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Research Summary Paper of

A Design Anthropological Study on Fully Autonomous Vehicles with a Focus On the Cycling Culture of Copenhagen

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INTRODUCTION

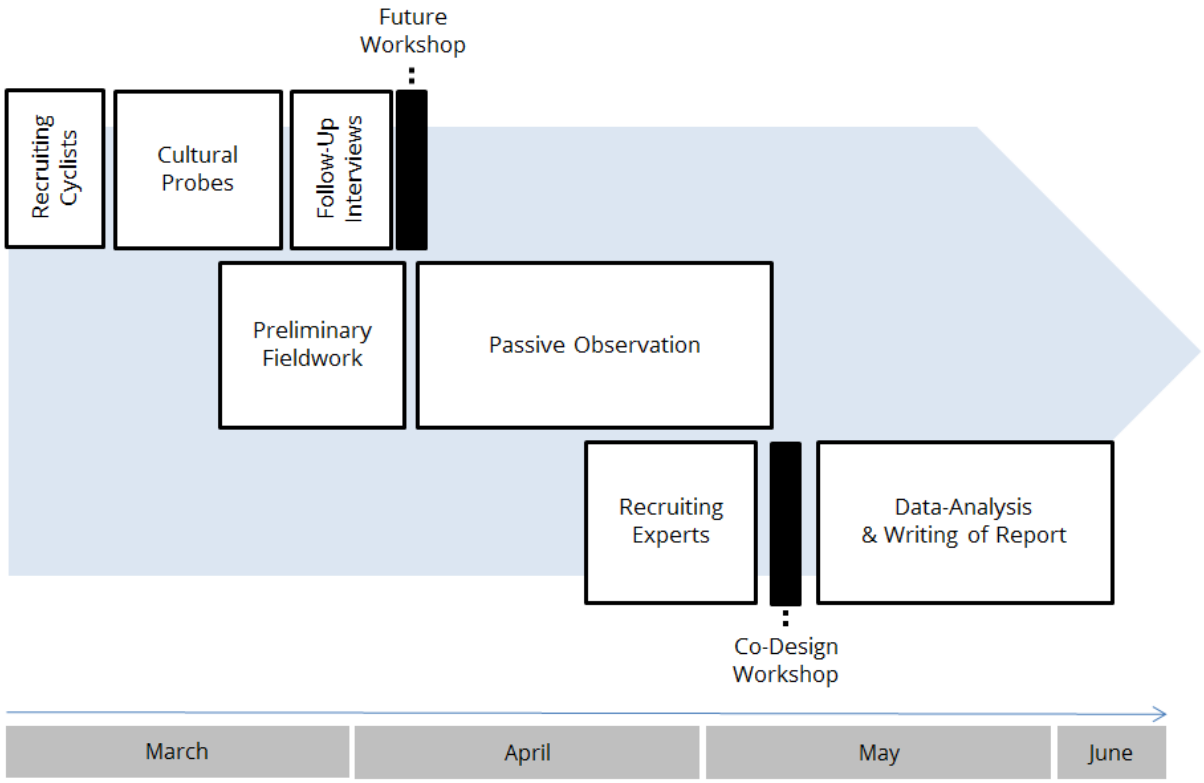
This report discusses the development and deployment of fully autonomous vehicles (fAVs) in mixed traffic environments. We assess the challenges of external communication between fAVs and vulnerable road-users with a focus on cyclists when exchanging human-human interactions with human-machine interactions. The report builds on an ethnographic study with the aim of exploring and analysing current interactions between vehicles and cyclists in unregulated crossings in Copenhagen and attempts to highlights concerns and demands of cyclists for the development of fAVs and the deployment in Copenhagen.

METHODOLOGY

To explore the current interactions between vehicles and cyclists and prospective challenges for the deployment of fAVs, we have applied a range of qualitative methods. The research was carried out from February till May 2017 in Copenhagen and consisted of:

- a cultural probe study (CP) with 10 cyclists
- a future workshop (FW) with 8 of the 10 cyclists from the CP
- passive observations in unregulated crossings in Copenhagen
- and a co-design workshop (CW) with 2 cyclists from the CP and FW, 2 representatives from Copenhagenize, 1 representative from the Mobility and Technology Department of Copenhagen's municipality (Region H), Melissa Cefkin from Nissan Research Center and Torben Elgaard Jensen, leader of the Techno-Anthropology Research Group

PROJECT TIMELINE



MAIN RESULTS

CYCLISTS INDICATING NEXT MOVEMENTS

Different forms of communications are used to indicate certain movements. We have identified 1) head movements, 2) hand gestures, 3) speed and 4) placement as the most important ones and outline the nature of these in the next paragraphs.

Head movements typically indicate a following action. In situations like surpassing others, lane merging or crossing lanes, cyclists turn their heads to check their close environment. The head movement itself also serves as a signal for others being close. The clarity of a turned head often varies from a strong to a nearly not visible movement, appearing very subtly. In many situations cyclists trust in their peripheral sight, not turning their head at all, which means that head movements might indicate a movement but do not serve as a reliable signal for any specific action per se.

Hand gestures are often used by cyclists when they communicate turning or stopping. Similar to head movements, hand gestures vary in their clarity of being signalled. Some cyclists show it very clearly, whereas others only raise their fingers. It was also observed that the expected action following a hand gesture might not occur directly after the signal given, meaning that the hand gesture serves to warn and prepare other road users well in time before a turn or stop happens. Furthermore, it was visible that certain other practices like greeting someone from the bike could be misinterpreted as a hand gesture. Lastly, it seems to be an unwritten rule that hand gestures are not at all used in specific situations. Sometimes this might also be the result of cyclists not having a free hand to signal, meaning hand gestures neither seem to be a reliable indicator for prospective movements. Moreover, multiple cases of contradicting behaviour were observed. For instance, cyclists raising the right hand to indicate stopping, but then keeping their speed, ultimately not indicating again right before the turn happens. Additionally, cyclists seem to place themselves actively on one side of a bike lane or road in order to preliminary indicate turns for example. Speed and placement, hence, play an additional important role to predict a cyclist’s prospective movement.

NEGOTIATING PRIORITIES

Negotiations are a central element of social regulations in traffic. Especially, unregulated crossings depend on these negotiations to ensure a continuous traffic flow. Therefore, it is necessary that priorities are given and taken in the right moment. Direct indication of turns, stops, etc. and the ability to understand those signals are essential for smooth unregulated traffic. However, road users often also negotiate the right for priority – especially, in situations of standstills before entering the intersection or crossing a lane or when it is unclear whose right it is to go.

Oftentimes, cyclists or other vulnerable road users simply claim priority for themselves when entering an unregulated intersection - well knowing that car drivers will not just run them over. This is ultimately a result of the respect being paid to cyclists by drivers in Copenhagen. Even though, it might not be one's priority to go, people make use of different sorts of dominant behaviour to overrule the priority of others. Cyclists use speed and their agility to rush through tight paths in between cars and pedestrians. This oftentimes leads to near-contact situations between cyclists and cars. Furthermore, safety in numbers - meaning the bigger the group the safer the feeling of passing a crossing - seems to account for vulnerable road users. Grouping generally seems to be a good method to gain priority. Using the shadow of other road users crossing the street might spark such a grouping behaviour leading to longer interruptions of traffic flow. While dominant behaviour seems not to be so much about negotiating priorities, in fact it is - in the sense that the dominant entering of a crossing is often the result of longer periods of waiting – unsuccessful negotiation so to say. During this period of waiting, some road users try to creep out (inch forward) into the intersection to signal that they want to cross as soon as possible.

Even more interesting, though, are situations where two or more road users wait for another to go first. In those moments, the road users negotiate by using hand gestures for waving the other one by and seek for final approvals. These are the situations where eye contact becomes an essential role in negotiation, as it serves as a form of link between road users, letting the other one know that they will enter such negotiations now. Once eye contact has been made, people look for a final approval of the opposed road user to confirm one's priority to go. Sometimes such approvals are very subtle and do not demand more than the exchange of

looks - as specific infrastructure, traffic rules or unwritten rules provide enough clarity for the situation at hand. In other cases, approvals are more explicitly communicated by using hand gestures or audio-visual signals of the car for example. Eye contact, hence, serves as a way to build a temporary relation between cyclists and drivers. Cyclists seek eye contact before finishing manoeuvres like turns or surpassing as well as in near-contact situations or other problematic moments. Otherwise, cyclists mainly focus on the movements, speed and placement of cars.

WHEN CYCLISTS BUILD THEIR OWN PROTOTYPE OF AN fAV

In the Future Workshop our participants were divided into two teams to generate ideas on what a fully autonomous vehicle could look like and how it should interact with vulnerable road users. The most important conclusions are summarised below:

- *"We want the fAV to be connected to other cars, we want it to be able to make sound, especially for the cyclists and pedestrians, we want it to be able to hear - other cars, sirens, and people yelling if something happens - we want it to make signals for bikers to indicate 'We have seen you in this path' and of course we want it to detect the surroundings."* As mentioned in the quote before, one intensely discussed topic was the necessity of fAVs *showing awareness of surroundings.* Our participants agreed that fAVs need to be able to communicate to cyclists or other road users that the fAV has 'seen' them. Therefore, it was discussed how different devices could send the signal 'I have seen you', for instance with blinking lights or sounds.

- *"When I bike, I am moving and cannot always focus on one specific spot of the car, rather I would prefer some signal really close to me, which I cannot oversee."* Another important point was to extend lights on the sides of the cars as a more visible form of indicating next movements. A green light on the side would then for example show cyclists that it is ok to pass, whereas a red light would signal that cyclists should not pass in this very moment. This would then serve as a new final approval, also substituting the necessity of eye contact in specific situations. In fact, our cyclists even discussed a coloured signal being visible all around the car, instead of at one specific spot of the car's exterior. After having discussed sounds, lights in form of arrows, and different colours, our cyclists finally agreed that the solution must be as easy to

understand as possible. Another thought was that a blinking light could indicate movement, or the AV's intention to move, while a steady illuminated light signals that the car does wait for someone to pass, does not intend to move.

- *"We concluded that in an autonomous future it is not enough to change the vehicles but we also need to change the infrastructure in cities."* Many of our participants argued that the infrastructure would need to be adapted, whereas the complete separation of fAVs and cyclists still seemed to be most imaginable for ensuring a safe deployment.

CONCERNS FOR THE DEPLOYMENT OF FULLY AUTONOMOUS VEHICLES

A safe deployment of fAVs requires the ability to differentiate between the multiple and very contextual meanings behind the communication and indication of intentions. A right raised hand, for example, could either mean 'I will stop' or 'Thank you'. This contextual nature of body language is a major concern, and we are questioning how this will be defined and differentiated. Also, how will a fully autonomous vehicle be able to interpret and understand different degrees of signalling hand gestures as well as all the very subtle indications like a weak head movement for example?

Moreover, we are concerned about how fAVs will be able to negotiate priorities to keep a steady flow. In unregulated crossings we found that social rules are of higher importance than official rules about priorities. Cities like Copenhagen, having streams of cyclists in often rather narrow passages and mixed traffic environments, bear a higher risk of collisions. How will fAVs be able to negotiate their way through a long lasting stream of cyclists then? And could they make sense of cyclists waving them by or stopping to let the vehicles pass? In connection to this, we learned that eye contact could be of importance when negotiating priorities. How will fAVs be able to communicate their approval or neglecting of other's intentions? Will they be able to avoid confusion amongst pedestrians and cyclists by clearly signalling agreement on next movements - and how will fAVs make sure that that signal has reached and been understood by other road users when eye contact as the link between two negotiators becomes missing? And, what is the final approval we humans need to show to an fAV to let it pass in front of us?

Furthermore, we see that cyclists are more flexible in the environment being able to navigate in near-contact situations. For instance, we observed a lane merge with a parked truck where cyclists and vehicles needed to navigate around it. How would fAVs deal with such 'near-contact'-situations, where inches count but today's drivers still know they can go on, expecting cyclists to be able to estimate whether they can make it through such very tight paths? Might fAVs need to signal their minimal use space to other road users?
Participants also questioned the technological ability to interpret cyclists' speed changes in order to predict next movements. Predictability showed to be a topic where our participants were quite indecisive. On the one hand, they expected that fAVs will be able to react and predict their environments correctly and at every moment. This sparked the concern that other road users could then easily abuse fAVs, knowing that they would react appropriately anyway. On the other hand, we found that movements from cyclists are oftentimes very spontaneous, not sticking to rules, not fulfilling the expectation we humans might have when we intuitively analyse traffic interactions. What is then the crucial element of a cyclist's behaviour which an fAV needs to react to and is it then enough to only react on movements for example?

To what extend do fAVs need to be proactive? Proactive, for example in the sense that a cyclist raises a hand to signal a stop 10 meters before stopping, simply to prepare other road users. Related to that, would fAVs react immediately to this hand gesture? We argue, the fAV must be able to understand the combination of a hand gesture and the following movement - for example speed reduction. We further concluded that the understanding of combined elements of such interactions must be further investigated, as for example a hand gesture signalling the stop in 10 meters, combined with slowing down and a head movement to the left might indicate the intention for a following left turn of the cyclist.

LOCAL CULTURE VS. STANDARDISATION

Copenhagen's inner city was originally built for people walking through the narrow short distanced streets. Today, these streets - similar to many other European city centres - are still narrow and many of them unregulated. Therefore, especially these areas are interactional rich and people heavily rely on social rules combined with infrastructural elements to ensure traffic flow. Today, Copenhagen has about 265.700 cyclists in the city and thereby exceeds

the amount of cars being about 252.600. Every day, 56% of the population in Copenhagen travels to work by bike, using more than "*1000 km of bicycle lanes in Greater Copenhagen"* (Copenhagenize, 2017)[1]. Furthermore, Copenhagen's infrastructure draws on a concept called 'Super Highways' to accommodate streams of cyclists (Copenhagenize, 2017). According to Copenhagenize, this concept has the potential to "*create 3 million more bicycle trips a year"* leading to the reduction of car trips by 720,000 a year. *"This will save the region 34,000 sick days and give a 1 billion EURO economic gain per year*" (Copenhagenize, 2017). Copenhagen's vision is to increase the number of cyclists and reduce cars in the inner city to promote renewable energy, public transportation, car sharing services and electric vehicles - a vision being shared by many other Western European capitals as well.

Furthermore, Copenhagen's focus on cycling culture seems to have caused a positive change in the attitude towards cyclists. Copenhagen is considered to be a safer environment for cyclists than other European capitals. Generally, cyclists feel that car drivers pay more respect, showing a rather caring attitude towards cyclists. Interestingly, Copenhagen's cycling culture also seems to play a dominant role in traffic, which is where we assume that this is related to drivers being more careful, well knowing that cyclists are more vulnerable.

It is the complexity of cycling practices, of different and for us, humans, often intuitively understood behaviours which we aimed to reflect on, as we think that a form of local familiarity with such practices - we called this *'native understanding'* - is needed to intuitively predict movements by interpreting signals like hand gestures, head movements, speed changes, placement and eye contact. We wonder if fAVs need knowledge about local social rules and the by region differing body language and intention indication? We believe that fAVs driving in mixed city traffic need to be able to deal with all those hidden social rules of interaction which to a certain extent might be the same or similar throughout one country or one continent. When talking about the harmonization of external-HMI or standardisation of AVs, we thus ask, to what extent is interaction the same? And what should adapt: technology to local culture or local culture to global technology?

[1] Copenhagenize (2017): Copenhagenize. The Blog. [Online access: copenhagenize.com/]