Can You Help Me?

Testing HMI Designs and Psychological Influences on Intended Helping Behavior Towards Autonomous Cargo Bikes

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ABSTRACT

Autonomous (cargo-)bikes offer many use cases, especially in urban areas. One challenge they have to face is their dependence on human assistance. This study examines the influence of light color, flashing rhythm, voices, a person's kindness and technological experience on helping behavior towards an autonomous cargo bike. An experiment with 233 participants was conducted. We found that technological experience and kindness had a positive influence on helping behavior, while light color, flashing rhythm and voice type did not have any influence. Our results imply that helping behavior towards an autonomous bicycle varies individually. However, an electronically generated voice should be used to make the vehicle appear autonomous, emphasize the absence of a human being and give clear instructions to promote helping behavior.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in interaction design**; **Interface design prototyping**;

KEYWORDS

human machine interface, autonomous vehicles, unmanned vehicles, helping behavior, psychology, human factors, external HMI, HMI design, GACS-72, vehicle pedestrian interaction

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1 INTRODUCTION

Transforming mobility towards a sustainable future is one of the main challenges humanity will face. Environmental hazards in general, but also private inconveniences such as a lack of parking spaces and being stuck in traffic are only a few reasons to find new mobility offers. One of the recent developments are autonomous cargo bikes [37]. Instead of driving on streets, they can drive on a bikeway, making short distances more easily accessible and time-and energy-efficient [4, 14]. For that reason, autonomous cargo bikes could become an alternative to cars in urban areas. Developing an autonomous bike, one has to face different challenges. While a car is robust, a bike could get into situations where outside support is needed, such as falling down because of vandalism, weather influences or unpredictable incidents. To address this problem, solutions to communicate with humans need to be developed. Other road users need to not only notice that the bike requires support but feel motivated to solve whatever issue it is facing. The following study explores different possibilities that an autonomous cargo bike could use to communicate with humans and successfully receive support.

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2 RELATED WORK

2.1 Intended Helping Behavior

Helping behavior can be divided into spontaneous helping behavior and self-reported helping behavior [23]. The former can be assessed in experiments, while the latter is often used in personality studies. Spontaneous helping behavior is greatly influenced by the situation [23]. For example, people being in a hurry were found to be less likely to help and a helping-relevant message was more successful than a task-relevant message when asking for support [9]. However, in a meta-analysis regarding helping behavior, Lefevor et al. [23] found that situational influences cannot predict helping behavior on their own. Since situational factors can rarely be manipulated by vehicles, it is more important to focus on individual factors to target specifically when asking for help and design approaches to elicit helping behavior. For individual differences, kindness turned out to be a good predictor when experimenting with spontaneous helping behavior [23]. People tend to help faster if they're convinced that a robot is working autonomously rather than being remotely controlled [36]. An explanation might be the computers are social actors paradigm, according to which computers are perceived as social beings [30, 35]. Another influence could be the perceived sense of agency ("mental capacities related to competence, such as self-control, memory, emotion recognition, and so on", [39], p. 472) and experience ("mental capacities related to feeling, such as hunger, fear, pain, and so on", [39], p. 472). Apparently, technologically experienced people assume more agency and less experience in machines than less technologically experienced people [39]. Overall, technological experience was found to influence perception of and interaction with automation, specifically trust in automation [16, 28]. Since trust is essential for helping behavior, technological experience could influence helping behavior as well.

2.2 Communication and Visual Anthropomorphism

Previous studies found that human practices like making eye contact are not necessary for communication between humans and machines [32]. Instead, the design could include different visual (or other sensory) cues to communicate with human beings. Such possibilities are typically implemented in external Human-Machine-Interfaces (eHMI). Löcken et al. [24] tested several eHMI design concepts with autonomous cars in virtual reality. They found further evidence for the advantages of omitting anthropomorphic features, such as eyes on vehicles, as it led to less efficiency and lower trust. This might be due to the uncanny valley and the perceptual mismatch hypothesis [22, 29]. Based on this hypothesis, decreasing affinity could occur due to specific sensory cues' unequal level of human-likeness. That could explain why artificial eyes are not an appropriate HMI for vehicles.

2.3 Light

Using non-verbal communication like facial expressions or body posture [15] is hardly possible for an autonomous vehicle. Instead of using these cues to communicate urgency, light is the best indicator [7]. While flashing light provokes peripheral visual attention, the color red typically indicates an error state [2] and green indicates a working system [25]. However, studies regarding the color red came to different conclusions and without green, it is not seen as an indicator for negativity [1, 2]. The link between colors and emotions is rather heterogeneous [31]. Signals seem to be intuitively comprehensible though, because humans tend to generalize based on earlier experiences with light signals [38]. The colors orange, red and yellow seem to be equally effective in terms of signaling the need for help [31]. This, however, applies to people with low technological affinity only. People, who are experienced with technology, perceive red as unsuitable and prefer orange. Thus, orange may be the best color to signal that a vehicle requires support. Not only light color is important when trying to communicate with humans, but also flashing rhythms to show the vehicle's state [8]. The flash rhythms "Beacon" (e.g. 200 ms on, 200 ms off, 200 ms on, 400 ms off, on repeat), "Bright Flash" (e.g. 400 ms on, 400 ms off, on repeat) were empirically found to be most suitable to signal a notification [6]. Combined with the orange light color, one of these rhythms could be well suited to show an occurring state of needing support in an autonomous cargo bike.

2.4 Sound

Acoustic signals can be divided into alarm sounds and speech [25]. Alarm sounds are difficult, because they are ambiguous and do not give clear instructions [38]. When using speech output, the vehicle could give clear instructions, display urgency and be more accepted by explaining what problem it is facing [11]. Another important factor to consider is that failure makes the machine seem more human, which could lead to more acceptance [20]. To elicit this feeling, voice output is more suitable than other acoustic signals. When designing the output, a strategy called "positive politeness" seems to be the best strategy to ask for help successfully [34]. This strategy also increases the likelihood to help, even if people are busy [36]. Despite using that politeness strategy, the vehicle should also explain why it needs support to motivate road users and increases the chance of receiving support [5]. Similar to using the positive effects of childlike expressions in a graphical user interface [25], the voice could be made childlike as well to promote supporting the vehicle, making use of the 'Kindchenschema' [21].

2.5 Research Question and Hypotheses

Interaction of pedestrians and autonomous cargo bikes is a promising, but understudied field. These bikes could potentially experience situations where they fall over and are not able drive on. As bikes usually move in close proximity to or on sidewalks, this could happen in places where pedestrians are close by.

This paper serves as a first exploratory study examining different factors that might impact successful interaction and promote helping behavior. Identified factors should then be further researched through field experiments.

Considering previous studies, we assume the following hypotheses:
H1: Technological experience increases intended helping behavior.
H2: People with higher kindness show increased intended helping behavior.
H3: Flashing lights have an impact on intended helping behavior.
H4: Flashing rhythms differ in their influence on intended helping behavior.
H5: A childlike voice leads to different intended helping behavior than an electronically generated voice.
H6: An electronically generated voice leads to higher perceived autonomy of the cargo bike than a childlike voice.
H7: Higher perceived autonomy leads to increased intended helping behavior.

3 METHOD

3.1 Participants

Overall, the online questionnaire was started 322 times. We removed data from participants not finishing the questionnaire and those who failed to reply to filter questions correctly, arriving at a sample of 233 German-speaking people. 132 participants identify as female, 98 as male and 3 as something else indicated as 'diverse'. The average age was 26.4 (SD = 8.98), ranging from 16 to 72.

3.2 Experimental Design

We used a 3x2x2 between-subjects design in this experiment. The first factor - light color - was manipulated by showing participants an animated picture (GIF) of an autonomous cargo bike laying on the ground without any light or with lights flashing in either yellow or orange, see Figure 1. We used these colors as they are perceived as best to signal the need of help [31]. The second factor - flashing rhythm - was manipulated by showing participants a different, but situationally similar GIF of the cargo bike laying on the ground with either the flashing rhythm Beacon or Bright Flash. We used these rhythms as they are commonly used to indicate notifications

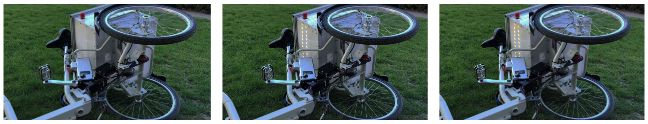

Figure 1: Factor light color – control group with no flashing lights, yellow and orange lights

[18]. No control group was used here, as the picture would have been nearly identical to the first factor and some participants might be randomized to the control group and see similar stimuli two times, thus biasing results. The last factor – voice - was manipulated by showing participants a video of the bike laying on the ground saying "I fell and I'm not able to get up. You look like you are strong enough. Could you pick me up?", making use of the positive politeness strategy and explainability [5, 34]. The voice was different for both factor levels. Participants heard either an electronically generated voice similar to voice assistants or the voice of a child (using Kindchenschema [21]). We did not use a control group again for the same reasons. Participants were randomly assigned to one level on all three factors respectively and were presented the stimuli one after another. They started with light color, followed by flashing rhythm and then voice. Using HTML code, all images and videos were scaled to the same screen ratio while keeping the aspect ratio.

3.3 Measures

To assess kindness, similar to Lefevor and Fowers [23], the kindness scale of the GACS-72 (3 items, example item: "Kindness is an essential part of who I am in this world") was used [26, 27]. In addition, the scales creativity and humor were utilized to reduce priming effects and socially desirable response patterns. The IT Familiarity Questionnaire (8 items, example item: "I use my computer or smartphone to bank and pay my bills") [12] was used to assess familiarity with technology. After showing participants a video of the bicycle driving autonomously, they were presented questions about perceived sense of experience and agency (3 items each), developed by Xu and Sar [39]. All questionnaires were translated to German. Intended helping behavior was assessed through the question "How much do you agree with the following statements?". Participants were asked to rate the statement "I would pick the vehicle up" on a 5-point Likert scale after each animation or video. Perceived autonomy was measured using a 4-point Likert scale by asking participants whether the vehicle was driving remotely controlled or autonomously. They could choose between "remotely controlled", "somewhat remotely controlled", "somewhat autonomous" and "autonomous".

3.4 Analysis

Our data was analyzed using linear models with either continuous or dummy-coded categorical predictors. Assumptions for these models were met despite heteroscedasticity for those used to answer H1 and H2, so we used robust standard errors. We utilized t-Tests and Omnibus F-Tests to examine our hypotheses and controlled – when appropriate - for kindness, sense of agency and sense of experience as additional predictors in multiple linear regression, because these factors were expected to influence intended helping behavior [23, 39]. To further control for influences from previously seen scenarios, we accounted for the first two assigned factor levels in our models used to answer H5 and H6.

Table 1: Perceived Autonomy by Voice Type

Electronically Generated Voice, M (SD)	Childlike Voice, M (SD)
3.02 (0.75)	2.79 (0.82)

4 RESULTS

Intended helping behavior increased with higher IT familiarity (β = 0.55) and higher kindness (β = 0.21), see Figure 2. These influences were statistically significant ($t(231)$ = 1.95, $p < .05$; $t(231)$ = 3.06, $p <$ .01). The effect sizes are small ($d_{IT\text{-}Familiarity}$ = 0.13, $d_{kindness}$ = 0.20). Thus, H1 and H2 are supported by these data.

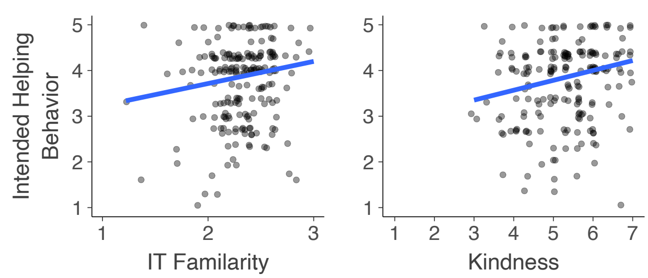

Figure 2: Intended Helping Behavior by IT Familiarity and Kindness

Participants seeing yellow and orange light showed slightly lower intended helping behavior compared to the control group (Δ_{yellow} = -0.03, Δ_{orange} = -0.18). Differences were neither for yellow ($t(231)$ = -0.13, p = .90) nor orange ($t(231)$ = -0.92, p = .36) statistically significant. H3 is not supported by these data.
Intended helping behavior of participants seeing the Bright Flash rhythm was slightly lower than of those seeing the Beacon flashing rhythm (Δ = -0.11). This difference was not statistically significant ($t(231)$ = .678, p = .50). H4 is not supported by these data.
Intended helping behavior was slightly lower for participants hearing the childlike voice compared with the electronically generated voice (Δ = -0.01). This difference was not statistically significant ($t(231)$ = -0.06, p = 0.95). However, those who heard the electronically generated voice perceived the vehicle as more autonomous than those who heard an electronically generated voice, see Table 1. This difference was statistically significant ($t(231)$ = -2.23, $p < .05$). The effect size is small (d = 0.29). H5 is not supported, while H6 is supported by these data.
Perceived autonomy was associated with higher intended helping behavior (β = 0.11), but the increase was not statistically significant ($t(231)$ = 1.34, p = 0.09). H7 is not supported by these data.

5 DISCUSSION

5.1 General Discussion

Technological experience was associated with higher intended helping behavior. Technologically experienced people might be more familiar with autonomously driving vehicles, technological malfunction and other problems and thus be more likely to help. This is in line with previous research that found experience with automated vehicles to influence use intention [17]. Also, they may be better than less technologically experienced at imagining these situations as real, as many participants commented they cannot imagine such a scenario in reality and would rather think they are being watched or filmed. Higher kindness led to higher intended helping behavior as well. This is further evidence for Lefevor's and Fower's [23] finding that people with higher kindness are more likely to help and expands it to intended helping behavior towards autonomous vehicles. It appears that this kindness is not only limited to humans, but also technological devices and is not dependent on human-like features. Flashing lights did not have an impact on intended helping behavior – neither color nor rhythm. This is surprising, because light was the only manipulated visual cue. Showing the cargo bike laying on the ground might be sufficient to signal that the vehicle needs support. Although light can be helpful to express the urgency of needing help [7], it may not be persuasive and therefore does not promote intended helping behavior directly. We did not observe a difference in intended helping behavior between an electronically generated voice and a childlike one. A problem using the latter could be the bicycle lacking other anthropomorphic features and, therefore, making that voice seem unsuitable, a phenomenon commonly referred to as the uncanny valley [29]. Indeed, many participants referred to the voice as being "creepy", "weird" or "inadequate". Since participants intended to help more often after hearing the voice than when seeing lights, we reason that it is important to use a voice at all - no matter the kind. Giving clear commands could also prevent mistakes due to misinterpretation. Similar results were observed by previous studies [11, 19, 33] which found a verbal message to be the most comfortable for pedestrians when crossing the road and that a conversational interface in autonomous vehicles is superior to a graphical one. Participants perceived the cargo bike with an electronically generated voice as more autonomous than the one with a childlike voice. Since humans tend to generalize their previous experience [13] and electronic voices are commonly used in technical devices (such as Siri in iOS), participants could be familiar with them and associate it with a technological device with higher autonomy. Perceived autonomy was, however, not associated with intended helping behavior. The message, brought to participants using the positive politeness strategy, might matter more than the sound of the voice. We expected the perception of autonomy to promote intended helping behavior, because diffusion of responsibility is minimized when it is not remotely controlled [10], but that was not the case.

5.2 Limitations and Future Work

The biggest limitation is that we only assessed intended helping behavior as a proxy for real-world helping behavior. While this method is commonly used and shows some predictive power of actual helping behavior, it is questionable whether results are generalizable [3]. Thus, our study should be replicated in the field to draw reliable conclusions. Another limitation we are facing is that this experiment was built as an online experiment and we could not control if all participants heard the voice in the same volume and saw the animations on the same screen size. It is also possible that kindness was associated with higher intended helping behavior, because participants were primed to express their previously stated kindness by intending to help the vehicle. We tried to minimize the priming effect by using different scales from the GACS-72, but we cannot make sure that it was eliminated completely. Lastly, we examined technology currently being developed and thus participants cannot rely on previous encounters when answering. They had to imagine the experience, which might have biased results. Future studies should identify other factors – such as auditive, visual or even olfactory cues, displays and projection technology - that could help elicit helping behavior. Another important contribution is finding other factors to let the bicycle appear autonomous and show technologically less experienced people that they are in a real situation and the vehicle indeed needs support. Lastly, it is important to identify ways such a vehicle could react to rejection.

5.3 Conclusion

Lights might be negligible when promoting intended helping behavior in autonomous cargo bikes but using a voice output with explicit instructions and a polite communication strategy could guide pedestrians towards giving support. An electronically generated voice should be used in that case to emphasize autonomy. If possible, people with high IT familiarity and kindness should be targeted specifically when asking for support.

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