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Interaction Between Humans and Autonomous Systems: Human Facing Explanatory Interface for an Urban Autonomous Passenger Ferry

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ABSTRACT

The goal of this research is to explore and identify the type of information an autonomous urban ferry should provide to its passengers to increase their perception of trust and safety. We explored this topic with 15 randomly selected passengers during a three-week public trial of an autonomous urban passenger ferry deployed in Trondheim, Norway, in September of 2022. Apart from interviewing passengers, we also performed a comparison test in which participants were asked to choose between two concepts of different real-time passenger interfaces (RTPI) and explain their choice. In addition, participants were asked to perform a card sorting task, in which they prioritised 15 information elements based on their perceptions of relative importance. A key finding of this study is that passengers only need a little information to feel comfortable and aware of the ferry's status. Our findings show that it is sufficient to display a real-time map with the planned course, present position, and vehicle state in a comprehensible informational screen. Even technologically savvy participants interested in the ferry's inner workings did prefer simple informational interfaces. However, participants indicated that further information might be necessary in extraordinary cases and unexpected events such as breakdowns or encounters with other vehicles.

Keywords: Human machine interaction, Information visualisation, Maritime autonomous surface ships, Interaction design, Human-AI communication, Automation transparency

INTRODUCTION

In the 2030 technology outlook, an international marine shipping registration and classification society (DNV GL, 2020) points out the impact and importance of transformative technology in the future. They underline the high-grade transformational potential of autonomous systems in the fields of logistics and transportation. We can also witness an increase in the number of autonomous systems that are being deployed at various degrees of autonomy. Even if we generally lessen human liability and supervision in these autonomous systems, humans have a strong desire to stay in the loop and receive continuous information Veitch et al., 2022). The need of information can vary strongly depending on their affiliation and interest. Persons that

Figure 1: milliAmpere2 during a journey on the intended route.

work with, supervise, or monitor autonomous systems, such as, autonomous ships or buses, may have a different interest in obtaining information than people who only use autonomous systems as a service. This growing demand for information visualization and processing necessitates more research to better inform the design of informational interfaces for autonomous systems. (Krupenia et al., 2014) This study uses a mixed methodology approach that includes a semi-structured interview and a card sort with information items after the passengers have travelled with an autonomous passenger ferry. The study investigates the information needs of urban autonomous passenger ferries. During a three-week public trial operation of milliAmpere2 (mA2) - which is as far as we know the world's first autonomous urban passenger ferry put in operation - around 1500 citizens took the 100-meter crossing of a canal in the Norwegian city of Trondheim (Figure 1). A subset of those, 150 passengers, were interviewed about their impressions of safety onboard and their trust in the autonomous ferry. A safety attendant was aboard the mA2 ferry during the three-week public testing to take over control in the unlikely case of an emergency circumstance or misbehaviour of the autonomous system. Observations of the passenger and their interactions with the safety host revealed a significant need for information and enquiries about the ferry's functionality, its current state, and progress of the trip. Many of the 150 passengers that were interviewed during the first week of the trial stated that they would expect more information from the autonomous ferry if no safety personnel were present. A lack of information leads to a greater sense of vulnerability.

Related Work

Even though the informational interface must be easily accessible to passengers, it could not be too large since there is limited space onboard the autonomous ferry. We did not find previous research on passenger information (PI) and real-time passenger information (RTPI) interfaces in the context of autonomous passenger ferries. Therefore, we investigated research from other, more traditional public transportation services such as railways, air traffic, buses, and ferries. Relevant research in the context of these services is mainly focused on travel planning and transitioning between various types of public transportation (Anderson 1993; Fonzone 2015; Zografos et al., 2009; McLay et al., 2001). The information gap in traditional forms of transportation is mostly due to a lack of real-time data, incomprehensible timetables, current vehicle positions, and route progress (Beul-Leusmann et al. 2014). Some informational interfaces can be encountered in in-flight passenger information, which focuses on the aircraft's approximate position on a map, current speed, altitude, and remaining trip time (Lufthansa 2022; United Airlines 2022).

Also, research on informational systems in autonomous cars is partly relevant, even though they are usually intended for smaller user groups and have greater customising possibilities compared to those intended for public transportation vehicles. Waymo (2022) provide good inspiration with their information screens, where they show the position of the vehicle on the street, detected pedestrians and other vehicles, as well as the remaining time and destination. But they allow the user to select which information should be displayed. However, we primarily focused our research on autonomous vehicles for public transportation, such as autonomous bus shuttles, because of greater similarities to the context of autonomous ferries. This body of research provides a better foundation for examining the information needs of passengers of urban autonomous passenger ferries.

Linnartz et al. (2021) investigated the information requirements of passengers in self-driving bus shuttles. This research reports the results of two focus groups. The study's key finding was that there is a demand for information that is comparable to that shown in regular buses. Passengers would only want technical information if it was explained in detail and provide valuable information. In addition, an accident statistic was provided to demonstrate the safety of self-driving cars. Both reference groups wanted information screens that displayed the current route and position, planned stops, current speed, time, date, and transfer choices to other means of transportation. Auditory cues were only considered useful in rare circumstances, such as service outages or before the vehicle began moving (Linnartz et al., 2021). Another study in the same area identified the necessity for information about the traffic situation, route, and vehicle position, as well as possible connections. The results of a survey revealed that participants would prefer human operators to be present in the vehicles (Linnartz et al., 2021). Currently, most autonomous vehicles operate at relatively low speeds. However, there may be different informational needs if, in the future autonomous vehicles would operate at higher speeds (Riener et al. 2020). Even though there are some valuable insights in most of the aforementioned studies that can help inform the design of informational interfaces in general, we specifically aim to explore the information needs of passengers of urban autonomous ferries.

In the next section, we provide a presentation of the methodologies we used in our attempt to answer the following questions:

- What information do passengers require on autonomous urban passenger ferries?
- Does the type of information affect passengers' perceptions of their own safety?

THE INFORMATION SCREENS

To answer these research questions, we conducted a study during the trail of the urban autonomous passenger ferry milliAmpere 2 (mA2). Details about the technologies used in this ferry are presented in Alsos et al. (2022). Two 10-inch touch screens with high luminance (1000 nits) were mounted on the mast of the mA2, allowing the user to see relevant information on both sides of the ferry, while embarking, disembarking, and travelling. Two distinct information interfaces were designed (Figures 3a and 3b) and displayed on the screens (Figure 3c). One of the designs (Figure 3a) was straightforward and depicted the journey's progress as a linear bar. Furthermore, the passenger could observe the ferry's status on a graphic combined with information about the ferry status in one word and a brief description. The second proposal (Figure 3b) was aimed at passengers who could be more interested in the specifics and technical aspects of the ferry. Concept B had an environment map that included the ferry's intended path, current position and heading, details for every single thruster, speed in knots, system health, battery level, a compass, object detection, and the ferry's status of operation.

PARTICIPANTS

Out of the 150 passengers who took the ferry over a span of two days, we randomly recruited 15 to participate in our study. Those participants voluntarily came to the ferry to try out the vehicle, mainly due to curiosity. The passengers (7 female, 8 male), aged between 21 to 53 years ($M = 32.87$, $SD = 10.15$) who took part in the public trial of the urban autonomous passenger ferry were asked in detail about their preference for data visualization and what information they would want on an autonomous ferry like this.

DATA GATHERING AND ANALYSIS

The research procedure we followed (Figure 2) included (1) a ferry trip with milliAmpere 2, (2) a post-trip semi-structured interview, (3) a comparison test of the screen concepts, and (4) a card sort exercise.

The study took place after the conclusion of the ferry trip with the mA2, which lasted approximately 3 minutes. First, we asked them about their overall experience during the trip, emphasising on what information they recalled seeing on the screens. The passengers were specifically asked to describe what information they observed on each screen, how they interpreted it, and what was most relevant to them. We also asked them to describe what other information they perceived from their surroundings including

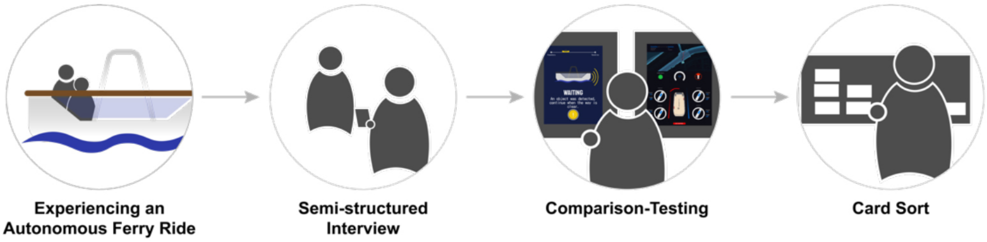

Figure 2: Workflow of applied methodology.

Figure 3: (a) Design A simple information display; (b) Design B technical information; (c) prototype of the passenger information screen.

observations of the safety host. They were also asked to describe how the information they gathered influenced their sense of safety and trust in the autonomous ferry. We also investigated how passenger safety perceptions were modified by information availability. Some passengers did not seek out any information at all, while some referred to the information screens or the safety host on board. We explored how safety perceptions were affected by these information-seeking approaches. In addition to the safety-related questions, the interviewees were asked to explain how this would affect their trust in the autonomous system. The participants were asked to rate their perceptions on a 5-point Likert scale that ranged from 1 (very unsafe or very untrustworthy) to 5 (very safe or very trustworthy). The interviews were first transcribed and analysed using an affinity diagram. The transcripts were coded and then clustered into categories, which were consolidated into higher divisions. In a comparative test, passengers were asked to select their preferred design for the previously described information screen and describe in detail the reasons for their choice.

All previously presented information elements from both screens were written on cards to be used in a semi-open card sort to determine which information is most valuable to the passengers. The passengers were asked to prioritize the presented information on a 10-point Likert scale (10 = very important to 1 = very unimportant) and fill in the blank cards with missing information. Each card was assigned points based on its position on the Likert scale. Items that were placed to the left received a higher number of points compared to those placed to the right. With the outcomes of the cart sort and additional answers from the interviews, we conducted a cluster analysis and principal component analysis (PCA), to see similarities in the preferences of the users, which are displayed in a reference mapping and dendrogram (Figure 4).

Results

The majority of the interviewed passengers (N = 13) stated that they would prefer the simpler version of the information screen using design A, whereas the remaining passengers (N = 2) would prefer the more technical interface because they are more interested with the functionality of the ferry and the reliability of the components. After transcribing, coding, and sorting the key statements of the interviews, 28 higher-level categories were discovered, which could be classified as journey-related information, technical information, safety, and information overload.

The descriptive analysis of the card sorting exercise (Table 1) shows which things are considered essential by the participants and which are not. The most common items requested by interviewed passengers were journey-related information, such as the current state of the journey, such as whether the ferry is halted, docked, or if an object was detected (M = 9, SD = 1.25), the planned path of the autonomous passenger ferry, including the current position on the path (M = 8.8, SD = 1.26), and continuous journey progress (M = 8.47, SD = 2.61). The elements detailing the visualization of the present status of the autonomous ferry (M = 7.53, SD = 2.61) and the explanation of the current condition (M = 6, SD = 1.17) are also relevant but of lower priority. When asked about journey-related information, the interviewed passengers stated that the location on the map and the planned course are very important. It was critical for the passengers to monitor the journey's progress, direction, what course the autonomous system had planned, and whether it was following the initial intended route. "It's important to see where you are and also recognize if the ferry is on the right track." (P2). Seven more of our participants emphasized the significance of this information. Similarly, the linear progress utilized in Design A shows the progress of the voyage, but it does not provide as much helpful information as the map with additional remaining time: "It is more like a loading bar, but it can't really make a connection without the map and an estimate of time." (P1).

Some passengers suggested that the traffic around the ferry should be shown on the map as extra information, so they can see why the ferry stopped or changed route. It was also mentioned that the screen should reveal information about unexpected objects that were detected on the path. The visualisations of the current steps showed the current process and stage-related information. For example, when preparing for departure, hatches of the ferry were shown in different colours and moving, so users directly knew they should stay away from the hatches and prepare for the imminent start of the journey. According to the passengers, it is also understandable for infants or individuals who cannot read, and it allows for the extraction of vital information from a greater distance, eliminating the need to be in close proximity to the information screen. Some passengers suggested that

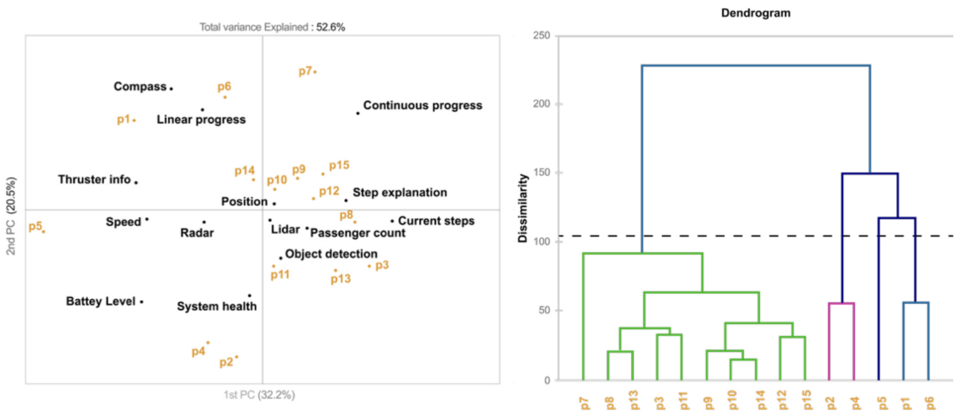

Figure 4: Principal Component Analysis (left) - Cluster Analysis Dendrogram (right) representing the main clusters of participants based on their card sorts.

an additional explanation could be added, for example: "It is safe for me to board the ferry" (P3).

"Technical information" was the second, largest, higher-level category. In general, the descriptive analysis (Table 1) indicates that this type of information was considered less important by the majority of our participants. Less important information includes LiDAR views (M = 1.93, SD = 0.8), radar views (M = 2.60, SD = 1.72), thruster information (M = 2.6; SD = 2.59), and a compass (M = 4.8, SD = 2.76). When the insights from the interviews are considered, it becomes clear that the majority of participants did not understand this type of information or that they did not think it would add significant value. "Thruster, battery level, radar, etc., are too technical for me and have no added value for me", "I don't like too much technical information; when I don't understand them, then it makes me feel rather unsafe" (P7). A closer look at the cluster analysis also reveals that the major group includes passengers who had a negative predisposition towards technical information. This also corresponds with the dendrogram, where you can see this group on the left (Figure 4) These passengers represent the general population, with diverse interests, backgrounds, and ages.

Nonetheless, even though technical information was considered as less relevant, it is clear that some passengers were interested in this additional information. The autonomous ferry's travel speed (M = 6.07; SD = 2.31) is among the most interesting pieces of technical information for passengers. It would probably have received a higher preference score if the data were displayed in km/h. Even though km/h is less common in the maritime environment, it is nonetheless more comprehensible for the average passenger than speed in knots. According to the interviews, those who found the technical information fascinating had a technical background or were engineers. "I enjoy the technical screen, it's a little nerdy!" (P1). This group is clustered on the right side of the dendrogram. However, the additional information is of high interest for the technically savvy group they don't really need it or see a purpose for the general passenger; "the technical knowledge doesn't really matter if I feel comfortable or would board the ferry or not," says one (P6).

Table 1. Descriptive analysis of 15 items investigated by each study participant in the cart sort.

Item	N	Min	Max	Mean	Std. Dev
Current State (halted, docking, object detected, journey)	15	6	10	9.00	1
Map with Planned Path and Current Position	15	6	10	8.80	1
Continuous Journey Progress	15	2	10	8.47	2
Visualisation of Current State	15	3	10	7.53	2
System Health	15	1	10	7.40	2
Speed in Knots	15	2	10	6.07	2
Explanation of Current State	15	3	9	6.00	1
Linear Progress of Journey	15	1	10	5.53	2
Battery Levels	15	1	10	5.40	3
Passenger Count	15	2	9	5.27	2
Object Detection	15	1	9	5.20	2
Compass	15	1	10	4.80	3
Thruster Information	15	1	10	2.60	3
Radar View	15	1	8	2.60	2
LiDAR View	15	1	3	1.93	1

The perception of importance of some items would change in the case of anomalies, e.g., in an emergency, which are clustered in the higher-level category of "safety." The system health is something that the passengers find interesting ($M = 7.4$, $SD = 2.35$). It was stated that it acts as a trust factor when the passenger sees that the system's health is okay. In the prototype, it was presented as a green status light with no further explanation. Eleven of the passengers we interviewed commented on the significance of the system's health. They wanted to know how the autonomous system was performing in general and if the behaviour or reliability of the system was changing. Some passengers were interested in receiving more details about system health. They did not think it was required to present more information when the status changed. Here, other facts like battery level and engine state could be useful to explain to passengers what's the root causes of a prospective service interruption. When the autonomous ferry simply stops because an obstruction is detected, the system's health and the graphic showing the current status of the procedure are adequate to retain the users' trust and safety perceptions. The most important thing in terms of system health is to inform passengers in an easy and understandable manner. As shown in Linnartz's (2021) it is important to display problems positively, for example, "during the docking process, we are pursuing a lower speed to keep you safe.". Some passengers stated that they do not care if this type of information is provided, "I just want to know if there is an emergency and if a human operator was notified about the problem, which is good demonstrated in design A." (P1).

The last category that was revealed by the affinity map was "information overload". No specific question was asked on the amount of information shown, although a considerable number of participants s ($N = 8$) stated that they "don't require much information" (P1, P8, P14). Design B, in particular, has an excessive amount of information. Users like "well-structured and visually appealing content" (P13). They also stated that "the second version (design B) contains too much information "I like that it is visually appealing but simpler" (P15). The consensus was that they didn't need that information because it could have a detrimental effect on their trust levels. Some even stated: "I'm not dependent on information", or "I would enjoy the trip more, and I have a horse sense, so I know when something isn't right" (P14).

On the subject of how the perception of safety and trust differed between no information, information provided by a human safety operator, and the information screen, the interviewed passengers' responses were largely consistent. 53% of passengers genuinely thought that an unmanned ferry would be less trustworthy, while 33% believe it is neither untrustworthy nor trustworthy. A similar finding may be seen in the question about safety perception in the absence of any kind of information. Out of all participants, 40% believe it was somewhat unsafe, while 46% believe it was neither safe nor unsafe. If information is presented by a PI or by a safety operator, none of the passengers felt unsafe or had a low level of trust in the system. Passengers indicated that receiving the information from the aforementioned sources made them perceive their experience with the autonomous ferry as safe and trustworthy. There was only a minor difference between receiving from the human safety host or the information screen. Some passengers trust the information screens more. Based on the interviews, some passengers stated that they would rather trust the information screens because a human cannot know everything, and each safety host interprets some data differently.

CONCLUSION

Our study reports similar results to those in the studies of Linnartz (2022) and Riener (2020), indicating that the current location, intended path, estimated time of a trip, and connection possibilities to other means of transportation are most important for passengers of autonomous buses, shuttles, and passenger ferries. Less important are technical and specific vehicle information such as system status, battery life, or fuel level. Some of these information requirements may vary in the event of an anomaly, such as an engine breakdown or lowered speed to avoid collisions or other harmful situations. Some people may be more interested in technical information because of their background and interests, but even they believe that it may be redundant to show this information to the broader public. It has also been demonstrated that providing passengers with less information results in greater trust than providing them with all available information. In general, our participants preferred information interfaces that were cleaner and only show key information. Furthermore, they preferred, visualized data, and continuous progress in the form of a real-time map with the vehicle's position and an easy-to-understand graphics representing the vehicle's state.

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