

CAN INFORMATION ABOUT AN APPROACHING BICYCLE'S CHARACTERISTICS INFLUENCE DRIVERS' GAP ACCEPTANCE AND TTA ESTIMATES?

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Summary: E-bikes, which have the potential to reach higher speed levels than conventional bicycles, but look basically the same, are suspected to be at a higher crash risk than such conventional bicycles. Other road users might misjudge the time remaining before the approaching bicycle arrives (time to arrival, TTA) and accept unsafe gaps (e.g. for turning manoeuvres) as a result of this combination of higher speed and well-known looks. Researchers have therefore suggested to make drivers aware of the higher speed of e-bikes, and give e-bikes a distinct appearance. Goal of this experiment was to investigate the effects of such a unique appearance, coupled with clear instructions about the capabilities of e-bikes, on gap acceptance and TTA estimates. Participants were presented with video sequences of approaching cyclists clearly identifiable as either riding a conventional bicycle or e-bike, and were required to either indicate the smallest acceptable gap for a left turn in front of the cyclist, or to estimate TTA in two different experimental blocks. The results showed no difference in accepted gap size between the two appearances of the cyclist, whereas there was a minor effect on TTA estimates. Overall, the results imply that simply informing other road users about e-bikes (in conjunction with a re-design that gives them a unique appearance), might not be sufficient to elicit a more conservative behavior.

INTRODUCTION

The number of so-called e-bikes, bicycles which support the rider while pedaling with the help of an electric motor, on roads worldwide has increased considerably in the past few years (Rose, 2012). Not surprisingly, different studies have shown that such e-bikes are indeed used at higher speeds than conventional bicycles under naturalistic conditions (Jellinek, Hildebrandt, Pfaffenbichler, & Lemmerer, 2013; Schleinitz, Petzoldt, Franke-Bartholdt, Krems, & Gehlert, 2017). Unfortunately, other than the battery that powers the motor, e-bikes usually have no specific features that set them apart visually from conventional bicycles. So, as the propensity to reach higher speed levels is coupled with the looks of an ordinary bicycle, there have been concerns that car drivers and other road users might underestimate the speed of an approaching e-bike (Jellinek et al., 2013; Popovich et al., 2014), which might result in critical situations or even crashes while turning and crossing at intersections.

Indeed, there is evidence that road users tend to rely extensively on superficial characteristics of a vehicle to judge its approach speed, with actual speed playing only a limited role. For example, observers' post-hoc assessments of the speed of different cars were found to be influenced by the vehicles' respective model (Davies, 2009; Davies & Patel, 2005). There is also evidence that not only vehicle type, but even just vehicle color (Cherry & Andrade, 2001) can influence the speed estimate. Even more problematic seems to be the fact that vehicle type has also been reported to influence drivers' gap acceptance and their estimates of time to arrival (Alexander, Barham, &

Black, 2002; Horswill, Helman, Ardiles, & Wann, 2005; Keskinen, Hiro, & Katila, 1998). *(In the literature, you also find the terms time to collision, time to contact, time to passage or arrival time, which all, more or less, describe the same concept. For reasons of consistency, the term time to arrival / TTA is used throughout this paper, as it best fits the experimental setup, and as it is broad enough to cover all the other terms. However, it has to be acknowledged that cited authors might have used different terminology.)*

Prolonged experience in road traffic with the respective types of vehicles is usually the source for such effects. Road users expect certain vehicles (e.g. sports cars, motorcycles) to be faster than others simply because they have personally experienced them being faster repeatedly. It could be argued that such effects are actually useful heuristics – rules-of-thumb that have developed based on individual experiences. Unfortunately, if e-bikes are mistaken for conventional bicycles, such a rule-of-thumb must be expected to result in an increased crash risk. As a consequence, it has been suggested that e-bikes and/or their riders should be made visually distinct from conventional bicycles/cyclists (Dozza, Piccinini, & Werneke, 2016), to avoid the potential for confusion in the short term. In the long term, it might also be suspected that, after sufficient exposure, other road users will be able to connect this unique appearance to certain behavioral characteristics of the vehicle (higher speed, stronger acceleration), which should ultimately lead to an overall more conservative approach when confronted with e-bikes.

However, the rapid growth of the share of e-bikes on the streets might result in a short term increase in crash risk, since, although a unique appearance might help avoid confusion, experience with e-bikes is still lacking. Just waiting for road users to learn from repeated exposure might not be the most efficient (or even ethical) approach. Instead, the question is whether a more conservative behavior with regard to (distinctly designed) e-bikes can also be achieved merely through instruction. Accordingly, it has been suggested to increase other road users' awareness of the higher speeds of e-bikes through matching campaigns (Jellinek et al., 2013; Scaramuzza, Uhr, & Niemann, 2015).

The goal of this experiment was therefore to assess the potential impact that a clear visual differentiation between conventional bicycle and e-bike could have on drivers' perceptions and actions if they were informed about the specific capabilities of the e-bike, and familiarized with their defining visual features. To address this question, we conducted a video-based laboratory experiment, using recordings in which a cyclist approached a driver at varying speed levels. As an extreme simplification of the idea of a distinct design, our cyclist wore a retroreflective vest to indicate he would be riding an e-bike, and did not wear this vest to indicate that he approached on a conventional bicycle. While this manipulation certainly does not correspond to actual design proposals, we nevertheless deemed it sufficient to address the research question in principle. Participants were informed explicitly about the e-bike and its capabilities, reflecting the information that a potential campaign could provide to road users. The size of the minimum acceptable gap for turning left in front of the approaching bicycle as well as judgments of TTA were recorded as indicators of other roads users' perceptions and actions.

METHOD

Participants

Forty participants took part in the experiment (14 male, 26 female), with a mean age of 26.1 years ($SD = 5.6$). Twenty-eight were students of Technische Universität Chemnitz, whereas the others were of various professions. All of them had a drivers' license, were active drivers (annual mileage of about 11,300 km per year) and had normal or corrected visual acuity. Participants received course credits or monetary compensation for their participation.

Material

Video material was recorded from a driver's point of view, i.e. the height of the camera position was comparable to the eye level of a driver sitting in a car. The observer/camera was put at a T-junction, in a position that resembled a car waiting to make a left turn. Meanwhile, a cyclist approached in the oncoming lane across which the left turn would have to be executed. Our cyclist wore an orange vest (retroreflective) to indicate he would be riding an e-bike, and did not wear this vest to indicate that he approached on a conventional bicycle. However, to be able to test the effect of the vest independent of other potentially confounding factors, the rider actually approached on a conventional bicycle in both conditions. In addition, the cyclist approached at five different speed levels, which ranged from 15 to 35 km/h in 5 km/h increments. In order to mark the position of a potential collision between the approaching cyclist and the observer's car when turning left, a white line was pasted on the road. Out of these videos, the clips for the two experimental blocks were created.

In the gap acceptance block, videos were cut so that the approaching cyclist was always in a distance of 100 m from the white line at the start of the clip. The video continued until the vehicle had passed the position of the observer (resulting in variable clip length, dependent on approach speed). Participants watching the clips were supposed to put themselves in the position of a car driver at the intersection, waiting to make a left turn. Their task was to indicate the minimum gap that they felt was acceptable to complete a left turn in front of the oncoming cyclist, which they would indicate by pressing the spacebar the moment the gap between observer and cyclist had reached this critical size. The crossing of the two factors (appearance x speed) resulted in 10 factor level combinations, which were shown twice in randomized order (i.e., 20 trials).

For the TTA estimation block, videos were cut to a length of 4 s. The participants' task was to indicate the moment they felt the cyclist would have arrived at the white line pasted across the road surface after a clip had ended by pressing the spacebar. In order to avoid potential learning effects that might allow the participants to use other strategies (such as distance at end of video) to infer TTA, the bicycle's actual TTA at the end of the clip was varied in two levels (4 or 6 s). This resulted in a total of 20 factor level combinations (appearance x speed x TTA). Again, all combinations were shown twice in randomized order (i.e., 40 trials).

Procedure

Participants were seated behind a desk in 60 cm from the screen (23 inch) on which the experiment was presented. First, they were informed about the differences between e-bikes and conventional bicycles, which included the fact that e-bikes support the riders while pedaling with an electric motor up to 25 km/h, which allows the rider to reach higher speeds than conventional bicycles. It was highlighted that therefore, in the following videos the e-bike rider would wear a retroreflective vest to better distinguish him from the conventional cyclist. After that, the specific instructions for the gap acceptance block were provided. Participants completed two practice trials in this block before the data collection started. After the gap acceptance block, they had to fill in a short questionnaire on demographic variables such as age and gender, followed by the instructions for the TTA estimation block. Again, participants completed two practice trials before data collection started. The whole experiment took about 30 minutes to complete.

Data analysis

For each factor level combination (appearance x speed) in the gap acceptance block, a mean of the two values collected per combination was calculated. In TTA block, raw estimates of TTA were transformed into a TTA estimate ratio, which was the proportion of estimated TTA relative to the actual TTA (e.g. Schiff, Oldak, & Shah, 1992) prior to the statistical analysis. A value above 1 indicates an overestimation of TTA, a value below 1 indicates an underestimation. We then checked in how far the two different TTA levels (which were only introduced as a means of experimental control, and not intended for analysis) would have an effect on the result. As we found no significant difference between the TTA estimate ratios for the different TTA levels ($t(36) = 0.83, p = .412$), we collapsed the data across this factor, which resulted in a single score for each factor level combination of appearance x speed as well. We conducted two separate two-factor analyses of variance (ANOVA) for repeated measurements for the analysis of TTA estimation and gap acceptance. Bonferroni correction was used for all pairwise comparisons.

RESULTS

For the analysis of gap acceptance, we had to remove the data of one participant from the dataset, as he accepted implausibly small gaps sizes. In Figure 1 left the results for the accepted gap size are illustrated for the different speed levels and the two appearances of the cyclist. The speed level had a considerable impact on the size of accepted gaps, as increasing speed resulted in decreasing accepted gap size, an effect that was confirmed through the ANOVA ($F(1.965, 74.685) = 726.79, p < .001, \eta^2_p = .950$, Greenhouse-Geisser-correction). The pairwise comparisons revealed significant differences between all speed levels (all $p < .001$). However, as can be seen in Figure 1, there was no significant difference in accepted gap size between the condition with vest or without vest ($F(1, 38) = 0.05, p = .833, \eta^2_p = .001$). The size of accepted gaps at the different speed levels was nearly identical for both appearances across all speed levels. As a consequence, there was no interaction between appearance and speed ($F(4, 125) = 1.40, p = .236, \eta^2_p = .036$).

For the analysis of TTA estimation, the data of three participants had to be removed from the dataset, as they produced TTA estimates close to zero. Figure 1 right shows the results for TTA

estimate ratios dependent on the different speed levels and the two appearances of the cyclist. As can be seen, higher speed levels went with higher TTA estimate ratios, again confirmed with the ANOVA ($F(2.963, 106.677) = 27.24, p < .001, \eta^2_p = .431$, Greenhouse-Geisser-correction). The pairwise comparisons showed significant differences between nearly all speed levels (all $p < .010$), with the exceptions of 15 km/h vs. 20 km/h ($p = 1.000$) as well as 30 km/h vs. 35 km/h ($p = 1.000$). In addition, we found a significant main effect of the appearance of the cyclist ($F(1, 36) = 24.24, p < .001, \eta^2_p = .431$). The TTA estimate ratio was smaller for the condition with vest ($M = 0.75, SD = 0.21$) than without vest ($M = 0.80, SD = 0.23$), an indication that participants perceived the alleged e-bike rider as arriving slightly earlier than the conventional cyclist. However, the ANOVA also revealed a significant interaction between the appearance of the cyclist and the speed levels ($F(1, 36) = 20.83, p < .001, \eta^2_p = .367$). As Figure 1 right shows, at 35 km/h, the TTA estimate ratio for the rider wearing the vest ($M = 0.92, SD = 1.6$) was much lower than without vest ($M = 0.78, SD = 1.6$), whereas differences at the other speed levels were rather small (or non-existent).

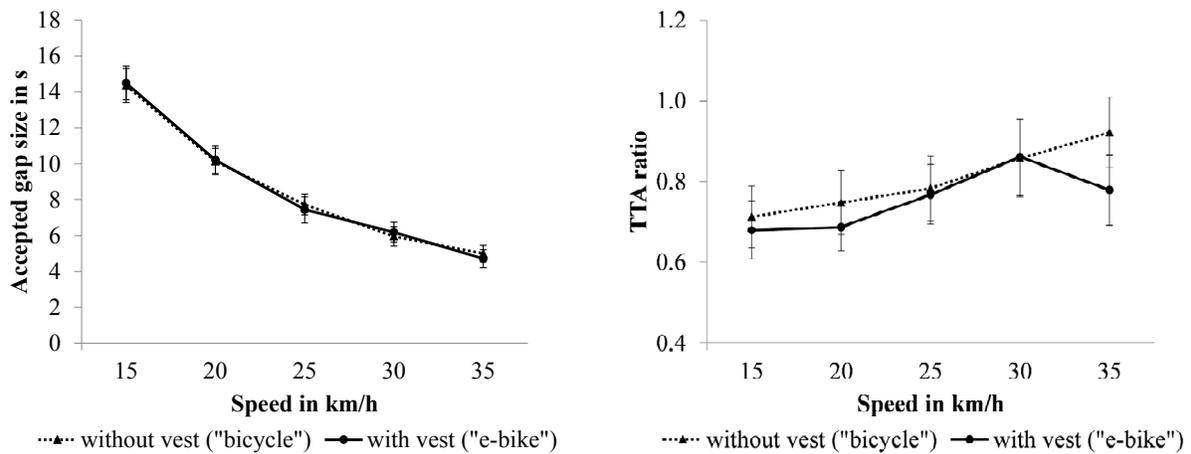


Figure 1. Accepted gap size in s and TTA ratio for the two appearances of the cyclist and the five speed levels. Error bars represent 95% confidence interval

DISCUSSION

The primary goal of our experiment was to investigate the potential effect of a distinct appearance of e-bikes, coupled with clear instructions with regard to their propensity to reach higher speed levels, on drivers' gap acceptance and TTA estimates. We found no such effect on the size of the accepted gaps, with both appearances eliciting nearly identical minimum acceptable gap sizes. The results were slightly different with regard to TTA estimates, as the alleged e-bike rider was, on average, judged as arriving earlier than the presumed conventional cyclist. Upon closer inspection, however, it became clear that this effect was mainly driven by a clear difference between the two appearances at an approach speed of 35 km/h. One potential explanation might be found in the fact that in this condition, the cyclist/rider was farthest away from the observer, and hence rather small. Its optical expansion was, initially, probably rather difficult to observe in the video material. As a result, participants could have relied on the vest as a cue for the approaching bicycle's speed to a higher degree than in other conditions, in which

the approaching rider occupied a larger portion of the visual field, and TTA judgments for the different appearances differed only marginally.

These findings indicate that a simple re-design, coupled with an information campaign about e-bikes, might not be sufficient to automatically elicit a more conservative behavior in drivers when confronted with such bicycles. It might be argued that this does not mean that such measures could not be helpful at all. Even if road users would not be more defensive when confronted with e-bikes as when confronted with a conventional bicycles, the fact that they no longer mistake one for the other could already solve a lot of problems.

However, it has to be pointed out that our results showed, just as many previous studies (Alexander et al., 2002; Horswill et al., 2005; Petzoldt, 2014), that higher speed levels resulted in longer TTA estimates as well as smaller accepted gaps. So, given the fact that e-bikes have been found to reach higher speed levels than conventional bicycles, not mixing these two vehicle types up might not be sufficient to reduce crash risk for e-bikes considerably. Naturalistic observations of e-bike safety showed that while overall risk was comparable, e-bike riders were at higher risk of being involved in a safety critical event at an intersection than conventional cyclists. It also occurred that motorists more often failed to yield to an e-bike (Petzoldt, Schleinitz, Heilmann, & Gehlert, 2016; Schleinitz et al., 2014).

It is clear, though, that our experimental task, which required the driver to estimate the TTA or indicate a turning decision by simply pressing a button, is not fully comparable to a turning manoeuvre in actual traffic. Likewise, our implementation of a “unique appearance” for the e-bike rider did not include an actual re-design of the bicycle. A more realistic setting, coupled with a more realistic implementation of a distinguishable design, would certainly be preferable to further investigate the potential safety effects of any measures that aim to increase other road users’ awareness of e-bikes and influence their behavior accordingly.

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