**Mobius Features**

**High mounted display**
Depicting relevant driving related information. While automated driving a Smartphone mirroring is available on the screen.

**Gaze detection**
distinguishing driver's attention on road or display.

**Hands-on detection**

**Steering Wheel** 2 touch displays with integrated press buttons to control display content.

# New HMI Concept for an Intuitive Automated Driving Experience and Enhanced Transitions

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## Abstract
A new Human Machine Interface (HMI) concept – called Mobius - for automated driving, which enables drivers to keep their hands on the steering wheel while completing non-driving related (NDR) task, is tested and evaluated. A surprise takeover request reveals faster reaction times when either using Mobius or monitoring the traffic compared with using a smartphone for NDR task. Usability and User Experience Rating showed that Mobius HMI was rated as usable as smartphone while driving automated and that driving automated with Mobius is rated significantly more convenient and less distracting. The results indicate the potential of this concept to combine safer automated driving and modern user interface experience.

## Introduction
As long as cars are equipped with steering wheels and pedals, there remains a dilemma when thinking about automation: the driver is degraded to monitor the car, but human beings are not made for this [1,12]. The main advantage of automation is that the driver is taken out of the loop and distracted but therefor can perform non-driving related (NDR) tasks, such as texting, reading or surfing [8]. Such tasks are highly demanded by the users [10]. HMI designers need to come up with concepts that allow safe transitions between automated driving and manual driving and

**Design and procedure of the study**

**Warm up drive:** Besides of general instructions Participants could get to know the driving simulator, the automated driving mode and the Mobius HMI system.

**Surprise Evasion:** in an in-between subjects design the participants had to react to a sudden takeover request. To each condition a third of the sample was assigned.

**Training:** The participants had 4-8 test drives and learned to evade either to the left or right lane after the takeover request.

**Learned Evasion**: In a within-subjects design the participants had to make 4 drives (3 conditions and one placebo) in randomized order. Subjective Rating of Systems Usability and takeover task after Smartphone and Mobius condition.

**Debriefing:** Subjective rating and evaluation of Mobius and Smartphone, Price Estimation of Mobius.

additionally provide a great modern user experience which help to shift from joy-of-driving to joy-while-driving.

Valeo's Mobius HMI from CES 2015 [4, 9] is such an approach which shall allow a safe and comfortable conduct of NDR tasks while assuring safe driving, a reasonable situation awareness and minimized reaction times for taking over the vehicle control from automated into manual mode. It is an innovative concept consisting of a steering wheel with integrated touch-press displays, a High Mounted Display (HMD), hands-on-wheel and eyes-on-road detection and the possibility of smartphone mirroring. The two touch displays in the steering wheel allow control of multiple, situation adaptive functions. Valeo Mobius is made to bridge the needs between SAE level 2 and 3 automation and hence to suite drivers who still must monitor the driving tasks and drivers who are out of this loop [11].

## Technical Setup and Test Scenario

In a driving simulator experiment the Mobius HMI was evaluated and tested. Therefor the Mobius HMI was installed and connected with the Fraunhofer IAO driving Simulator (for more details compare [6, 7]). This setup also included a mirrored Samsung, Galaxy Note 4 smartphone. In the Baseline condition the participants had to keep their hands on the wheel and monitor the traffic while driving in automated driving mode through a traffic jam on the motorway. This setup represented today's series state of the art. In the Mobius and Smartphone condition the participants had to read a newspaper article as secondary task, either on the Mobius HMD or on the 5.7 inch screen smartphone in their lap. Scrolling with Mobius was conducted with the touch-press buttons on the steering wheel with the right hand. Scrolling on the Smartphone was done by swiping the text. The three conditions are also depicted in Table 1 and Figure 1 regarding distraction and position of head and hands.

| Distraction | Condition | | |
|---|---|---|---|
| | **SAE Level 2 Baseline** | **SAE Level 3 Mobius** | **SAE Level 3 Smartphone** |
| Manual | – | – | ✔ |
| Visual | – | o | ✔ |
| Cognitive | – | ✔ | ✔ |

**Table 1.** Type of Distraction for each condition.

**Figure 1.** The position of the head and hands for each condition. From left to Right: SAE Level 2 Baseline with hands on wheel, SAE Level 3 Mobius and SAE Level 3 Smartphone.

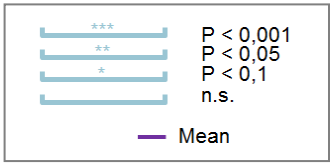
The car was driving with 60 km/h in a traffic jam, when the automated driving mode turned off. The participants were informed by a take over request (TOR), consisting of a gong sound, red flashing lights on the windshield and a change of the screen on the cluster screen to take over the control of the vehicle.

They had 3.6 sec to react otherwise an automated emergancy brake would have stopped the car.

**Figure 2.** The scenario in the moment of TOR.

| SUS | Mobius | Smart-phone |
|---|---|---|
| Mean | 72.3 | 71.4 |
| Median | 72.5 | 70 |
| Max. | 97.5 | 97.5 |
| Min. | 37.5 | 37.5 |
| Variance | 337.9 | 219.2 |

**Table 2.** The Scores of the SUS for both conditions (N = 41). A t-Test revealed no significant differences.




## Results and Interpretation

A total of 49 participants were tested (Age mean 36.5 years, Range 23-71 years), including few dropouts depending on the analysis. In Figure 3 the results of the reaction time to the over taking request are depicted. A more detailed description and analysis regarding the reaction time can be found in [5].


**Figure 3.** Brake reaction times after TOR (Baseline N = 12, Mobius N = 16, Smartphone N = 13 + 1 who did not react within 3.6 s).

The reaction times show 100ms faster reaction in baseline condition compared with Mobius, which does not become significant in a two tailored, in-between subjects t-test. Smartphone condition shows significatly slower reaction times compared to Mobius 520ms in average and Baseline (620ms).

After this surprising take over situation all participants got involved several times more in NDR reading tasks that they should perform either with Mobius or with the Smartphone, in order to compare the user experience of both HMI concepts for NDR tasks. Several take overs where introduced. The usability and comfort of using Mobius or Smartphone for NDR tasks and take over situations was compared with the standardized System Usability Scale (SUS) by [3] and tailor made interview questions. The SUS revealed no differences in the subjective rating on usablity between Mobius and the Smartphone (see Table 2). On the single items of the SUS, Mobius is always equally or higher rated than the Smartphone, it significantly exceeds the Smarptphone in the items on confidence and frequency of use.

A 5 point Likert scale with statements concerning the driving experience with Mobius or Smartphone reveals that our participants rated significantly (*,**,***) in favor of Mobius (see Figure 4):

1. If I would drive autonomously, I was relaxed when using the system. ***
2. The use of the system increases the joy of driving.
3. The system distracts from dangers. ***
4. The system increases traffic safety.
5. Whilst automatic driving the driving comfort is increased with the system. **
6. The system increases stress while driving. *

**38 out of 41 prefer to use Mobius rather than the smartphone**

**Qualitative statements** of participants when asked for advantages/ disadvantages of each system (# of mentions)

**Mobius advantages:**

- Eyes are on the road (34)
- You are closer to the traffic situations (34)
- Hands stay on the wheel (17)

**Mobius disadvantages:**

- You have to get used to the handling (16)
- Maybe false sense of security due to cognitive distraction (3)

**Smartphone advantages:**

- Handling is well known (19)
- Smartphone has more functions (5)

**Smartphone disadvantages:**

- You have to put Smartphone away before you can react (18)
- Eyes are too far from traffic (17)
- It's a distraction (14)

7. The use of the system stresses the driver.
8. In automated driving sections I feel safe when using the system. *
9. In automated driving sections, I am a little distracted from the driving process.

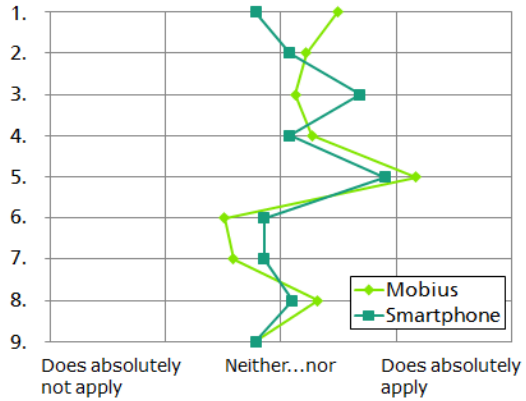



**Figure 4.** The 5 point Likert Scale. The corresponing items to the numbers can be found in the text.

These results indicate that an HMI enabling to monitor the surrounding traffic whilst automated driving not only increases convenience and comfort but also the percieved safety while automated driving.

At the end of the study the participants were asked to rate which system they would use if they had to choose, which system is safer to use and which system is more comfortable to use. In addition the participants had to base their decision (the most common arguments can be found in the textbox on the left side). 38 out of 41 participants would use the Mobius HMI and not the smartphone for reading while automated driving. Mobius is rated safer than Smartphone by 36 out of 41 participants. For the task of reading and scrolling text the use of Mobius was more comfortable than Smartphone for 22 out of 41 drivers.

## Discussion

All in all the results support the hypothesis that a HMI concept like Mobius has the potential to disarm the tradeoff dilemma between taking the driver out of the loop via NDR tasks, whilst leaving him with full accountability for the driving process since both distraction of the NDR task and the effort to monitor the traffic are minimalized. The concept enables the driver to accomplish highly demanding NDR tasks and to take over manual control within a significantly shorter time than when using a Smartphone. The short reaction times may be traced down to the hands on wheel position, but also peripheral visual contact to the traffic scene may help to maintain fundamental situation awareness and faster attentional shift. However there is a strong need for further research – especially on the question which tasks can be performed with Mobius safely even in SAE Level 2 automation and further insight on the maintenance of situation awareness while being heavily involved in NDR tasks. Even though 16 users stated that they need to get used to handling of Mobius, all users were able to operate all functions of Mobius after the initial learning phase of approx. 5 minutes. User comments naming a possible false sense of security while using Mobius need to be taken seriously. Such effects are known for Head-Up Displays and have been called cognitive or perceptual tunneling [2, 13]. Hence further in depth studies are needed to conclude on the potential of this concept, understand which features of the concept contribute most to the results and which further enhancement is eventually needed.

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