SUMMARY OF "INDICATING CHANGE: COMPARING TRADITIONAL AND MODERN TURN SIGNAL CONTROLS"

This study investigates how alternative turn signal interfaces affect driver attention and experience, particularly in comparison to the conventional stalk interface. As modern vehicles increasingly transition toward digital controls, manufacturers like Tesla have replaced traditional stalks with steering wheel-mounted buttons. This trend raises questions about safety, usability, and driver distraction, prompting this research.

Research Motivation

Most prior research in human-computer interaction (HCI) within vehicles has focused on tertiary tasks (e.g., infotainment). However, secondary controls—like turn signals—are crucial for road safety and driver communication. With regulatory bodies such as Euro NCAP emphasizing the importance of physical buttons for key functions, this study addresses an important research gap.

Methodology

The authors conducted a within-subject lab-based driving simulation using *Euro Truck Simulator 2*, modified to simulate a passenger car. Twenty licensed participants (10 frequent and 10 infrequent drivers) completed four driving routes using four different turn signal interfaces:

(1) Traditional stalk
(2) Tesla-style steering wheel buttons
(3) VW-style inner rim buttons
(4) Citroën-style fixed rocker switch

Each interface was recreated using tactile push buttons and connected to the simulator via an Arduino. Eye-tracking data were collected with Tobii Pro Glasses 3, while perceived usability was assessed using the System Usability Scale (SUS) and semi-structured interviews.

Key Findings

- **Usability:** The traditional stalk achieved the highest SUS score (95.1), significantly outperforming the Tesla (59.3), VW (63.5), and Citroën (69.4) interfaces.
- **Driver Attention:** Eye-tracking showed the stalk exhibited the lowest gaze duration and visit count. Tesla and VW interfaces, especially, demanded more attention due to their position on the rotating steering wheel.
- **Error Rate:** Turn signal error rates were low and not significantly different across interfaces, though a small number of participants were responsible for most errors.
- **Qualitative Feedback:** The stalk was perceived as intuitive and easy to use. Tesla and VW interfaces received strong criticism, especially regarding usability in roundabouts. Citroën's interface received mixed feedback, with some appreciating its familiarity and others noting physical awkwardness.

Conclusion

The conventional stalk remains the preferred method for turn signaling in terms of usability, minimal distraction, and user satisfaction. Tesla and VW's modern interfaces, while sleek, introduce cognitive and physical challenges that can compromise safety. The Citroën interface presents a potential compromise but yielded mixed reactions. Results also suggest that user familiarity plays a major role in interface preference.

Limitations and Future Work

Limitations include the use of simulated interfaces and environments, and potential bias due to participant familiarity with the stalk. Future work could involve novice drivers to isolate intuitiveness from learned familiarity, and testing with higher-fidelity interface prototypes.

Indicating Change: Comparing Traditional and Modern Turn Signal Controls

Jane Asp Strøm
jstram20@student.aau.dk
Aalborg University
Aalborg, Denmark

Oliver Esman Pust
opust20@student.aau.dk
Aalborg University
Aalborg, Denmark

Thomas Baaré Cornelius
tpe17@student.aau.dk
Aalborg University
Aalborg, Denmark

ABSTRACT

The automotive industry's shift toward digital interfaces has led to significant changes in how drivers interact with in-vehicle controls, including turn signals. This study investigates how alternative turn signal input modalities, such as steering wheel buttons inspired by Tesla, a VW patent, and Citroën's pod-type interface, affect driver attention and usability compared to the traditional stalk. Using a simulated driving environment, 20 participants evaluated four interfaces through a mixed-methods approach involving eye-tracking, System Usability Scale (SUS) questionnaires, and post-test interviews. Results consistently showed the traditional stalk as the most effective interface, requiring the least additional attention from the driver and receiving the highest usability scores. Interfaces mounted on the steering wheel (Tesla and VW) were less intuitive and more distracting, particularly in roundabouts, while the Citroën interface offered a compromise with mixed feedback.

KEYWORDS

HCI, Turn signaling, stalk, alternative input modalities

1 INTRODUCTION

The automotive industry has undergone a significant shift with the adoption of advanced Human-Machine Interfaces (HMIs), such as touchscreen interfaces, which have become a prominent feature in modern vehicle design [16]. These advancements have also caused the automotive industry and automobile manufacturers to move previously physical interactions and functions to touchscreens, resulting in a loss of driving safety [20].

The car safety performance assessment programme, Euro NCAP, have begun tackling this problem by revamping their rating system to require physical buttons or switches for functions such as the car's horn, windshield wipers, turn signals, hazard warning lights and SOS features in order to get the highest safety rating [7].

Geiser establishes a distinction between three categories of tasks involved in driving [8]. Primary tasks, which are essential for vehicle control (such as accelerating, braking, and steering), secondary tasks, which are task related to safely operating the vehicle (gear shifting, using windshield wipers or operating lights), and tertiary tasks, which involve non-essential functions such as adjusting comfort settings, entertainment, or infotainment systems. Among the secondary tasks, turn signals are essential in ensuring road safety as they communicate intent to other drivers, and a stalk-based turn signal is the established standard for controlling the turn signal.

In the 1970s and 1980s Citroën attempted to move the interaction to buttons on a pod behind the steering wheel. This did not gain widespread adoption at the time, but newer attempts have been made to move the turn signal, most notably with Tesla moving the turn signals to buttons on the front face of the steering wheel. This move has been criticized for causing difficulty while the steering wheel is turned and requiring more attention from the driver [6, 18].

The effects of this have not been studied; therefore, we explored existing research on the impact of different input modalities for turn signals in vehicles. We search for academic literature using variations of keywords related to turn signals. Our exploration resulted in no articles relating to activating turn signals. However, a number of articles explored various input modalities for manipulating the car radio and similar tertiary driving tasks [8]. With the new development of changing the placement of the turn signal, as Tesla did with the Model 3 [17]. We want to explore the effect of different input placements and modalities, resulting in the following research question:

"How do alternative turn signal interfaces affect driver attention and experience in a simulated driving environment?"

2 RELATED WORK

2.1 Interface research on tertiary tasks

Previous work investigating alternative input modalities has largely focused on tertiary tasks, such as those found in In-Vehicle Infotainment Systems (IVIS). These studies typically explore the integration of voice commands, touch interfaces, and gesture-based controls to support user interaction in non-critical contexts. In 2008, Bach, et al. [3] compared tactile, touch, and gesture when interacting with a radio. Their results showed that gesture interactions caused largest amount of rapid eye glances, less than 0.5 seconds, for hand/eye coordination, but finding no glances longer than 2 seconds, which they considered devastating for driving performance. Tactile was found to have the highest average task completion times, the most eye glances, and the highest number of incomplete assignments, although the feedback of tactile interactions was appreciated by the participants. Touch interaction had fastest task completion time and fewer eye glances although not significantly better than tactile, additionally touch had more glances longer than 2 seconds.

Another study from 2016 compared two modalities; speech & touch, while interacting with IVIS [2]. The study found that the time taken to complete tasks were lower when using touch, however the number of interactions were lower when using speech. They also did not find any significant difference when it came to usability, subjective workload, and emotional response [2].

Additionally in 2023, Zhang, et al. [22] conducted a study comparing three modalities of interaction, when using IVIS; touch, speech, and gesture based interactions. The study compared the modalities based on impact on driving performance. The results showed that touch-based interactions had the largest negative impact on driving performance, with gestures following closely. Speech-interactions had the least impact on driving performance overall.

In their evaluation both Bach, et al.[3] & Angelini, et. al.[2] looked at both *Primary driving performance* and *Secondary driving performance*. However, the same measures were not used. Bach, et. al. measured *primary driving performance* by lateral and longitudinal control errors (i.e. loss of lateral control, lane excursions, speed maintenance, acceleration, etc.), while Angelini, et. al. used the driving task completion time, traffic violations, and accidents/collisions. Their definitions for *secondary driving performance*, are closer related. Both papers used task completion time. Bach. et al. used the amount of interaction errors, while Angelini, et al. counted the number of interactions to complete the task.

In addition to this, Bach, et al. [3] also used *Eye-glance behavior* as a measurement of driver attention, where Angelini, et al.[2] used the DALI questionnaire to measure subjective workload. Angelini, et al. also used additional questionnaires; for 'Percieved usability' they implemented a System Usability Scale (SUS) and a PANAVA-KS to measure the 'Emotions' of the participants.

Different from the other articles, Zhang, et al. [22] evaluated 'driving safety' by using a combination of metrics. They used mean velocity of the vehicle, mean lateral position, minimum Time To Collision (TTC), & reaction time to hazard. While mean velocity and mean lateral position relates to the lateral and longitudinal controls of the other articles, TTC and reaction time to hazard are new metrics here.

2.2 Alternatives for stick/stalk turn signal switch

The standard interaction type for operating the turn signal is the stalk, a stick most commonly placed on the left side of the steering wheel, in countries with right-hand driving. However, there has been experimentation from different manufacturers throughout the years, these experiments include but are not limited to:

Steering wheel mounted buttons can be seen in Tesla's model 3 2024 edition [17], see **Figure 1a**, where the turn signal is controlled via two capacitive buttons placed on the left side of the steering wheel. A similar implementation have been tried by Ferrari with the Ferrari 458, see **Figure 1b**. The buttons are mounted on their respective sides of the steering wheel within thumb reach for the driver.

A patent by Volkswagen [21], see **Figure 1d**, describes a different approach to buttons on the steering wheel. Here several buttons are placed along the inner rim of the steering wheel. These buttons are multifunctional and dependent on input from the driver, and fulfill either secondary tasks, such as controlling light systems, or tertiary tasks, such as operating the infotainment system.

A lever-like solution was used by the Isuzu Impulse, see **Figure 1c**, where a three-step lever switch is placed where the end of the stalk would normally be. It could be engaged in the same manner as a stalk, by flicking it up or down.

Citroën has with the CX, Axel, and Visa experimented with a pod-type solution to replace the stalk, as shown in **Figure 1e-g**. With the pod-type, the turn signal functionality was fulfilled by a rocker switch that followed the directionality of the steering wheel. These pods were placed behind the steering wheel with placement generally in the same area as where a stalk would have been.

3 METHODS

To evaluate the different turn signal control interfaces, we conducted a lab test, in which we used a mixed methods approach, as we wanted both quantitative measures of how the interfaces affected the participants ability to drive safely, and qualitative measures of their experience using the interfaces. The experiment was conducted as a within subject design, such that all participants used all interfaces. As installing systems in a car and driving on the roads would be too dangerous, we decided to create a lab study using a driving simulator.

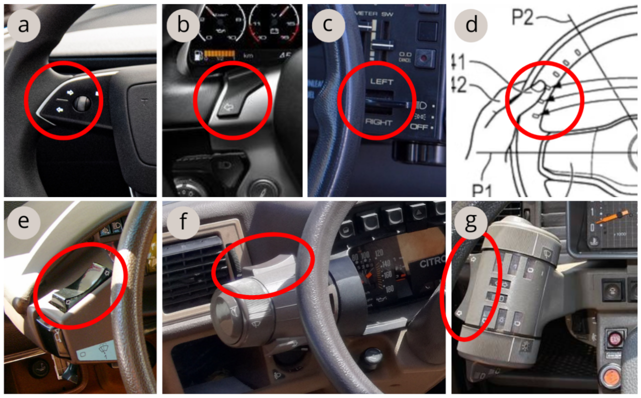

Figure 1: Images of various vehicles: (a) Tesla Model 3, (b) Ferrari 458, (c) Isuzu Impulse, (d) VW Patent, (e) Citroën CX, (f) Citroën Axel, and (g) Citroën Visa.

3.1 Test Setup

For the driving simulator, we used Euro Truck Simulator 2 (ETS2) as the driving program controlled by a Logitech G29 Driving force steering wheel with pedals. The participants were driving with a simplified automatic gear shift, as this did not require additional hardware. To get a more correct field of view, we incorporated a mod that replaces the truck with a car. The mod is a Toyota SW4 SRX vehicle [14]. It was chosen based on positive feedback on online forums highlighting its realistic driving dynamics [5].

We used Tobii Pro Glasses 3 to track if an interface made the participant take their eyes off the road, which is crucial for safety, as inattention to the surroundings was part of the cause of 79% of fatal accidents in Denmark in 2023 [19]. The Tobii Pro Glasses 3 allowed us to track the participants' gaze data, while being able to move their head freely. Additionally, because our area of interest was located at and around the steering wheel, the glasses were chosen as they allowed tracking and recording. This allowed us to follow their point-of-view around the simulator setup instead of being limited to screen capture.

The setup included triple monitors, each measuring 24 inches, to extend the field of view in a way that allows the participant to turn their head to check their surroundings, instead of relying on in-game camera controls.

To minimize distractions and create a more uniform experience, weather settings and traffic violation penalties were turned off. Four driving routes were created. Each took approximately five minutes to complete. They were designed to present similar driving challenges, including multiple left and right turns and at least one roundabout. The route was visible to the participant on the in-game GPS.

3.2 Procedure

Each participant was introduced to the setup and asked to drive around freely, until they felt comfortable with the simulator controls. At the same time, the study procedure was explained.

When the participant was ready, the first turn signal interface was installed and eye tracking glasses worn to record the participants field of view and gaze data. The participant was told how to operate the current interface and then asked to drive the first predefined route according to the in-game GPS. Afterwards, the participant answered a SUS questionnaire, while the interface was changed. This procedure was repeated for each of the four interfaces with a different route for each interface. Both the route order and the interface order were randomized to avoid order bias.

At the end of the session, a short semi-structured interview was conducted to gather further insights regarding their experience and preferences.

3.3 Participants

The test included 20 participants recruited using convenience and snowball sampling. All participants had a valid drivers license. As the Tobii eye tracking glasses were not compatible with prescription glasses, all participants were also required to able to legally drive without glasses. The participants were divided in two groups according to their driving habits. 10 were frequent drivers, defined as driving more than once per week, and 10 were infrequent drivers, defined as driving less than once per week. Of the 20 participants, 6 identified as female and 14 as male, and their ages ranged between 20 and 35.

3.4 Test Metrics

Both qualitative and quantitative data were gathered during the experiment, see **Table 5**, in **Appendix A**

Quantitative data was gathered during each of the evaluations. We collected data from a self-reported questionnaire about the perceived usability in the form of a SUS questionnaire [4]. The SUS consists of 10 statements, where the participant answers based on a 5-point scale ranging from "Strongly disagree" to "Strongly agree". During the calculation of scores, the even numbered items were reversed.

These metrics also include eye tracking data recorded with the use of Tobii glasses, these recordings consists of field-of-view recording from the participant's perspective along with gaze data. The recordings and gaze data was then processed with Tobii Prolab. The raw gaze data was processed and produced data about the number and duration of visits, as these describe how often and how long the participant looked in our Area of interest. We processed the exported data from the Tobii recordings, by first eliminating outliers from the datasets, then checking for normality by using the Shapiro-Wilk normality test. As the data from every interface was not normality distributed, we chose to use Kruskal-Wallis rank sum test to see if there was a significant difference between the interfaces.

3.5 Data Analysis

Qualitative data was gathered after the participant had finished sessions for each of the interfaces, in the form of a semi-structured interview. First, participants were asked about their overall impression of driving with the interfaces. Second, if they felt the need to pay additional attention during any of the four sessions compared to how much attention it required for them to drive normally. Lastly, they were asked if they felt that any part of a particular session was challenging and if they preferred any interface over the others. To analyze the interviews, Conventional Content Analysis (CCA) was utilized[9]. The data was first read repeatedly to gain a sense of the whole, then words were highlighted to capture thoughts and concepts. Through this process, codes emerged and became keywords. The statements were lastly divided between positive and negative statements regarding each keyword.

3.6 Interfaces

To ensure a diverse representation of interaction types, we created four turn signal interfaces. These were based on the alternatives for stalk turn signal control in **subsection 2.2**, see **Figure 1**. The selection was narrowed down to include the conventional stalk and three alternative interfaces. We aimed to include different types of interactions and as both Tesla's and Ferrari's interfaces involve interactions on the face of the steering wheel, we chose to only include the Tesla interface, because it is a more common car. We created an interface similar to the Isuzu and the Citroën. The Isuzu Impulse features a vertical switch similar in functionality and placement to the conventional stalk and the Citroën pod. The last one chosen was the Volkswagen (VW) patent, because it is unique in placement and form.

The interfaces created can be seen in **Figure 2**. All interfaces were created using tactile print push buttons and were connected to the simulator as a controller via an Arduino.

Figure 2a shows the stalk, which was mounted behind the steering wheel and was able to move up and down to activate the turn signal. **Figure 2b** shows the VW type, which was a simplified version of the VW patent **Figure 1d**. In the patent there are 12 buttons on the steering wheel, 6 by each hand. We reduced this to two buttons at the left hand to only include the functionality of operating the turn signals. The top button activated the right turn signal and the bottom activated the left signal. This was chosen to mimic the directionality of the stalk. Originally the Tesla had capacitive buttons, but our interface was created using buttons and therefore had tactile feedback. The surface had arrows to show the direction of the activated turn signal to mimic the original Tesla model. The Tesla type interface can be seen in **Figure 2c**. For the Citroën interface we had **Figure 1e-g** as references and decided to mimic **Figure 1e and f**, as they were similar in placement. We mimicked the placement behind the steering wheel and the rocking switch for the Citroën interface.

For all of the interfaces auto canceling of the turn signal was turned off, as the stalk was not able to be mechanically returned to the neutral position.

4 RESULTS

4.1 SUS data

The results of the SUS score show a preference for using the stalk, as it has the highest mean score of **95,1 (SD = 5.4)** across all participants, as seen in **Table 1**.

The other three interfaces VW, Tesla, and Citroën received lower mean scores **63.5 (SD = 19.8)**, **59.3 (SD = 23.2)**, and **69.4 (SD = 20.7)**, which was not statistically significant from each other($p > .05$), but all are significantly different from the stalk ($p < .0001$).

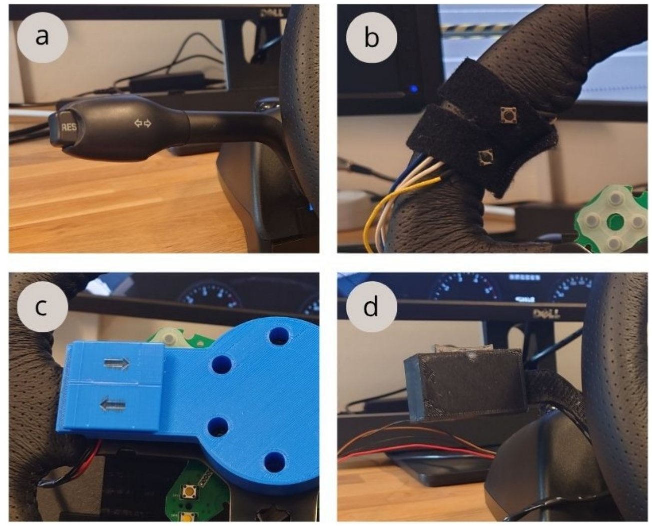

Figure 2: Examples of our interface: (a) Stalk type, (b) VW patent type, (c) Tesla type, and (d) Citroën type.

	Stalk	VW	Tesla	Citroën
Frequent	97.5 (4.2)	62.3 (24.5)	56.3 (26.1)	69.3 (21.5)
Infrequent	92.8 (5.6)	64.8 (15.1)	62.3 (20.7)	69.5 (21.0)
All	95.1 (5.4)	63.5 (19.8)	59.3 (23.2)	69.4 (20.7)

Table 1: Mean SUS score and (standard deviation)

When comparing scores between the participant-groups, **Table 1**, the only interface with a significant difference was the stalk ($p < .05$). The group of frequent drivers scored it a mean score of **97.5 (SD = 4.2)** and the infrequent drives scored it **92.8 (SD = 5.6)**.

Although not statistically significant the frequent drivers scored the other three interfaces lower than the group of infrequent drivers, as seen with VW scoring **(62.3 (SD = 24.5)** against **64.8 (SD = 15.1)**, Tesla scoring **56.3 (SD = 26.1)** against **62.3 (SD = 20.7)**, and Citroën scoring **69.3 (SD = 21 .5)** against **69.5 (SD = 21.0)**.

4.2 Eye Tracking Data

We analyzed the data from the eye tracking using the Tobii Pro Lab, focusing on three main data points: total duration of visits, average duration of each visit, and number of visits. We will forego going through the differences between frequent and infrequent driver on these data points, due to there being no statistical significant difference, except for number of visits using the Tesla interface. Total visit duration ($\chi^2 = 1.7902, df = 1, p > .05$), Average visit duration ($\chi^2 = 0.08316, df = 1, p > .05$), and number of visits ($\chi^2 = 8.5686, df = 1, p < .01$), specifically ($p < .05$) for Tesla. Infrequent driver averaging more visits than frequent drivers.

The eye tracking data shows that across the different metrics the interfaces show a similar pattern. The Stalk exhibited the lowest means and deviations with a mean total visit duration of **1801.95 ms (SD = 2544.46 ms)**, a mean average visit duration of **132.80 ms (SD = 87.50 ms)**. These being spread across **13.90 (SD = 12.40)**

Measure	Stalk		VW		Tesla		Citroën	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total Duration (ms)	1801.95	2544.46	7624.70	2719.29	9675.05	5117.41	3655.35	3339.34
Average Duration (ms)	132.80	87.50	260.95	116.36	340.20	159.01	186.65	105.63
Total Visits	13.90	12.40	33.45	14.71	30.65	18.43	19.90	15.29

Table 2: Performance Metrics by Interface Type

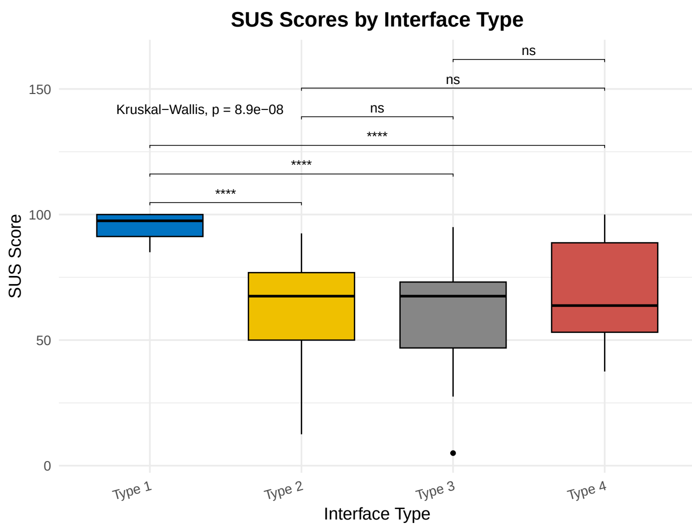

Figure 3: SUS score for each interface type

Significant effects are denoted by ns (p > .05), * (p < .05), ** (p < .01) *** (p < .001), **** (p< .0001).

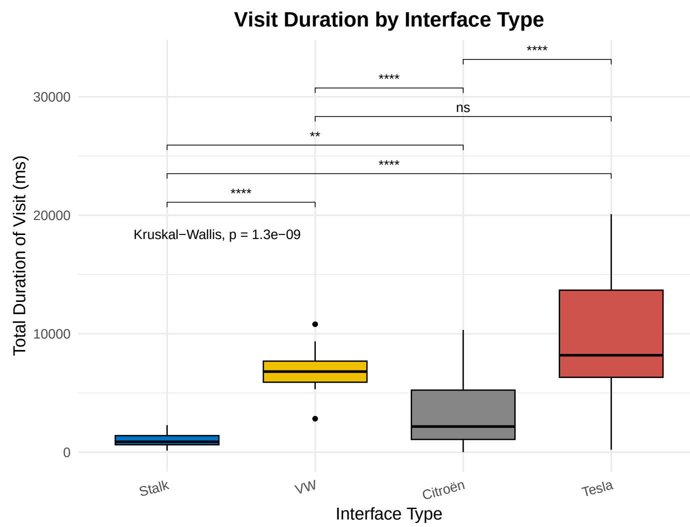

Figure 4: Total duration of visits for each interface type

Significant effects are denoted by ns (p > .05), * (p < .05), ** (p < .01) *** (p < .001), **** (p< .0001).

visits on average. Citroën performed slightly worse, with a mean and standard deviation of **3655.35 ms (SD = 3339.34 ms)** and **186.65 ms (SD = 105.63 ms)**, spread across **19.90 (SD = 105.63 ms)** total visits.

VW and Tesla interfaces performed significantly worse than the Stalk across all metrics as seen in **Table 2**. Both VW and Tesla showed consistently higher total **7624.70 ms (SD = 2719.29 ms)** and **9675.05 ms (SD = 5117.41 ms)** and average visit duration **260.95 ms (SD = 116.36 ms)** and **340.20 ms (SD = 159.01 ms)** as well as increased visit counts **33.45 (SD = 14.71)** and **30.65 (SD = 18.43)**.

Figure 4 shows the mean total duration of visits in the area of interest around the steering wheel for each interface.

There are significant differences between the total duration of the different interfaces ($\chi^2 = 44.382, df = 3, p < .0001$). Participants spend significantly less time looking at the interface when using the **Stalk** compared to **VW** ($p < .0001$), **Tesla** ($p < .001$), and **Citroën** ($p < .01$).

Similarly there is also a significant difference between total durations of **Citroën** compared to **VW** ($p < .0001$) and **Tesla** ($p < .001$).

Whereas no significant difference between the total duration of visits of **VW** and **Tesla** ($p > .05$) were found.

Figure 5 shows the Average duration of a visit, the mean varies from **132.80 ms** to **340.20 ms**.

A significant difference in the average duration of visits between interfaces was found ($\chi^2 = 30.331, df = 3, p < .0001$).

Pairwise comparisons shows a significant difference between the **Stalk** & **VW** ($p < .001$), **Stalk** & **Tesla** ($p < .0001$), and **Stalk** & **Citroën** ($p < .05$), as well as between **Tesla** & **Citroën** ($p < .001$).

There were no significant difference between **VW** compared to **Tesla** ($p > .05$) and **Citroën** ($P > .05$)

Figure 6 shows a significant difference in number of visits between the **Stalk** compared to **VW** ($p < .0001$) and **Tesla** ($p < .001$). There were also a significant difference between **VW** & **Citroën** ($p < .01$). However, there was no significant difference between the **Stalk** & **Citroën** ($p > .05$), **VW** & **Tesla** ($p > .05$), and **Tesla** & **Citroën** ($p > .05$).

4.3 Roundabout differences

Figure 7 shows the different average duration of each interface depending on wether they are driving through a roundabout or following the route. The **Stalk** ($p < .0001$) and **Citroën** ($p < .001$) shows a significant difference between roundabouts and sessions with a lower average visit duration in roundabouts in both, as compared to the whole session. While both **VW** ($p > .05$) and **Tesla**

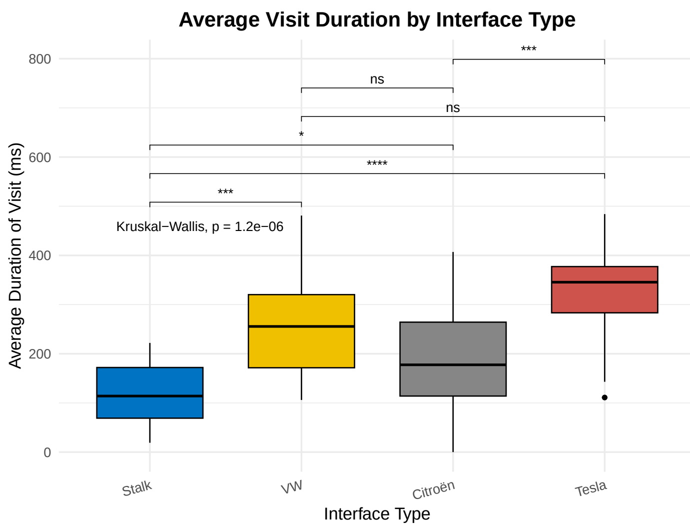

Figure 5: Average duration of visits for each interface type

Significant effects are denoted by ns (p > .05), * (p < .05), ** (p < .01) *** (p < .001), **** (p< .0001).

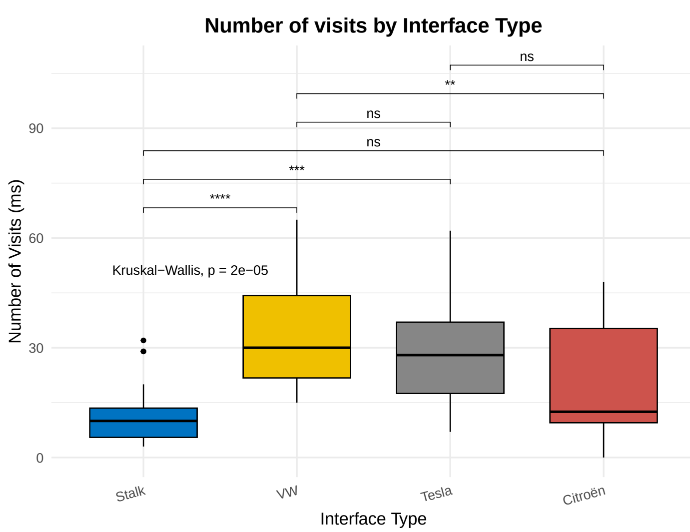

Figure 6: Number of visits for each interface type

Significant effects are denoted by ns (p > .05), * (p < .05), ** (p < .01) *** (p < .001), **** (p< .0001).

($p > .05$) show no significant difference in mean between sections, the variance differs greatly. This indicates that drivers experiences differ to a higher degree using these interfaces compared to the Stalk and Citroën.

4.4 Error Rates

Error rates across the different interfaces were compiled to discover any statistical differences, an error is defined as a participant failing to engage the turn signal before a turn. Failing to disengage the

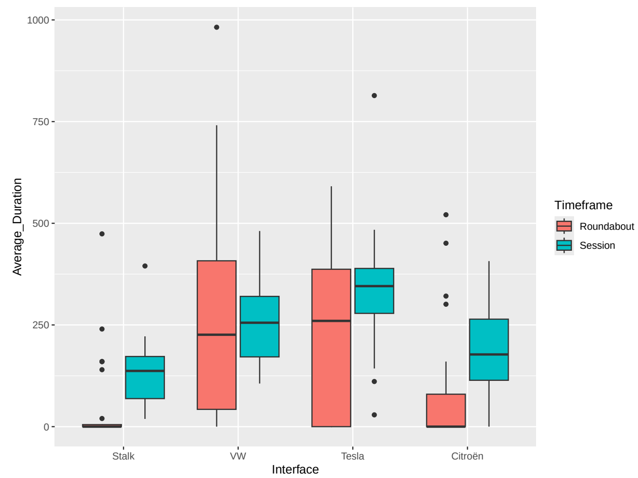

Figure 7: Average duration of visits for each interface type in roundabouts v session

Only type 1 and 4 showcase significant differences between roundabout and session

Interface	Errors	Turns	Error Rate	Chi-square	df	Sig.
Stalk	6	220	2.8%	0.22507	3	$p > .05$
VW	8	218	3.6%			
Tesla	7	224	3.0%			
Citroën	5	220	2.4%			

Table 3: Error counts and rates by interface type

turn signal was not counted as an error. Differences in the total amount of Turns between interfaces are due to the randomization of routes across sessions. A Kruskal-Wallis test shows no significant difference in the error rates between the different interfaces ($\chi^2 = .22507, df = 3, p > .05$). Additionally the data shows that the errors made using each interface were limited to a small number of participants:

- **Stalk**: 5 participants were responsible for the 6 errors
- **VW**: 4 participants were responsible for the 8 errors
- **Tesla**: 4 participants were responsible for the 7 errors
- **Citröen**: 5 participants were responsible for the 5 errors

Lastly, one participant stood out by having made 6 errors alone across the four sessions.

4.5 Interview data

A total of 217 statements were gathered and divided into seven keywords using CCA [9], as described in **subsection 3.5**. The seven keywords were **Roundabout, Safety, Recognizability, Mobility, Attention, Ease of use, and Preferences**. The keyword **'Roundabout'** consists of statements relating to the use of the interface, while driving through a roundabout. The keyword **'Safety'** contains statements relating to the safety of the placement of the interface.

Some participants mentioned that they recognized aspects, e.g the placement or the movement of the controls, these statements were counted in **'Recognizability'**.

Some of the interfaces affected the mobility of the participants by positively matching their movement or negatively hindering their mobility. These statements were counted in **'Mobility'**. The keyword **'Attention'** encompasses statements relating to, if the participant felt that the interface required more or less of their attention to operate. **'Ease of Use'** counts statements regarding if the participants felt that it was easy or difficult to operate the interface and if the placement and functionality of the interface was intuitive to the participant. The last category **'Preferences'**, contains statements offering approval or disapproval with an interface without elaborating further on the reason. These statements were not part of the last interview question about which interface they preferred.

After generating keywords from the statements, they were also divided into positive and negative statements, as done by Kim et al. [11]. The number of positive and negative statements is summarized for each interface and for each keyword in **'Frequency'**. The results of the analysis can be seen in **Table 4**

The results of the analysis revealed that the participants mainly focused on two themes, Ease of Use and Attention, which were mentioned 74 and 34 times. Highlighting their need for an interface that is easy to use and does not require additional attention to operate.

The stalk was mentioned the least among the interfaces, with only 39 total statements, and none of them in a negative context. Most statements were regarding the stalks 'Recognizability' and 'Ease of use'. More than one participant commented that it was what they were familiar with and that it was easy to use. One participant said that, *"Because I am used to driving with the stalk, which is really nice, if you turn to the left, you just flick it on the way, and if you turn right then you flick it again on the way."* Highlighting that the placement and movement of the stalk follows the movement of the participants hand while turning and therefore requiring no additional attention to use.

In contrast, the Tesla and VW interfaces received the most criticism, with 49 and 44 negative statements. Participants expressed frustration and confusion, especially when driving in roundabouts. This keyword was only discussed in relation to these two interfaces and only in a negative context. Participants mentioned that when attempting to use the turn signal in a roundabout, the interface would turn with the steering wheel and no longer be by their hand. As one participant said *"In roundabouts, it is frustrating to have to locate it if you are halfway turned."*

Both the VW and Tesla interfaces had 12 negative statements regarding Attention. The participants mentioned that they needed to look at the steering wheel to locate the buttons before turning, and because the wheel were turned, they sometimes confused the direction of the buttons. A participant said in regards to the buttons being at the bottom of the steering wheel, while turning using the VW interface *"And then you also had to think about the fact that the top button was still higher than the other one"*. The placement of the VW and Tesla interfaces was also a safety concern for some, with one saying *"I don't think it's very safe. I looked down to see where it was"*. Safety was mentioned in a negative context 6 times for VW and 7 times for Tesla. Safety was mentioned in a positive context twice for both, where participant found that the ability to feel the placement enabled them to not look at the steering wheel.

The Citroën interface received mixed reactions with 27 positive and 20 negative statements, but it did not stand out among the other interfaces in any of the categories. A couple of the participants were concerned about the safety of having to move their hand away from the steering wheel to engage the turn signal. Regarding manual gearshift, one participant said: *"It was not possible to change gear on the Citroën while pushing the turn signal and turning. All three things at the same time was difficult to do"*. However, some participants had a different experience, where they preferred the placement of the Citroën, because the placement was similar to the stalk and was stationary. We observed that the participants had roughly two different methods for activating the Citroën turn signal. One was moving their whole hand away from the steering wheel and the other was extending only one finger to touch the button, while keeping the rest of the hand on the wheel. This difference could be part of the reason for the diverse reactions to the Citroën interface.

Keywords	**Interface**								**Freq.**
	Stalk		VW		Tesla		Citroën		
	+	-	+	-	+	-	+	-	
Roundabout	0	0	0	7	0	8	0	0	15
Safety	1	0	2	6	2	7	1	3	22
Recognizability	10	0	2	0	3	3	4	3	25
Mobility	1	0	1	7	0	7	3	4	23
Attention	3	0	1	12	0	12	1	5	34
Ease of use	17	0	14	10	6	10	12	5	74
Preferences	7	0	4	2	3	2	6	0	24
Frequency	39	0	24	44	14	49	27	20	217

Table 4: Conventional Content Analysis of interview data

Table presents interview data sorted into categories and keywords, showing positive (+) and negative (−) mentions per interface.

5 DISCUSSION

The findings across all three data types; SUS scores, interviews, and eye tracking data, consistently show that the conventional stalk interface remains the most effective solution for operating turn signals, while requiring least additional attention from the driver. This aligns with the stalk being the industry standard. However, it is unclear whether this is because of the increased familiarity with the stalk from drivers, as it is the industry standard for turn signals, increasing the bias of the participants. The data revealed differences between user groups. Frequent drivers rated the stalk higher than infrequent drivers, suggesting that habitual use reinforces preference and ease of use. In contrast, infrequent drivers were slightly more open to alternative interfaces, although their overall ratings remained lower than for the stalk.

The Tesla and VW interfaces received the most negative interview statements, lower SUS scores, and the highest visit durations, indicating greater distraction. These interfaces were particularly challenging in roundabouts, where participants reported difficulty locating the buttons mid-turn, due to the rotating steering wheel. However this sentiment were not reflected in the eye tracking data, as no significant difference were found between driving normally and in a roundabout for these interfaces.

In regards to the Tesla interface, this has been an issue in Norway where trouble using the turn signal buttons in roundabouts, have lead to these Tesla models being banned from being used in driving schools [12, 13]. Additionally, this aligns with findings of Bach, et al.[3], as the tesla interface is closer to a touch interface, and they found that touch interfaces produce more eye glances above 2 seconds, which can be critical for driving safety. Our test, however, did not produce any results exceeding an average visit duration above 2 seconds. Our participants' experience using the Tesla interface in roundabouts emulates part of the criticism that Tesla have received in regards to the placement of the turn signal buttons, and lacking feedback. This criticism has led to various journals reporting that Tesla seem to move away from the turn signal buttons, and move back to the stalk[1, 10, 15].

The Citroën interface yielded more mixed results. While not as intuitive as the Stalk, it avoided some of the major issues observed in the Tesla and VW interfaces. This could be explained by it having a placement similar to the Stalk, adding familiarity. Additionally, several participants commented on the direction of the buttons being side by side, as they follow the natural direction of the steering wheel, in contrast to the Tesla and VW buttons being above one another.

The results suggest that user familiarity play a critical role in interface usability for secondary driving tasks. Interfaces that require the user to search visually or demand attention, introduce unnecessary friction and potential safety risks.

The rate of failure to engage the blinker by participants during the trial shown in **subsection 4.4** showed that the failure rate were similar across all interfaces. Participants consistently described the conventional stalk as being the most easy to operate and requiring the least attention. This suggests that using the stalk should result in fewer errors. A possible explanation for this discrepancy is that participants are so familiar with the stalk that they operate it automatically, and therefor may forget it more. In contrast, the alternative interfaces required more deliberate action, which could have increased their awareness and led to more consistent signaling behavior. Additionally, the lab setting could have influenced their behavior, as they were aware that the study focused on turn signals, they may have been more focused on signaling throughout the session, regardless of interface type. However, a few participant were responsible for most of the errors observed, for example, for VW, one participant was responsible for 50% of the errors. This could indicate that the errors were due to outlier behavior by a few participants, therefore, having more participants could decrease the error rate.

6 LIMITATIONS

Several limitations are present within our study. Firstly, the design of the interfaces are all designed and 3D printed, based on pictures of the interfaces they are related to. This presents the issue of not being able to closely represent the original interfaces. An example of this is the Citroën interface, as we have not been able to test and measure the original interface. Specifically the feedback and placement of the interface, which resulted in us estimating these. Furthermore the Tesla variant are made of capacitative buttons, which have not been available to us during the construction of the interfaces, therefore the feedback and design is once again estimated as closely as possible. Although we had a stalk available, the clicking mechanism was not able to be fitted to the G29, the recreated the stalk lacked some functionality (i.e. being softer, and unable to reset itself upon turning the steering wheel) compared to the original, which was also noticed by participants. As the VW interface was from a patent, we could not know exactly how and where it is meant to work, and the feedback of it, therefore making this interface an educated guess and representation.

Finally, in our setup we also had limited choices in regards to steering wheels, causing the steering wheel available to be much smaller than most steering wheels in cars. This was also represented in the size of the interfaces, in an attempt to make them proportional to the wheel.

7 FUTURE WORK

As seen in the interview data, all participant referenced their familiarity with the already established Stalk, resulting in skewed data as seen in Figure 3. We therefore propose redoing the study with participant unfamiliar with driving a car to determine if the stalk is naturally more intuitive and easier to use than the other interfaces showcased in this paper.

8 CONCLUSION

This study explored the impact of alternative turn signal interfaces on driver attention and user experience within a simulated driving environment. Our findings indicate that the conventional stalk remains the user-preferred input modality. While also demanding the least attention from the driver. It outperformed alternatives in all key metrics, including perceived usability, attention demands, and qualitative user feedback.

In contrast, both the Tesla and VW interfaces, featuring steering wheel-mounted buttons, were found to demand more attention. The participants highlighted their grievances with the positions of the interfaces on the steering wheel while driving through a roundabout, due to their movement.

The Citroën interface offered a middle ground between the stalk and the VW & Tesla. In regards to safety, it required less attention from the driver, as they had eyes off the road less. The participants' perceived usability of the Citroen is not statistically significant different from the VW and Tesla interfaces, but scores a little higher. This aligns with their statements in the interview, where participants either liked the placement and directionality of the Citroën or found it to be cumbersome to use.

Overall, the results indicate a clear preference among participants for the traditional stalk interface when operating the turn signal. However, it remains unclear whether this preference is driven by familiarity or by objectively better user experience.

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APPENDICES

A DATA COLLECTION SUMMARY

Data type	Category	Measurement Type	Item	Description	Format
Quantitative data	Eye Tracking Data	Total Visit Duration		The total duration of the visits inside this area of interest during an interval.	Milliseconds
		Average Visit Duration		The average duration of the visits inside this area of interest during an interval.	Milliseconds
		Number of Visits		The number of visits occurring in this area of interest during an interval.	Number
	Self-Reported Questionnaire	Usability (SUS)	SUS1	I think that I would like to use this interface frequently.	
			SUS2	I found the system unnecessarily complex.	
			SUS3	I thought the system was easy to use.	
			SUS4	I think that I would need the support of a technical person to be able to use this system.	
			SUS5	I found the various functions in this system were well integrated.	
			SUS6	I thought there was too much inconsistency in this system.	
			SUS7	I would imagine that most people would learn to use this system very quickly.	
			SUS8	I found the system very cumbersome to use.	
			SUS9	I felt very confident using the system.	
			SUS10	I needed to learn a lot of things before I could get going with this system.	
Qualitative Data	Post-hoc Interview	Pros and cons		What worked and didn't work for each interface.	
		Experience		What were your experiences during the experiment?	
		Attention		Did the participant feel the need to pay extra attention?	
		Challenging		Were any parts of the experiment particularly challenging?	
		Preference		Was there an interface you preferred, and why?	

Table 5: Metric Data Summary