Conditionally Autonomous Drive from a Driver's Perspective: A Survey

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***Abstract*—Since one of the key factors for successful introduction of conditionally autonomous vehicles is a properly designed user interface (UI) for take-over requests (TOR), we believe a systematical approach including drivers' opinion and preferences should be pursued. We have conducted a short online survey with 126 participants asking for drivers' preferences of UI modality, level of transferred information and vehicle behavior during TOR. The participants' answers were in favor of auditory UIs (90%) and followed the "simple is the best" principle – preferring only a single alert, i.e., a beep (37%), for TOR.**

I. Introduction

Autonomous vehicles carry the potential of not only improving road traffic safety, but also of reducing fuel consumption, person's individual carbon fingerprint and costs due to car-sharing possibilities, increasing time efficiency, providing elder mobility etc. [1]. However, before full autonomy in any driving environment is achieved, scientists expect an era of the so-called *"conditionally autonomous vehicles"* when the vehicle is expected to drive autonomously only in specific scenarios (e.g., on the highway) while expecting the driver to take over if the vehicle determines it is unable to safely handle an unexpected situation. In this case, it initiates a take-over request (TOR) and the human driver has to take over (TO) the control in a short period of time [2]. According to Melcher et al. [3], there are two key challenges for conditionally autonomous vehicles: determining time needed for a successful TO and designing a proper user interface (UI) for performing the TOR. These two challenges present the most common motivation of almost every recent research including take-over situations.

Many innovative approaches have been applied for the design of TOR user interface. For example, Borojeni et al. investigated the use of ambient light pattern cues and tactile shape changing steering wheel [4], [5] to inform drivers about the proposed steering direction (left/right) in case of an obstacle on the road. Petermeijer et al. used spatial information with vibrators in driver seat and later compared the unimodal to multimodal approaches [6], [7]. Furthermore, they investigated whether directional TOR stimulus evoked any spontaneous responses. Gold et al. [8] also tried to model driver's responses using machine learning techniques to obtain a deeper insight into TO. However, very few researchers have systematically followed the drivers' opinion of what a satisfactory TOR UI would have been. Therefore, the main motivation of this paper is analyzing drivers' preferences in the design of a TOR UI.

Since we believe a systematical approach including drivers' opinion and preferences should be pursued, we conducted a short survey. Although the drivers' choice may not result in the most efficient UI, not taking drivers' preferences into account may lead to disuse of such products, which could present a huge issue for massive introduction of autonomous vehicles, despite the benefits they offer. Regarding UIs for TOR, only few evident crowdsourcing surveys have been reported. In the most recent, Bazilinskyy et al. reported that users' preferences for stimulus type depend on the urgency of the situation and that multimodal TORs are most preferred for urgent requests [9]. While their work focused on different stimulus types (e.g., a male or female voice, a bell, a horn) and the perceived urgency of a TO, our research divided the stimulus types based on the level of information they could transfer to the driver and included questions about preferred vehicle behavior during TOR. As also reported by Bazilinskyy et al., a drawback of lengthy crowdsourcing surveys is that usually only the very interested population is surveyed. Our work is based on a very short survey (3–5 minutes) where participants did not receive any stimulation.

The three general aspects of vehicle-driver interaction during the TOR that we wanted to survey are: used modality, level of transferred information and driving/personal circumstances. Since we usually cannot influence the latter, this paper only focuses on modality and level of information with an additional insight on preferences about vehicle behavior during TO. It presents the following research questions:

1. *What kind of UI modality is preferred by drivers for TOR?*
2. *What level of information do drivers find useful during the TOR?*
3. *How should the vehicle behave during TOR?*

The rest of the paper is structured as follows: Methodology and the design of the survey are presented in the next section; followed by a graphical presentation of the results, a section with brief Discussion and a Conclusion section with further work.

II. Methodology

A. Survey Design

An online survey was conducted with 1ka.si web platform. It consisted of 14 questions, divided into five groups:

1. Previous experience with driving automation (2 questions),

2. UI modality preferences (2 questions),
3. Information level preferences (2 questions),
4. Expected vehicle behavior during TOR (3 questions),
5. Demography (5 questions).

In the two questions from the second group, the considered UI modalities included:

- Visual stimulus (on the dashboard),
- Auditory stimulus (beeps),
- Tactile stimulus (vibrations),
- Ambient stimulus (ambient light).

Participants also had to choose whether they prefer a constant (static) or a changing (dynamic) stimulus. We divided the possible levels of transferred information (third group of questions) into four types:

- Alert: only a take-over request (TOR), with no additional information;
- Directional alert: alert including the information of the obstacle's direction (e.g., sound beeps from a specific direction);
- Category: predefined possible categories of take-over scenario with specific stimuli patterns;
- Description: a brief description of the situation as perceived by the vehicle (textual or narrated).

One of the questions also included the interaction between UI modality preferences and information level preferences, see example in Figure 1.

	None	Alert	Direct. alert	Categ.	Desc.
Visual		X			
Auditory			X		
Tactile		X			
Ambient		X			
Other	X				

Figure 1. "Choose, which level of information would you prefer in combination with each UI modality (one per row)." An example of the question regarding interaction between UI modality and information level preferences.

Besides that, the participants were asked whether they would like the vehicle to perform any automatic maneuver in case of TOR, namely, slightly brake, and/or prevent sudden unwanted driver's reactions.

B. *Procedure*

Participants' primary task was to provide answers to the survey questions. For all questions, they had to imagine they were using a conditionally autonomous vehicle in the following scenario:

- The vehicle was completely self-driving (fully autonomous) on the highway;
- Participant was reading the news on his or her mobile phone;
- Meanwhile, the circumstances on the road changed and the vehicle is soon no longer able to drive autonomously;
- The vehicle requests the participant to take over in the next five seconds.

The participants were sent a direct hyperlink to the survey which started with an introduction paragraph that explained the nature and purpose of the survey. After accepting the terms, they were forwarded to the three-page survey, see screenshot in Figure 2.

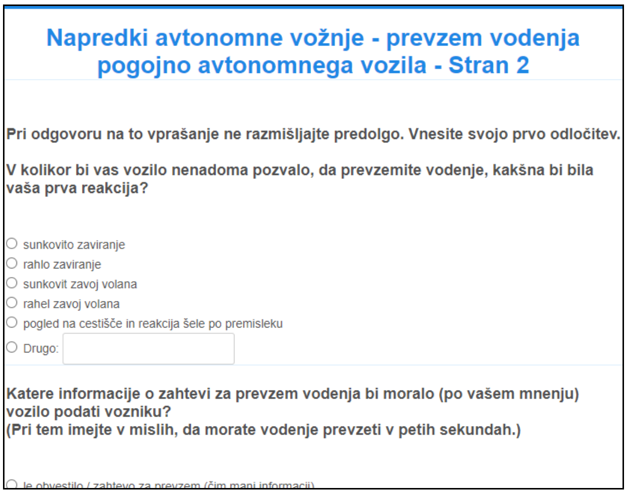

Figure 2. Screenshot of the survey in Slovenian language.

On the first page, they explained previous experiences with driving automation and answered the questions on UI modalities. The questions on preferred levels of information and expected vehicle behavior during TOR were placed on the second page, while demographical questions were on the last page. After the survey, participants were offered the possibility to participate in real driving simulator user studies on autonomous driving that are to be performed in the near future.

Each survey page took about one to two minutes to be completed, therefore, complete participation time was three to five minutes per participant.

C. *Demographical Data of the Acquired Sample*

151 participants (74% male, 26% female) volunteered to participate in the survey. They were recruited via Faculty and authors' personal emailing lists. The most represented age group was 21-40 years (80%), the mean value of driving license possession years was 11.25 ± 10.97, see Figure 3. Participants' level of previous experiences with automated driving was recorded on a scale from 1 to 5, counting how many of the following assistance systems had they already experienced: cruise control, adaptive cruise control, lane-keeping system, automatic parking and automatic road-sign detection, see Figure 4.

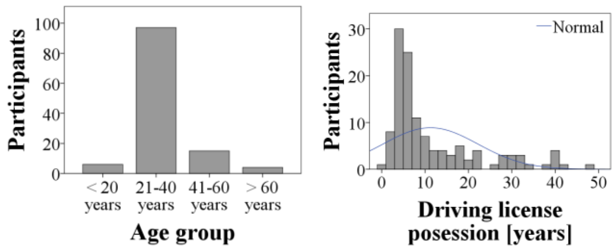

Figure 3. Demographic structure of the research sample. Left panel presents age distribution, right panel presents the histogram of participants' driving license possession.

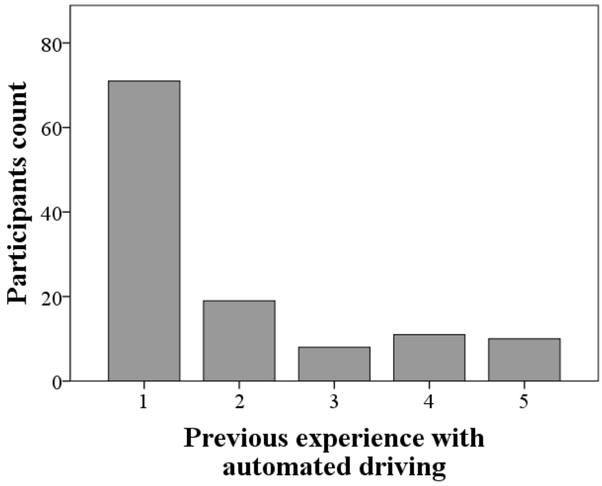

Figure 4. Previous experience with automated driving, counting how many different assistance systems had the drivers experienced prior to participation in the survey.

III. RESULTS

126 valid responses were gathered from 151 participants that started the survey. Participants without a valid driving license and those that did not complete the entire survey were considered invalid.

Regarding UI modality, the vast majority (90%) preferred auditory stimuli, followed by tactile (56%), visual (45%) and ambient (43%) stimuli, see Figure 6. Dynamic stimuli were preferred (66%) over static stimuli.

When choosing the overall most appropriate level of information for TOR, regardless of UI modality, participants voted in favor of alert only (37%). Categorical information was the second most preferred (31%) information level, followed by directional alerts (27%), see Figure 7. Considering UI modality, directional alert was preferred for auditory, tactile and ambiental stimulus, while categorical information was preferred for visual stimulus, see Figure 5.

Regarding vehicle behavior during TOR, the participants' majority opinion was that the vehicle should automatically start braking at the moment of TOR (75%), see Figure 8.

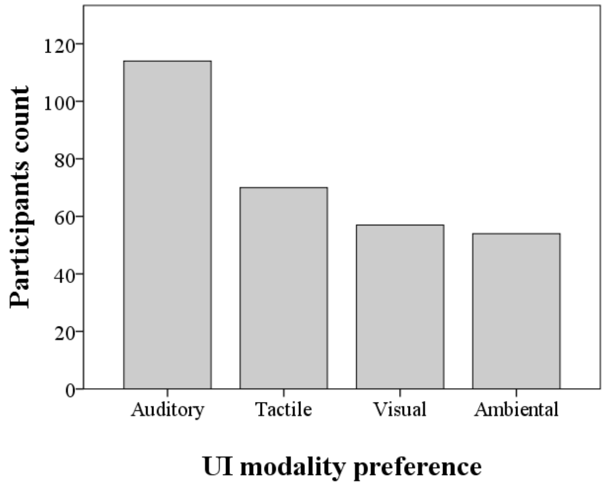

Figure 6. Preferred UI modality for the take-over request.

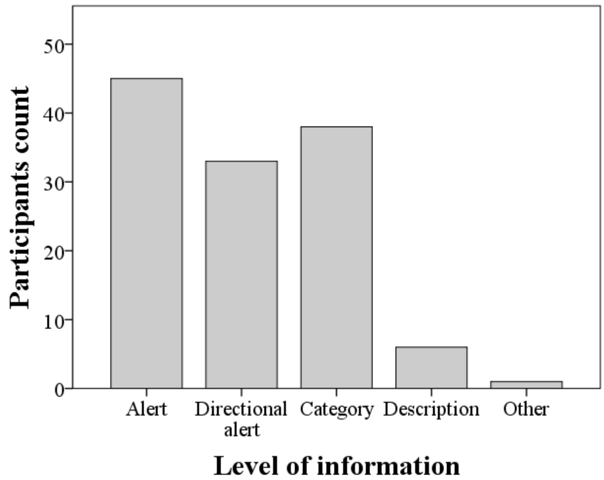

Figure 7. Preferred level of information for the take-over request.

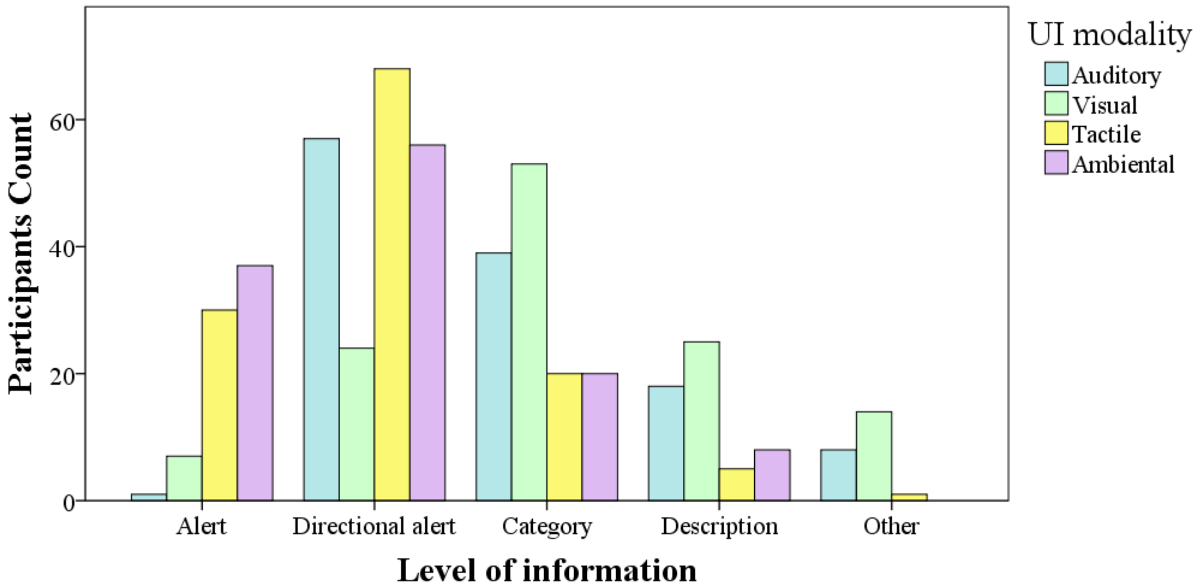

Figure 5. Preferred level of information for TOR considering different UI modalities.

On the other hand, the answers of the participants do not clearly indicate whether and which sudden unwanted reactions should be prevented. 15% chose that only sudden steering should be prevented, 10% chose only sudden braking, 33% chose both and 36% chose neither should be prevented, see Figure 9.

When asked about what their first reaction on real take-over request might be, the majority of participants (52%) answered they would probably first look at the road and react after careful consideration. 43% of the participants would immediately brake, either severe (18%) or mild (25%), see Figure 10.

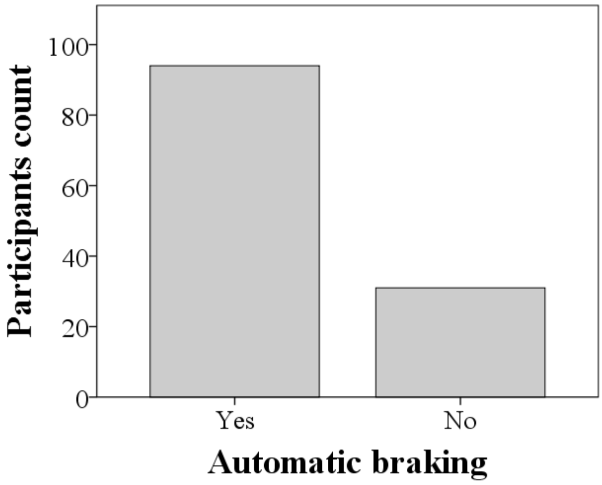

Figure 8. Preferences of automatic braking maneuver by vehicle at the moment of TOR.

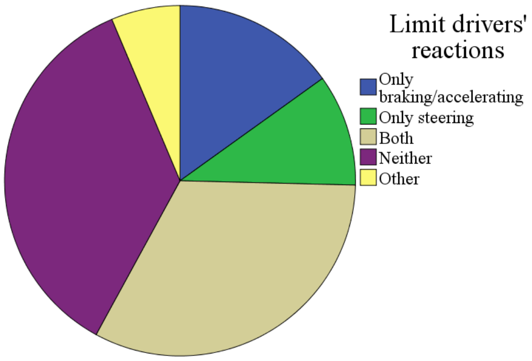

Figure 9. Preferences regarding automatic limitation of too severe drivers' reactions.

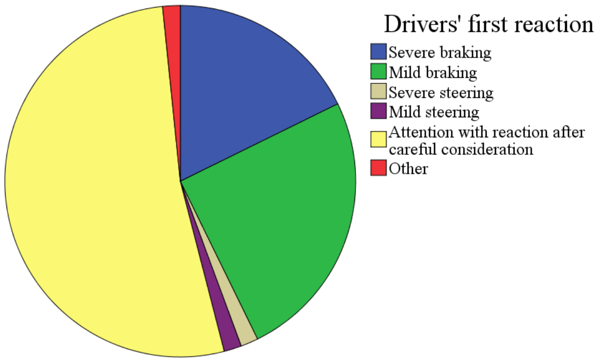

Figure 10. Drivers' anticipated first reactions on a take-over request.

IV. Discussion

The majority (90%) of surveyed drivers preferred auditory UI modality for take-over requests. Participants' preference of auditory stimuli is not surprising, since auditory warnings are already common in vehicles in case of detected errors. From the low popularity of visual stimuli, we can speculate that drivers' visual input channel is already overloaded with information and should therefore not be the only source of critical information. We would therefore like to stress the importance of auditory UI modality and suggest that it should not be omitted during TOR, although it may seem unnecessary or too straight-forward for some researchers. As tactile stimuli were the second most preferred, they should be considered as a possible addition to the auditory stimuli for the TOR.

The preferred level of information was a simple alert (37%), followed by categorical information (31%). Participants' answers suggest that "simple is the best" in case of communicated level of information, possibly because of limited time the driver must respond in. Somewhat surprising or contradictory is that categorical information is preferred over directional alert. Therefore, the default setting for a TO request could be alert only with the addition of categorical information, if available.

Taking different UI modalities into account, directional alert was preferred for auditory, tactile and ambient modalities, while categorical information was preferred for visual modality. These participants' answers (Figure 5) seem contradictory to the ones, preferring alert only (Figure 7). Possibly, drivers are willing to "consume" additional information when it is provided by appropriate stimuli type/modality. Considering that, a multimodal approach with different information levels per modality may provide TORs of better quality. However, this should be further studied and experimentally confirmed prior to implementation.

TOR mechanisms in vehicles should, according to drivers' preferences, include some sort of automatic braking maneuver. However, the answers of the participants do not clearly indicate whether and which sudden unwanted reactions should be prevented. It seems that, for some drivers, limiting their reaction is not an option – when a TO is performed, they assume their action would be the ultimately best solution and should have full control over the vehicle. However, it could be beneficial for other drivers to receive assistance whether at lateral (steering) or longitudinal (braking) coordination of the vehicle. This could present a new approach with only partial TOs, where drivers could take-over only lateral or longitudinal control of the vehicle, which is effectively only lowering the automation level instead of completely disabling it.

The drivers' anticipated first reactions on TOR were collected only as an interesting addition to the proposed research questions. It could be however concluded from the data that since the majority of drivers would only react after careful consideration, there is a probably critical, non-negligible time interval from the moment of a TOR until the first reaction when some automatic maneuvers could be performed to enhance the overall quality of a TO. Also, the results suggest that no automatic/reflex reaction to the TOR could be expected from the drivers.

V. Conclusion

Results of the survey will be considered during the design of UI for our future take-over experiments. We therefore suggest the use of auditory alerts as primary TOR indicators with an optional addition of tactile stimulus and categorical information.

We should state once again that the drivers' choice may not result in the most efficient UI, however not taking drivers' preferences into account may lead to disuse of such products. Therefore, the presented survey is only the beginning of a much wider research.

Acknowledgment

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