APPENDIX A

“SAFETY FIRST FOR AUTOMATED DRIVING” WHITE PAPER
12 GUIDELINES:

Along with Aptiv, Audi, Baidu, BMW, Continental, Fiat Chrysler Automobiles, HERE, Infineon, Intel and Volkswagen, Daimler has published a white paper entitled Safety First for Automated Driving. As well as covering all relevant safety methods for Level 3/4 SAE automated driving, the paper introduces a traceability system, which extends from the primary goal – being safer than the average driver – right down to the individual safety objectives of the various components.

The foundation of the “Safety First for Automated Driving” white paper are its 12 Guiding Principles:

- **Safe Operation**: How the system reacts if critical components become unstable or cease functioning
- **Safety Layer**: The system recognizing its limits and minimizes risk in returning control to the driver
- **Operational Design Domain (ODD)**: The operating conditions in which the system is designed to function
- **Behavior in Traffic**: The system behavior needs to be easy to understand and predictable for surrounding road users
- **User Responsibility**: The user’s state must be suitable for a takeover procedure
- **Vehicle-Initiated Handover**: If the driver does not comply with a takeover request, the automated driving system must perform a maneuver to minimize risk.
- **Driver-Initiated Handover**: Activating and deactivating the automated driving system shall require an explicit driver’s intent
- **Effects of Automation**: Overall evaluation of system safety shall take automation effects on the driver into account
- **Safety Assessment**: Verification and validation shall be used to ensure that the safety goals are met
- **Data Recording**: When an event or incident is recognized, automated vehicles shall record relevant data in a manner that complies with applicable privacy laws
- **Security**: Steps shall be taken to protect the automated driving system from security threats
- **Passive Safety**: Vehicle layout shall accommodate changes to crash scenarios brought about by vehicle automation
APPENDIX B

RESULTS OF ONLINE QUESTIONNAIRE

How old are you?
25 responses

- 25 - 35: 28%
- 36 - 45: 20%
- 46 - 55: 28%
- 56 - 65: 12%
- 65 and older: 12%

How many years of driving experience do you have?
25 responses

- More than 1 year: 50%
- 1 - 5 years: 36%
- 6 - 10 years: 6%
- Over than 10 years: 8%

While you are driving on your own, to what extent would you rate your performance?
25 responses

- 7
- 6
- 5
- 4
- 3
- 2
- 1
- 0

How often do you use the Autopilot function?
25 responses

- Everyday: 32%
- Often: 18%
- Usually: 6%
- Rarely: 18%
- Never: 23%

Did you ever have bad or unexpected experience while using Autopilot? Can you try to describe one worst experience when using the autopilot?
23 responses

- In less than 1% of total distance I used AP it suddenly brakes sometimes. Most of the times due to wrong speed adjustments or a fly over (radar) I am passing.
- Sometimes phantom breaks on the autobahn. Ignoring barricades in construction zones.
- Car aweswing towards a truck on the autobahn, several phantom breakings, trouble getting into construction sites
- Misidentified lanes when automatically changed lanes, ended up changing 2 lanes instead of 1
- Never
- Phantom braking - when the car slams on the brakes for no apparent reason.
- Not yet
- Nothing really bad. The odd phantom brake. But they have been away for a while

While you are using autopilot, for instance, adaptive cruise control or lane centering, to what extent would you rate your performance at that state?
24 responses

- 7
- 6
- 5
- 4
- 3
- 2
- 1
- 0

Did you ever perform non-driving related tasks while using autopilot? And why?
25 responses

- Yes: 60%
- No: 40%

If yes, what kind of non-driving related tasks did you ever do?
19 responses

- Check phone..... but would do that without AP also
- Using the main Display for settings, navigation or music selection.
- Everybody does, even when not using autopilot. Strange question
- change navigation settings and radio station
- Eat some snack and stretch my back.
- Radio, or picking something up the kids dropped.
- WhatsApp
- E-mails, Reading on internet etc.
- Adjust music for less than a minute
- Looking out of window, Checking about.  etc.

Tesla will give some notifications when it detects, for instance, your hands off the steering wheel, what do you think about the notifications?
25 responses

- Yes: 28%
- No: 72%

- Skillfully: 4%
- It is too alarming: 4%
- It is alarming but also quite understandable: 4%
- What alarming is that after having 2 hands or the wheel you get warning...: 4%
- I'm happy they do this, it's making us drive more safe: 16%
- Tesla does not differentiate and how severe...: 44%
- It does not differentiate and how severe...: 44%
Tesla will give some notifications when it detects, for instance, your hands off the steering wheel, what do you think about the notifications?

25 responses

- 41% It is very annoying,
- 18% It is a little annoying,
- 22% I find it annoying but also quite necessary,
- 12% It is pretty good,
- 6% Most annoying is that when testing 3 hands on the wheel you get warning,
- 4% Happily they do this, I think they do it to discourage those who just hit too,
- 2% It does not differentiate and has some...

Are the notifications strong enough to bring you back to the driving loop when you are distracted?

25 responses

- 52% Yes, sometimes.
- 24% Yes, most of the time.
- 20% No, not at all.
- 4% I am not there.

Imagine in the future, when there are highly automated vehicles, you can even play video games/head books, etc while the car drives, but need to prepare to take over the control at any given moment. What’s your attitude towards it?

25 responses

Very excited - 17 (68%)
Worried - 2 (8%)
Annoyed - 3 (12%)

Wouldn’t happen as long as a driver isn’t ...

- 5 (20%)
- 2 (8%)

That will not happen using cameras, etc...

- 1 (4%)

Is there anything else you would like to address?

9 responses

- AP is a helping tool, its not self driving. It is very good if you use it like you should. I am happy with it and makes me a safer driver in traffic especially on longer trips.
- Current EU laws are too restrictive! Especially on steering in corners. Can even be dangerous.
- Het is een hulpmiddel, ik zie autonoom rijden echt nog niet voor me. Aantal variabelen is te groot
- I really feel like autopilot is more beta testing of the technology at the moment. It is constantly changing and improving. At this point, you almost have to be MORE aware driving on autopilot as it can be unpredictable.
- If you have never experienced auto pilot I would gladly take you on a trip to experience it.
- It should be faster self learning
- Did autopilot ever save you from an accident? Yes side and front side impact. When I
# APPENDIX C

## EXPERT INTERVIEW QUESTIONS

**Expert Interview**

**Introduction**

Hi. First of all, thank you very much for giving me the opportunity to interview you. My name is Xinyi Wang, and I am from design for interaction of industrial design engineering faculty. I am doing the master thesis which for now is to design the HMI in order to enhance driver's sense for a seamless and intuitive takeover transition. It will be narrowed down and more focus on a specific topic with the research. The interview will contain 3 parts mainly: 1. Discuss about the takeover transition, the experience, the existing or potential problems; 2. Discuss about the scenarios of takeover request, basically when would it happen; 3. The importance of situational awareness.

**Aim:**

- Validate the takeover transition experience and current pain points.
- Principles or criteria or rules HMI design needs to take into account.
- Validate scenarios that TOR might happen and try to conclude them with several parameters.
- Before TOR, how could we measure/increase drivers’ situational awareness?
- During TOR, when communicating, what is the current pain points? What is the role of HMI in communicating TOR?
- After: Takeover transition is such a short experience, any guidance suggested for guiding driver how to respond to the takeover control?

**Takeover transition experience**

1. Since below level 2. humans are fully responsible for the driving task, so there is no so called takeover for level 1.0. What is the takeover transition experience like? Can you plz describe it?

2. Here is the takeover transition that I concluded based on online research, is there anything incorrect or incomplete? Do you have anything to add?

3. For the takeover experience, what are the potential problems/pain points in the takeover experience from your point of view?

4. During the takeover transition, what do you think the role of HMI is?

5. More specifically, during the takeover transition, what kind of shortcomings or pain points of current HMI do you see?

6. Are there any principles that HMI designers need to follow or strict rules?

**Situational awareness**

7. Would you think low situation awareness one of the critical problems during automated driving and why?

8. How could we enhance drivers’ situational awareness? Or why do you think currently, the drivers situation awareness is quite low before the takeover request?

9. How could you measure or tell whether the SA is low or high?

10. Now if the car wants the driver to take over the control, what kind of information do you think the car need to communicate to the driver?

11. For the current communication of takeover request, what kind of pain points do you see?

12. After communicating TOR, do you think the system needs to guide the driver how to respond to the TOR? For example: drivers may be confused why they need to takeover, what happens and how to take over?

**Scenarios**

13. Under what kind of circumstances would the takeover request or deactivation of automation happen?

14. If you were asked to use some abstract parameters to conclude/categorize the scenarios, how would you categorize the scenarios when takeover requests happen?

15. I prepared some abstract criterias to describe/categorise the scenarios, can u rate each scenarios from 0 to 3? 3 means high and 0 means low;

**Update**

What is the difference between the takeover experience in level 3 and level 4?

<table>
<thead>
<tr>
<th>No.</th>
<th>Scenario</th>
<th>Urgency</th>
<th>Complexity of drivers reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The presence of road/low markings or lack of markings or secondary lane marking due to construction</td>
<td>Urgent</td>
<td>Medium</td>
</tr>
<tr>
<td>2</td>
<td>The lateral vehicle guidance is discontinued during a straight or curved road segment high road curvature</td>
<td>Non-urgent</td>
<td>Low</td>
</tr>
<tr>
<td>3</td>
<td>The failure of sensors</td>
<td>Urgent</td>
<td>Low</td>
</tr>
<tr>
<td>4</td>
<td>Road works require change to another lane</td>
<td>Non-urgent</td>
<td>Medium</td>
</tr>
<tr>
<td>5</td>
<td>Bad visibility due to bad weather conditions like fog, heavy rain etc.</td>
<td>Urgent</td>
<td>High</td>
</tr>
<tr>
<td>6</td>
<td>Cut in vehicle is not detected</td>
<td>Non-urgent</td>
<td>Low</td>
</tr>
<tr>
<td>7</td>
<td>Pedestrians enter road</td>
<td>Urgent</td>
<td>Medium</td>
</tr>
<tr>
<td>8</td>
<td>Obstacles on the road</td>
<td>Non-urgent</td>
<td>Low</td>
</tr>
<tr>
<td>9</td>
<td>The driver is requested to select a particular route or terrain than highway</td>
<td>Urgent</td>
<td>High</td>
</tr>
</tbody>
</table>

**Reference**


APPENDIX D

EXPERT INTERVIEW TRANSCRIPT

Bastiaan

My research is more focusing on the forced takeover request that something happened and the machine couldn’t handle it. It would keep and show the attention from the driver. They then take over the control and deal with whatever the situation is in front of them.

And the whole community found this is not the most safe way to deal with these kinds of problems because people will start to do other stuff.

But nowadays we’re more going towards the less forced take overs we’re trying to avoid using technology.

That’s how it’s looked at and it’s more focused on the driver monitoring and making sure that the driver is in a good state before he or she takes over right? If he is not then you say no you cannot take over.

For level 4, if you know the takeover is coming, it can prepare more to a good mental state. It’s hard to say something definitive if it is level 4, then the car not necessarily knows the problems.

In level 4, it is a problem when someone takes over and they are not in a good state of mind.

If they don’t know what’s going on around and they grasp the steering wheel. That could also be more catastrophic than a safe pullover. It could even be that the system says well, maybe take a moment before you takeover.

For level 4, driver initiated takeover is more interesting. For level 4, it would be stupid to let a driver who is not in a good state, just woken up or to say ‘oh, there is the control back and have fun.’

That is one thing I guess, making sure that the driver is in the good state before the takeover in level 4 at least.

In level 3, it is keeping the driver engaged and make sure he is at least awake and ready to takeover.

On the other hand, sometimes, the safe pull over is not that safe. Pullover to the hard shoulder is not super safe right. It is safer than crashing into another car. But you wouldn’t prefer it.

Making sure the driver gets back to the good state or situational awareness is one of the most important thing in level 4, especially there is a long drive.

Level 4. Getting the driver back to the state, you can approach it in different ways. For example, you can check if he is in the right state. Do we give back control? If not, don’t give back the control. Or we may help him getting back the control, help him look around. You should check the mirrors first for example. I would help him to prepare the TVR, make sure he check his surroundings, make sure his eyes on the road for at least 2 mins before we takeover. Not only say takeover is coming up but also help him regain SA.

Other problems a lot of the issues I foresee are those human factors’ issues that we talked about people start to get bored or start to get completely distracted.

We have been investigating stability control, stability off control after you take over so especially in dangerous situations where you have to steer.

We see people sometimes had a bit of a stability issue so they steer a lot to make sure the cars stay in the lane. Sometimes it said that might get worse when we’re longer out of the loop so if we drive automated vehicle for like 30 minutes or an hour or whatever and all of a sudden we have to takeover. We have to get used to the steering dynamics.

Scenarios

It is more in dangerous scenarios. Time Budget would be low. Leaving the odd. When the situation is not normal. If your system is not able to understand its surroundings anymore.

I am not sure about the complexity of the driver’s reaction. It is more about the complexity of the situation. I think outside determines what happens inside in that sense.

Joost

Level 4 there is also not much research about it, maybe it is to far into the future.

But of course we have this question about how should the car go to this minimal risk condition. How should human being informed about it in principle.

So for level 4 there is also transitions the planned transition which actually very important.

For some reason they are studied less nowadays but it is also quite important. I would say. Maybe because it is less exciting than the takeover with 5 or 7 s. You have quite some dynamic process, you have eyes on the road, you have to capture the steering wheel, look around and check the cars around you. So it is a quite challenging task. You can measure all kinds of interesting things. But for a planned transition, you have to exit in one minute.

What could you measure there? Maybe aftereffects which mean after long driving you are not really consistent with your steering wheel anymore.

pct just do very much the same thing. It’s all level 2 and level 1 in literature. Actually everyone is talking about automation. Why not? I don’t know? It’s a more fashionable topic but it does not mean the most important. Pct sort of jumped into the topic and start doing it.

Of course, there are questions like what is situational awareness if it is even one dimensional variable?

Sa depends very much on voluntary process like is the driver instructed or voluntarily willing to engage in secondary tasks. Then sa low. But you can also ask the driver to look around and detect objects on the road. Then automation can help you because you don’t have to control the car. The therapist is quite high. It depends on the task you give. Talk about current Tesla. Pct don’t really do a lot secondary tasks. They are actually very attentive because they are relaxed they can look around. I don’t believe that the sa is always low it really depends on the context or the task.

Feedbacks give to the driver during automated driving. There are actually some research suggests that you should show continuous information to the driver. You have this cc continually tells you where other cars are. It would allow you to maybe maintain sa during automated driving.

You could have a car talks what it is doing. The problem however is also it distract pct’s attention. Pct start to look at the display. It’s not all positive. Not only visual, because it will not work.

Pct has used vibrations. I think that is sort of solved problem.

I think that is sort of solved problem. If you have sa and you have to intervene asap. I think car manufacturers have this under control. There are so much research and very much knowledge on that area.

Many manufacturers have warning during automated driving like tesla/ Volvo. You are not touching the steering wheel so you get notification, firstly visual notification then auditory then loud auditory warning. There are all kinds of concept.

And the big question is “is it reasonable to ask the driver to takeover the control in like 7s on the road?”

This is the big question that I think has not been answered. Or the whole level 4 should be skipped.

Think nobody knows were the future brings us.

It should be proven whether driver takeover the control in the middle of the highway unexpectedly.

For the notification, what you need is auditory and then plus vibration. There are two things, firstly you should “wake up” and you need to grasp the steering wheel quickly. Secondly, the driver should also make an action. They driver should have sufficient time to do that.
APPENDIX E

VISUALISED USE CASES

1. Level 3: Automation initiation driver ready TOR

Handover to the well-prepared driver

Informs the driver TOR in advance

Help driver get prepared and evaluate driver’s state

Car decides handover or not according to evaluation

2. Level 4: PLANNED TOR when exiting the operational design domain (ODD)
APPENDIX F

ARDUINO CODE

```cpp
#include <Wire.h>

void setup()
{
  Wire.begin(2); // I2C interface
  Wire.beginTransmission(0x70); // I2C address of OLED
  Wire.write(0x40); // Set mode to normal
  Wire.endTransmission();
}

void loop()
{
  if (Wire.requestFrom(0x70, 1)) // Receive something
  {
    int buttonValue = Wire.read(); // Read button value
    state = buttonValue; // Update state
  }
  else // No new data
  {
    state = 0; // Reset state
  }
  if (state == 1) // Button pressed
  {
    Wire.beginTransmission(0x70); // Request OLED to display
    Wire.write(0x0C); // Clear display
    Wire.write(0x01); // Set contrast
    Wire.write(0x0A); // Start display
    Wire.endTransmission();
    delay(1000); // Wait for display
    state = 0; // Reset state
  }
  else if (state == 2) // Button released
  {
    Wire.beginTransmission(0x70); // Request OLED to display
    Wire.write(0x0C); // Clear display
    Wire.write(0x01); // Set contrast
    Wire.write(0x0A); // Start display
    Wire.endTransmission();
    delay(1000); // Wait for display
    state = 0; // Reset state
  }
  else if (state == 3) // Button long pressed
  {
    Wire.beginTransmission(0x70); // Request OLED to display
    Wire.write(0x0C); // Clear display
    Wire.write(0x01); // Set contrast
    Wire.write(0x0A); // Start display
    Wire.endTransmission();
    delay(1000); // Wait for display
    state = 0; // Reset state
  }
}
```

Printing canceled.

1 - 101
APPENDIX G
QUANTITATIVE RESULT FROM THE FIRST USER TEST

AUTONOMOUS DRIVING

In general, do you find the information on the head up display understandable (speed limit sign, takeover icon, journey overview)? Anything missing?

Do you understand why your car decided to change lanes?

WAKE UP CALL

To what extent can you understand the “wakeup light”?

To what extent are you attracted by the “wakeup light” from what you were doing?

After being woken up from ST, are you more attentive to the driving situation compared with during autonomous driving?

To what extent do you feel the degree of urgency of the wakeup light?

Do you find the wakeup light annoying?
TAKEOVER REQUEST

Is the “takeover light pattern” understandable for you? Can you describe it?

0 not understandable at all 5 totally understandable

Do you find it clear how much time left for you to takeover?

0 not clear at all 5 very clear

Do you find the actual takeover time in consistent with what you assume?

0 not at all 5 The same as I assumed

To what extent do you feel the degree of urgency of the takeover light?

0 not urgent at all 5 very urgent

Do you find the takeover request annoying?

0 not annoying at all 5 very annoying

OVERALL

Do you see clear mode distinctions(clear vibe differences) among autonomous driving, wakeup and takeover?

0 not clear at all 5 very clear

In general, how much do you think the system is reliable in terms of bringing you back to the loop properly and on time?

0 not reliable at all 5 very reliable
INVITATION FOR AN ONLINE EVALUATION

HMI design for a better takeover experience for level 4 long-out-of-loop scenario

Content

1. Virtually experience the takeover transition by watching an animation;

2. Give feedback by filling out a questionnaire and also through conversations.

General info

DATE: Any time between Tuesday to Friday (7th - 10th April)

DURATION: Approx. 20 - 30 mins   LOCATION: Online via Skype or Zoom