Similar to battery electric vehicles (BEVs) [2], the range of motorised bicycles (i.e., pedelecs) is limited. Although conventional cycling is always a fallback-option, running out of charge is an adverse event for users due to the high weight of pedelecs. For BEVs, eco-driving (i.e., applying an energy-efficient driving style) has been found to be helpful in coping with critical range situations (i.e., when remaining range is equal to less than the distance to destination) [2–5]. In this context, we conducted a field experiment examining a highly automated eco-assistance system for pedelecs (EAS) which aimed to support users in dealing energy efficiently with the limited battery resource by automatically changing between support levels. The user-centred evaluation revealed lower ratings of trust, acceptance and usability for the EAS, specifically in comparison to cycling without the EAS. Wheras users perceived a potential of the EAS to reduce workload and increase comfort while cycling, the high degree of automation was perceived as a barrier. Possible solutions may be a higher transparency of the system’s actions or the opportunity to personalise the EAS to a higher extent.

Abstract

Eco-Pedaling – Examining a highly automated eco-assistance system for pedelecs from a user perspective

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Method

Participants

• N = 30 users with pedelec experience (0.5 to 6 years pedelec ownership)
• N = 8 women, N = 22 men, M pedelec = + 49 years (SD = 17.6)
• Highly educated (72%) with university degree
• About 50% of users experience sometimes to almost often critical range situations with the pedelec (use case)

Experimental Design

• Within subject design; randomised order

Independent variable

• Assistance with EAS versus manual

EAS: eco-assistance system for pedelecs [7]

• EAS which aimed to reduce the energy consumption by automatically changing between support levels (Fig. 1, Table 1)
• Aim: energy-efficient pedaling to destination
• Typical use case: trips with critical range distances
• Interface: smartphone application paired to the handlebar (Fig. 2 & 3)

Dependent Variables

• Subjective assessments: acceptance [4]; subjective usefulness & satisfaction); Usability (Technology Usage Inventory [4]); Trust [1,3]
• Logdata: energy consumption, speed, support level

Test track & instruction

• All participants drove a predefined route in real traffic (Fig. 4) twice: once with the EAS and once by manual cycling (i.e. without assistance)
• Scenario: “Imagine you have to cycle 80 km to destination and the pedelec displays a range of 80 km (in eco-mode).”
• Instruction: drive the route as energy efficiently as possible to increase compliance 56 extra for energy-efficient driving in condition manual

Subjective evaluation

• Acceptance: Less perceived usefulness (Fig. 5) for EAS than manual (F(1, 25) = 10.50, p = 0.003, η² = 0.30); No difference between pre and post (F(1, 25) = 0.06, p = .817, η² = 0.01). No significant differences for perceived satisfaction (Fig. 6) between cycling with EAS versus manual (F(1, 25) = 3.39, p = 0.070, η² = 0.13); no differences between pre and post (F(1, 25) = 0.13, p = .719, η² = 0.01).
• Trust: Higher trust (Fig. 7) in manual compared to EAS (F(1, 24) = 26.23, p < 0.01, η² = 0.52); no difference between pre and post (F(1, 24) = 1.55, p = .225, η² = 0.06)
• Usability: Higher perceived usability (Fig. 8) for manual compared to EAS (F(2, 45) = 1.90, p = 0.06, η² = 0.05), and also higher intention to use manual compared to EAS (F(9, 245) = 4.06, p < 0.01, η² = 0.05).

Objective logdata

• Trip parameter

Significantly higher energy consumption with EAS (Fig. 10) compared to manual (F(16) = 4.07, p = .001, η² = 1.60) with no differences for speed or travel time. Usage of lower support levels in condition manual.

• Influencing variables on energy consumption:

High inter-individual differences for energy consumption during which is... ... correlated with BMI (r = -0.45, p = .041) ... correlated with rated physical fitness (r = -0.55, p < .010).

Perceived advantages and disadvantages of the EAS

• EAS has the potential to reduce distraction & workload (Fig. 11; support level choice, planning)
• But: high degree of automation with very limited options to personalise is experienced as big disadvantage (Fig. 12, especially combined with prototype status)

Conclusions

• Results revealed lower ratings of trust, acceptance and usability for the EAS, especially in comparison to manual cycling.
• Logdata showed significantly lower energy consumption in the manual cycling condition compared to the EAS condition, whereas no differences for velocity or travel time were observed.
• Results of the qualitative analysis reflect the dichotomy of users’ assessment of the highly automated system: On the one hand such systems bear potential such as a possible increase of traffic safety and comfort while driving. On the other hand findings imply that the high degree of automation was perceived as a barrier by users as it was impossible to override the system.
• This issue might be solved by the possibility to personalise the EAS to a higher extent (personal level of comfort; take into account physical fitness etc.) in combination with a more transparent feedback about the actions of the system.

Open air lab ‘New Mobility’ at Sachsingen

The project is one of forty other projects investigating electric mobility embedded in the German ‘Showcase Regions for Electric Mobility’ (elektromobilität connect [Elektromobilität verbinden]). In the test environment of the Sachsingen-circuit a consortium of partners from industry and university wants to investigate the safety, reliability, use, user acceptance and also the economy of electric vehicles. Additionally, specific assistance systems for electric mobility are examined.

Figure 4: Pedalec with EAS

Advantages EAS

- EAS has the potential to reduce distraction & workload (Fig. 11; support level choice, planning)
- But: high degree of automation with very limited options to personalise is experienced as big disadvantage (Fig. 12, especially combined with prototype status)

Disadvantages EAS

- EAS has the potential to reduce distraction & workload (Fig. 11; support level choice, planning)
- But: high degree of automation with very limited options to personalise is experienced as big disadvantage (Fig. 12, especially combined with prototype status)

Figure 5: Perceived usefulness.

Figure 6: Perceived satisfaction.

Figure 7: Trust.

Figure 8: Usability.

Figure 9: Situation to use.

Figure 10: Energy consumption.

Figure 11: Perceived advantages of EAS.

Figure 12: Perceived advantages of EAS.