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An Investigation into Design Engineering Aspects of a Shared Autonomous Micro Vehicle Concept

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ABSTRACT

Future transport will require fundamental changes if we are to tackle the climate crisis efficiently. Autonomous vehicles could play a crucial role as alternatives for private cars without hindering basic individual transport needs. That is especially true for the first and last mile, which is not covered by the public transport network. The scientific project AuRa ("Autonomes Rad", engl. autonomous bicycle) comes in here. It develops a use case in which an electrified three-wheeled cargo bike will become an on-demand, shared autonomous vehicle for the city. The present work in progress focuses on the development of a user-centered design for such a vehicle. Recently, there has been a growing interest to illustrate the potential early involvement of future users can have on the successful introduction of new products. A better understanding of user needs, behavior, and expectations could inform designers and enable them to develop products that better correspond with the true needs of users. For the investigation into design engineering aspects of the future concept, a qualitative method was selected. A series of moderated discussions (focus groups) were conducted with potential users. The main goal was to investigate features regarding safety, comfort, personalization, and interaction, which enable comfortable usage for the user and might increase the acceptance of the vehicle. The results were used to inform engineering designers and support the further development of the next prototype of the autonomous cargo bike.

Keywords: Micro-vehicles, User-centered design, Focus groups

INTRODUCTION

An autonomous driving function can enable the next level of e-bike sharing, where users could better link rental bikes with public transport and bike-sharing (Zug et al., 2019). Increasing the efficiency of sustainable transport models motivates the scientific project AuRa ("Autonomes Rad", engl. autonomous bicycle) at the Otto von Guericke University in Magdeburg. An interdisciplinary research team works on a concept of on-demand, shared, autonomous, cargo e-bikes, which is currently in early-stage prototype development. The team works with three-wheeled cargo e-bikes, because they are more stable and can cover broader transportation needs (transport

of children, groceries, etc.) than conventional bikes. The conceptual use case scenario is that a self-driving cargo e-bike can be ordered to any location from a user using an app. After being used in manual mode, the bike should return autonomously to a depot or to the next user. The goal is to make daily individual transportation in the city easier for citizens and more ecological. The advantages of this concept system can turn autonomous cargo e-bike fleets into a better fitting solution for cities than cars and even scooters and e-bikes (Schmidt et al., 2021). The future acceptance, attractiveness, and success of such a novel mobility concept depend on the end user (Schnieder & Gebhardt 2016). (Calantone, Chan & Cui, 2006) find that innovativeness decreases customer familiarity, and without a high enough level of product advantage, new products have less chance of being successful. From this starting point, the project includes important challenges, related to the design of the vehicle, the usability, but also the ability to communicate with other road entities such as: pedestrians, cyclists, and car drivers. User-centered design approaches can illuminate those aspects and win information about users' needs, expectations, and opinions, that are valuable in assisting the designers to produce more satisfying products (McDonagh-Philp & Denton, 2000). Colleagues from the Department of Environmental Psychology have already conducted initial experiments on the interaction of the vehicle concept with its environment. The present research study focuses on its usability. The main research question here is: How should the AuRa micro- vehicle be designed to satisfy users' needs and expectations? It involves various design engineering aspects (Bruder, 2004).

RESEARCH METHOD

Study Design

The present study aims to explore users' perceptions regarding design specific questions of the AuRa-concept. Their involvement is critical to the success of this project because these are the people who can best determine what motivates them to use such a vehicle in daily life. More importantly, they can provide insight on the perceived barriers that keep them from using it. To effectively address the purpose of our study, a qualitative method was selected. The method attempts to use the potential for positive synergy in group work to gain a detailed probing of the users' perceptions and expectations (Berg, 2009). Since focus groups can be applied at various stages of the product development process, they particularly suit the iterative nature of the user-centered design (McDonagh-Philp & Bruseberg, 2000). In this study, three focus groups were conducted with the help of a digital discussion guide consisting of four core themes with open-ended questions (Table 1). The four themes were determined by a former methodological criteria analysis (Draganov, 2016), which created a detailed profile of the functions, the users, and the use case. Four main design engineering aspects were identified: safety, comfort, personalization, and interaction (Manoeva, Assmann & Schmidt, 2019). These were the four core themes used to generate the moderator's schedule.

Table 1. Summary of themes and sub-questions.

I. SAFETY	I.1.	Who has already had experience with a cargo bike?
	I.2.	What would you prefer: a conventional cargo bike construction or a cover cabin for better safety and weather protection?
II. COMFORT	II.1.	Imagine you get a cargo bike as a gift. What would you transport with it first?
	II.2.	How must the cargo box be equipped - what must it have, so that it satisfies the need to transport both shopping and children?
III. PERSONALIZATION	III.1.	How do you usually adjust the seat height of your bicycle?
	III.2.	Would you prefer to use the same manual method for the AuRa-bike, or a novel automatic seatheight adjustment technology?
IV. INTERACTION	IV.1.	What would you prefer: mount with a charging cable for your own smartphone or an integrated display on the handlebar?
	IV.2.	What other technical improvements do you wish to have when using the AuRa-bike.

Study Participants

To ensure sufficient diversity of opinion among groups, the target population was identified only by one limitation: individuals that are at least 18 years old. The application was voluntary. In this study there were a total of 24 participants (N = 24), and more than half (55%; n = 13) of the participants were female. The pilot group had eight participants (4/4 male-to-female), the second – seven participants (2/5 male-to-female), and the last – nine participants (5/4 male-to-female). From sociodemographic means, 71% of the participants were below the age of 25 and 29% were between 25 and 40 years old. The participation was voluntary and included monetary compensation. A declaration of consent was confirmed by all participants.

Data Collection and Analysis

The discussions were conducted online because of the ongoing pandemic. Three focus groups were conducted between March 02 and March 25, 2021. The participants were randomly mixed in heterogeneous groups to promote easy and lively discussions of individuals with different perspectives. All focus groups were conducted in German. Two moderators were present; one ensured the moderation of the sessions, and the other made sure that the discussions were progressing technically and thematically smooth. Each discussion lasted approximately 90 minutes and was audio-recorded with participants agreement and later transcribed. A conceptual content analysis (Shannon & Hsieh, 2005) was used to analyze and quantify the data: the presence and frequency of the transcribed answers. This is an interpretive approach, both observational and narrative in nature. To begin, an examination concept including coding rules was chosen for a better validity of the

coding process. answers were encoded into a set of categories for each theme of discussion guide. This allowed us to conduct a more focused evaluation of the data. Irrelevant text was ignored.

RESULTS

In this section, the following terminology was used to tally the number of responses for a category of a theme: 'few' for 1–6, 'some' for 7–11, 'half' for 12, 'most/the majority' for 13–23 and 'all' for 24. The four core themes included: safety (1), comfort (2), personalization (3), interaction (4) and are summarized below.

The first theme is discussed under two sub-questions, including (I.1) experience with cargo bikes and (I.2) concept perception on two design alternatives – comparison between a typical cargo bike concept and a futuristic cargo bike concept (with protective cabin) incl. argumentation of the participants choice. Only a few participants (n = 5) had already used a cargo bike. The majority (n = 19) had no experience with cargo bikes. Although the study participants held different opinions, some (n = 7) found the futuristic concept with a cover cabin beneficial, only one participant was neutral about it, but the majority of them (n = 16) agreed that the conventional cargo bike concept works much better for them. Their arguments were encoded into the following statements about the disadvantages of the futuristic concept: unbeneficial, inflexible, unable to interact with its environment, unpractical, unsuitable for bike roads, unusual, unsecure, too big, to wide, too heavy, restrictive, slower, bad balanced, overcomplicated.

The second theme is comprised of two sub-themes, (II.1) the luggage which the participants would like to transport and (II.2) the equipment and functionality of the cargo-box. We aimed to examine different user needs. Each participant stated their individual idea of a common cargo object. The responses were encoded into the following 8 categories: shopping bags n = 6, luggage for daily trips in the city n = 5, kids n = 3, animals n = 2, furniture n = 3, travel luggage n = 2, diverse packages n = 2, adults n = 1. In the second sub-theme the participants shared useful ideas for solving the challenge of designing a box, that can safely transport both shopping bags and children. The responses of the participants were encoded into the following categories: theft protection, child safety, rain protection, sun protection, boarding assistance, easy cargo loading, versatility, cargo security, and cleanability. The categories child safety, rain protection, sun protection and cargo security were the four most frequent answers.

The third theme is divided into two sub-themes, including (III.1) adjusting the seat height of the cargo bike to individual preferences and (III.2) opinions on a novel concept for automatic seat height adjustment, part of a student's thesis. The majority (n = 21) adjust their bike saddle manually (with toolkit or with a quick release seat clamp). The second sub-theme evaluates their preferences regarding a novel alternative concept for automatic seat height adjustment via smartphone or web-based application. Mixed responses were conveyed. The majority of them (n = 14) preferred the traditional way: manually, some (n= 7) expressed their interest in the novel way: automatically,

while few (n = 3) were neutral. The statements against the novel concept are categorized as follows: unpractical, unsuitable, unnecessary, too heavy, slower, costly, complicated, inaccurate. The statements in favor of the novel concept are categorized as follows: comfortable, practical, no tool kit needed, cannot be stolen.

The fourth theme is discussed under two sub-themes, including (IV.1) comparing two design concepts -a mount with a charging cable for the individual's smartphone or a custom display integrated into the handlebars and (IV.2) suggesting other technical improvements for better user experience. Half of the participants (n = 12) preferred a mount with a charging cable. The statements in favor of it are categorized as follows: familiarity with the usage of their own smartphone, familiar navigation interface, charging option, cannot be stolen, cost overview option, flexibility, and freedom. Some of the participants (n = 7) identified barriers to the usage of their own smartphone and encountered some challenges. Thus, they found the concept with a display integrated on the handlebar better suitable for this use case. Their statements against the mount with a charging cable are categorized as follows: danger (the smartphone distracts the user), unfamiliarity with the usage of the app, unpractical (all smartphones have diverse sizes and ports), expensive (mobile data usage), susceptible (smartphones are not always suitable in winter conditions (battery), summer (display-reflection) and when raining (waterproof)). Only a few participants (n = 4) found both concepts unnecessary and only one participant suggested to integrate both solutions. In the second sub-theme the participants were asked to share their ideas for technical improvements they would like to see when using the AuRa-bike. Two entries were collected in this sub-theme. One participant suggested the integration of speakers and a vocal horn system to signal visually impaired people on the streets. One other participant suggested a virtual travel guide, which will inform the user about interesting history facts and locations in the urban surroundings.

DISCUSSION

In our analysis, we have identified the first major finding, that the experience with cargo bikes of the sample was generally low. Thus, we assume that there is a need to popularize cargo bikes as an eco-friendly alternative to cars. For example, Berlin is promoting the use of cargo bikes by citizens and companies (delivery operators) through the "fLotte Kommunal" and "KoMoDo" projects, and ways of developing dedicated cargo bikes parking and infrastructure (C40knowledgehub, 2020).

The second major finding is that our study participants were more likely to use a conventional cargo bike and encountered numerous challenges in adopting a cover cabin. For many of them this was mainly connected with the freedom and the sense of riding a bike, what would get lost when adapting a cabin. They would rather just change the vehicle and switch to a tram or bus when it rains for example. They were generally skeptical about the safety aspects of the futuristic concept and if it would be suitable for the city infrastructure. For this result we suspect the following reasons we

found in literature. As (Egbue & Long, 2012) point out, consumers tend to resist innovations that are unfamiliar, alien, or unproven. The literature categorizes resistance into two main categories: psychological and functional (Ram & Sheth, 1989; Kleijnen, Lee & Wetzels 2009). Psychological barriers include tradition and image. Functional barriers to technology adoption include usage, value, and risks. Thus, in the future design stages of the vehicle concept is recommended that designers consider all these barriers, so they can create a successful product.

The third major finding was the specific design requirements set for a cargo box according to informants needs and proposals. We found out that shopping bags, luggage for daily trips in the city and kids were the most common needs which the sampled users would take on a cargo bike. It can be concluded that the majority of the participants would use a cargo bike in the city for every day, family or free time scenarios. The cargo box must therefore be functionally designed precisely according to the requirements of these objectives. The resulting specific requirements for a box that can safely transport both shopping bags and children was also consistent with this finding, since the most frequently mentioned entries relate exactly to the needs of a family or free time scenario. The conclusion we have made for the user-centric design of the AuRa-box is that it must correspond to the "family" cargo bike type with optimal loading volume, child-friendly design, and rain/sun protection. This information was already used for creating a first concept cargo box design for the AuRa-bike.

The next finding was that our study participants were more likely to use a conventional technology for personalization of the saddle position such as a quick-release seat clamp. The majority of the participants encountered numerous challenges in adopting automatic adjusting technology interfaced with a smartphone app. According to our study participants, the main disadvantage for this novel technology was mainly the need to pre-measure body parameters, which would take more time.

The final finding was that many of the participants were more likely to use their own smartphone to interact with the vehicle, while some participants disregarded the need for such a device entirely. The most critical disadvantage of the smartphone was pointed out in the sessions, and it is the distraction, which could corrupt the safety of the user. Therefore, we recommend excluding this alternative and including an integrated display. An entry about desired technical innovation - a vocal horn signaling system, in addition to light signaling - is consistent with previous studies (Manoeva, Gehlmann, Maiwald, Riestock & Schmidt, 2020) and will be accommodated in the design process.

The relatively small number of participants makes our findings relevant to this specific sample group. Future research should be designed to include larger samples of participants to further capture the evolution of the current objectives regarding design engineering aspects. To ensure the permanent involvement of users in the design process and solve as many barriers as possible, design outcomes should be rigorously and regularly evaluated.

CONCLUSION

Overall, the focus groups were well received by the participants. The findings of this study provide important data for the project's designers and engineers and underline the need for an intuitive and simple design that can meet the diverse experience of individuals involved with technology and time limitations due to the hectic daily life in the city. At the same time, many challenges for our study participants included psychological and functional barriers regarding innovative approaches in the concept design process. An interesting observation of the data analysis showed that in their argumentation, participants were more likely to view and share a disadvantage of the novel concepts, than a benefit of the conventional concepts. Thus, we conclude that beside technical feasibility, core attention in the design process must be paid to psychological and functional barriers. Based on our findings we believe that considering all this information, together with continuous user research, can result in creating an adequate concept for most future users.

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