APPENDIX A

"SAFETY FIRST FOR AUTOMATED DRIVING" WHITE PAPER 12 GUILDLINES:

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:

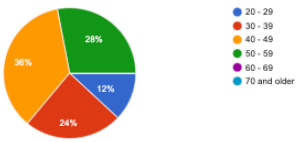
- **Safe Operation:** How the system reacts if critical components become unstable or cease functioning
- **Safety Layer:** The system recognizing its limits and minimizes risk in returning control to the driver
- **Operational Design Domain (ODD):** The operating conditions in which the system is designed 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

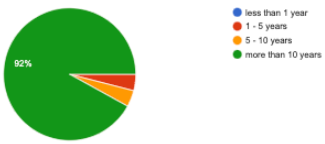
How old are you?

25 responses



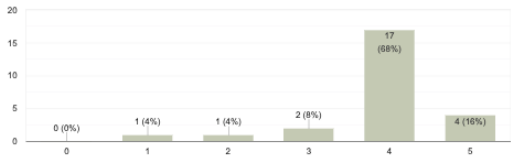
How many years of driving experience do you have?

25 responses



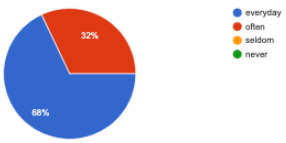
While you are driving on your own, to what extend would you rate your performance?

25 responses



How often do you use the Autopilot function?

25 responses



Under what kind of circumstances would you use the autopilot function?

25 responses

Highway
Highway and primairy roads (N-wegen)
Use normal autopilot on Autobahn, country roads and major city streets.
Autobahn, lane changes, acc, highways outside of germany almost entirely driven by ap
Everywhere, to help train the network
outside of cities: on motorways and country roads
On the highway during my commute.
Highway and traffic jam
Highway using NOA

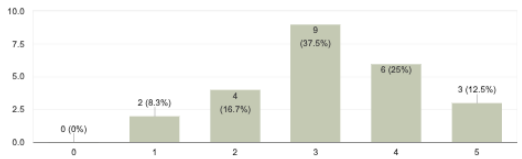
Did you ever have bad or unexpected experience while using Autopilot? Can you try to describe one worst experience when using the autopilot?

23 responses

In less then 1% of total distance I used AP it suddenly brakes sometimes. Most of the times due to wrong speed adjudtments or a fly over (viaduct) I am passing.
Sometimes phantom breaks on the autobahn. Ignoring barricades in construction zones.
Car swerving 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

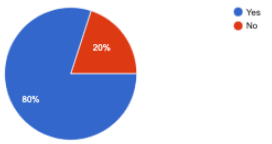
While you are using autopilot, for instance, adaptive cruise control or lane centering, to what extent would you rate your performance at that state?

24 responses



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

25 responses



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 phone, 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

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

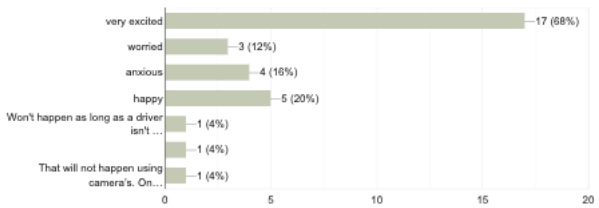
25 responses

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

25 responses

Imagine in the future, when there are highly automated vehicles, you can even play video games/read 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



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 fleel 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 unpredictible.

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 site 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 sa 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 tor happen; 3. The importance of situational awareness.

Aim:

- Validate the takeover transition experience and current painpoints
- 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 r the current painpoints? 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?

Take over transition experience

1. **Since below level 2, human are fully responsible for the driving task, so there is no so called takeover for level 0,1,2. 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 are 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?

No.	Scenario	Urgency urgent<5s non-u<10s	Complexity of drivers reaction
1	The absence of road/lane markings or blurred lane markings or secondary lane marking due to construction		
2	The lateral vehicle guidance is discontinued during a straight or curved road segment(high road curvature)		
3	The failure of sensors		
4	Road works require Change to another lanc		
5	Bad visibility due to bad weather conditions like fog, heavy rain etc		
6	Cut-in vehicle is not detected		
7	Pedestrians enter road		
8	Obstacles on the road		
9	The driver is requested to select a particular route or leave the highway		

Table. Scenarios of takeover request

Reference:
Bazilinskyy, P. (1970, January 1). Auditory feedback for automated driving. Retrieved from https://doi.org/10.4233/uuid:51dbba63-ba7c-4958-ab7d-d6dc182ec5b5.
Kuehn, M., Vogelpohl, T., & Vollrath, M. (2017, May). Takeover times in highly automated driving (level 3). In 25th International Technical Conference on the Enhanced Safety of Vehicles (ESV) (pp. 1-11).

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 beep and draw the attention from the driver. They then take over the control and deal with whatever the situation is in front of them.
Bastiaan	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.
Bastiaan	but nowadays i see more going towards the less forced take overs we r trying to avoid using technology.
Bastiaan	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 she is not, then we say no you cannot take over.
Bastiaan	for level 4 if you know the takeover is coming. It can prepare ppl more to a good mental state. It's hard to say something definitive. If it is level 3 then the car not necessarily know the problems.
Bastiaan	In level 4, it is a problem when someone takes over and they are not in a good state of mind.
Bastiaan	If they dont know whats going on around and they grape 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.
Bastiaan	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 sth to say "oh, here is the control back and have fun."
Bastiaan	That is one thing i guess, **making sure that the driver is in the good state before the takeover in level 4 at least.**
Bastiaan	In level 3 is **keeping the driver engaged and make sure he is at least awake and ready to takeover.**
Bastiaan	On the other hand, sometimes, the safe pull over is not that safe. Pullover to the hardshoulder is not super safe right. It is safer than crashing into another car. But you wouldn't prefer it.
Bastiaan	Making sure the driver gets back to the good state or situational awareness is one of the most important thing in level4. Especially there is a long drive.

Bastiaan	Level 4: Getting the driver back to the state, you can approach that in different ways. For example, you can check is he in the right state. Do we give back control? If not, don't give back the control. Or we maybe can help him getting back the control, help him look around, you should check the mirror first for example. I would help him to prepare the TOR, 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.
Bastiaan	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
Bastiaan	We have been investigating stability control, stability off control after you take over so especially in dangerous situations where you have to steer.
Bastiaan	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.
Bastiaan	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.
Bastiaan	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.

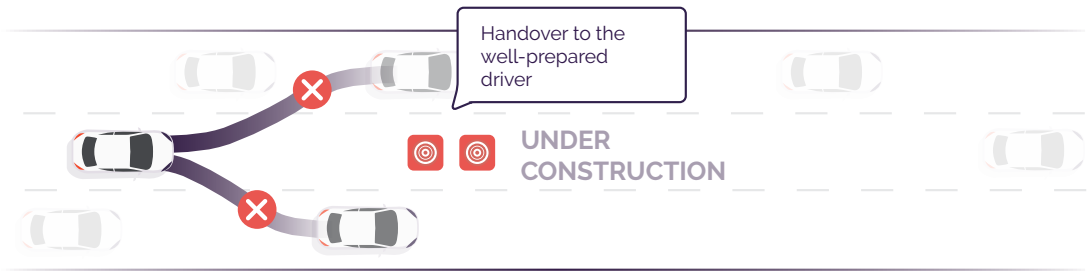
Joost	Level 4 there is also not much research about it, maybe it is too far into the future.
Joost	But of course we have this question about how should the car go to this minimal risk condition. How should human being informed about it. In principle.
Joost	So for level 4 there is also transitions the planned transition which actually very important.
Joost	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.
Joost	What could you measure there? Maybe aftereffects which mean after long driving you are not really consistent with your steering wheel anymore.
Joost	ppl just do very much the same thing. It's all level 2 and level3 in literature. Actually everyone is talking about automation. Why not? i dont know? It's a more fashionable topic but it does not mean the most important. Ppl sort of jumped into the topic and start doing it.
Joost	Of course, there are questions like what is situational awareness if it is even one dimensional variable?
Joost	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 the sa is quite high. It depends on the task you give ppl. Talk about current tesla, ppl 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 in that the sa is always low it really depends on the context or the task.
Joost	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 xx continually tells you where other cars are. It would allow you to maybe maintain sa during automated driving.
Joost	you could have a car talks what it's doing. The problem however is also it distract ppl's attention. Ppl start to look at the display. It's not all positive. Not only visual, because it will not work.

Joost	Ppl has used vibrations. I think that is sort of solved problem.
Joost	I think that is sort of solved problem. If you have 10 s 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.
Joost	Many manufactures have warning during automated driving like tesla/Volve: 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.
Joost	And the big question is "is it reasonable to ask the driver to takeover the control in like 7s on the road."
Joost	This is the big question that i think has not been answered. Or the whole level 3 should be skipped.
Joost	I think nobody knows see where the future brings us
Joost	It should be proven whether driver takeover the control in the middle of the highway unexpectedly.
Joost	For the notification, what you need is auditory and then plus vibration. There are two things, firstly you should "wake up" and quickly grape the steering wheel quickly. Secondly, the driver should also make an action. They driver should have sufficient time to do that.

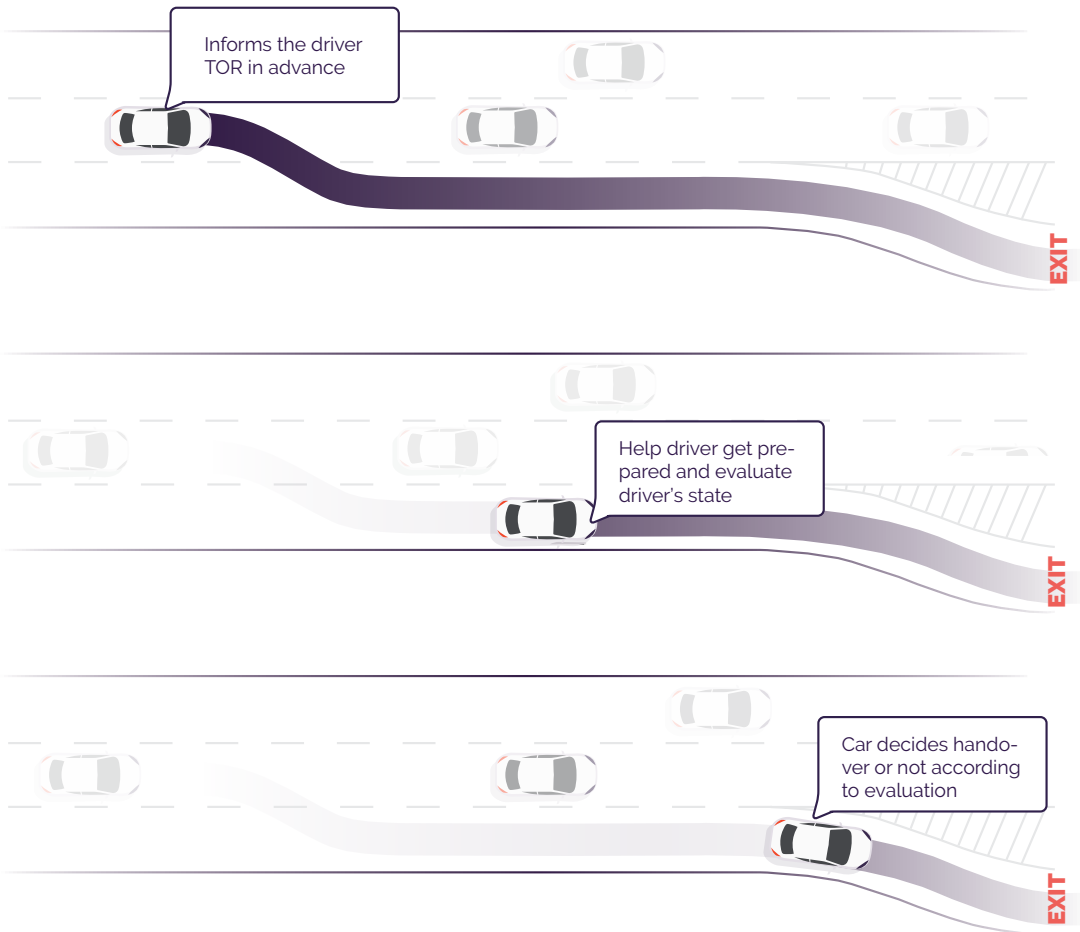
APPENDIX E

VISUALISED USE CASES

1. Level 3:Automation initiation driver ready TOR



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



APPENDIX F

ARDUINO CODE

sketch_feb27a

```
#include <ArduinoSTL.h>

#include <FastLED.h>

CRGB b[30];
CRGB x[30];
int i;
int Button1Value = 0;
int Button2Value = 0;
int Button1 = 2;
int Button2 = 3;
int c = 0;
int d = 0;
int a = -600;

int state = 0;

void setup() {
  pinMode (Button1, INPUT);
  pinMode (Button2, INPUT);
  FastLED.addLeds<WS2812, 7, RGB>(b, 30);
   FastLED.addLeds<WS2812, 5, RGB>(x, 30);
  Serial.begin(9600);
  for (i = 0; i < 30; i++) {
    b[i] = CRGB(198, 78, 199);
        x[i] = CRGB(198, 78, 199);
  }
}

void loop() {
  Serial.print(a / 300);
  FastLED.show();

  Button1Value = digitalRead(Button1);
  Button2Value = digitalRead(Button2);

  if (Button1Value != 0) {
    state = 1;
  }

  if (Button2Value != 0) {
    state = 2;
  }

if (state==1) {
    for (i = 0; i < 30; i++) {
      b[i] = CRGB(198, 78, 199);
        x[i] = CRGB(198, 78, 199);
    }

    FastLED.setBrightness(c);


    if (d == 0) {
      c++;
    }

    if (c > 254) {
      d = 1;
    }

    if (d == 1) {
      c--;
    }

    if (c < 1) {
      d = 0;
    }

    FastLED.show();
    delay(5);
  }

if (state==2) {

    FastLED.setBrightness(c);

    if (d == 0) {
      c = c + 2;
    }

    if (c > 254) {
      d = 1;
    }

    if (d == 1) {
      c = c - 2;
    }

    if (c < 2) {
      d = 0;
    }


    a = a + 1;
    b[a / 200] = CRGB(0, 0, 0);
    x[a / 200] = CRGB(0, 0, 0);


  }
}
```

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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?

not understandable at all — *totally understandable*

Do you **understand** why your car decided to change lanes?

not understandable at all — *totally understandable*

WAKE UP CALL

To what extent can you understand the "wakeup light"?

not understandable at all — *totally understandable*

To what extent are you **attracted** by the "wakeup light" from what you were doing?

not attracted at all — *completely attracted*

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

less attentive — *fully attentive*

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

not urgent at all — *very urgent*

Do you find the wakeup light **annoying**?

not annoying at all — *very annoying*

TAKEOVER REQUEST

Is the "takeover light pattern" **understandable** for you? Can you describe it?

not understandable at all *totally understandable*

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

not clear at all *very clear*

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

not at all *The same as I assumed*

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

not urgent at all *very urgent*

Do you find the takeover request annoying?

not annoying at all *very annoying*

OVERALL

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

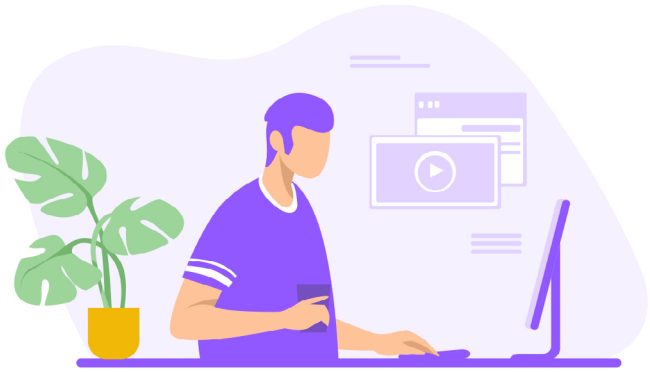
not clear at all *very clear*

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

not reliable at all *very reliable*

APPENDIX H

INVITATION LETTER TO THE FINAL EVALUATION

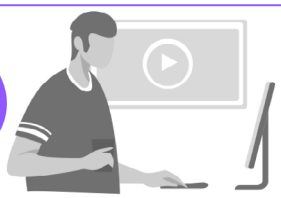


INVITATION FOR AN ONLINE EVALUATION

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;

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

2

General info

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

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

Mediator

TU Delft