Passenger trust in autonomous transportation

How to use design to establish trust between passenger and autonomous ferries.

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ABSTRACT

This article focuses on how to design a safe journey for passengers who has previously never taken any form of autonomous transportation. This type of transportation is still unchartered waters to many people, and they are used to put their trust in people operating transportation technology rather than the technology itself. This article addresses the world's first attempt at an autonomous passenger ferry in Trondheim, Norway. The aim of this article is to explore how the ferry can convey information about how the technology is in control of the situation, with the purpose of increasing the passengers trust and confidence in the system. Three different cases with comparable problem areas to autonomous ferries are discussed in order to uncover how we can design for a good user experience. Together with design principles on trust, a design concept was developed to test the amount of information necessary to increase trust in autonomous transport.

KEYWORDS: Autonomous Systems, Autonomous Ferry, Design For Trust, Concept design

1. INTRODUCTION

Since the dawn of the first computer, technology has been developing at a rapid pace. Systems are now able to not just compute, but learn from their interactions with their environment, essentially making a machine "intelligent" enough so that it has the ability to perceive, adapt, and make decisions based on what it learns, creating an autonomous system
(Lacher, 2014). A sister company of Google, Waymo, was the first to introduce self-driven (driverless) cars without any safety driver. These cars have been designed to safely navigate the state of Arizona's traffic. Equipped with sensors and lasers that give the car a 360 degree view and a visual range of 300 metres, with the "ability" to perceive things that the human eye does not and react almost a hundred times faster than a human being, these cars truly are fully autonomous (Hawkins, 2017) (Bjørkeng, 2015). Human error is the main cause of road accidents, and by allowing a machine to make decisions that are faster and more transparent than a human being, we can reduce the rate of road accidents significantly (Robinson, 2017) (Bjørkeng, 2015). The number of registered autonomous companies and means of transport in the US has increased in recent years, simultaneously, more accidents have been reported involving driverless cars (Hook, 2017) (California Department, 2017). Despite the accident rate of human controlled vehicles being significantly higher, this is not an acceptable outcome for autonomous technological development, and it is therefore

important to make this technological transition feel safe for all passengers in the future.

1.1 What is an Autonomous System?

Autonomous means that it is self-reliant (autonom, 2013). Autonomous transport is divided into six categories of how self-managed they are, ranked on a scale from zero to five, where zero is not self-driving and five is self-driving. When a vehicle is categorized as level three or higher, the vehicle will make human decisions by analyzing its surroundings and taking action based on what it observes. The famous car brand -Tesla, for example, is on level two of the autonomous scale. It means that the car can “help” you drive but you have to keep a careful eye on it (SAE INTERNATIONAL, 2014) (Davies, 2016). This level of autonomous transport technology is becoming more commonly seen and used on roadways. The increasing use of autonomous vehicles has also increased the number of situations where an accident has occurred in a way that people are generally to blame (Hook, 2017). Two renowned brands within autonomous transport have recently had accidents with their autonomous vehicles. Both an autonomous shuttle bus from Navya and Ubers self-driving taxi (Statt, 2017) (Randazzo, 2017). In a report from Deloitte, research was conducted to see how much we trust autonomous vehicles, it turned out that just one out of four people in the United States felt safe in an autonomous vehicle (Felton, 2017). The reason was the lack of understanding of this new technology that replaces human qualities.

1.2 Autonomous Shipping

In 2016, the world’s testing of autonomous ships was given to Trondheim in Norway. It is important to develop the shipping industry to improve safety, the environment and streamline processes, something that autonomous technology can contribute to (Trondheim Havn, 2016). Norway is the world's leader in the development of autonomous ships. The focal points being in technology and safety at sea (Rødseth, 2016). Yara Birkeland is one of the most mentioned autonomous ship projects in Norway: an electrically autonomous ship that will replace 40.000 lorries annually (Stensvold 2017).

During this venture of developing autonomous ships in Norway, there is another project that has started the development of an autonomous passenger ferry called Milliampere. The Milliampere project plans to be able to transport a maximum of 12 passengers across a channel in Trondheim. The ferry will go between Vestre Kanalkai and Ravnkloa. This is a stretch of about 100 meters and, it will take about 1 minute to cross this distance. This is an area that is not exposed to much sea but there is crossing boat traffic. The autonomous boat will be operated electrically and autonomous technology will be used to navigate passengers on board safely back and forth. It will have the function of "ferry on demand", which means that passengers can call the boat whenever they wish. The safety of the passengers on board is of utmost importance, with contingency plans and other procedures regarding the operation and safety of an autonomous passenger ferry not yet being complete. This is something that must be in place before the ferry can be approved for commercial operation. Not much thought has gone into the possible interactions passengers will have on board Milliampere, but there should be a possibility of stopping the ferry (Stensvold, 2016) (Heggdal, 2016).

1.3 Research Questions

New technology within autonomous ships also leads to new laws and standards that must be in place before autonomous ships are approved for commercial operations. The International Maritime Law SOLAS Regulation 33-1 is required to assist others at sea if they are in need (Solas Chapter V). This is a problem the Norwegian Maritime Authority must discuss when approving the use of boats that do not have a captain or crew. The purpose of Milliampere is to carry passengers, but without the assistance of an onboard Captain or Crew. When cargo on board a boat is not containers but people then other issues arise. Who is responsible for the passengers in an emergency and how will it be solved - is important to discuss. This article will only look at a limited part of how passengers will experience this autonomous journey on water in normal operations. The focus area will be how to proceed with designing information to passengers that can contribute to a safe experience onboard Milliampere.

To gain insight into something that has previously had little research conducted, this article reviews cases that address problem areas comparable to Milliampere some of Milliamperes challenges. The most important thing has been to look at people's behavior in these cases so that one knows what can and can’t be done when designing for human safety.

2. DESIGN FOR TRUST

This chapter explains different perspectives of trust. How trust can increase and affect human interaction with autonomous systems. There are many different perceptions of how to make people trust a system, and varying definitions of trust. The Oxford dictionaries definition of trust for instance, is: *“Trust is a firm belief in the reliability, truth, ability, or strength of someone or something”* (Oxford Dictionaries, trust).

In autonomous system people need to establish technology trust. Trust between human and the machine (Lankton, 2010). Human trust in machines is affected by evidence and perception. Engineering challenges as well as several human factors, for instance - cultural, organizational, sociological, interpersonal, psychological, and neurological perspectives are essential for establishing and maintaining trust (Lee, 2004).

2.1 Trust in new technology

Humans acclimatise to new technology over time. We modify our mental models of doing things and start to trust technology and machines when they work as expected and when we can predict what they will do. The problem is that humans have little to no expectations on how autonomous system will perform.

People rely on strangers all the time - on-demand car service drivers, commercial airline pilots, bus drivers - but these are people who trust other people. In autonomous ferries the persons trust will shift from trusting the person who is driving to the vehicle itself and the underlying technology controlling the vehicle. When you are entering a ferry, today you are not only putting trust in the ferry driver, but in the entire system; the company; the city; the state; the manufacturer. In autonomic ferries, you will still judge the appearance of the vehicle but there will be no driver to judge. You will need to trust the manufacturer that they wouldn’t use a system that could cause any harm, and make them liable for significant damages (Lacher, 2014).

2.2 Trust in the environment

People feel less confident when using airplanes or ferries than cars. At the same time, there is a greater risk that an accident occurs when on the road than in the air or on water. People perceive the environment as safer where the means of transportation are based on how much they have been exposed to it (Alm, 2000). In order to gain trust in an autonomous system, it is important to show that the machine effectively perceives the environment where it will be used. It is also important to set conservative limitations on how an autonomous system should behave in an environment so that people that do not grasp the mechanisms of the system can still trust the system. After people trust in using an autonomous system in the environment in which it operates grows, the conservative limitation can be suppressed (Lacher, 2014).

2.3 Creating trust

When Uber proceeded to design a user interface for its self-driving taxis, there were three principles they assumed to gain the users confidence in an autonomous system. The principle of Transparency, Control and Comfort (Nix, 2017).

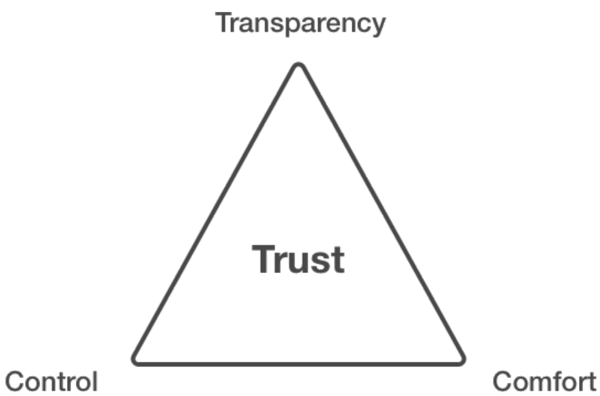

Figure 1: Three principles used to gain trust.

Transparency
Transparency is a precursor and it's a key factor for creating and maintaining trust.
"People trust what they can see and can clearly understand" (Nix, 2017).
Macro transparency covers all things that makes a person feel taken care of- in the case of autonomous systems, this means showing the user where it is going, where it intends to go and when it intends to be there.
Micro transparency shows what the autonomous system can see and how it interacts with the outside world.

Comfort
"People need familiar things in order to make sense of what's in front of them." (Nix, 2017). When designing for a whole new system it is important to include recognizable things so that the transition to new technology does not feel too overwhelming, this can be done with the implementation of human traits that can be recognized by all people. By seeing how the vehicle can communicate, respond to hazards on the road, and manage the navigation, people's trust and familiarity may increase. Introducing human qualities, also called anthropomorphism, on an autonomous car increases the trust of the passenger sitting in it (Waytz, 2014).

Control
"The ability to manage a machine, vehicle, or other moving object" (Oxford Dictionaries, control). In an autonomous ferry it will not be suggested that a passenger should be able to take over or control the ferry, but they will be given some control as they will have the ability to start and stop it. The ability of a passenger to communicate with the person in charge of remotely monitoring the autonomous transport, provides an opportunity for the user to control the vehicle by voice.

3. CASE STUDY

Milliampere is the world's first autonomous passenger ferry, therefore, there is little access to research on how to proceed with designing a user interface for autonomous passenger ferries. However, it has been useful to gain insight into how others have proceeded in designing a user interface that makes people trust machines and technology that have drastically altered the way humans interact with objects and their environment. This section will therefore present machines / objects that are comparable to Milliampere.

3.1 Driverless Elevators

When discussing autonomous transport, there are several researchers who like to use the analogy of a driverless elevator. You press a button and it takes you to the floor you wish. The same can be said about how people feel when using autonomous vehicles: Press a button and it takes you wherever you want. The transition from someone whose job was to control and "drive" the elevator for its passengers to nobody other than yourself pressing the button for your desired floor was not as painless as you may think.

It took 50 years before people were comfortable taking a driverless elevator. There were several methods used to convince people that it was safe to take a driverless elevator. Marketing was used in an attempt to portray how easy it was to press a button in the elevator: By installing the elevator with speech, floor plans, physical stop buttons and an opportunity to communicate with help if something was wrong. This was the way people would adapt to accepting a driverless elevator. This transition was also "pushed" forward when the 'professional drivers' of elevators went on strike in 1945 (Henn, 2015).
Elon Musk has also used this analogy when he talks about how people will become comfortable using autonomous cars. He believes that it will take 20 years to replace ordinary cars with autonomous cars and this will be helped by placing a ban on the use of regular cars (Lowensohn, 2015).

Elevators have alarms that activate when a weight capacity is reached, preventing it from being used until it is at a safe level, in addition there is an alert if there are any other extraordinary events. Direct contact with someone who can help if a problem occurs, which occurs rarely due to machine maintenance and development.

When placing yourself in a lift, you often use a dice analogy, if you are a person in the elevator, you are in the center of the elevator, five people will be in the center and the rest will be in their corner (Kremer, 2012). So if you should think about the correct balancing of weight on board the boat, this may happen automatically when strangers stay together in a restricted area.

3.2 Cable ferry

In Norway there are some cable ferries where passengers operate the vessel themselves, manually or with the help of a motor. Cable ferry is a possibility between a mainland and an island where the distance is about 100 meters. A cable ferry is a boat that is attached to a cable that is pulled back and forth the sea (ferge, 2013). Between Nesøya and Brønnøya, a cable ferry can take place between 1 May and 15 September. This cable ferry is operated by a manual crank and can only be driven by people older than 6 years. If you see a crossing boat traffic, you can not swing the cable ferry. The ferry can not exceed 15 passengers and 5 bikes, and it is the swivel who has the responsibility on board the ferry. In 1982 an accident occurred, when a ferry registered for 20 people had 40 people on board and who overloaded resulting in a capsizing. The result was that one man was brain damaged from the accident. Brønnøya Vel was the owner of the ferry and was held responsible for the event (GiØrtz, 2017).

Outside the west coast of Norway on the island community of Fedje, there is a similar cable ferry. This ferry crosses a stretch of about 50 meters and is registered for 8 persons. In 2009, this ferry also crashed after it was overloaded by 30 people. This happened in the evening after some tourists had been to a party and were returned with the cable ferry. Passengers on board were under influence of alcohol, but were seafarers, who managed to make it back to land quickly (Ebbesvik, 2009). The main problem for both accidents is that the number of passengers exceeded the safety limits of the vessels.

3.3 Self-driving Taxi Uber

Uber is a transport platform that facilitates various transport opportunities for people living in cities around the world (Uber, 2017). It is a company that started in 2010 and has 40 million monthly users in 83 different countries (Dogtiev, 2017).

In 2016, Uber launched a research program in Pittsburgh, USA, with self-driving taxis. Only invited people were able to participate in a trip by a self-driven taxi. After booking a taxi via the Uber app, a self-driving Uber taxi arrived with two Uber engineers in the front. All the self-propelled taxis in this project were accompanied by two engineers. One engineer sat in the driver's

seat and was ready to take over the taxi if something undesirable was happening or if the passengers in the backseat were not comfortable with the self-propelled taxi. The other engineer sat with a PC and observed how others in traffic and passengers in the backseat responded to this technology.
After entering the taxi, the user pressed a button on a tablet to say they are ready to go (Brewster 2016). The tablet shows whether the taxi is in self-propelled mode or not, the speed, steering angle when the car is slowing down and how far it has driven in autonomous mode. You also get information about where you have driven and how long it is until you arrive at your destination. Users also have the opportunity to see what the car sees. This autonomous experience also allows you to document with this screen by taking a selfie. Last but not least, the passenger has the opportunity to stop the car by pressing a button on the screen that causes the self-driven taxi to stop (Staff, 2016).

Uber often had the problem that the self-driven taxis did not drive as desired. On average the self-driver functionality did not last for longer than about 1.5 km before it was taken over by the engineer who was behind the wheel. (Bhuiyan, 2017). This project was terminated after a self-driven taxi from Uber crashed with another car in March 2017. The reason for the crash was not technological reasons, but human (Isaac, 2017).

Uber taxi is a good start for people to be introduced to this new technology. A technology that is presented through a reputable company where passengers are curious about how the new technology shift will be. It is difficult for passengers to gain a great deal of confidence in a technology that is only partially tested. It is advisable to follow up the technology with two engineers in the initial stages, but in the long run when the technology is good enough to be considered safe, there will be no need for human "babysitting" or security. While it is important to test new technology with many users, it is also important to think that humans are much less understandable when accidents occur due to technological failures and not human errors (Waytz, 2014). Testing the interaction that Uber has had with its passengers in the back of a self-driven taxi is definitely a real step towards making people feel comfortable with autonomous transport.

3.4 Summary

It took some time to get used to the transition from a single man whose job was to control the elevator to making the process more automated so that any person could press a button to get to their destination. There was a gradual transition, giving the elevator human characteristics, such as speech and communication. The few means of transport that are somewhat similar to Milliampere, have been exposed to accidents due to alcohol and poor insight into the use and handling of the ferry. They did not follow the rules for how many could be onboard and passengers were usually not familiar with the use of this means of transportation. Uber's introduction of a self-propelled taxi for passengers has not gone as painless as they wanted due to technological weaknesses, but when it did work, it has been almost the same as a regular taxi ride.

When the Milliampere project starts, it may be valuable to optimize the user experience based on what is being discussed in the different cases. Here are some points I'll introduce as we go ahead when designing a safe user experience for the passengers on board Milliampere.

- Human abilities.
- Communication options.
- Prevent overload.
- Prevent rule violation.

When implementing human properties on board Milliampere, it makes it difficult to break the rules and requirements for taking this autonomous boat (Waytz, 2014).

4. CONCEPT DESIGN

A user test was conducted using three different concept systems for the passengers on board Milliampere. The design was made on the basis of the three different cases, and the use of theory and design principles of trust. The goal of the test was to see how much information the passengers on board Milliampere needed to feel comfortable with and make the most of an autonomous ferry with a controlled route of 100 meters. The test took root in the design principles about transparency, comfort and control, to gain confidence previously used for autonomous vehicles on the road.
The test was conducted on a specific scenario, where the test user received pictures and illustrations on paper sheets throughout the process. Each test person was presented with three different systems in the same scenario so that they could compare the systems with each other. They were asked how they perceived the different situations in the scenario, after which they were told to choose the system they trusted the most.
The scenario in the test started with the user seeing a picture of how the ferry looked as if they were going to take a trip with it. When they were at the pier where the ferry was due, they were shown a sign indicating where they were, where the destination was, and the route that would be taken to the destination. The next picture was of a control panel inside the ferry which showed the possibilities they had with reference to controlling the ferry. Then the passengers were told that everyone was on board the ferry and that a message from the speaker said that the door was closing and what the next stop was. After the ferry had taken half a minute, the test person was shown a picture where there was a kayak in the way of the ferry.
The three systems had different amounts of information that were presented in the same scenario. System 1 tested whether speech and a control panel on board was enough to gain confidence in an autonomous ferry.
System 2 tested whether speech, a control panel and a screen that illustrated a map of where the ferry was and what route it was taking, to see whether this was necessary to gain more confidence in an autonomous ferry.
System 3 tested for speech, a control panel and a screen that showed a live video image of what the ferry saw, where it was, and where it was going.

The test was conducted with eleven people: seven were female and four were male. The age of the test subjects varied from 25 to 55 years. All subjects felt comfortable that the control panel was onboard and they all felt adequately in control of the interaction with the panel. The differences in the experience the test subjects felt were associated with how much information they needed in order to trust the system:

System 1: The principle of Control and Comfort was sufficient for two out of eleven to trust the system. The stretch was so short that a voice telling them that the kayak had been noticed and that the ferry would take evasive maneuvers was sufficient and that it was unnecessary with more information.

System 2: The principles of Control, Comfort and Macro Transparency was sufficient for three out of eleven test subjects. They felt a screen clearly showing information about the route and the kayak in addition to the voice was sufficient for them to trust the system. More information than this would be superfluous.

System 3: Six out of eleven needed the principles of Control, Comfort, Macro Transparency and Micro Transparency in order to trust the system. They felt it was important to get a visualization of what the ferry registered and understood before they would trust the system entirely. They were of the opinion that autonomous means of transport were tantamount to futuristic means of transport, and had been disappointed had this perception not been met by the system.

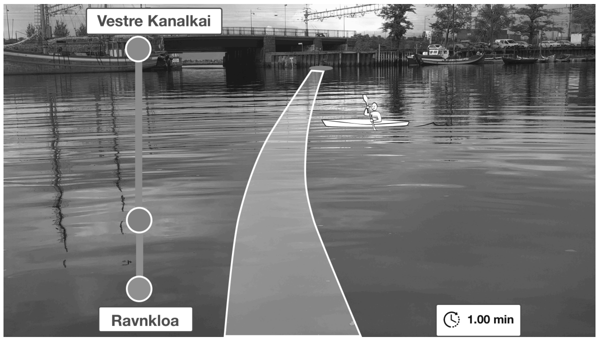

Figure 2: An illustration of System 3.

5. DISCUSSION AND CONCLUSION

People are introduced to new and incomprehensible technology that needs to be explained before they gain confidence in it. When the transition from human controlled elevator to driverless elevator took place, it took a long time before users were willing to trust a system where man did not have enough evidence and perception of how things were functioning, the system was too new and incomprehensible. The autonomous passenger ferry Milliampere will be a project that will make people observant of new technology, it will be introduced to society as more of an experience than a means of transport. The distance the ferry will go is short and there is little crossing traffic. This is a good opportunity to make more people aware of autonomous transport systems that in turn can build trust in the prominent technology. The test that was carried out in this article did not include how the onboarding of the ferry would happen. If you are boarding the autonomous ferry in the same way as entering a lift, I think you can recreate the same trust as you have for an elevator. Unauthorized use and vandalism aboard the autonomous ferry can occur. Monitoring the ferry and the ability to inform passengers on board of any circumstance that arises will limit such behaviour and can help make you feel safer.

Voice control and hearing a “captains” voice on board the ferry is something everyone from the test expressed was important, and that is something that corresponds to the research. Information and messages given by a human voice are something that instilled trust in the system for all test subjects.

The majority of the test subjects wanted a system that gave them visual information about the boat's position and time, and what the boat perceives to be within its surrounding environment. This visual information was not essential for building trust in this autonomous ferry, but it would contribute to a safer experience. Research says that one will gain the right / better confidence in an autonomous system by giving human qualities, such as sight. Two of the test subjects found it unnecessary to display information on a screen in addition to audio as the route of the ferry was so short.

The journey length of the ferry I think is decisive for how much information a traveler will need/receive on the route. If it becomes too much information in a short period of time, it may be perceived as overloading and acting against its purpose. It is therefore very important to test this for every possible situation. At the same time, I think the boat's design and size have a lot to say about the amount of information that is conveyed to travelers.

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