s view. The grid can be laid over these beams in the program. An example can be found in figure 4.

Figure 4, Using wooden beams to calibrate real-life distances inside the program

The questionnaires used were the System usability Scale (SUS) (Brooke, 1996), the acceptance scale (van der Laan, Heino & de Waard, 1997), and two self-constructed questionnaires. One measuring participants' opinion on the lighting system and the other determining preferences when using a test-bicycle in real life. Both questionnaires were constructed by taking questions that were asked in previous iteration of testing the prototype, and integrating feedback from earlier participants. The SUS was slightly changed from the original, following recommendations from Finstad (2006) and Bangor, Kortum & Miller (2008), after which it was translated to Dutch. The Dutch acceptance scale was used and validated in earlier studies (van der Laan, Heino & de Waard, 1997). The questionnaire about the general opinion on the lighting system asks questions such as 'Would you use this product yourself?' and 'Do you think the system improves traffic safety?' as well as asking participants about positive and negative aspects of using the system. The questionnaire that asks participants' about their preferences when taking a bicycle equipped with the new lighting system home starts with an open front, so that participants are not influenced by leading questions, where they can fill in anything that comes to mind. On the back side there are a few leading questions, for example, how often they want to receive a questionnaire and what aspects, for example saddle bags and a bike gear, they would like to be present on a test-bicycle. The full questionnaires can be found in appendices B, C, D & E.

Design

This study follows a within subject design with two conditions. One control condition, in which participants cycle behind the bicycle with the intelligent lighting system turned off, and one experimental condition, in which participants cycle behind the bicycle with the intelligent lighting system turned on. Participants will not be cycling on the bicycle equipped with the intelligent lighting system, except for testing it out once. The independent variables are whether the system is turned on or off and age. The dependent variable is the distance between the participant's bicycle and the bicycle equipped with the new lighting system, either lateral or longitudinal. Each participant with an even subject number starts with the system turned off and each participant with an uneven subject number starts with the system turned on. The participants numbered 1 through 6 are the younger age group while those numbered 7 through 12 are in the older age category.

Procedure

Potential participants were called and received an explanation of the research. If they were still interested, a time and date were planned. Participants then received a confirmation E-mail, containing information on the location, date and time, an information letter and a reminder to bring their own bicycle. On the planned date, participants met the researcher at the head entrance of the University of Twente (UT). After this, they both cycled to the starting location, located a little further on university terrain, on the cycling path 'de Knepse'. The starting position can be seen in Figure 5.

The experiments were conducted on university terrain, on roads where little other traffic was present. At the starting position, participants received a short verbal explanation of the research. They were told they would be cycling four rounds in total, fill in a few questionnaires and test the new turning operator. They were also told that they could comment on the process of the tests itself. The information was also presented on an information form, which was also attached to the confirmation E-mail. If participants had any questions, these were answered before they were asked to fill in the informed consent form.

First, participants received a short explanation of all the functions of the lighting system, after which the researcher took place on the bicycle and cycled to a predetermined point to showcase what the turning signal, breaking light and speed indicator looked like to others. After this, the participants received a short explanation on how the turning operator worked, and they could test the turning signal by cycling to the predetermined point as well. Once they returned, they were asked what they thought of the system. Their answers were written down in appendix A. After this, participants were instructed to fill in the SUS. Once that was filled in, they were asked whether the questionnaire fully reflected their opinion on using the system, or whether they would rather have been asked other questions.

While the participants filled in the SUS, the researcher would turn on and calibrate the cameras. This was done by placing one of the wooden beams vertically relative to the camera and one horizontally relative to the camera.

Second, participants were instructed to follow the researcher, who used the bicycle equipped with the new lighting system, for two rounds. One round the system would be turned off, one round turned on, randomized between participants. One round was around 970meters in length and is visualized through black arrows in Figure 5. In this route, they would turn left on each intersection, following 'de Knepse', 'de Achterhorst', 'Boerderijweg' and 'de Horst'. This is called the "following task". On 'de Horst' there was a boom barrier. Participants were instructed beforehand that the researcher would stop cycling once they passed this so that the participants could overtake the researcher. Once the passing action was completed, the researcher cycled next to the participant shortly, to tell them they would cycle the same round once again. The system would then be turned either on or off, depending on the first condition, before the researcher cycled in front of the participant again for the second round. If the starting position would be reached again, participants received a short explanation on the crossing task.

In the crossing task, participants were instructed to wait for one minute so the researcher could get to the other side of 'de Knepse'. Once this minute was over, the participant cycled towards the other side of 'de Knepse' as well, and would return to the starting position right after. The researcher cycled towards the starting position and once back to the end of 'de Knepse' concurrently. This way, the participant and researcher would pass each other twice. One time with the system turned on and once with the system turned off. This route can be seen in Figure 5 in red and had a length of 472m, 236m one way and 236m back. With both the following and crossing tasks, the researcher used an odometer to continuously cycle 12km/h. When both were present at the starting position again, the researcher would calibrate the cameras once more before turning then off.

Figure 5, the route, black being the 'following' task and red the 'crossing' task

Lastly, participants were instructed to wait at an intersection and estimate the speed of the researcher. This was done by letting the researcher cycle towards them four times total. Twice the system was turned on, cycling 12km/h and 18km/h. Twice the system was turned off, also cycling 12km/h first and 18km/h the second time. The on and off conditions were randomized in the same way as with following and crossing. Once the researcher passed the participant, the participant called out the estimated speed. After all four tries, the estimations were written down. Participants were then instructed to fill in two questionnaires. One with open questions about the perceived usefulness of the lighting system and one measuring acceptance on the basis of 9 terms. These can be found in appendix C & D. After this, participants were told that in the later study, people would be using one of the bicycle equipped with the new lighting systems in their daily lives for a period of one week. Participants were instructed to imagine themselves in such a situation, and write down anything that they would find important in the questionnaire found in appendix E. The rest of the questionnaire was filled in shortly afterwards.

If participants had any additional comments on the testing procedure or the questionnaires, they were able to give those now. These answers were again written down in appendix A. If needed, participants were primed with neutral questions such as 'I see there's still something on your mind…'. If no further comments were given, participants were thanked for their help. If someone was interested in the results of the follow-up study, they could write down their name and E-mail address. Each test would roughly take around 50 minutes.

Data analysis

Questionnaires

The comments by participants in appendices A, C & E were written down and if necessary, split into different components. For example, if a participant mentioned in one sentence "I am not sure if I would use the turning operator because the light is barely visible and it is hard to press the buttons" then these would be written down as "The light (turning signal) is barely visible" and "It is hard to press the (turning operator) buttons". Words between brackets are added by the researcher and are meant to make the sentence clearer at first glance. All comments are ranked on how easy it would be to implement and how much of an effect it would have on either the system or the tests. The results that are either easy to implement or have a large positive effect are discussed in further detail. The suggestions on improving the lighting system will be sent to the project team, but will not be discussed in detail here.

The score on the System Usability Scale was calculated through the process described by Brooke (1996). Each item is assigned a value from 0 to 4. Uneven items are scored by taking the answer and subtracting one, while even items are scored by subtracting the answer from five. These scores are added up and multiplied by 2.5, resulting in a score from 0 to 100. A score of 70 or higher indicates that a product scores above average in the usability category (Bangor, Kortum & Miller, 2008).

The scores on the acceptance scale were calculated through the process described in van der Laan, Heino and de Waard (1997). Each item receives a score from -2 to 2, -2 being the leftmost square and +2 being the rightmost square. The scores on items 3, 6 and 8 were mirrored, the leftmost square being +2 while the rightmost square was -2. Averaging the score on all the even items yield a satisfying score ranging from -2 to 2, while the average from all the uneven items yields a usefulness score.

In appendix C, the average and standard deviation of the amount of money participants were willing to spend on the system were also calculated. For appendix E, the number of times participants were willing to fill in a questionnaire was also averaged.

Raw data

The distance between the bicycle equipped with the new lighting system and the bicycle of the participant was measured in Kinovea. Using the wooden beams, a square of 125cm x 125cm was drawn into the video. It is possible to use any object or surface of which you know the real-life measurements to drawn a grid inside the program. Two sides of the square were laid over the wooden beams, after which the square was finished and the real life measurements were entered to calibrate measurements done inside the video. Lines can then be drawn inside the program which display the real life distance between the two ends of the line. In table 1 the moments of measurement can be seen, and in figure 6 and 7, example of measuring the distance.

Table 1, Calculation table for distance between the participant's bicycle and the bicycle equipped with the intelligent lighting system

Task	Measuring	Time of measurement	Points measured (distance between)
Following	Following distance	15s, 25s and 35s after the participant's front wheel went over the road marking on the second intersection	A predetermined point(25 or 50cm) behind the test bicycle and the front wheel of the participant
Following &Crossing	Lateral distance	When the bottom bracket of both bicycles are aligned	Middle of the bottom bracket of both bicycles

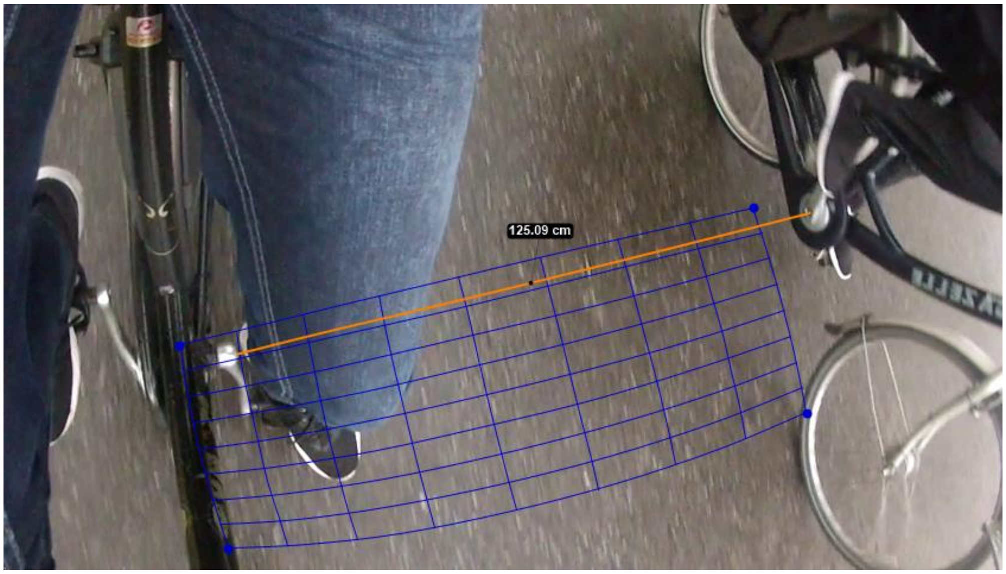

Figure 6, Example of measuring lateral distance (in the following task)

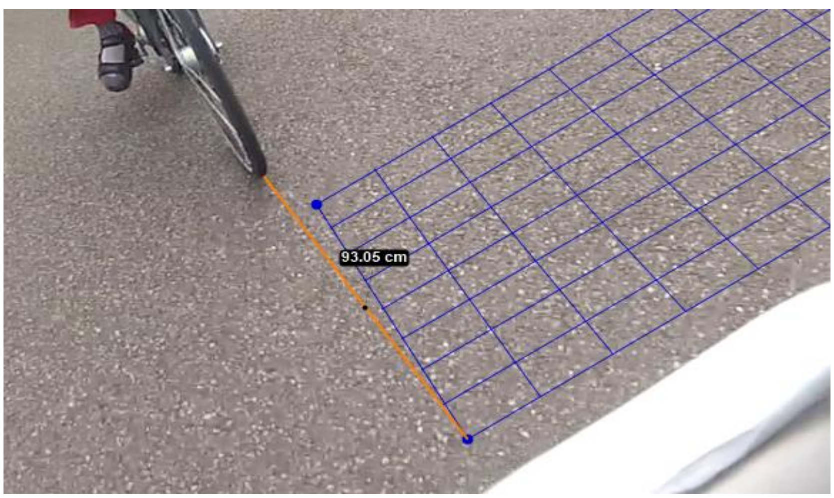

Figure 7, Example of measuring following distance

As can be seen in Table 1, a total of three measurements (FD1, FD2 & FD3) were made for the following distance. These three distances were averaged to get the average following distance (AFD), which was assumed to be a better fit than taking one moment in which you measure following distance. For 6 participants, 3 older and 3 younger, 25cm was added to the average following distance because that was the distance between the predetermined point and the back wheel of the bicycle. For the other 6 participants, 50cm was added to the average following distance, because that was the distance between the back wheel of the bicycle and the predetermined point. To calculate TTC, the speed of the participant first had to be calculated. This was done by averaging ((FD1-FD2)/10) and ((FD2-FD3)/10) to get the average difference in speed(ADS) between the participant and the bicycle equipped with the new lighting system in cm/s. Since the researcher always cycled 12km/h or 333.33cm/s, the ADS was added or subtracted from 333.33cm/s. This resulted in a value between 330cm/s and 336cm/s, the participant's real speed (RS). Assuming the bicycle equipped with the new lighting system would instantly go to 0cm/s by breaking, the TTC would be AFD/RS. It was also explored whether the use of real speed differed much compared to assuming each participant cycled exactly 12km/h. The TTC calculated by assuming participants were cycling 12km/h was called TTC1 and the TTC calculated by using the participant's real speed was called TTC2.

Before data was analysed, all data files were checked for normality. This was done by running a Shapiro-Wilk test on the data and by checking normality visually through a histogram, Q-Q plot and P-P plot. In the case of the following distance and TTC, the residuals were plotted to check for heteroscedasticity. All data seemed to be normally distributed.

Following distance, TTC1 and TTC2 were analysed through paired sample T-testing, comparing condition on to condition off. The lateral distance was measured through mixed-model analysis with lateral distance as the dependent variable and condition (whether the system was on or off) as the independent variable. The reason mixed-model analysis was chosen over paired sample T-testing was because there were three missing values in the lateral distance data file, and mixed-model analysis can estimate these missing values based on the other participants. If paired sample T-tests were to be used, three participants would be excluded completely, resulting in even less power. The reason this data was missing because the camera grip broke during testing for two participants, and for one participants the camera stopped recording after 18 seconds for unknown reasons.

To see whether age had any effect on the data, a mixed model analysis was used with following distance as dependent variables and age and condition as independent variables. This analysis was repeated using TTC2 as dependent variable to see whether the results from following distance differed from those of TTC2.

Results

Feedback on the lighting system

The following four sections will only shortly go over the general opinion of participants. The full lists of comments (in Dutch) can be found in Appendices F, G & H. The relevant comments will be discussed in the recommendations section of the discussion. The comments given were in response to participants seeing others use the system, rather than using the system itself. When a theme is mentioned below, about as many younger as older participants mentioned this.

Once it was demonstrated how the system communicates intentions, participants were asked to give their first impressions on the prototype. These first impressions were generally positive with all 12 participants mentioning something like ‘it works fine’ and ‘it is convenient’. Five participants mentioned it having a small downside. Right before the test ended they were once again asked what they thought of the system. Six participants mentioned liking the breaking signal, turning signal or both. These participants mentioned that they thought the speed indicator was less useful. Another participant specifically mentioned she did not use the speed indicator, but liked the idea. When writing down their opinion, ten out of twelve participants were positive about the general idea of the product, but had a few points of critique, mainly focussing on ease of use and visibility. Two participants mentioned that the core of the idea might be flawed, because they did not believe this system would actually increase traffic safety unless everyone uses it. They elaborated on this by explaining that some cyclists would be using this new system and other cyclists would still be using their hands, which they would find confusing.

System Usability Scale

Participants were generally positive about the completeness of the SUS for measuring what they thought of the usability of the system. All twelve participants mentioned that there was nothing they wanted to add after having filled in this questionnaire. A few small translation errors were pointed out.

Results of the questionnaires

Aside from filling in aspects that they would find important, the back side of the questionnaire also asked participants whether they would like certain features to be placed on their bicycle. These preferred features can be found in Table 2.

Table 2, number of times a certain feature was mentioned to be preferred by a participant (out of 12)

Luggage carrier	Gears	Saddlebags	Odometer	Bell	Handbrakes	Kickstand	Other
10	9	7	3	2	1	1	4

The three preferences in the 'other' category were two participants who wanted the base light to be bright enough to really serve as a substitution for conventional lighting systems, one participant wanted to choose what hand-brake triggers the front-wheel brake and one participant wanted absolutely no backwards kick brake.

The answers participants gave on the questions asked in the questionnaires is visualized in appendix I. On average, people are willing to fill in a questionnaire 5 times a week (4.67, sd=2.23). With younger participants willing to fill in questionnaires a little more often, 5.3 (sd=1.97) times a week compared to 4.0 times for the older participants (sd=2.45). One participant that would use this system commented that he would only use it once the system was fully developed, not the way that it is currently.

The average amount of euros people are willing to spend on this system is around €50 (49.55, sd=17.67), with older people willing to spend a bit more than younger ones (€57 compared to €43). This excludes one participant who filled in he would spend 0 euros, because he did not like the system.

The System Usability Scale measures the usability of a certain product and scores from 0-100. The average score on the SUS was 80.63(sd=11.63), with younger people rating the system a bit higher than older people, with a score of 82.92(sd=8.13) compared to 78.33(sd=14.80). The acceptance scale measures two concepts, usefulness of a product and how satisfying it is. The scores on the acceptance scale are visualized in the boxplot found in Figure 8.

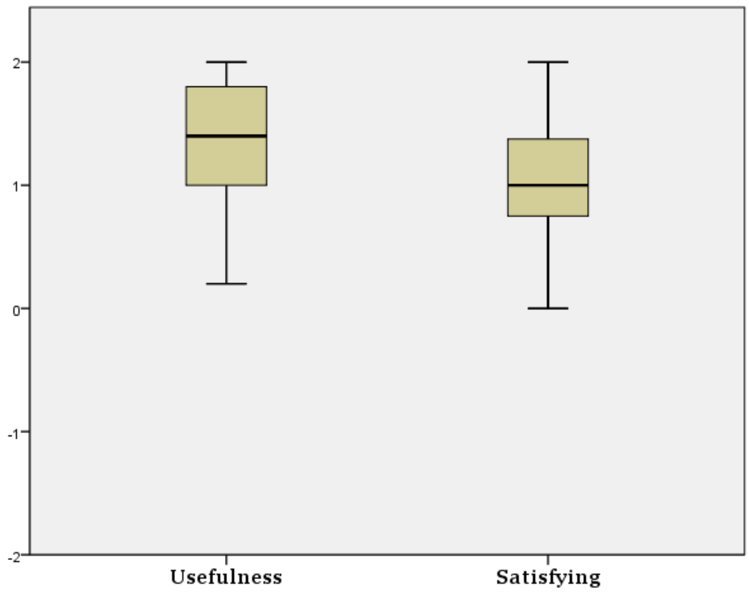

Figure 8, Scores on the acceptance scale, ranging from -2 to +2

Speed estimations

Participants also estimated the speed of the bicycle with either the system turned on or off. The average estimations divided by age category can be found in table 3.

Table 3, Speed estimations for both the 12km/h and 18km/h condition when the system was either on or off, divided into the average, young and old age

	12km/h-off	12km/h-on	18km/h-off	18km/h-on
Young	16.83(sd=2.14)	19.17(sd=3.55)	23.67(sd=5.75)	24.50(sd=5.61)
Old	19.67(sd=3.20)	19.33(sd=2.81)	23.83(sd=3.97)	23.50(sd=3.83)
Average	18.25(sd=2.99)	19.25(sd=3.05)	23.75(sd=4.71)	24.00(sd=4.61)

There were no significant differences in both the 12km/h, $t(11) = -1.086$, $p = .301$, 95% CI [-3.027, 1.027], and 18km/h condition, $t(11) = -.609$, $p = .555$, 95% CI [-1.154, .654].

Lateral distance (passing- & crossing task)

The lateral distance in the passing task was the distance a participant kept when overtaking the bicycle with the new lighting system. The lateral distance in the crossing task was measured when the researcher and participant cycled in the opposite direction. The average lateral distance participants kept in respect to the bicycle equipped with the new lighting system in the following task was 148.13cm (sd=27.12) with the system turned off and 151.67cm (sd=20.63) with the system turned on. There was no significant difference between the off and on condition, $t(8) = -.343$, $p = .740$, 95% CI [-27.30, 20.22]. The lateral distance in the crossing task was also not significantly different, $t(8) = -.422$, $p = .684$, 95% CI [-11.12, 7.68]. Data from the younger and older age category are not compared because data from three elderly was missing.

Following distance

The distance a participant kept behind the bicycle equipped with the new lighting system was called the following distance. The average following distance with the system turned off was 187.99 (sd=59.09). The average following distance with the system turned on was 192.55 (sd=45.65). These results were not significantly different, $t(11) = -.608$, $p = .555$, 95% CI [-21.09, 11.96]. The average following distance in the younger age category was 183.83cm (sd=29.82) with the system off and 198.57cm (sd=22.85) with the system on. The average following distance in the older age category was 192.14cm (sd=19.60) with the system turned off and 186.53cm (sd=15.08) with the system turned on. Younger participants held more distance with the system turned on while older participants held less distance with the system turned on.

Time-to-collision

TTC is the time it takes for the following bicycle to hit the bicycle in front, assuming the front bicycle suddenly brakes. The measured TTC in all conditions can be found in table 4. The standard deviation is stated between parentheses.

Table 4, average TTC per condition and age category, using standardized speed (TTC1) or real speed (TT2) to calculate TTC (in seconds)

	Average	Young	Old
TTC1 (off)	.564 (0.177)	.551 (.089)	.576 (.059)
TTC1 (on)	.578 (0.137)	.596 (.069)	.560 (.045)
TTC2 (off)	.564 (0.177)	.551 (.089)	.577 (.059)
TTC2 (on)	.577 (0.137)	.595 (.068)	.559 (.045)

All effects that used TTC1 as the dependent variable were not significant, showing the same results as the following distance, since TTC1 is just the following distance divided by 333.33(cm/s) for each participant. There were also no significant differences between the off and on condition with TTC2, $t(11) = -.567$, $p = .582$, 95% CI [-.06, .04].

TTC1 and TTC2 hardly differ from each other, with a percentual difference of <1%. The younger age group has a longer TTC with the system turned on while the older age group has a shorter TTC with the system turned on. In both the following distance and TTC2 measurements, both condition and age had no significant effect on the average following distance or TTC with $.295<p<.582$. Even though condition had no significant effect on following distance or TTC, the data shows that some people do indeed hold more distance with the system turned on while others hold less distance, this is not affected by the order in which the conditions were administered, with an average distance of 190.33 for the first try and 190.21 for the second try, independent of whether the system was turned on or off.

Conclusion

A feasibility study was carried out to see whether and how the distance between two cyclists can be measured, whether time-to-collision (TTC) is a useful indicator of cycling safety compared to following distance and whether the System usability Scale (SUS) can be used for systems with less (complex) functions. This was done by letting participants cycle a predetermined route, following or crossing the researcher that used the bicycle equipped with the new lighting system, as well as letting participants fill in different questionnaires. The general opinion on the lighting system as well as the effect the lighting system has on cycling behaviour are explored, but it is important to remember that these results are not conclusive. In short, distance between two bicycles can be reliably measured by using camera footage. Since speed cannot be measured reliably, following distance is a better indicator than time-to-collision. The system usability scale can be used for systems with less (complex functions). The general opinion on the lighting system was positive, however, the system did not seem to have any significant effect on participants' following distance. All results are discussed in more detail below.

Measuring the distance between cyclists

The distance between two cyclists can be reliably measured by using camera footage that is analysed in a program, like Kinovea, that uses real-life measurements of pre-measured objects to determine the distance between two points anywhere in the video. A few other measurement tools were considered, which will be discussed later.

Time-to-collision

Time-to-collision (TTC) was compared to following distance by dividing the following distance by a set speed, in this case 333.33cm/s. This resulted in a TTC that assumed every participant cycled exactly the same speed, which did not give any additional information compared to following distance. This measurement was called TTC1. The real time-to-collision was calculated by dividing following distance by the participant's actual speed and was called TTC2. These two measurements were compared with each other, showing that TTC1 and TTC2 differed less than 1%

from each other. TTC takes longer to calculate than just the following distance, and using the current set-up TTC does not give additional information compared to following distance. For this reason it is recommended to not use TTC in studies where participants follow a certain person or object, rather than cycling freely.

The System Usability Scale

All twelve participants mentioned that they thought the System Usability Scale (SUS) fully reflected their opinion on the usability of the system, and did not feel that they wanted to make other comments after having filled in the questionnaire. This points to a high validity. However, some participants pointed out a few translation errors in the SUS, for example using past tense in one question and present tense in another. These recommendations were used to update the translated (Dutch) SUS, which can be found in appendix J. This updated version can be used in the follow-up research, as well as other Dutch studies that need a translated version of the SUS.

General opinion on the lighting system

The first impressions of all twelve participants was positive, with ten out of twelve participants still being positive about the lighting system once they experienced it for a longer period of time. Out of the two participants who were not necessarily positive after having experience the lighting system for longer, one participant really liked the idea but felt that this prototype needed a bit more work before he would use it, while the other participant mentioned he would never buy a system like this. An important distinction that needs to be made, however, is that different participants were positive about different aspects of the lighting system. Many participants liked the turning signal the most, closely followed by the breaking signal. The speed indicator was appreciated less. The scores on both the acceptance scale and the SUS were generally high and many participants would either like to buy the system or would like others to use it.

Effect on cycling behaviour

The lighting system did not seem to have any effect on participants' cycling behaviour, specifically the distance a participant kept in respect to the researcher. When inspecting the data, it becomes clear that some participants hold more distance in the following task with the system turned on while other participants hold more distance with the system turned off. This effect could not be explained by the order of conditions. Elderly held less distance in the following task when the system was on compared to the younger age group, but this effect was not consistent over all participants. The lighting system also did not seem to influence the lateral distance in both the passing and the crossing task.

Speed estimations

On average, participants estimated the speed of the bicycle to be the same with the system turned on or the system turned off. The system did not seem to help them estimate closer to the real speed. Elderly seemed to estimate the speed to be a little higher in the condition with the system turned off compared to the system turned on. The younger participants estimated the speed when the system was turned on to be a little higher compared to system turned off, but these differences were both not significant. Consistent among all participants was that they estimated the speed to be 4 to 7 km/h higher than the actual speed, regardless of condition.

Discussion

In this section, the results will be discussed in the light of existing literature. After that, the limitations of this study will be mentioned, as well as the effect these limitations had on the results. Following both the results of this study and keeping the weaknesses of this study in mind, recommendations will be made for the follow-up study. Some of these recommendations are case-specific, while others can be used for other research in this domain. Not all recommendations follow from the data or user feedback, but also using feedback from the researcher himself, using introspection as a tool (Weger & Wagemann, 2015). Finally, recommendations for future research, specifically focused on feasibility studies, will be given.

Measuring the distance between cyclists

Originally, other measurement tools were planned to be used to determine the distance between the researcher's bicycle and the participant's bicycle. These tools included sound waves, GPS or lasers. Lasers can precisely measure distance, but need to target an exact point. Because of the natural swaying during cycling, lasers would continuously fail to measure the distance reliably. Therefore, lasers were excluded. GPS is not affected by swaying and can reliable measure great distances. Because it is often used to measure large distances, the standard error on average is at least 50cm (Jennings, Cormack, Coutts, Boyd & Aughey, 2010). This was considered too much for this type of research, since distance between 50cm and 4.50m were expected. Sound waves seemed reliable enough to use in this study, but after having tested these in the lab it was found that they reliably measure up to 3m, which again would not be enough. There exist sound waves that can reliable measure greater distances, but this technology is currently too expensive. LIDAR (light detection and ranging) has the same problem currently, the cheaper models are not reliable enough while the more precise models are too expensive.

Something else that became apparent when analysing the data is that the cyclists in this test cycled differently 10 to 15 seconds before or after an intersection, compared to the rest of the road. Some participant held more distance just before an intersection, while others held less. They likely need to prepare for the intersection in some way, but literature on this topic could not be found.

Time-to-collision

Time-to-collision is usually used in the automotive industry as an indicator of safety and says more than the distance between two vehicles (Vogel, 2013). It was assumed that this was also the case for bicycle research. The current paper shows that there is practically no difference between following distance and TTC. This is possibly because of the way this test was set up. In other TTC research, they usually give drivers a certain task such as "drive home" or "cross the intersection" rather than letting the driver follow someone. Because of the following task, the speed of each participant is practically the same as that of the researcher, resulting is very comparable TTC's.

General opinion on the lighting system

In the current study, some participants mentioned liking the turning signal and breaking signal more than the speed indicator. This is in line with research by Manzey, Reichenbach & Onnasch (2012) who say that different functions of a system might have different effects on different people.

If some cyclists use this new lighting system, specifically the turning signal, while others still use their hands then this might create unclear traffic situations where people are unsure whether they should look at someone's hands or bicycle. Even though this was a concern of two participants, currently many scooters already use comparable systems and some cyclists are not able to use their hand. This system ensures that those people can also convey their intentions in some way.

Effect on cycling behaviour

There are individual differences between participants. Some participants hold more distance with the system turned on while others hold more distance with the system turned off. In the following task, the elderly seemed to hold less distance with the system turned on, but this was not significant and not the case for all elderly. In a (not yet published) study that was worked on concurrently, elderly also held less distance in respect to another bicycle when using assistive technology on a bicycle. In this study, a front- and rear-view assistant were tested that would give a warning using haptic feedback if another cyclists cycled in front or behind them. When the rear-view assistant was used, elderly participants would give the upcoming cycling less space to pass. Two possible explanations for this behaviour can be found in the literature.

The first explanation follows risk homeostasis theory (Wilde, 1998). This theory states that people exhibit riskier behaviour if their level of perceived risk becomes lower. It is possible that elderly feel more safe when using the system and therefore exhibit riskier cycling behaviour. No conclusive statements can be made about why this does not happen in the younger age category, but it is possible that the younger age group already feels more safe and the system does not specifically decrease their perceived risk. This could also be why some elderly do not show the same behaviour as others, these elderly still feel relatively safe during cycling.

The second explanation is that (certain functions of) the system increases workload. Parasuraman, Sheridan & Wickens (2000) mentioned that some systems increase workload rather than decrease it, following the levels of automation theory. The more a certain system supports in a task, the less mental resources are needed (Wickens, Li, Santamaria, Sebok & Sarter, 2010; Onnasch, Wickens, Li & Manzey, 2014). Different electronic aids in the automotive industry also have different effects on the behaviour of drivers (Brookhuis, de Waard & Janssen, 2001; Carsten & Nilsson, 2001). The amount of monitoring seems to be an important aspect of when a system increases or decreases safety. Generally, the more time a system needs to be monitored, the more unsafe traffic behaviour gets. This is in line with the levels of automation theory, Dingus & Noble (2015) mention that elderly take longer glances at electronic aids than younger people do, although this effect was barely practically relevant in their test. It might be that in bicycle research this effect is more pronounced, and influences the time it takes to interpret the signals, causing elderly to take longer to respond. Additionally, Moorman et al. (2017) found that the effect on cognitive load is bigger when systems only provide information rather than intervene. Since our system actually does not intervene, it might be that the system actually increases workload, and that the younger participants can more easily deal with this than the older participants. It is recommended to further explore these hypotheses in other studies.

Limitations

In the current prototype, the operating system and battery pack were not yet incorporated in the lighting system. This will be done in later prototypes. Because the battery and operating system were not integrated and had to be placed in a bag on the steering wheel, the camera placement on the steering wheel was limited. The fact that not everything was integrated in the light yet also likely influenced the opinions of some participants.

It is hard to find the right balance between ‘being a controlled experiment’ and ‘testing the product in a real-life setting’. In the current study, roads with relatively little traffic were chosen to decrease the risk of accidents. But the lighting system should be useful in situations where there is a lot of traffic as well. By choosing a more controlled experiment, the effects on real cycling behaviour become less pronounced. This way, the differences between participants could be compared more equally though.

Speed could not be reliably measured in this study, which affected TTC as well. The current way of measuring was calculated by averaging the distance between the participant and the researcher, and adding or removing this speed difference from the average estimated speed. Added to this is the fact that it was hard for the researcher to always reliable cycle exactly the same speed, so the average speed was not always exactly 12km/h but often between 11.5 and 13km/h.

The measurements done by using the wooden beams was not as precise as tested before. This way of measurement was used in a study that was worked on concurrently as well, and showed almost no measurement error when comparing sizes of real-life objects with the measured distance in Kinovea. The measurement error of laying the grid and line was 1 or 2 cm at most. The other test used a high stationary camera, and measurements done outside the grid were reliable and valid as well. Because of the low camera angle in this study, measurements done outside the grid from farther away were not as reliable. Since this was the case for each participant, data could still be compared, but the distances presented in this study were smaller than the real-life distances.

The final limitation is also the biggest limitation. It was assumed that the system would decrease workload, but workload was never measured, neither objectively or subjectively. However, acceptance and behaviour were measured. If participants show improved behaviour while also showing interest in the product, then it is of less practical relevance whether the system increases or decreases workload.

Recommendations

A few recommendations were made for improving the follow-up study. These recommendations are split into changes to the main test, recommendations for when participants take a bicycle home for a period of one week, recommendations for the questionnaires and recommendations for data analysis.

The main test

The route should have at least one road of 170 meters or more. A road of at least 80m is needed to properly gain enough speed when needing to cycle 18km/h in the estimating speed task. If the road is shorter than 80m, then the intended speed cannot always be reached reliably. The road of 170m is the road where the following distance measurements are done. Since participants cycle differently about 10 to 15 seconds before or after an intersection, the measurements should be done between 15s after leaving the first intersection and 15s before entering another intersection. When cycling 12km/h, this should be possible on a road of 170m.

When planning a certain route, it is also useful to use roads that have certain indicators placed on them. These indicators can be different kinds of bricks in the road or anything else than can be measured. These indicators can easily be used to determine where the camera is filming when reviewing the data. Measurements from these indicators can also be used to determine whether the grid you laid reliably measures the distance. For example, when a certain brick in the road is measured, these real-life distances can be compared to the distance the program shows. Lastly, certain indicators are useful to determine start and stopping times of measurement. In our example, a white traffic line on the second intersection was used as an indicator on when to start measuring following distance.

A better odometer needs to be installed that updates more often. Currently it was hard to determine the exact speed you were cycling. This was especially problematic in the speed estimation condition, where this could actually influence the results.

The crossing task was hard to carry out because of several reasons. Firstly, it was hard to continuously cycle exactly the same distance from the side of the road. Secondly, it is unclear whether this part measures the effect of the lighting system or the confidence of the participant to cross someone closely. Lastly, this task took significantly longer to analyse than the other sections. This task could be used in the follow-up study by decreasing the width of the cycling path, but it is recommended changing this task to a task where the participant cycles straight towards an intersection and the researcher comes from the opposite direction. The researcher then turns left on that intersection before the participant passes it. This can be done once by cycling 12km/h and once by cycling 12km/h, to see whether and how quickly the participant would stop. If the original crossing task is used, the camera needs to run on more FPS, since the difference between two frames was often too big.

It is possible to add in a section where three to five participants are invited at once to cycle at their own leisure in a predetermined area. Some participants could be using the bicycle equipped with the new lighting system while others use a regular lighting system. By placing cameras on all bicycles and using GPS-apps on someone's mobile phone the distance between bicycles as well as their speed can be used to determine TTC. This is a lot of work though, and is something that was not tested for in this feasibility study. It is recommended to not do this, but it would be a more realistic measurement, being able to use TTC as well as more natural cycling behaviour.

Lastly, it is possible that the effect of researcher who uses the bicycle equipped with the intelligent lighting system influences the distance some participants keep. For this reason it is recommend to always let the same researcher use that bicycle, or otherwise track what researcher was using the bicycle for each participant and try to keep this change relatively constant.

Using the bicycle in real-life for one week

When people receive the bicycle, it should be corrected to their height. Each bicycle should be equipped with a luggage carrier and gears, saddle bags should be optional for some participants. It is possible participants only mentioned wanting these features because they were offered, but the downside of not having these features could be that participants are not willing to use the bicycle (as often). Following this trend, the system should be waterproof, be able to run for more than four hours and possibly be available on electric bicycles as well. By not offering electric bicycles, many potential participants are automatically left out.

When giving participants the bicycle, it should be made clear to them that they are not responsible if something gets stolen. It needs to be clear that it is more important for this study to use the bicycle in such a way that they would normally use their own bicycle. It would also help if the system looked like it was less easy to steal. Participants should also be able to contact someone if they have questions about the study or the bicycle, or when they want to report that something on their bicycle broke.

Questionnaires about the use of the bicycle should be sent once a day via E-mail that contains a link to an online web-based survey. These questionnaires are not mandatory to fill in each day, and should start with an option comparable to "I did not use the bicycle today or have nothing special to report". The last questionnaire is mandatory to fill in so that each participant has filled in at least one questionnaire. It should be clear to participants that it is preferred if they fill in as many as they can. If possible, a reminder via text or WhatsApp can be sent.

It is possible that just taking a new bicycle home, even one without a new intelligent lighting system, might have certain effects on people's cycling behaviour. It might be beneficial to let some participants take a bicycle home that does not have the intelligent lighting system installed to see whether there are certain aspects that are typical for just taking home a new bicycle rather than being specific for using this new lighting system.

Questionnaires

Rather than asking about participants' opinion on the whole lighting system, participants should be able to give their opinion on the different aspects on the lighting system. Some participants were more keen on the turning indicator while others liked the breaking signal. This distinction should be made in the results of the follow-up.

The back side of appendix C was never used so it can be left out. Added to the question of how much participants are willing to pay for the system should be the question "I'd be willing to pay x more for this system compared to a regular lighting system". A question about the subjective safety could be added, since currently only objective measurements are used while subjective safety is a useful measurement tool (Heinen, van Wee & Maat, 2010). It is recommended to use the SUS as an indicator of usability of the system, since it appeared to validly reflect participants' opinion.

A questionnaire that measures subjective workload should be added. A possible questionnaire would be the Rating Scale Mental Effort by Zijlstra and van Doorn (as cited in Widyanti, Johnson & de Waard, 2013). There are also other questionnaires that measure subjective workload, the specific questionnaire does not really matter as long as one is added. Another way workload is often measured is by adding a secondary task to a primary task. This measures the objective workload rather than the subjective workload. This is not recommended though, since it takes relatively long to implement.

The questionnaire that people receive when using the bicycle for a period of one week should make a clear distinction between whether participants used in during daylight or when it was dark. Participants should also be encouraged to let people they usually cycle with fill in part of the questionnaire. This can be done by always adding a second questionnaire link in each E-mail that participants can send to friends and family. This way not only the opinions on the users of the new lighting systems are gathered, but also those from people that look at rather than use the system.

Data analysis

The grid, used inside Kinovea for deciding real life measurements, was not big enough and measurements done outside the grid were less reliable than in previous tests. For this reason, the grid size for both the rear- and the front camera should be increased. The grid to the side of the bicycle should be at least 3m in length and the grid at the rear of the bicycle at least 4.5m in length. This can be done by placing two wooden beams behind each other, then removing the first one and placing it behind the second, continuing this process unless the desired length is achieved. The width does not need to be as long. For this it is recommended to place the last beam perpendicular on the beam the furthest away from the camera. This can then be used for measuring more reliable distances.

An alternative to this way of placing the wooden beams is to start filming on a road with stone bricks rather than asphalt. These bricks can be measured beforehand and the grid for video analysis can be as big as you need it to be as long as you know how large all bricks are. Even if the wooden beams are used, it is recommended to measure the real life sizes of some object on-route, so that the validity of the video images can be checked against those measurements.

The reason the grid does not need to be as wide is because of another change to measuring following distance. During the test, participants swayed a lot which could change the following distance over 20cm within one second. Rather than measuring from the predetermined point to the front wheel of the participant, it is suggested to draw a straight line upwards from the predetermined point and stop at the point where the end of that line is on the same length as the front wheel of the participant. This way you pretend as if each participant is cycling straight behind the bicycle equipped with the lighting system. It does not matter if the participant is either to the left or the right of the end of that line. Important here is to still measure the distance from the predetermined point to the back of the bicycle equipped with the new lighting system, and add that to the measured distance

When measuring the lateral distance, the bottom bracket was used to determine this distance. The bottom bracket was often obstructed by either the participant or the researcher. For this reason, it is recommended to use the front wheel, the part that touched the ground, rather than the bottom bracket for measuring distance between participants. The back wheel was sometimes obstructed by saddle bags, that is why the front wheel is recommended over the back wheel.

Finally, when inspecting the participants' data, it is recommended to look at individual differences between participants. In this short feasibility study there were no clear indicators as to why some participants held more distance with the system turned on and others did not, but maybe this becomes apparent with a greater sample size. Additionally, the results of the follow-up study might be interpreted wrongly if the following distance averages out so that it seems the system has no effect at all. While in fact the system does have an effect, but this effect is different on different people.

General overview of the suggestions ranked in order of importance

Table 5 contains the most important suggestions that were made in the previous paragraphs that are also applicable to other studies, mainly those focused on bicycle research. For this reason, these suggestions are written down as a more general statement. Importance was ranked by how many research domains could use that specific recommendation. For a full list of recommendations or a more in depth explanation of the key-points mentioned here, please consult the 'recommendations' section. Ease of implementation is not accounted for in this table.

Table 5, Suggestions ranked in order of importance

Suggestion:	Relevant for:
Do not ask participants to assess a system as a whole if the goal of each of those functions is different. Assess each function individually.	Human Factors
The SUS is a good tool for assessing usability of less complex systems.	
Check all results for individual differences, since results might average out.	
Following distance is a better indicator than TTC if participants cannot cycle freely	Bicycle research
The age of the researcher using a bicycle (equipped with a new system) might influence the behaviour of certain or all participants.	
Make sure that participants know that using the system practically is more important than safeguarding the system unnecessarily.	Practical system research
When testing in a practical setting, make sure that participants can easily contact one of the researchers in case of need.	
Do not only let the user of the system fill in the questionnaires, but also offer one to people who experienced the system by observing it (family/friends).	
To check for differences of just taking a new bicycle home, let some participants take home a bicycle without the new system installed.	Practical bicycle research
Make sure a possible replacement bicycle is as comparable as possible to their own (correct it for their height, add certain features).	
Make systems available on electric bicycles as well unless it was a conscious choice to not do so.	

Usefulness of feasibility studies

Many of the recommendations were already discussed and implemented by the project team. For this reason, it can be said that the goal of this study has been achieved and this study has been a success. It is expected that the follow-up study will yield useful results and be successful. Doing a feasibility study can hugely increase the validity of a test and decrease the amount of unusable data. Because of this, it is recommended to conduct and report on feasibility studies more often.

Feasibility studies are not reported that often, and when they are, specific guidelines for setting up feasibility studies are not presented. There are recommendations on when a feasibility study should be conducted, for example when you want to measure an unexplored concept (Arain, Campbell, Cooper & Lancaster, 2010). No specific recommendations on when a feasibility study should be considered a success or what a feasibility study should look like can be found in the literature.

As discussed in the introduction, reviewing several feasibility studies in different domains showed that feasibility studies usually have three inexplicit guidelines. The first is that participants should not only use the product, but also comment on their perception and the acceptance of that product. The second common theme is that it is best to try several forms of data measurements, rather than trying whether one thing works and having not found a proper solution at the end of the study. The last guideline is that results are not considered conclusive, but serve as a stepping stone for further research. These three guidelines seem usable for any type of feasibility study, also since they are rather broad. To motivate other researchers to conduct feasibility studies more often, the first step could be to better specify specific guidelines for setting up feasibility studies, as well as better visualizing the benefits of feasibility studies. This specific study can serve as a first indicator of main guidelines that can be used in feasibility studies. Others researchers are more than welcome to critique these three guidelines in order to create more exact guidelines for setting up feasibility studies.

Feasibility studies and exploratory studies in general are not conducted often, but can give insights into processes that were not studied before. This can results in novel studies, new measurement tools and possible whole new study domains. One reason feasibility studies are not conducted as often is because of the focus on publishable research. Since the focus in current research is on publishing, the exploratory step in research is often skipped. Because of this, it is often unclear why certain techniques or procedures are used. If the acceptance of feasibility studies as useful research increases, the number of (published) studies will increase. Increasing this acceptance can be done by better specifying specific feasibility study guidelines and by highlighting the benefits of conducting feasibility studies. This study showed how useful feasibility studies can be and how feasibility studies can raise interesting questions for follow-up research. Three guidelines were specified in order to help other researchers get a better grasp on how feasibility studies are conducted, in the hopes that other researchers, also those in other domains, will conduct and report on feasibility studies more often. Because of this, the exploratory nature of research is stressed more clearly, resulting in a more open and clear understanding of scientific research procedures.

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Appendix A, Feedback on the testing process

(To be filled in by the researcher)

Deelnemer nr.:_____ **Geslacht:_____** **Leeftijd:_____**

Estimated speed (off) : _____
Estimated speed (on) : _____

First Impressions

Feedback on the usefulness of the SUS:

Feedback on the lighting system:

Feedback on the questionnaires:

Feedback on taking the bicycle home with you:

Additional feedback:

Appendix B - SUS with changes, translated to Dutch

Deelnemer nr.: ___
De volgende vragen gaan over de richtingaanwijzer die u net gebruikt heeft. Omcirkel het antwoord waar u het ‘t meest mee eens bent. Lees de vraag goed door voor u antwoord geeft.

	Heel Oneens	Oneens	Neutraal	Eens	Heel Eens
1. Ik denk dat ik dit product graag vaak zou willen gebruiken	1	2	3	4	5
2. Ik vond het product onnodig complex	1	2	3	4	5
3. Ik dacht dat het product makkelijk te gebruiken was	1	2	3	4	5
4. Ik denk dat ik de hulp van een technisch persoon nodig zou hebben om dit systeem te gebruiken	1	2	3	4	5
5. Ik vond dat de verschillende functies in dit product goed geïntegreerd waren	1	2	3	4	5
6. Ik dacht dat er teveel inconsistentie in het product was	1	2	3	4	5
7. Ik kan me voorstellen dat de meeste mensen dit product zeer snel leren te gebruiken	1	2	3	4	5
8. Ik vond het product erg ongemakkelijk om te gebruiken	1	2	3	4	5
9. Ik voelde me erg zelfverzekerd tijdens het gebruiken van het product	1	2	3	4	5
10. Ik moest een hoop leren voor ik met dit product aan de slag kon	1	2	3	4	5

Appendix C - Lighting system questionnaire

Deelnemer nr.: ___
In de volgende vragenlijst wordt naar een paar specifieke standpunten over het nieuwe verlichtingssysteem gevraagd. U krijgt na de tijd ook de mogelijkheid om algemene opmerkingen over de verlichting te plaatsen (zie achterzijde document).

1. Wat vond u van het verlichtingssysteem? (in 1 zin)

____

2. Wat vond u positieve en negatieve aspecten van het verlichtingssysteem?

Positief	Negatief

3. Zou u zelf dit verlichtingssysteem gebruiken? □ ja □ nee

Toelichting: ____

4. Hoeveel zou u voor dit verlichtingssysteem over hebben? €______

5. Zou u willen dat andere mensen dit systeem gebruiken? □ ja □ nee

Toelichting: ____

6. Denkt u dat het systeem verkeersveiligheid verbetert? □ ja □ nee

Toelichting: ____

Als u nog andere opmerkingen heeft, plaats ze dan graag in het veld hier onder. Dit kan iets zijn dat eerder bij de vragen nog helemaal niet genoemd is, of misschien wilt u iets meer kwijt over een bepaalde eerder gestelde vraag. Mocht u suggesties voor de verbetering van het systeem hebben, dan kunt u deze hier ook kwijt.

Appendix D, Acceptance scale

Deelnemer Nr. ______

Zet per onderdeel 1 kruisje in het vakje dat uw mening weergeeft over het verlichtingssysteem.

1 Nuttig	|___|___|___|___|___|	Zinloos
2 Plezierig	|___|___|___|___|___|	Onplezierig
3 Slecht	|___|___|___|___|___|	Goed
4 Leuk	|___|___|___|___|___|	Vervelend
5 Effectief	|___|___|___|___|___|	Onnodig
6 Irritant	|___|___|___|___|___|	Aangenaam
7 Behulpzaam	|___|___|___|___|___|	Waardeloos
8 Ongewenst	|___|___|___|___|___|	Gewenst
9 Waakzaamheidverhogend	|___|___|___|___|___|	Slaapverwekkend

Appendix E, Preferred ways of measurement

Deelnemer nr.: ___

Bij het invullen van deze laatste vragenlijst moet u zich voorstellen alsof u de fiets 1 week meekrijgt, om in uw dagelijks leven te gebruiken. Op de voorpagina kunt u invullen wat u belangrijk zou vinden als dit het geval is. Op de achterkant staan enkele leidende vragen, bekijk deze pas nadat u eerst zelf hebt nagedacht. Mochten er na het bekijken van de leidende vragen toch nog enkele dingen te binnen schieten, dan kunnen deze op het tweede deel van deze pagina geplaatst worden.

Dingen die ik belangrijk vind als ik een fiets met dit verlichtingssysteem een week in mijn dagelijks leven zou moeten gebruiken:

Idem, maar nu dingen die me te binnen schoten nadat ik de vragen op de achterkant las:

In een later stadium van het onderzoek zal mensen gevraagd worden om de fiets een week lang mee te nemen om deze in hun dagelijks leven te gebruiken. Om er achter te kunnen komen wat mensen opvalt bij het gebruik van de nieuwe fiets willen wij hen vragenlijsten opsturen of meegeven. Hieronder kunt u aangeven hoe u zelf deze vragenlijsten het liefst zou ontvangen.

1. Ik zou vragenlijsten graag … invullen. □ Op papier □ Digitaal

2. Ik zou de vragenlijsten het liefst ontvangen en opsturen via…

□ E-Mail □ Internet (link) □ SMS □ Anders, namelijk: ___________

3. Het invullen van 1 formulier neemt hooguit 5 minuten in beslag, hoeveel dagen in een week zou u bereid zijn een vragenlijst in te vullen?

□ 1 dag □ 3 dagen □ 5 dagen □ 7 dagen

-

Verder hebben we nog enkele vragen over het daadwerkelijke gebruik van de fiets als u deze 1 week mee naar huis zou nemen.

4. Zou u de verlichting (tijdelijk) op uw eigen fietswillen laten monteren of wilt u een fiets meekrijgen waar de verlichting al op is gemonteerd?

□ Eigen fiets □ Voorbereide fiets

5. Zijn er bepaalde aspecten die de voorbereide fiets zou moeten hebben voor u deze zou willen gebruiken? (meerdere antwoorden mogelijk)

□ Bagagedrager □ Fietstassen □ Kilometerteller □ Versnelling

□ Anders, namelijk:__________ □ Niet nodig voor een week

Mocht u nog andere punten hebben die u belangrijk vindt dan kunnen deze op de eerste pagina geplaatst worden (in het tweede vak).

Appendix F – Results of the ‘feedback on the testing process’

Gebruik elektrische fiets door deelnemers: 7 & 10

First impressions

1: Werkt prima en duidelijk
1: Handig dat er weinig bediening is.
2: Verschil in kleuren is erg handig om snelheid te zien
2: Had verwacht dat de snelheidsmeter om het system heen ging i.p.v. aan beide kanten omhoog
3: Licht is prima
3: Kan makkelijk met duim bij bediening
3: Snapte middelste knop bediening niet zo
4: De ring bij het voorlicht zie je niet zo, misschien groter contrast?
5: Handig. Richtingaanwijzer erg prettig
6: Ziet er strak uit
6: Richtingaanwijzer bedienen was makkelijker dan gedacht
6: Snelheid voor is slechter te zien dan achter
7: Zou eigenlijk een rood knipperlicht willen i.p.v. oranje
7: Verlichting in de wielen zou fijn zijn, zodat het ook van de zijkant te zien is (wist niet precies hoe)
8: Erg mooi
8: Is waarschijnlijk wel erg duur
9: Prachtig
9: Had verwacht dat snelheid als een cirkel er om heen ging, als je het weet is het prima
10: Insteek is geweldig. Neemt niet veel ruimte in
10: Zou mooi zijn als het was geïntegreerd in het frame van een E-bike
10: Richting aangeven en remmen is geweldig, wist niet direct wat snelheidsring was
11: Goed, maar de fiets kraakt.
12: Richtingaanwijzer lijkt me vooral erg handig

Usefulness SUS

1: Heel algemeen, ik miste niets
2: het is onduidelijk dat sommige vragen in de verleden tijd staan
4: Lastige vraag over ‘zelfverzekerdheid’ bij gebruik van product. Vond niet zo passend.
6: Las 1 woord (consistentie) verkeerd, was niet zo’n probleem
7: Alles moet wel in de tegenwoordige tijd
8: Vond niet alles even makkelijk te beantwoorden en gaf dan neutraal aan. Vond dat alles was gezegd
9: Alle vragen in de tegenwoordige tijd zetten.
11: Zou bij vraag 3 zeggen “Ik vond dat het product…”

Lighting system
1: Fietsverlichting in de middag is niet zo handig, mensen letten daar niet zo op
2: De snelheidmeter is wel heel erg snel vol (maximale snelheid wordt te snel bereikt)
3: Kon nu het buiten licht was niet goed zien wanneer het licht brandde (zowel voor als achter)
3: Kon goed zien dat er een verschil in snelheid was met behulp van verlichting
3: De balken gaan wel heel snel vol (maximale snelheid te snel bereikt)
4: Knipperlicht ging in de eerste bocht te snel uit (automatisch)
5: Snelheidsindicator voorlicht heel erg slecht te zien. Maakte wel gebruik van achterlicht.
5: Richtingaanwijzer en remlicht zijn handige functies, de rest niet per se
5: Snapt niet waarom de knop voor rechts afslaan niet rechts zit
5: Verlichtingssysteem mag er wel wat moderner uitzien (bijv. matzwart maken). Het ziet er nu erg oud en saai uit en jongeren zullen het zo niet snel halen.
6: Het licht doet wel heel erg denken dat iemand heel erg snel gaat
6: Mogelijk intuïtiever om zowel links als rechts een knop voor afslaan te hebben
7: Ik gebruik de lichten eigenlijk niet
8: Ingewikkeld systeem, moet ik erg aan wennen
8: Wel makkelijk met 2 handen aan het stuur
8: Veel mensen verwachten het niet, daardoor wordt de verkeersveiligheid niet beter
8: Ik vraag me wel af of mensen het zien, het is maar een klein lampje
10: Snelheid inschatten ging veel beter met behulp van licht (schatte ook daadwerkelijk beter)
11: Bij de snelheid voor was er weinig verschil te zien tussen de kleuren
11: De richtingaanwijzer gaat te snel (automatisch) uit
12: Duidelijk, wil ik best op de fiets hebben

Questionnaires
3: Vond vraag 3 onduidelijk. Wist niet of het over dit model ging of over wanneer het complete perfect doorontwikkeld was. Vind compleetheid erg belangrijk.

Taking the bicycle home with you
4: Je moet erg wennen aan de fiets. Meet je tijdens het testen wel alleen het effect van het verlichtingssysteem of ook het effect van het leren van een nieuwe fiets?
5: Het hele systeem moet waterbestendig zijn. Ik neem het niet mee als het kapot kan regenen.
5: Hoe krijg je deelnemers die hier echt belang bij hebben als je geen elektrische fiets aanbiedt?
7: 7x meten is wel het best
8: Het is teveel toestand om het elke dag in te moeten vullen

12: Wil graag veel versnellingen, anders trap ik me kapot (alleen 3-versnelling was niet goed)

Additional feedback

1: Ik gebruikte niet echt het verlichtingssysteem bij snelheid inschatten
1: Raad aan om ook in het donker te testen
5: Veel mensen zouden dit moeten gebruiken voor het product zin heeft. Anders krijg je alleen maar twee soorten informatie.
6: Vind niet dat je mag verwachten dat jongeren dit halen, zeker als het duur wordt. Het richtingaanwijzer-systeem was wel erg handig. Stelde voor om alleen dat in het stuur te laten bouwen zodat ook mensen die moeite hebben met hand uitsteken hier iets aan hebben. Dit drukt kosten enorm.
7: De tests zouden in het donker moeten worden uitgevoerd
7: De prijs van systeem is de extra kosten die het mag hebben als het voor gemonteerd is
8: Zou het wel gebruiken als het net zo duur is als standaard verlichting
8: Snelheid en remmen zijn wel erg handig
8: Het werkt niet als de helft van de mensen dit systeem gebruikt en de andere helft nog de hand uitsteekt. Vraagt zich om die reden af wie dit nou zou willen.
9: Zou niet willen dat het systeem zo fel is dat je daardoor teveel opvalt
11: Bestaat zoiets niet al? (noemde Huka en Nijland)

Appendix G – Comments on the lighting system questionnaire

Opinion in one sentence:

1: Het lijkt mij makkelijk & handig in gebruik
2: Over het algemeen duidelijk, met kleine mitsen en maren
3: Best handig
4: Duidelijk en simpel systeem
5: Duidelijk en veiliger dan normale fiets
6: Ziet er tof uit! Slim bedacht
7: Nog niet duidelijk genoeg
8: Een klein beetje ingewikkeld
9: Ik vind het mooi en bruikbaar staan
10: Uitstekend, je kunt erop anticiperen als weggebruiker
11: Ik denk dat het de veiligheid verhoogd
12: Zeer goed

Positief	Negatief
1: Duidelijk te zien wat de fietser gaat doen 1: Makkelijk in gebruik 2: Knipperlicht was duidelijk 2: Duidelijke kleuren aan voorkant 3: Richting, remlicht en snelheidsmeter 4:(richting) gaat automatisch uit 4: Duidelijk zichtbaar 5: Richtingaanwijzer/remlicht 6: Je kan snelheid zien en dat iemand remt 7: De richtingaanwijzer 8: Makkelijk 2 handen aan het stuur 9: Simpel, handig, veiligheidsverhogend 10: Eenvoudig en praktisch 11: Voldoende zichtbaar 11: Remlicht positief 12: Goed zichtbaar	2: Remlicht deed het niet geloof ik 2: Gaat beide omhoog ipv rond ((↖↗) ipv (↑→)) 3: Voorlicht niet goed te zien 3: Accu neemt veel ruimte 4: Snelheid voorlicht niet heel goed zichtbaar 5: Voorlichtsnelheidsindicator niet goed zichtbaar 6: Weet niet of dit wat toevoegt naast gewoon naar iemand kijken 7: Daglicht verstomt waarneming 8: Even aan wennen 9: Wennen aan knopjes voor afslaan 9: Snelheidslampjes ietsje leuker 10: Accu nodig 11: Snelheid voorop overdag niet goed zichtbaar

Appendix H – Suggestions for improvement when taking the bicycle home

1: Is een slotje genoeg om ervoor te zorgen dat het niet gestolen wordt? Ik zou liever het apparaat meenemen omdat ik anders bang ben dat hij gestolen wordt. Ik zou de fiets ook niet in de stad laten staan.

2: Ik heb niet zoveel eisen aan een fiets, behalve goede verlichting, een bel en een niet-kapotte bagagedrager (liefst met snelbinders).

3: Ik wil prettig kunnen fietsen, het zadel is nu iets te hoog ingesteld voor mij. Hij moet diefstalbestendig zijn, ik wil hem overal neer kunnen zetten, ook bij de supermarkt.

4: Het mag niet te ingewikkeld zijn. Ik wil niet ergens in moeten kijken om te zien hoe iets werkt. Familie en vrienden kijken er ook veel naar, kijk daar naar de reactie i.p.v. alleen jezelf.

5: Ik wil direct geholpen kunnen worden als iets kapot is. 4 uur accu is niet veel, hij kan dan niet continu aan staan.

6: Ik wil duidelijke uitleg over de dure onderdelen die er op zitten, ik wil daardoor namelijk niet belemmerd worden. Zou graag een herinnering hebben om het systeem ook overdag aan te zetten. Verder is een standaard erg belangrijk om er op te hebben.

7: Wil juiste afstelling van de fiets op zijn hoogte. Ook wil hij graag zelf kunnen kiezen welke handrem bij welk wiel hoort. 'Basis' lamp moet fel genoeg zijn!

8: Het moet er niet te kostbaar uit zien (diefstalbestendig). Lijkt zoveel mogelijk op een normale fiets. Richtingaanwijzergebruik moet niet verplicht zijn, steek liever de hand uit.

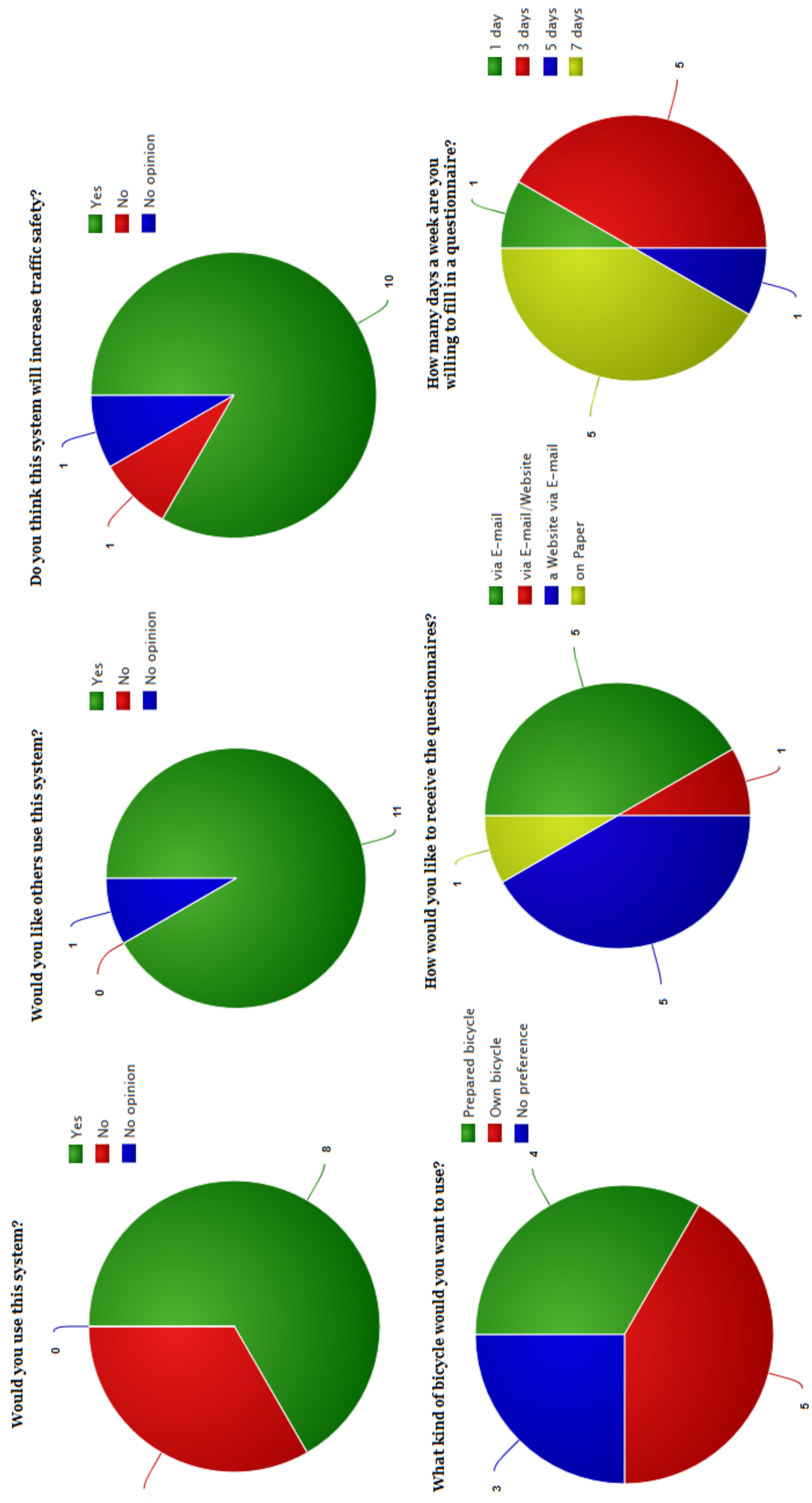
9: Goed lopende fiets, i.i.g. met versnelling. Vraagt zich af of je er iets af moet halen. Zou het mooist zijn als de bediening geïntegreerd was, bijvoorbeeld in de handvatten.

10: Het moet werken en eventuele storing moet direct worden verholpen.

11: Richtingaanwijzer lijkt me nuttig, snelheid niet zo en remmen is twijfel. Eigenlijk zou je dit moeten proberen met groepen die fietsen (i.p.v. individuen). Zou mooier zijn als je richting kon bedienen aan beide kanten (bijv. geïntegreerd in handvat)

12: Ik ben gauw tevreden, maar ik zou absoluut geen elektrische fiets willen.

Appendix I – Answers on the questionnaire questions



Appendix J – Changed System Usability Scale

De volgende vragen gaan over het intelligente verlichtingssysteem dat u net gebruikt heeft. Omcirkel het antwoord waar u het ‘t meest mee eens bent. Lees de vraag goed door voor u antwoord geeft.

	Erg mee oneens	Oneens	Neutraal	Eens	Erg mee eens
1. Ik denk dat ik dit systeem vaker wil gebruiken	1	2	3	4	5
2. Ik vind het systeem onnodig complex	1	2	3	4	5
3. Ik vind het systeem makkelijk te gebruiken.	1	2	3	4	5
4. Ik denk dat ik de hulp van een technisch persoon nodig zou hebben om het systeem te gebruiken	1	2	3	4	5
5. Ik vind dat de verschillende functionaliteiten in het systeem goed geïntegreerd zijn.	1	2	3	4	5
6. Ik denk dat er teveel tegenstrijdigheden in het systeem zitten.	1	2	3	4	5
7. Ik kan me voorstellen dat de meeste mensen snel leren hoe ze het systeem moeten gebruiken	1	2	3	4	5
8. Ik vind het systeem erg omslachtig/lastig in gebruik.	1	2	3	4	5
9. Ik voelde me erg zelfverzekerd tijdens het gebruiken van het systeem	1	2	3	4	5
10. Ik moet nog veel leren voordat ik het systeem kan gebruiken	1	2	3	4	5