Effect of Post Take Over Situation Complexity on Take-Over Behaviour and Driver's Trust in Conditionally Automated Driving

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by

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TU Delft

Preface

Dear Readers,

This thesis is written as part of the Master Program in Mechanical Engineering at Delft Institute of Technology, Netherlands. The development of automated driving systems (ADAS) has resulted in extensive research pursued enthusiastically in the automotive industry. Partially automated cars are already in the market and the industry is transitioning towards a conditionally automated car. However, automation-initiated authority transfer in conditionally automated car driving has been a topic of great interest. During my master thesis project, I have done research on driver behavior during automated driving and transitions of control from automation to manual driving, intending to make a valuable contribution in the research and development of novel driver assistance systems.

During the whole project, there were many ups and down, the biggest being the ongoing pandemic. But I was never alone, and I would like to express my gratitude to all the people who made this possible.

First of all I would like to thank my supervisor Dr. Diane Cleij, who believed in my potential and provided me this opportunity to work on such an extremely interesting research topic. I am grateful to Dr. Diane for her all-around support and guidance throughout the project, and for sharing her invaluable experience in the field of scientific research. My special thanks to my thesis chair, Prof.dr. David Abbink, who provided continuous supervision and mentoring through my project. His high academic research standard pushed me further than I could imagine, and I will forever benefit from what I have learned from him. I am lucky to have David as a supervisor, who helped me through the obstacle when the road got bumpy and for all the inspiring and encouraging talks that gave me motivation not to give up. I am grateful to Dr. Niek Beckers, who was always there to help me out when I got stuck in some bottlenecks related to the simulator. I would like to thank you all for your time and patience and for your intellectual contributions to my project.

I cannot express how grateful I am to my beloved family and friends. Thanks to my parents, who were my constant support and provided me this opportunity to study at TU Delft, despite being far from home. My grandmother for her love and encouragement and my brothers, whose humor lit up my mood. For her unconditional love and tolerance for hearing my tiring monologues about the subject and constantly motivating me to do better, my best friend, Swati. Special thanks to my friends Sanjay, who never hesitate to help me whenever I had technical problems relating to the simulator and the program. Furthermore, many thanks to my housemates and friends, Shweta, Sagarika, Sam, Girish, Animesh, Sumit, Abhinav, Vishruth, Nagaraj, Pepijn, and Kristen, for keeping the company and all the support you guys gave me through out the time.

Tarbiya Khanam
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Contents

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***Abstract*—In conditionally automated driving, drivers should be free to engage in non-driving-related tasks until warned by the system to take over. Over-reliance on automation can lead to dangerous driving behaviour such as engagement in non-related driving tasks during the transition phase and delayed response to take over requests. Take-over time and quality were shown to be influenced by several factors such as involvement in a secondary task, the complexity, and criticality of the driving situation, or the modality and intensity of the take-over request. We found a paucity in research into the effect of post-take-over complexities. Understanding the effect of traffic situation just after transition phase on driver's take-over behavior is crucial for developing highly automated driving systems regarding safety. Therefore, we conducted a driving simulator experiment and tested the influence of post take-over situation complexity on take-over behaviour and driver's trust during automation initiated take-overs. Twenty-four participants drove two conditions, one with high situation complexity and the other one with low situation complexity in a fixed-based driving simulator. Participants were driven with conditionally automated driving and asked to play a game until warned by the automation to take over. The take-over performance was assessed based on safety performance (take over reaction time and no. of collisions) and subjective measures (self-reported perceived trust and technology acceptance). Sub response times in terms of the first gaze and hands on the steering wheel time after the first TOR is prompted, were also analyzed using video annotations. Results showed that situation complexity does not affect take over reaction time, though it significantly affects trust in automation rating. No significant relationship has been found between sub response time and overall take-over reaction time in both situation complexity. Eleven collisions occurred, which indicates that some participants fail to resume control on time. Some participants did not resume control at all and trusted on the automation in both complexities. Higher trust rating in low complexity situation indicates that drivers might develop complacency, resulting in degraded take over ability in unexpected take-overs and delayed response to take-over. This suggests that people develop a wait-and-see attitude and only reclaim control when they feel the need for it. These findings can help design automated technology and policies to ensure the inherent risk in conditionally driving automation can be eliminated.**

***Index Terms*—Take over process, Take over reaction time, highly automated driving, situation awareness.**

I. Introduction

With the advent of Advanced Driver Assistance Systems (ADAS), fully automated driving (FAD) is becoming an engineering reality. FAD promises to be beneficial for road safety as it eliminates the chance of an accident due to human error. It also promises to bring more productivity due to less congestion, better traffic management, less pollution and improvement in the use of urban infrastructure [1]. Nevertheless, the journey to have FAD is a long way to cover. We have to start from no automation to full automation via passing through different levels of automation in between. The SAE [2] and NHTSA [3] defines six different levels of automated driving system, ranging from level 0 (no driving automation) to level 5 (full driving automation) based on what extent of the primary driving task are performed by the human driver or the system. Various car manufacturers have introduced partially automated driving (PAD), SAE Level 2 cars, equipped with active lane-keeping and adaptive cruise control. The next step is to have conditionally automated driving car (CAD), SAE Level 3 cars, in the near future and hence extensive research is going to have a robust ADAS system in such cars. The only difference between PAD and CAD is that driver has to constantly monitor in PAD, whereas in CAD, human driver is not expected to monitor the driving task continuously but has to be attentive and situational aware during the take overs. Recently, there have been few accidents in level-2 cars where drivers fail to resume control, subsequently resulting in a crash [4]. Post investigation of these accidents purported that drivers fail to resume control in time. When taking over at the last moment, the driver does not have enough time to create situation awareness and might come to unsafe decisions. According to SAE and NHTSA, as the level of automation increases, the role of human driver shifts from an active operator to passive supervisor. While in some cases, automation may actually act to increase situational awareness, by freeing the driver with the driving task and give opportunity to look around more, this advantage has been found to decrease over time, as drivers become more trusting of vehicle automation [5], and as they increasingly engage in other tasks [6], [7]. A loss of vigilance and increase in complacency associated with the assumption of a monitoring role, are the major causes of reduced situational awareness [8]. For example, [9] found out in their driving simulator study that drivers engage themselves more with in-vehicle entertainment task than they were in manual driving, suggesting that drivers forgo their responsibility of supervision in preference of a more entertaining non driving related tasks (NDRTs) during highly automated driving. Driving simulator studies have shown that drivers are willing to engage in NDRTs, increasing the demand of a take-over situation [10]–[12], and this so-called out-of-the-loop performance problem get worsen [13]. [14] has defined a driver as fully aware of a situation if he or she can perceive the critical elements in the situation, understand what these elements imply about the driver's current state, and project what needs to be done to continue on a safe path forward. People with high levels of situation awareness are not just reacting to events; they are constantly projecting ahead [15]. This allows them to be proactive rather than just reactive, able to avoid many dangerous and hazardous situations. Therefore, one of the significant preconditions of safe transfer of control in CAD is that drivers correctly perceive and interpret the current traffic situation's relevant objects and elements during transition period and integrate them into planning and comprehend them according to their relevance to their goals. Drivers with low situational awareness might not be able to avoid dangerous and hazardous situation and hence risk of accident increases. Poor situation awareness has often been implicated in vehicle crashes [16]. Therefore, the major and critical problem during take overs is found to be loss of situation awareness due to over-reliance in CAD. A number of studies found that the higher complexity of the traffic increased the take-over time due to longer situation awareness regaining [17], [18]. [19] provided an overview of 17 take-over studies, focusing on the effect of the time budget, traffic complexity, NDRT, and driver age and concluded that 10 seconds seems an adequate time budget.

A. Aim of the Study

The studies mentioned in previous section investigated the factors which affects the take over reaction time in situation where the automation detects the presence of an impending hazard (unexpected take over) or when reaching system boundary (expected take overs). Interesting would be to analyse driver's take over behaviour in take overs, where automation gives a warning that it is reaching it's system limit, but driver's are not expecting a critical take over after the transition. It is crucial to understand the effect of complex post take over situation which are not anticipated by the drivers on their take-over behavior, for developing highly automated driving systems regarding safety. As mentioned in the introduction, poor situation awareness can be related to over-trust and complacency. Some drivers might over rely on the system which result in delayed response in resuming control. In normal driving conditions, where there is no hazard or post take over difficulty, delayed response might not be a serious problem, given that drivers are cognitively back in the driving loop. [20] in a driving simulator study found out that drivers over-rely on the system and developed a wait and see behaviour. But does this wait and see behaviour developed due to over-reliance results in degraded take over quality conditionally automated driving? To answer this question, it is pertinent to assess driver's behaviour during take over request when there is post take over complexity which is not anticipated by the driver. Moreover, most studies only focus on mean or median take over reaction time values and found large variances in take-over reaction time [21]. Rather than taking mean or median values of take-over reaction time as a standard metric, sub response times (first gaze, hands on steering wheel time [22], that conglomerate the over all take-over reaction time should be taken into consideration. While the studies referred in the previous paragraph provide important initial insights on the factors that effect take-over reaction time, a closer examination of the sub response/reaction process underlying the driver take-over and how these processes are affected by post take-over situation complexity has not been addressed so far.

Therefore, the aim of this study to assess driver's take-over behaviour and trust during automation initiated authority transition via traded control in high and low post take-over situation complexity. To achieve our goal, we conducted a simulator study to investigate how different post take over situation complexity affects the take over reaction time and perceived trust toward the automated system during authority transition initiated by the automated driving system, given a time budget of ten seconds. When a automation initiated take-over request is prompted during highly automated driving, a visually distracted driver will initially redirect his or her gaze from the secondary task to the road and may his hands back to the steering wheel and to move his feet toward the pedal systems. Therefore, this study also focuses on processes Fig. 2, underlying the driver take-over behaviour after highly automated driving and examines the relationship between these sub response (first gaze and hands-on time) and the take-over reaction during different post take over situation complexity. This relationship between response movement is expected to be crucial to explain where does the variability in take over reaction time occur. Measures of participant's technology acceptance (perceived trust, perceived ease of use, & perceived usefulness) were taken immediately after the drive.

B. Hypotheses

- H1: Participants are expected to have longer take-over reaction time in low complexity scenario than in high complexity scenario.
- H2: First gaze reaction time is positively correlated with hands on time and Hands on time is positively correlated with Take over reaction time.
- H3: Exposure to situation complexity changes the user's trust on the system. It is expected that participants will rate higher trust score in low complexity situation than in high complexity situations.

- H4: It is expected that no. of take overs in which driver's does not intervene will be higher in low situation complexity than in high situation complexity.

The next sections are distributed as follows: Section II explain the methodology followed to complete the research. Section III presents the statistical results, followed by Section IV where discussion on the results obtained, limitation, recommendation and impact that this research might have on future research or policy decision on the automated vehicle technology field, are made. Finally, Section V recapitulates the conclusion made based on the finding.

II. METHOD

A. Participants

A total of 24 individuals participated in the experiment, between 22 and 33 years old (Mean=25.43;SD=2.66). Four participants were female and rest were male. All the participants had valid driver license. Nine participants had left hand driving license while the rest had right hand driving license. Thirteen participants reported to be familiar with automated vehicles. Six participants had external locus of control based on internality-externality scale [23] while the rest had internal locus of control. The experimental data of 22nd participant(female) is omitted due to some technical issues arrived during experimental run, therefore data of 23 participants is analyzed in this study.

B. Apparatus

The experiment was conducted in a fixed-base simulator of the Department of Cognitive Robotics at the faculty of Mechanical, Maritime and Materials Engineering (3ME), Delft University of Technology. The steering wheel used is an electronically actuated Sensodrive SENSO-WHEEL SD-LC running at 1000 Hz. A 4K LED 65" screen refreshed at 60 Hz displayed the simulated environment. The virtual environment is created using CARLA, a driving system simulation platform, plug-in for UNREAL engine 4, a real time virtual environment visualization platform. JOAN, a human automated vehicle experiment framework, facilitates the connection of CARLA and the steering wheel controller. The logging frequency was set to 100 Hz. The test track was designed using RoadRunner, an editor that helps in designing road environment for simulating and testing automated driving systems. We video annotate the first gaze reaction time (moment in time when the participant looks at the screen after the TOR is prompted) and hands on steering wheel time. For video annotations, a 2 Megapixel webcam was used to record the eye movements and and hand movements to analyze the first gaze reaction hand on steering wheel time of each participants respectively, see Fig. 2.

C. Implementation of Traded Control

Traded control refers to a scheme where a specific task is entirely performed by a unique agent, either human alone or automation alone [24]. In the this study, traded control is used to transfer control from ADS to human and vice versa. Four Design Choice Architecture (FDCA) [25] controller has been used to implement traded control. FDCA controller has separate feedback and feedforward control loop. The feedforward control loop allows for a continous haptic feedback, to minimize the feedback errors. The setting of the FDCA controller are based on four design parameters:

1) *Human Compatible Reference (HCR)*: Generation of a reference for the control, com- patible with user strategies and the device and environment constraints.
2) *Level of Haptic Support (LoHS)*: The torques based on the desired steering wheel angle to follow the HCR (feedforward). 0% means no assistance at all, and 100% represents autonomous driving.
3) *Strength and Strategy of Haptic Feedback (LoHF)*: The torques by the feedback control to correct for the deviations of the HCR, based on the heading error and lateral error.
4) *Level of Haptic Authority (LoHA)*: A choice for the level of haptic authority; i.e. how is the balance between human input and automation. Virtual springs can dynamically change the steering stiffness in order to change the level of resistance on the steering wheel.

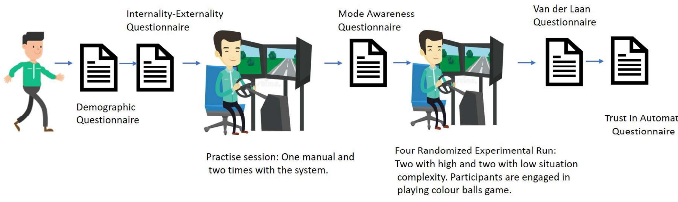

Fig. 1. Experiment walk-through:

D. Experiment Design

For this study, a repeated measures within-subject experiment was designed with one within-subject factor: situation complexity. Situation complexity contains two-level; High complexity scenario and low complexity scenarios, explained in the following section.

- *Automation and system boundaries:* According to SAE taxonomy [2], Level 3 automation is defined as an automated system which takes over longitudinal and lateral control for a specific period and in specific situations. The driver does not have to continuously monitor the system during the system is driving in its operational design domain, but if required the system can request a takeover while approaching its functional limits. Transition phase requires sufficient time budget for take overs. The implemented automation fulfills all the requirements for a highly automated vehicle (Level 3), however the system is not design to make lane change by itself. The longitudinal control is based on an cruise control (ACC) system that maintains a constant speed of 80km/h, and the lateral control is performed by the FDCA controller described in section subsection II-C. The strength of the LoHS are set to 100% and the LoHA is set high (7Nm/rad) to simulate fully autonomous driving.

- *Transition Method:* When a system limit is detected, the ADS gives an auditory warning " Prepare to take control". The moment TOR is issued, transition phase begins and driver has ten seconds to resume control. The motivation behind 10.5 second time budget is from the study [26] where they found that drivers require minimum 8 secs to reacquire situation awareness during transfer of control. Also, the situations were designed in a non-time critical way so that the drivers all had enough time to react. After 10.5 the ADS itself get deactivated (both cruise control and lane keeping) and the car switched to manual mode and will stop if the driver do not take over. The experiment was originally designed for 10 seconds but due to some last minute changes in logging frequency, 0.5 seconds got added. However, during the transition phase, the car will remain fully autonomous but more on level 2, pushing driver to do passive monitoring of the environment. The driver needs to have a clear mental model about the automation capabilities and limits. Therefore, in order to avoid mode confusion, manual over-riding of the system through steering and pedal was not implemented. The drivers can resume control only by pressing a button mounted on steering wheel, which deactivates the system. This control transfer method avoids unintentional disengagements such as inadvertently turn the steering wheel with enough torque or by pressing the pedals when the driver is preparing to take control by readjusting and repositioning her/himself. This methods indicate that the driver consciously making a decision and is fully prepared to take control.
- *Test Track:* The subjects had to drive on two lane highway. The highway is straight road surrounded by forest with few sharp curves along the hills.
- *Driving Scenario*
  There are two driving scenarios; High and low situation, see Fig. 4. The ADS system issued a TOR to resume control after reaching it's system boundary (a sharp curve which blocks the camera view). A take over request (TOR) is issued at the beginning of a sharp curve (curvature). At the end of the curve, there is a stationary vehicle standing at an angle, bit towards left side of the driving lane. In between the curve, there is also an accident happen along the right side of the highway (a car crashed into a tree) and there is some gathering around the accident site. The hill along the curve and the accident site obstruct the view of driver and hence driver is not expecting any obstacle on the road. The stationary vehicle is standing 40 meters away from the moment transition phase end, if the driver do not take control by his/herself. Clearly, this requires to driver perceive the critical elements (the road environment, the accident site and the stationary vehicle), comprehend those elements (there is a stationary vehicle possibly just after transition phase ends), and project what could happen (it might lead to accident with the stationary vehicle if not resume control before in time). To make the scenario more complex, one traffic vehicle were introduced that comes from opposite lane during the transition phase. The scenario is designed as such that if driver does not resume control, the car will hit the obstacle, and if driver tries to make an overtaking maneuver, then he/she might hit the traffic vehicle. Low complexity scenario is as same as high complexity except the fact that there is no obstacle after the transition phase. So if the participant do not intervene and let the automation shuts by itself, then he/she will hit the oncoming traffic vehicle.
  It is important to note that this high situation complexity was designed as an safety critical situation. Furthermore, collision avoidance systems was not incorporated in the simulated vehicle. The aim was to examine a critical scenario that was not expected by the drivers and is difficult to handle if driver reacts late to the take over requests.
- *Non-Driving Related Task:* In order to simulate driver out- of-the-loop effects, it is required to make the drivers perform a secondary task and take their eyes off the forward roadway. This experiment adopted an approach in which drivers were asked to perform a task inside the vehicle for more than a minute before control was transferred. The task was to play a game Color Ball on a hand held device i.e a touch screen tablet, which can be seen in Fig. 1. The motivation for this game is that it is an uninterruptible game which keeps the driver distracted throughout HAD. The goal of the participants was to break the high score. The objective behind this is to make the secondary task more engaging.

E. Procedure

Fig. 1 gives an overview of the experimental procedure of the current study.

- *Before the Experiment*: Participants were given a document containing the information about the experiment. Then the participants were asked to sign an informed consent form. After signing the form, participants were asked to fill out a demographics questionnaire. In order to measure driving locus of control participants were given the driving internality-externality scale [23] where they were asked to rate thirty questions on a 1-5 likert scale. Next, four practise sessions were performed. The first practise run was of manual driving to make the participant familiarize with the driving simulator and get a feeling of vehicle dynamics response. The second practise run was observational run with traded control where participant were instructed to observe how the vehicle behaves during the transition zone and what will happen if they don't resume the control. In the third practise session, the participants were asked to try manual over-riding via pedals and steering in order to make them understand the system limitations. Finally, the participants were verbally instructed how to disengage the automation system followed by one practice session. After the practise sessions, a questionnaire on mode awareness was asked to be filled,

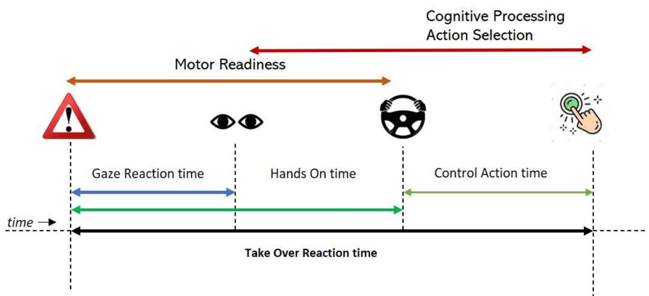

Fig. 2. The take-over process from highly automated to manual driving, adapted from [22], [27], [28]) ,,

to have the user's understanding of the automated system during the transition phase.

- *During the experiment*: Participants were instructed to put a headphone all the time during the experimental run. A tablet was handed over to them to play the game, explained in previous section. At the beginning of the driving experiment, the participants spawned on simulated Nissan GTR on the starting of a highway. The ADS was switched on by the experimenter and the participants were instructed to play the game and beat the high score during the automated driving. The duration during which ADS is active is 2 minutes in each trial. The participants were instructed that in case of a TOR they had to take back control of the vehicle and drive naturalistically as well as follow the proper traffic rules as they are driving in real traffic environment. There were total four randomize trials, two high situation complexity and low situation complexity. After the second trial of both scenarios, the participants were asked to fill out a Van der Laan questionnaire on usefulness and satisfaction and an other short questionnaire on perceived trust.

F. Dependent Variables

Objective Measures:

1) *Take over reaction time (TOrt) (secs)* : In this study TOrt is taken as the time from the take over request to the moment driver resume control via pressing the deactivation button.
2) *Number of Collisions*: If the ego vehicle hits the stationary vehicle or any other traffic vehicle from rear or from sideways, then the event is referred as a collision.

Timing of driver response: Fig. 2 outlines theoretical assumptions about the processes underlying the driver take-over. In this study, the TOrt is divided into three reaction times: The sub responses in time reflects the moment when the driver senses take over stimulus, starts perceptual and cognitive processing of the driving environment and establish motor readiness respectively [29].

1) *First Gaze Reaction time (secs)*: The first gaze reaction time i.e the moment in time when the driver shift her/his attention from NDRT to screen (gaze fixation greater than 2 ms) after the first take-over request is issued.
2) *Hands On time (secs)*: Then comes the hand on time, that is the time between the first take-over request and the moment in time when the driver put both of her/his hands on the steering wheel.
3) *Control Action time (secs)*: The third is control action time which the time between *hands on* and the moment in time when the button is pressed.

Subjective Measures:

1) *System Acceptance:* The Van der Laan questionnaire [30] assesses the acceptance of the two system in both situation complexity, on a Satisfaction scale and on an Usefulness scale. The usefulness and the satisfaction are evaluated based on nine Likert items.
2) *Perceived Safety:* Trust scale by [31] is used to evaluate the trust of human driver on the automated system. The original questionnaire have 11 questions where participants have to rate intensity of their feeling of trust on the system while operating a machine. In this study, last six questions were only included in the questionnaire which ask the participant to rate according to the impression they get while driving with autonomous mode during the transition phase.

G. Data Analysis

Figure Fig. 4, shows that spaghetti plots of the take over behaviour in both situation complexity. Though the participants can only resume via pressing button mounted on the steering wheels, torque conflicts were observed during the transition phase. It shows that participants did to try to control the steering wheel but did not take over the control completely. Appendix B.3 shows the raw data of each of the participants in both the situation complexity.

H. Statistical Analysis

A total of 92 take-over performance were analyzed (2 levels of Independent variables x 2 repetitions x 23 participants). For each level of the independent variables of situation complexity, there have been 23 mean within subject observation. Prior to statistical test, all objective measures were checked for normality using Shapiro Wilk test. The objective measures violates the parametric test assumptions and hence non parametric statistical; Wilcoxon matched sample rank test have been used for those variables.

The subjective measures of the Trust rating and Vanderlaan questionnaire were also checked for normality using Shapiro Wilk Test. Homogeneity of variance was checked using Levene's test. These measures met the assumption of normality and homogeneity of variance and hence dependent t test was used.

III. RESULTS

1) *Take Over Reaction time (secs)* : After performing Wilcoxon Signed Rank t-test, the analysis shows that no significant difference between high situation complexity

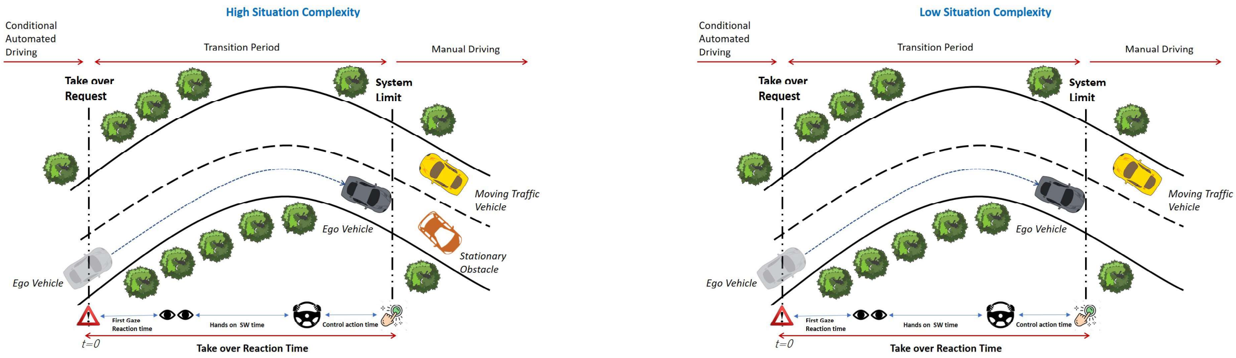

Fig. 3. A schematic overview of a take-over maneuver in post take over difficulty due to different situation complexity. This picture represent a time snap shot at t=10th second when the participants do not intervene during the transition phase. Note that the vehicles in the figure are not to scale. Below each figure is the timing of driving response if the driver intervene at the 10th second, adapted from [29]. LEFT: High Situation Complexity Scenario - Due to the stationary vehicle ahead and the oncoming traffic vehicle post take over becomes difficult in high complexity scenario. If the driver did not intervene during the transition phase, ego vehicle can hit the obstacle or the traffic vehicle in case an evasive maneuver is made to avoid collision with the obstacle. RIGHT: Low: Situation Complexity Scenario -If the driver did not intervene during the transition phase, the ego vehicle can hit the traffic vehicle.

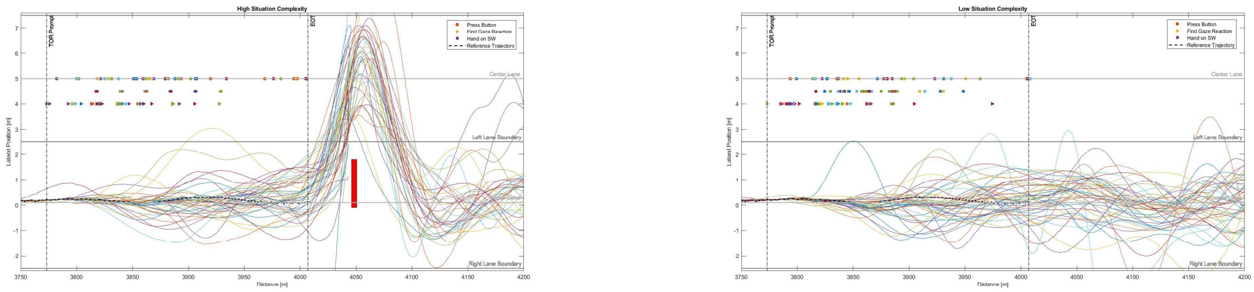

Fig. 4. LEFT: Raw data with time traces of all the participants after the first TOR is issued till the driver passes by the location of the stationary vehicle (red rectangular box). RIGHT: Raw data with time traces of all the participants after the first TOR is issued till the driver resume control and passes the transition phase. Both figures contain the sub reaction times i.e first gaze reaction, hands on steering wheel time and take over reaction time.

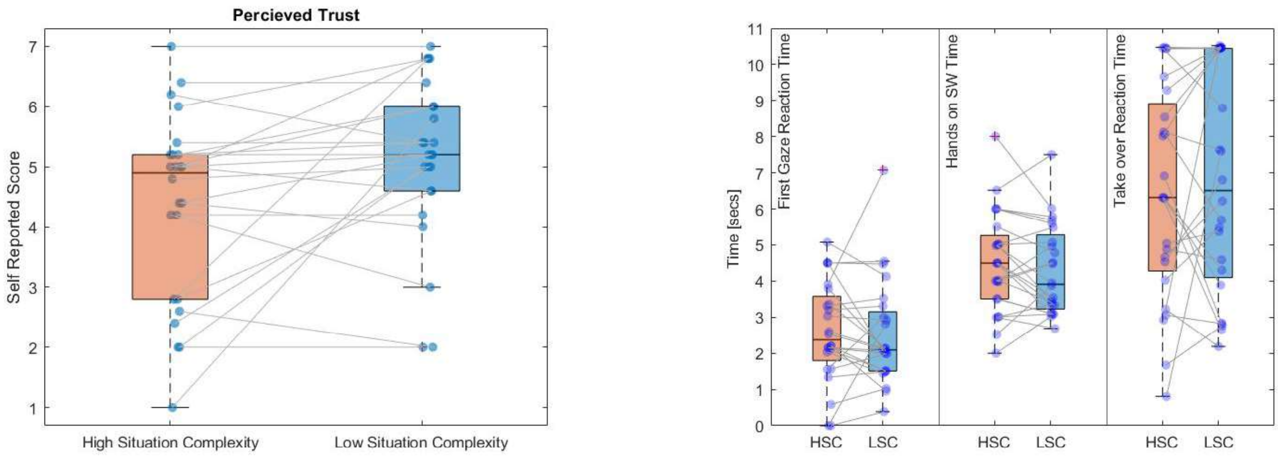

Fig. 5. LEFT: Results of Perceived trust in high and low complexity scenario. The median is illustrated by a black horizontal line. The dots represent each participant in one level of complexity, connected to a dot of the same participant in the other level of complexity. The perceived trust scores were taken once after two repetitions of each conditions. RIGHT: Box plots showing participant's preparatory behaviour for first gaze reaction time, hands on steering wheel time and take over reaction time of 24 participants for both situation complexity. The dots represent each participant in first response time in low situation complexity (LSC), connected to a dot of the same participant in the high situation complexity (HSC) scenario. Note that these observations are taken as mean over two repetitions.

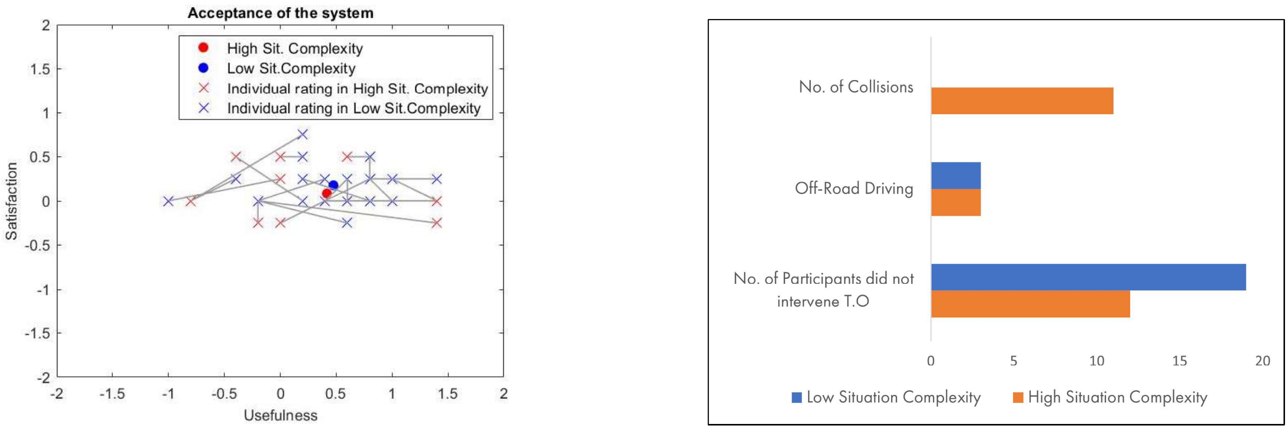

Fig. 6. LEFT : Results of the Van der Laan questionnaire with the mean satisfaction and usefulness per transition approach represented as a dot. RIGHT: Overview of take over performance in terms of number of take overs participants intervene and collision/off road driving occurs in both high and low situation complexity.

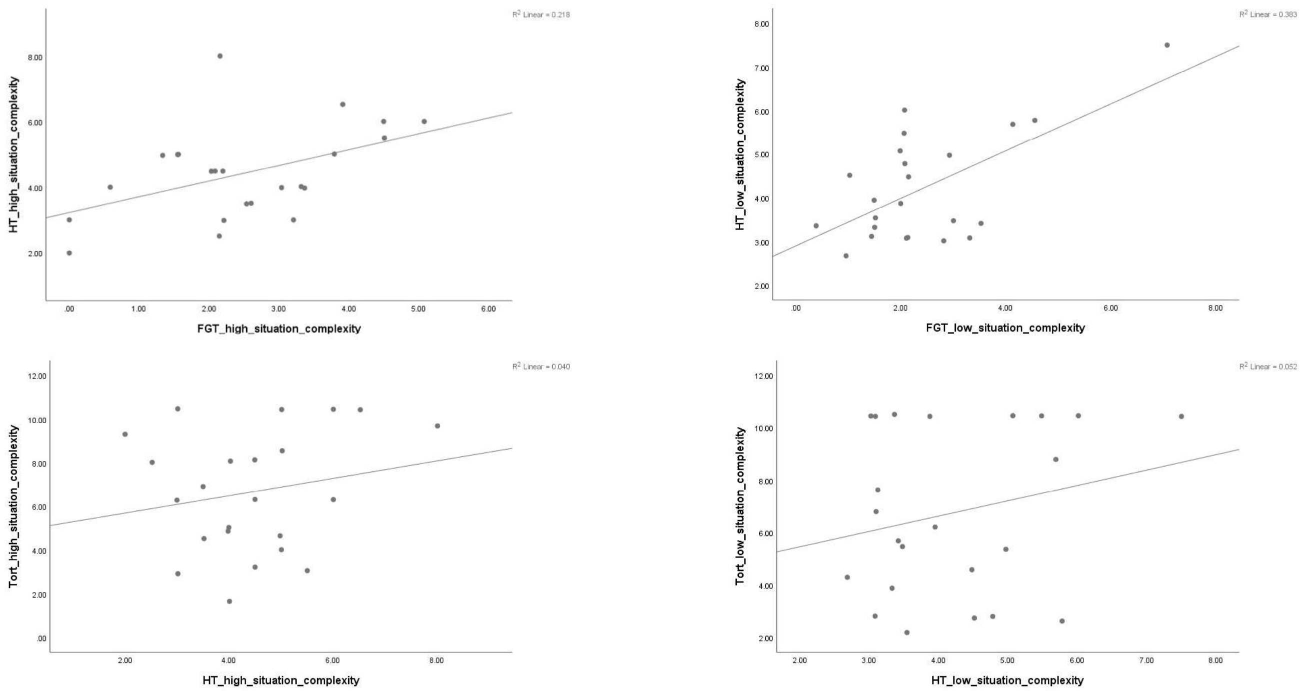

Fig. 7. TOP : Scatter plot of the mean hands on time over two repetitions of 23 participants as a function of mean take over reaction time over two repetitions, with a fitted least square regression line in both situation complexity. Bottom: Scatter plot of the mean hands on time over two repetitions of 23 participants as a function of mean hands on time over two repetitions, with a fitted least square regression line. HT: hands on time, FGT: first gaze reaction time, TOrt: Take over reaction time

(Mdn= 6.32) and low situation complexity (Mdn= 6.31), Z=-0.030, p >0.05, r = -0.004. It thus rejects our first hypotheses. It can be observed from Fig. 5, that there is a lot of variance in TOrt for both conditions.

2) *First Gaze reaction time (secs):* After performing Wilcoxon Signed Rank t-test, the analysis shows that no significant difference between high situation complexity (Mdn= 2.07) and low situation complexity (Mdn= 2.21), Z=-0.882, p >0.05, r = -0.13 on first gaze reaction. The Fig. 5 shows that first gaze reaction is quicker in both the conditions. This indicates that the first gaze reaction is more like a reflexive action performed by the driver after hearing the auditory warning.

3) *Hand on time (secs)* After performing Wilcoxon Signed Rank t-test, the analysis shows that no significant difference between high situation complexity (Mdn= 3.87), and low situation complexity (Mdn= 4.49), Z=-0.943, p >0.05, r = -0.14 on Hands on time. From Fig. 5 it

can be seen that hands on time is generally after the first gaze reaction and not a lot of variability is found in hands on time for both conditions.

4) *Relationship between First Gaze Reaction time and Hands on time*: From the Fig. 7, there seems to be a linear direct relationship between the first gaze reaction time to hands on time. However, after performing Spearman's correlation test, it was found that there is no significant relationship between the first gaze reaction time and hands on time in high complexity situation, r=0.395, p >0.05. In low complexity situation, there was no significant relationship between these two response time, r=0.31, p >0.05. The effect size found to exceed Cohen's convention for a medium effect size (d=0.3). This suggests that effect do exist but study is needed to perform on large sample size.
5) *Relationship between Hands on time and Take over reaction time* after performing Spearman's correlation test, no significant relationship between Hand on time and Take over reaction time was found in high complexity situation , r=0.167, p >0.05. Similarly, no significant relationship between these two response time was found in low complexity situation, r=0.09, p >0.05. The Fig. 7 also shows a lot of variance in the plots. This rejects our second hypotheses.
6) *Perceived Trust* : From Fig. 6, the boxplot shows the difference of self reported trust scores on the system in case of hazard present as well as absent, Fig. 6. After performing, dependent t test, on average, participants rated significantly higher scores in low complex situation (M=5.1,SE=0.289) than in high complex situation (M=4.26, SE=0.323), t(22)= -2.68,p <0.05, r=0.49. The effect size found to exceed Cohen's convention for a large effect size (d=0.5).
7) System Acceptance The results of the VanderLaan Questionnaire are shown in Fig. 6. For both situation complexity, participants rated in the top right corner. After performing dependent t-test, no significant effect was found between the two situation complexity for usefulness or satisfaction, (M=3.3, SE=0.067), (M=0.25, SE=0.077), t(22)= 0.904, p >0.05,r=0.19.
8) *Number of Collisions:* Eleven collisions were reported that includes eighth with the obstacle and three with the traffic vehicle. In eight out of eleven collisions, participants did not resume control and let the automation shuts off by itself. This is clearly an act of over-reliance. Six instance of off road driving were also observed, which could have result in collision with trees on the road sides.

IV. DISCUSSION

As the technology is becoming more advanced, the system is supposed to replace human operation essentially and put them into a supervisory role. However, even in these cases, driver interventions due to system limitations or failures or the exceedance of the system's operational design limits, are still needed. The main challenge at this stage is how drivers respond to these conditions and how they can be supported in taking back control safely and smoothly. The study aimed to analyze driver's take over behavior during the transition phase in conditionally automated driving in two different post take over situation complexity. The following subsection reflects some key findings from the study.

A. Effect of situation complexity on take over reaction time

The introduction mentioned that previous studies focused on determining take over time required to resume control by varying different traffic conditions, modalities, and different NDRTs. Few studies [28], [32] were done to assess the effect of these factors in safety critical situation where unexpected take overs happened due to presence of hazard/obstacle. In this study, we tried to assess whether participants were able to resume control in different complexities just after transition phase in take-over that first appears to be non-critical. We hypothesized that participants will be able to react early and reclaim control quicker than they will do in low situation complexity. But on the contrary, no statistically significant difference was found in the take over reaction time in both the situation complexity. A lot of variance in take over reaction time in both situation complexity can be seen from the Fig. 5. These inter-individual variation in take over time indicates that outliers in take over reaction time distribution are more prone to safety critical scenario.

It is obvious that in high complexity scenario, due to the presence of a stationary vehicle, participants felt the need to intervene and hence the number of take-overs in which driver intervene is lower in high situation complexity than in low situation complexity. However, there were some cases in high complexity scenarios where participants did not intervene and crashed with the other vehicles. This indicates that even when these participant's experienced the vehicle in the practise session, they tended to overestimate the vehicle capabilities, as the practise session does not involved any complex post take over scenario.

B. Relationship between driver sub response times and take over reaction time

Previous studies measured and analyzed the overall take-over reaction time. The introduction pointed out that take over reaction time can be divided into sub response time, which might tell where the actual delay is happening. Not a lot of study has been done to analyze driver's take over behaviour at a fine-grain level by measuring response time through video annotations. In this study, we tried to analyze the sub response time and to see whether there is some relation between take over reaction time and sub response times. From From the Fig. 7, it can be seen that there is a linearly increasing trend between first gaze reaction and hands-on time, i.e., as late the participants shift their attention from the NDRT, the longer is the time when the participants put their both hand on the steering wheel. The relationship is not statistically significant, though it has a medium effect size. On the other hand, there is a large variability in hands-on time with TOrt. Some participants instantly took control after grabbing the steering wheel while some wait and intervene only when they feel the need of it. Another important finding from this study is that first gaze reaction time and hands on time, in both situation complexity is generally quicker and has less variance, see Fig. 5. This align with the assumption made by [28] that early motor processes of driver take-over (i.e. hand and foot movements, redirecting the gaze at the roadway) might be mostly reflexive with little influence of the driver's mental state. In contrast, the time the driver needs for an intervention in vehicle control appeared to be affected by the driver's cognitive processing and his/her mental state. This goes hand in hand with results reported by [32] which show that expecting an event influences the time needed for perceiving and mentally processing a warning stimulus. However, expectation does not seem to affect the preparation and execution of a motor reaction in manual driving. This clearly supports our finding that variability in TOrt occurs due to variability in control input time. It seems clear that cognitive (control input time) and not motor processes (first gaze and hands on time) determine take-over reaction time, and this insight is expected to have design consequences for real-world automated driving systems. However further analysis of this response behaviour, it was found that not all participants followed that same order of timing response, as shown in Fig. 2. The following behaviour was observed among the 23 participants:

- First gaze –> Hands on steering wheel –> Control input (N=14) : Slow response group, see (Appendix Figure B.2).
- First gaze –> Control input –> Hands on steering wheel (N=6) : Fast response group, see (Appendix Figure B.2).
- Control input –> First Gaze –> Hands on steering wheel (N=1)
- Hands on steering wheel –> First gaze –> Control input (N=1)

Though most of the participants showed the an expected sequence of response behavior, as shown in Fig. 2, we found that quite few participants (N=8) showed different response behaviour. This suggests that in some cases intervention in vehicle control (control input time) is also a reflexive action and cognitive processing occurs after the participant intervenes. The assumption made by citegold, [27], [28]) did not hold true in this case. This suggest thst there are inter-individual differences in driver response behaviour, which also account for variability in TOrt.

C. Effect of situational complexity on system acceptance and trust in automation

Literature studies have shown that over-reliance results in negative behavioural adaptation such as delayed response time such as engagement in NDRTs [10], and fewer glances on the road [33]. This behaviour may prevent drivers from noticing failure in automation when they occur [34]. Most previous research shows that trust increases following exposure to automated vehicle technology [35]–[37], although a recent study suggest that whether it increases or decreases is dependent upon specific situation that drivers are exposed [38]. However, that study was done on level 2 automation. Therefore, we hypothesized that situation complexity has effect on the perceived trust user developed after their exposure to the situation in level-3 automation.

The results of trust in the automation questionnaire show a statistically significant difference in terms of reported perceived trust. It can be observed from Fig. 6 that after testing the system in both complexities, trust in automation significantly reduced when exposed to high situation complexity. This shows that drivers exposed to less safety critical situation might develop over-reliance (trust scores were higher in non-critical scenarios). Another interesting finding is that participants who responded fast to take over time showed higher trust in the system than a participant who had slower response time (Appendix Figure B.3). This confirms that only after exposure of the system to the situation, trust is affected in level-3 automation.

We also hypothesized that number of take overs in which participants did not intervene will be higher in low situation complexity than higher situation complexity. It can be seen from the results, Fig. 6 that number of take over in which participants does not intervene is higher in low complexity scenario. This indicates that participants did develop the wait and see attitude and reclaim control only when the felt the need of it. This behaviour can also prevent drivers from noticing failure in automation when they occur and reclaiming control on time. Though the number of takeovers in which participant did intervene was greater in high complexity scenario, most of the participants did develop the wait and see attitude in high complexity scenario, few of them resulting in crashes (Appendix B.3) .

The Van der Laan Questionnaire results show no statistical difference in terms of reported satisfaction and usefulness. From the Fig. 6, it can be seen that participants found both systems marginally useful and satisfying.

D. Additional analysis

Though this study did not analyze the braking and steering behaviour during take overs as manual over-riding was not implemented in the design. We were interested in analyzing the behaviour during transition time that affects take-over behaviour in different situation complexities. However, we find that most of the participants put their feet on the throttle, and as soon as automation shuts off, they tend to speed up. In high situation complexity, almost half of the participants applied a very late brake, though they initially put the foot on the throttle. In low complexity scenarios, as there was no obstacle, most participants tend to speed up. This is dangerous behaviour. Driver's should be first put foot on the brake so that in case of hazard, they can timely react.

E. Limitations and Recommendation

The current study was performed in a fixed-based simulator. Due to the low fidelity of the simulator, participants may not have performed realistically as they could have performed in natural conditions. The analysis of the dependent variable was made on mean over repetitions of the two independent levels. The effect of the trial was not analyzed. The first trial was likely more of a surprise, and behavior during the first trial tells more about unexpected take-overs. The participants become more familiar with the road condition and can perform differently in the second trial, even though the conditions were randomized. The statistical analysis does show that there is no significant effect of situation complexity, but we see that most of the participants did not intervene during low complexity situations and let the automation shut by itself. This induced over-reliance on the system is needed to be tested. Study needs to be done to find solution to have systems that induce appropriate reliance in the system. Only first gaze reaction time and hands-on steering wheel were analyzed through video annotations. Monitoring frequency could have also been analyzed to give more information about situation awareness gained during the transition phase, which is much easier to do using an eye tracker.

F. Implications

The finding of this study has important implications for future research and design of ADAS. Collision cases suggest we cannot take a mean or median take over time as a good assessment metric to ensure that all drivers gain control of the vehicle within the required time to enhance road safety. Thus, the outliers also need to be accommodated by ADAS designers and policymakers to ensure the inclusive design of modern systems and safety during control transitions. In most cases, we found out that redirecting gaze and putting hands on the steering wheel is more like a reflexive action towards TOR. We also found that the quicker the hands-on time, the faster is TOrt. Variability occurs in control input time. Hence if we can design a system that pushes the driver to take control as soon as the driver grabs the steering wheel, we might resolve the problem of delayed take-over response. One way to encourage such interaction is implementing shared control as a transition method, pushing the driver to engage early in the driving loop. As soon as the driver grabs the steering wheel, the mode changes to shared mode, thereby pushing the driver to resume control early.

V. CONCLUSION

By investigating the effect of post take over situation complexity on take over reaction time and driver's trust, the current study conclude that:

1) On the contrary of our hypotheses, there is not effect of situation complexity on take over reaction, r = -0.004. Large spread in TOrt suggest there is a lot of variability in take-over response. Some participants took early control while some do not take control at all, as can be seen from Fig. 6. Eleven collisions incidents showed a delayed response and poor situation awareness (inability to anticipate hazard) during the transition process. This indicates that extreme cases and outliers are pertinent for the design objectives of ADAS.
2) Further, again contrary to our hypothesis, sub response times are found not to be significantly correlated with the take-over reaction time. Fig. 7 shows a linear trend between first gaze and hands on time for high and the effect size found to be r = 0.39 & r = 0.31 for a high and low situation complexity respectively. This suggest that with large sample size we might find a significant relationship between them. No significant relationship and trend is observed between hands on and TOrt in both situation complexities. Effect szie found out to be r = 0.167 & r = 0.09 for high and low situation complexity respectively. We found in most of the cases these sub reaction might be mostly reflexive actions with no effect of the situation complexity. Additional analysis revealed that behaviour of participant in resuming control was random. Not everyone followed the same order of timing response, which can also account for the the variability in take over reaction time observed in this study.
3) As we hypothesised, we found that exposure to complex and critical situations significantly affects the perceived confidence of the user in the system, r = -0.49. Exposure to difficult take-over situations reduces the user's trust have with the system, Fig. 5 whereas to non-critical safety scenario the user's trust increases. Therefore, people might over-rely on the system as driver hardly face any safety critical situation, leading to negative behavioural adaptation and they might fail to react to such safety-critical situations. However, the participants accepted the system in both complexities, Fig. 6.
4) Fig. 6 shows that number of take over in which participants intervene were higher in low situation complexity scenario than high situation complexity scenario. This shows that most of the participants had this wait and see attitude. They resume control only when they feel the need of it.

To summarize, situation complexity does not affect take over reaction time however confidence in terms of trust is affected. Most of the participants developed wait and see attitude and relied on the system until they feel the need to take over, which is a negative behavioural adaptation effect. Delayed response resulted in risky driving behaviour and accidents.

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A
Project Scope

A.1. Shared Control as Authority Transition

This thesis project was originally focused on assessing situation awareness in Automation Initiated transitions using Shared control. Literature has proven that shared control to provide smooth authority between HAD and manual driving by improving the physical task of steering. Still, no study has been found in the literature that investigated the benefits of HSC during authority transition in enhancing situational awareness. The project was designed to question *"Does haptic shared control, which switches off automation gradually, reduce over-reliance, and help the driver create situational awareness during unplanned take-overs with SAE level 3 vehicles?"* There were four independent variables which includes two level of transitions i.e. Traded Control and Shared Control, and two levels of situation complexity i.e. high and low. It was hypothesized that shared control will result in having safer authority transition than traded control in terms of minimum time to collision and no. of collision. It was also hypothesized that shared control will induce appropriate trust in the users and hence users in shared control will disengage themselves from NDRT more early in the transition phase by showing shorter response time in terms of hands on time and control action time. The last hypothesis was that with the use of shared control, induces appropriate reliance on the system and will force driver to resume control early. Overall eight trials were conducted four four each transitions and 24 participants performed the experiment. The two transition modes were expected to be compared in terms of safety performance and driver's response behaviour. However, just before the main experiment, some technical issue occur of frame rate occur in CARLA. In process of fixing this issue, the logging frequency of JOAN got changed, which in turn affected the shared controller function, as it was sensitive to time step (an exponentially decay function). The experimenter overlooked this fact and ran the simulation at incorrect logging frequency. During data analysis, it was realized that the controller does not performed as designed and hence results were not coming as expected. Due to time constraint, we were unable to repeat the experiment. The scope of the project was reduced and only traded control conditions were analyzed. New research question and hypotheses were formulated later after the experiment.

B

Supplementary Results

B.1. Additional Results

Following variables were also measured, as initially we are assessing the difference in two transition mode.

- *Minimum Time to Collision (secs)*: The minimum TTC is evaluated here in the critical scenario if the participant tries to do an evasive manuever to get pass the stationary vehicle. TTCmin is the minimum recorded value until sufficient steering input has caused the ego vehicle's trajectory to be clear of the stationary object.

- *Standard Deviation of Lane Position (m)*: SDLP is generally used to determine the standard deviation around the lane center. It indicate how well the driver keep the vehicle on the lane. SDLP is measured only for Non-critical scenarios where there is no lane change.

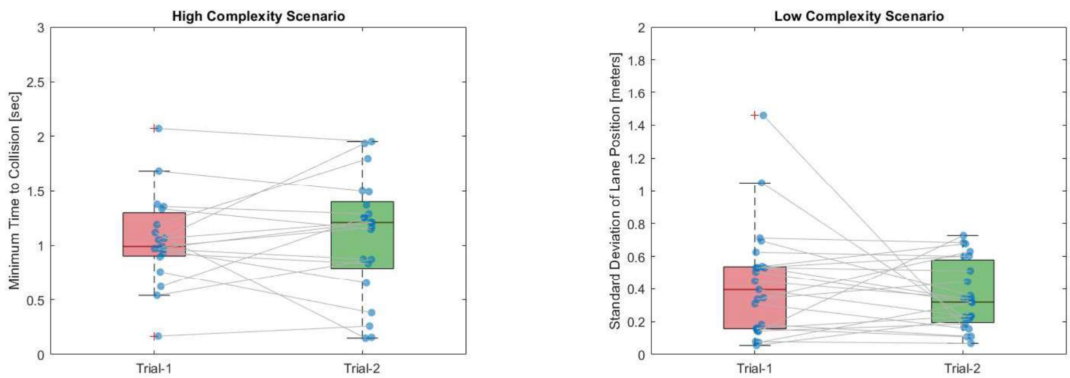


Figure B.1: LEFT: Results for the minimum time to collision of high complexity scenario. The dots represent each participant in first trial, connected to a dot of the same participant in the second trial. RIGHT: Results for the standard deviation of lane position of low complexity scenario. The dots represent each participant in first trial, connected to a dot of the same participant in the second tria

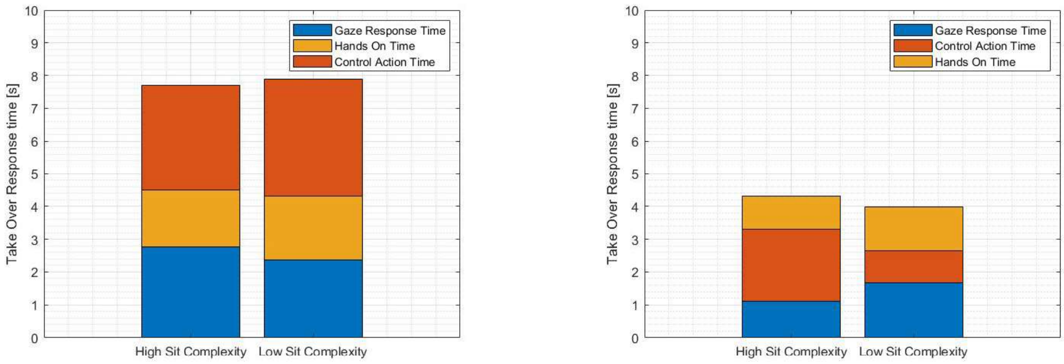


Figure B.2: LEFT: Mean take over reaction time of all the 13 participants (Slow response group). RIGHT: Mean take over reaction time of all the 5 participants (Fast response Group).

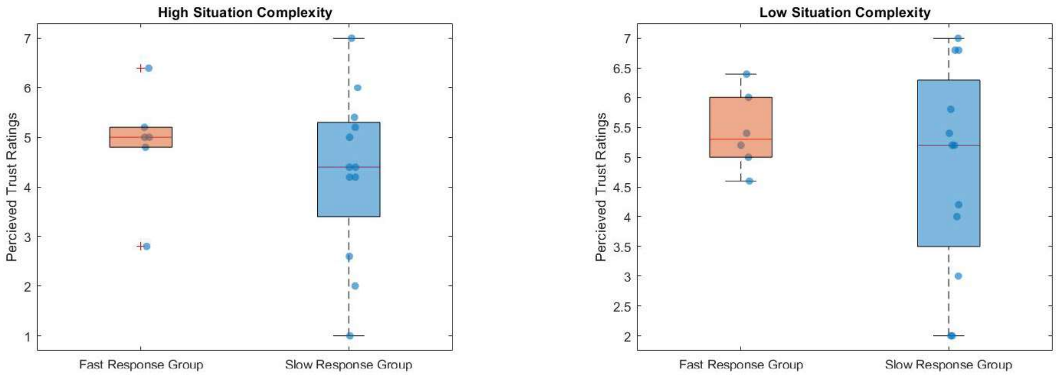


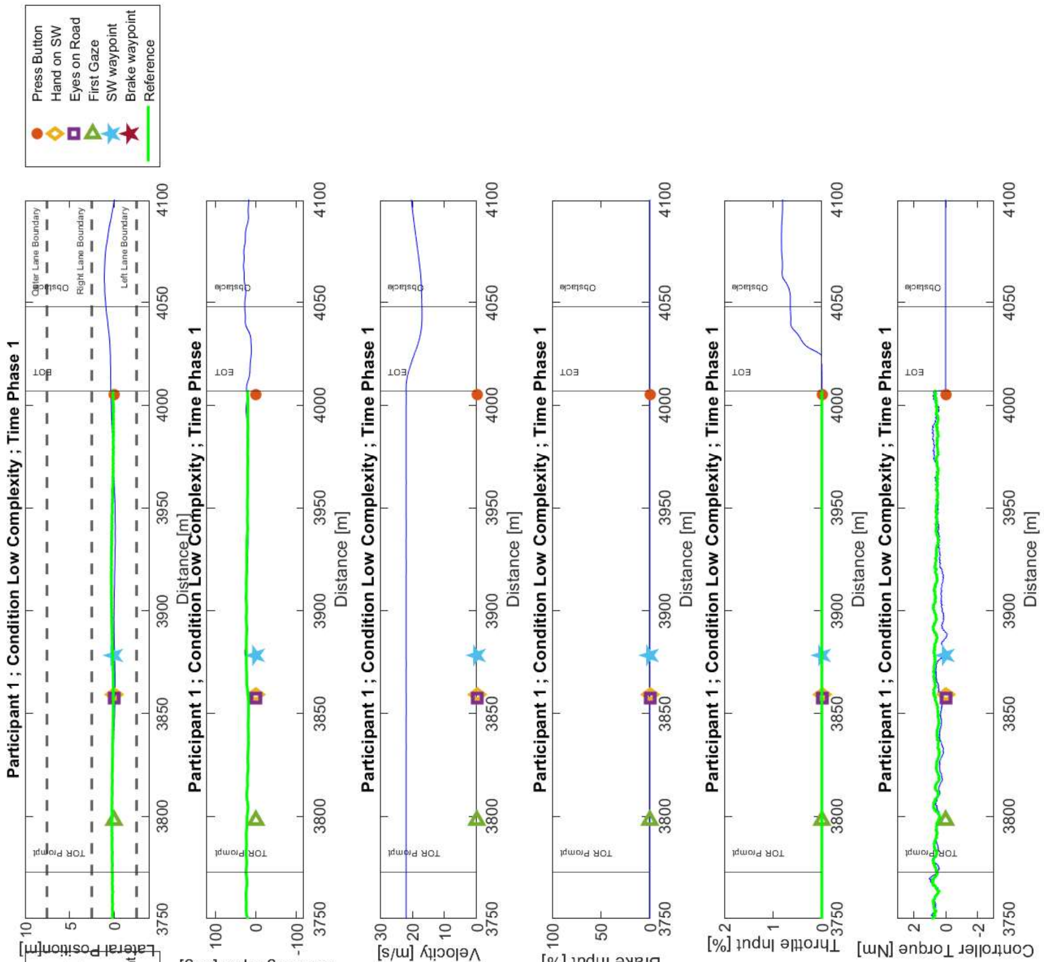
Figure B.3: Results of Perceived trust in high and low complexity scenario by slow and fast and slow response group. The median is illustrated by a black horizontal line. The dots represent each participant in one level of complexity, connected to a dot of the same participant in the other level of complexity. The perceived trust scores were taken once after two repetitions of each conditions.

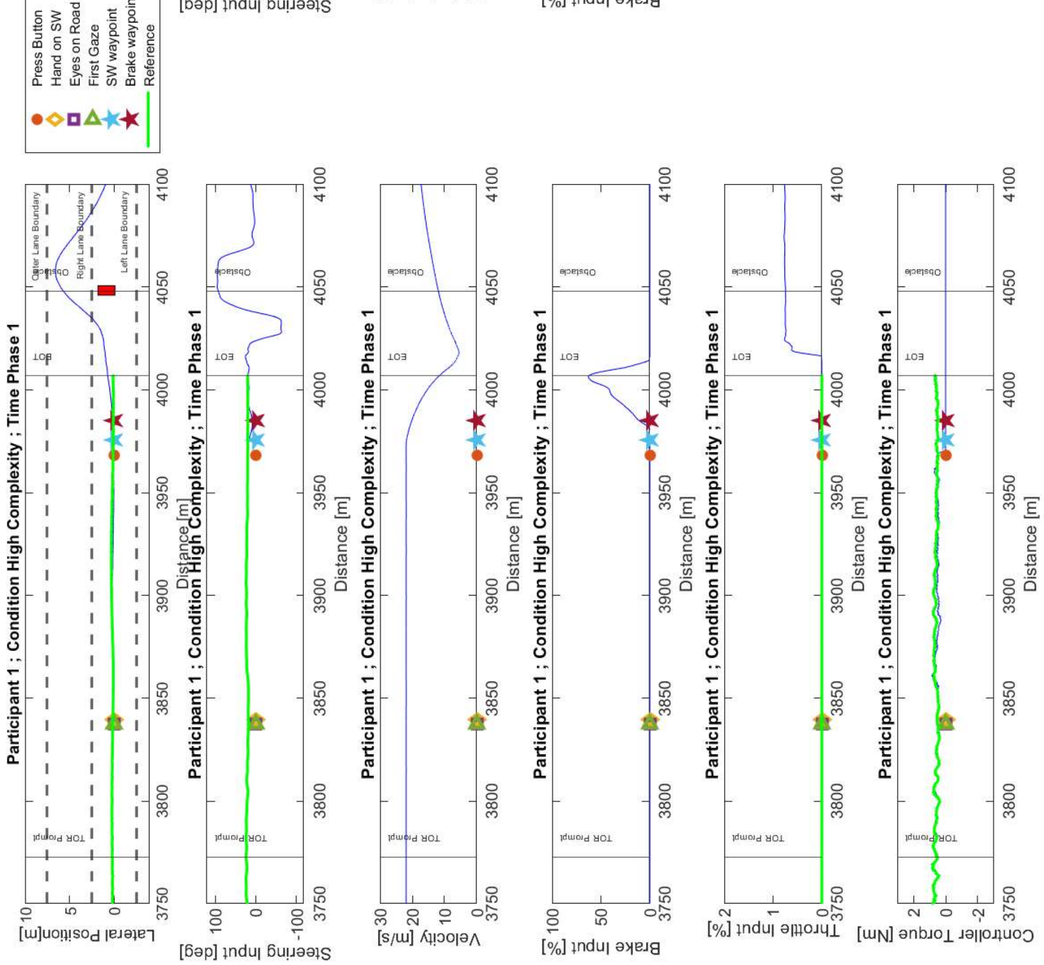
B.2. Descriptive Statistics of Dependent Variables

Measures	**Low Situation Complexity**				**High Situation Complexity**			
Objective	**Mean (SD)**	**Min**	**Max**	**Median**	**Mean (SD)**	**Min**	**Max**	**Median**
Tort (secs)	6.77(3.18)	2.19	10.5	6.21	6.66(2.76)	1.67	10.5	6.32
First Gaze Time (secs)	2.44(1.42)	0.39	7.07	2.07	2.51(1.34)	0	5.08	2.21
Hands on Time (secs)	4.23(1.244)	2.69	7.5	3.87	4.44(1.392)	2.00	8.01	4.49
Subjective								
Percieved Trust Scores	5.10(1.39)	2.00	7	5.2	4.29(1.55)	1.00	7	4.8
Vanderlaan acceptance	0.25(0.37)	-0.44	0.78	0.22	0.33(0.322	-0.56	0.89	0.33

Table B.1: Descriptive statistics of all the dependent measures, Standard deviation in Parantheses (N=23)

B.3. Raw data plots of each conditions per repetition


Participant 1 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary


Participant 1 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
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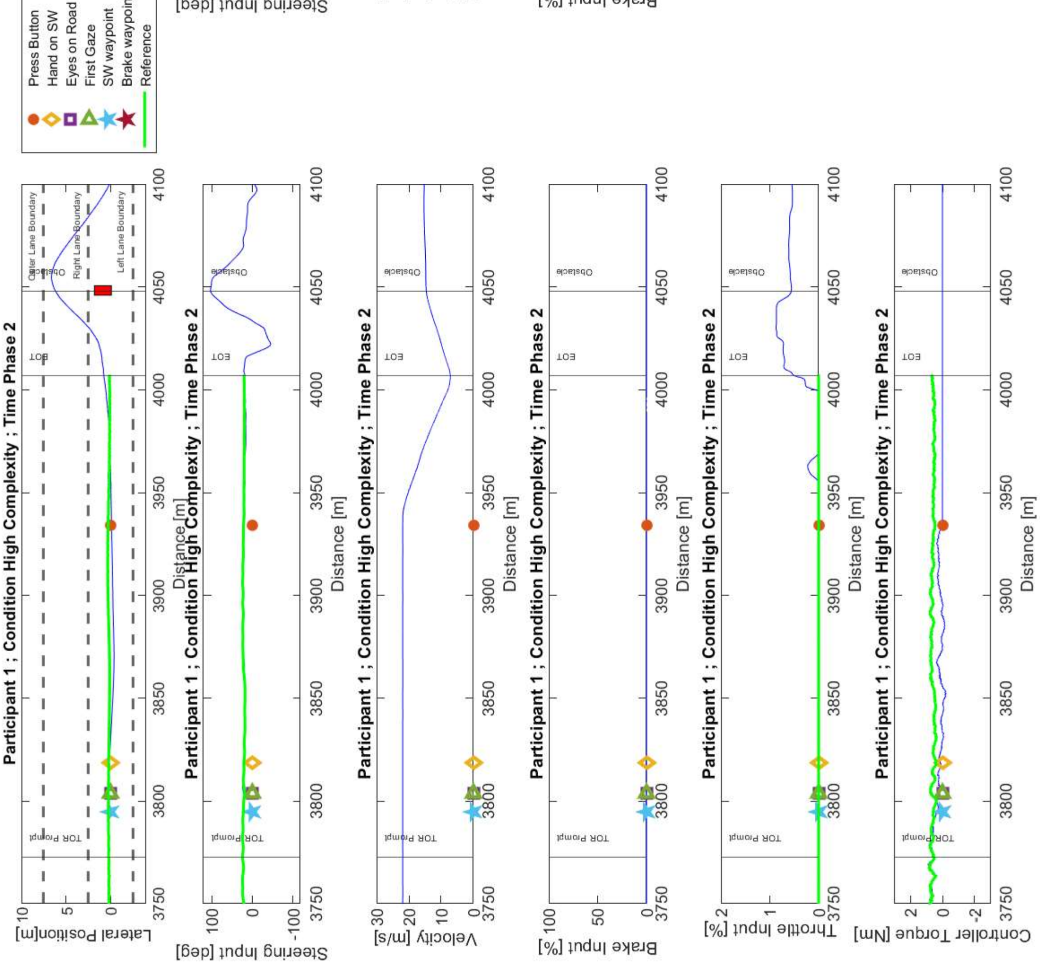
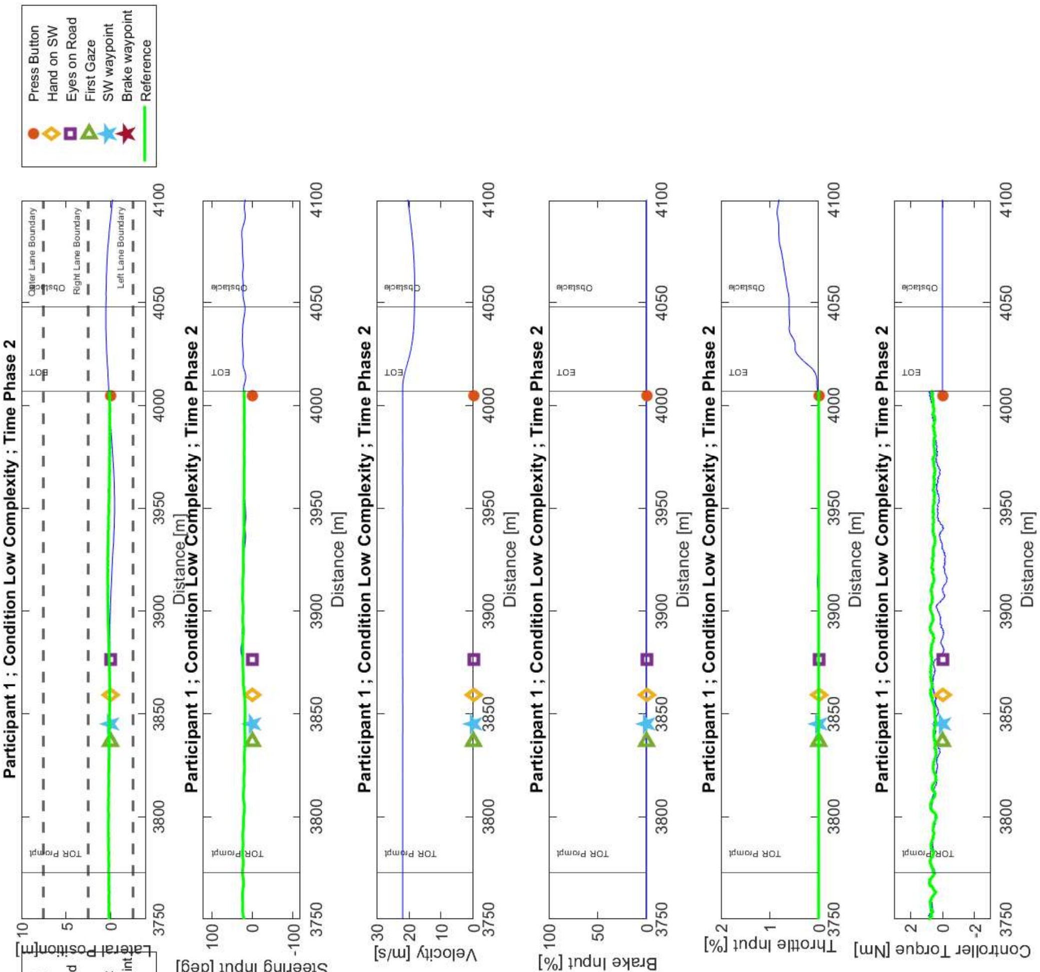
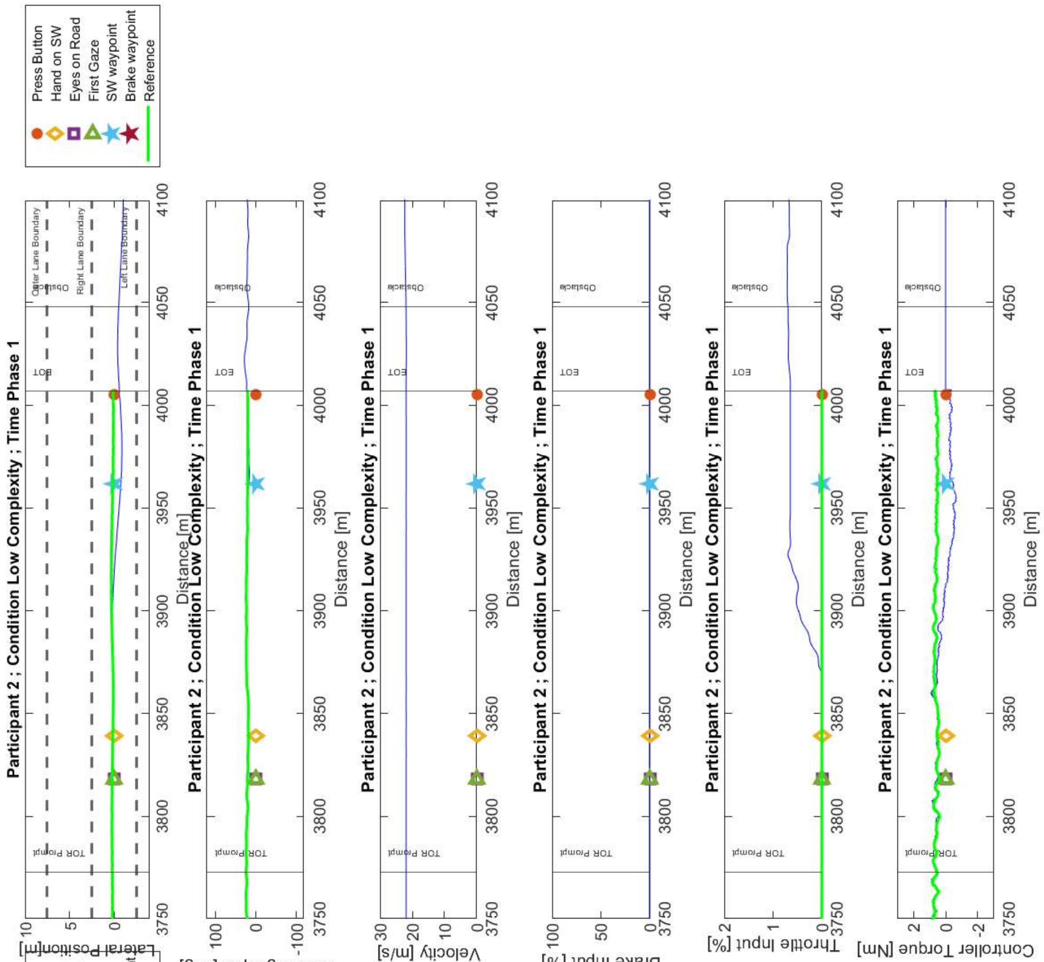
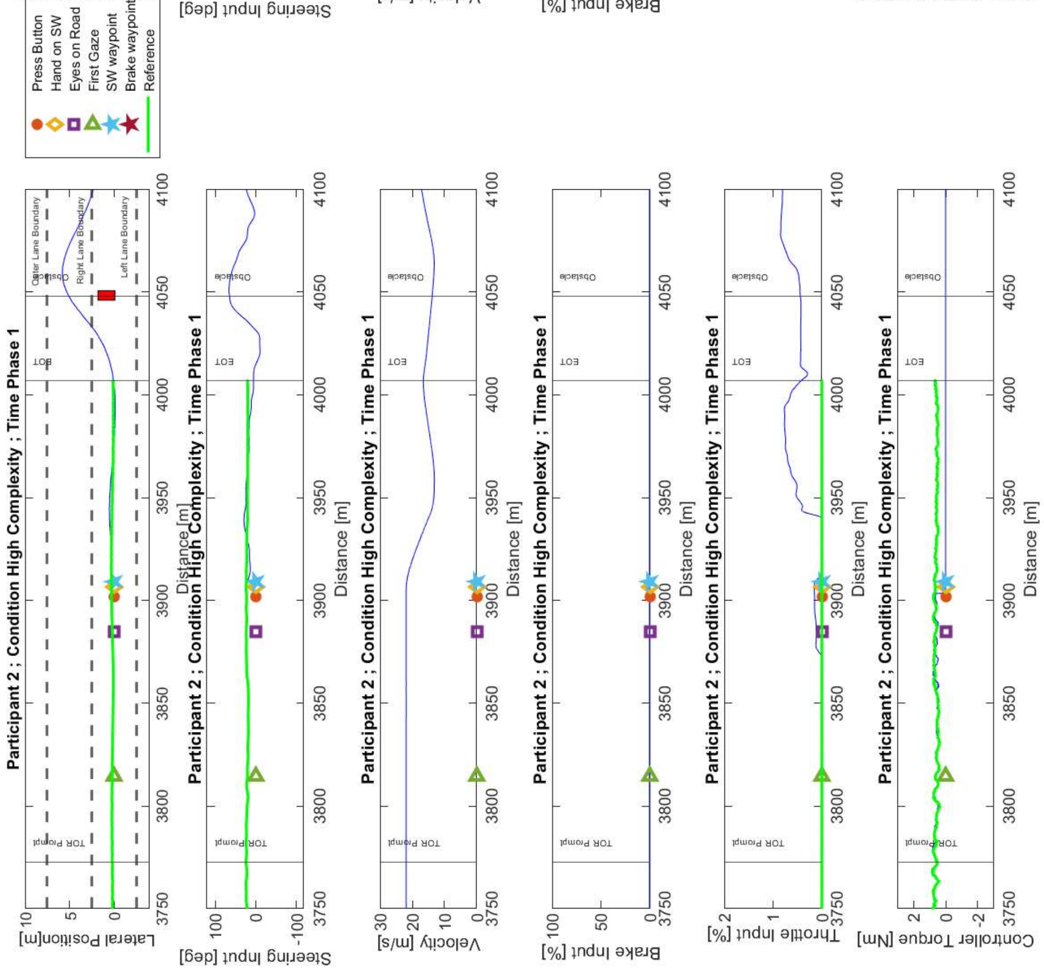
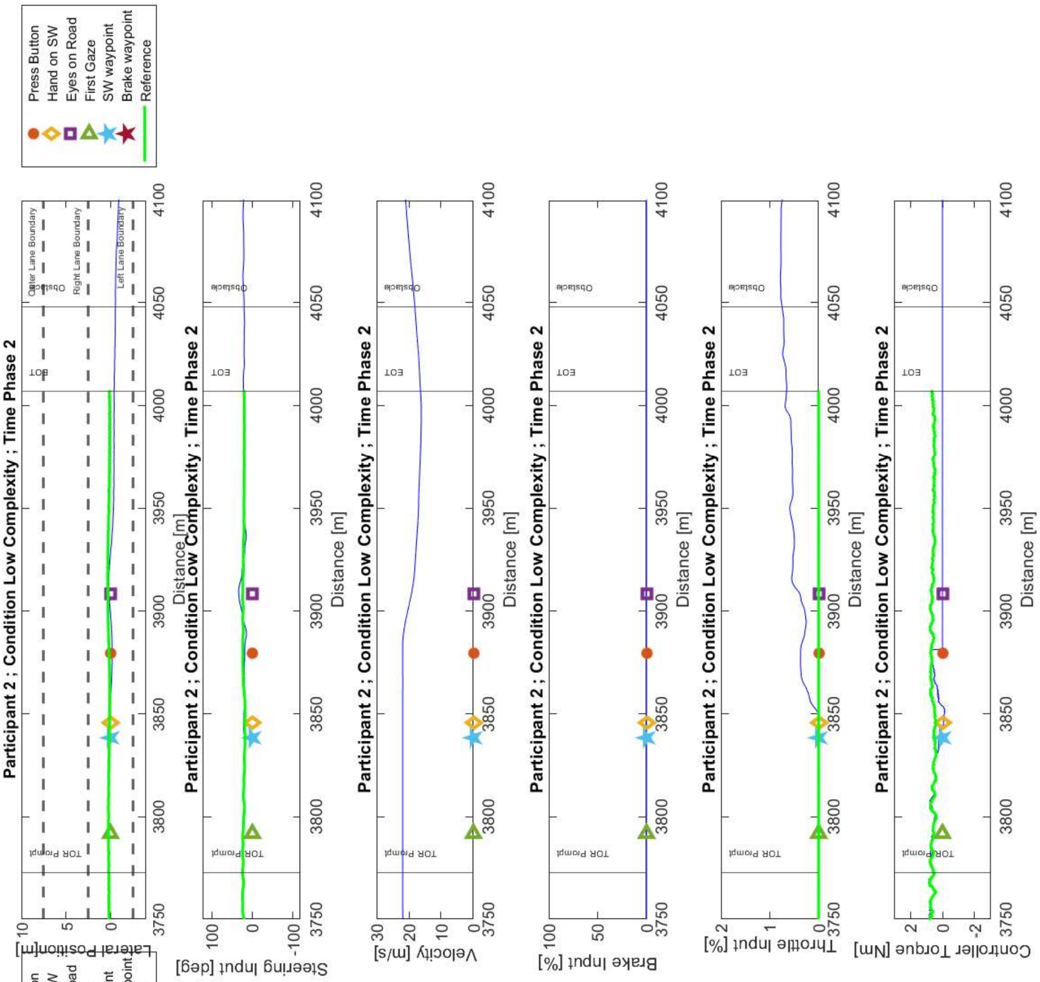
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

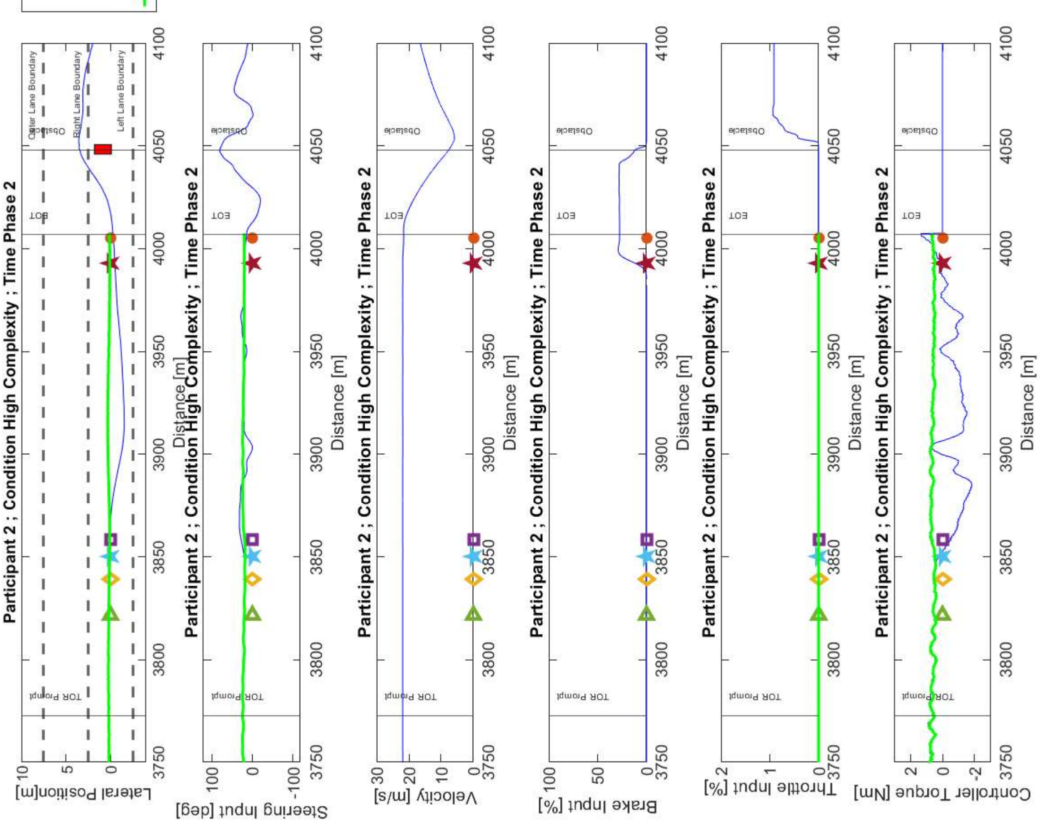

Participant 1 ; Condition High Complexity ; Time Phase 2
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

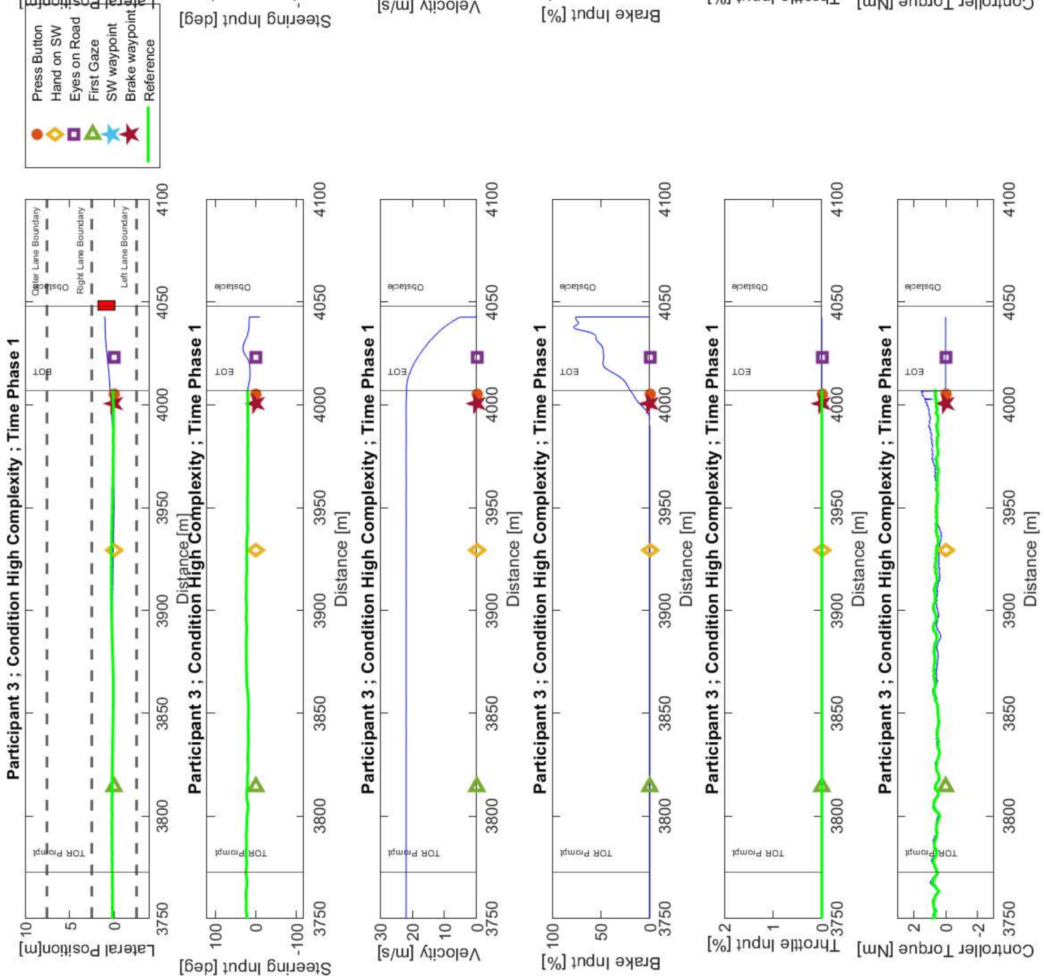

Participant 1 ; Condition Low Complexity ; Time Phase 2
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

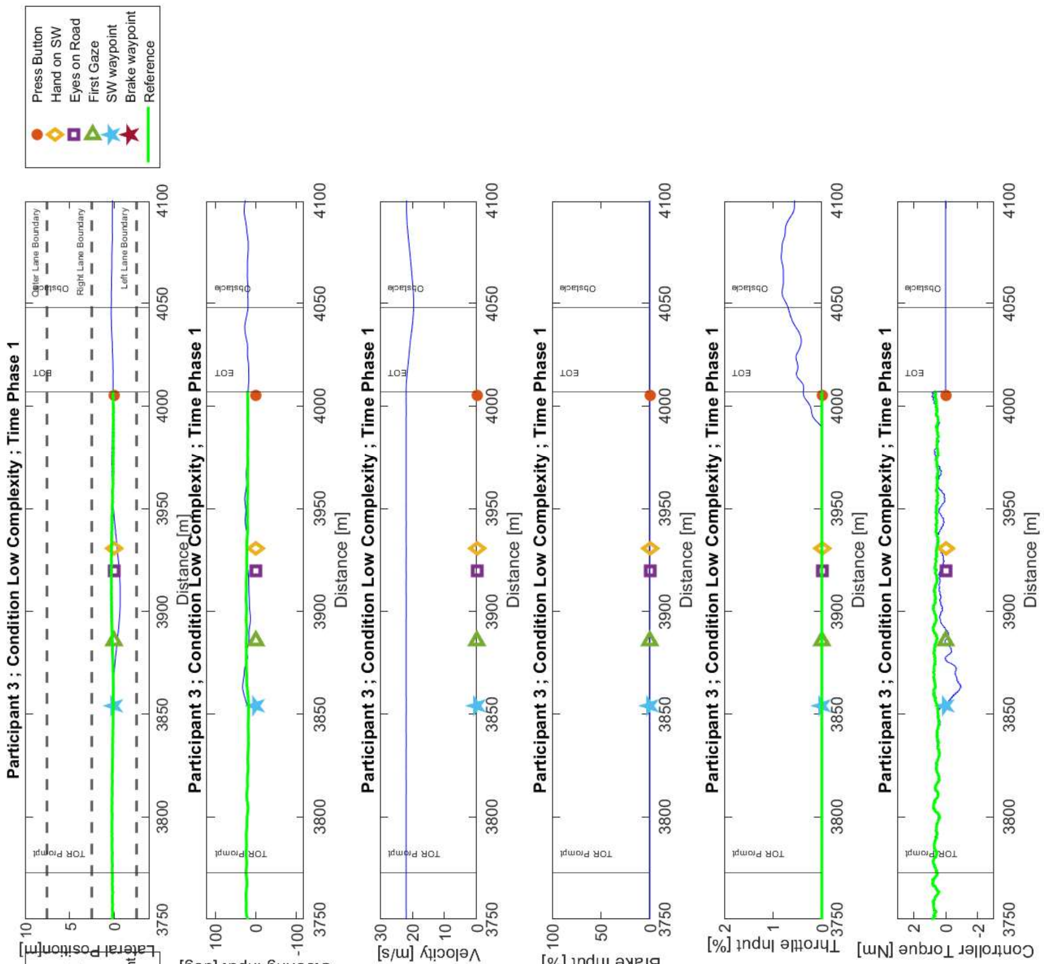

Participant 2 ; Condition Low Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

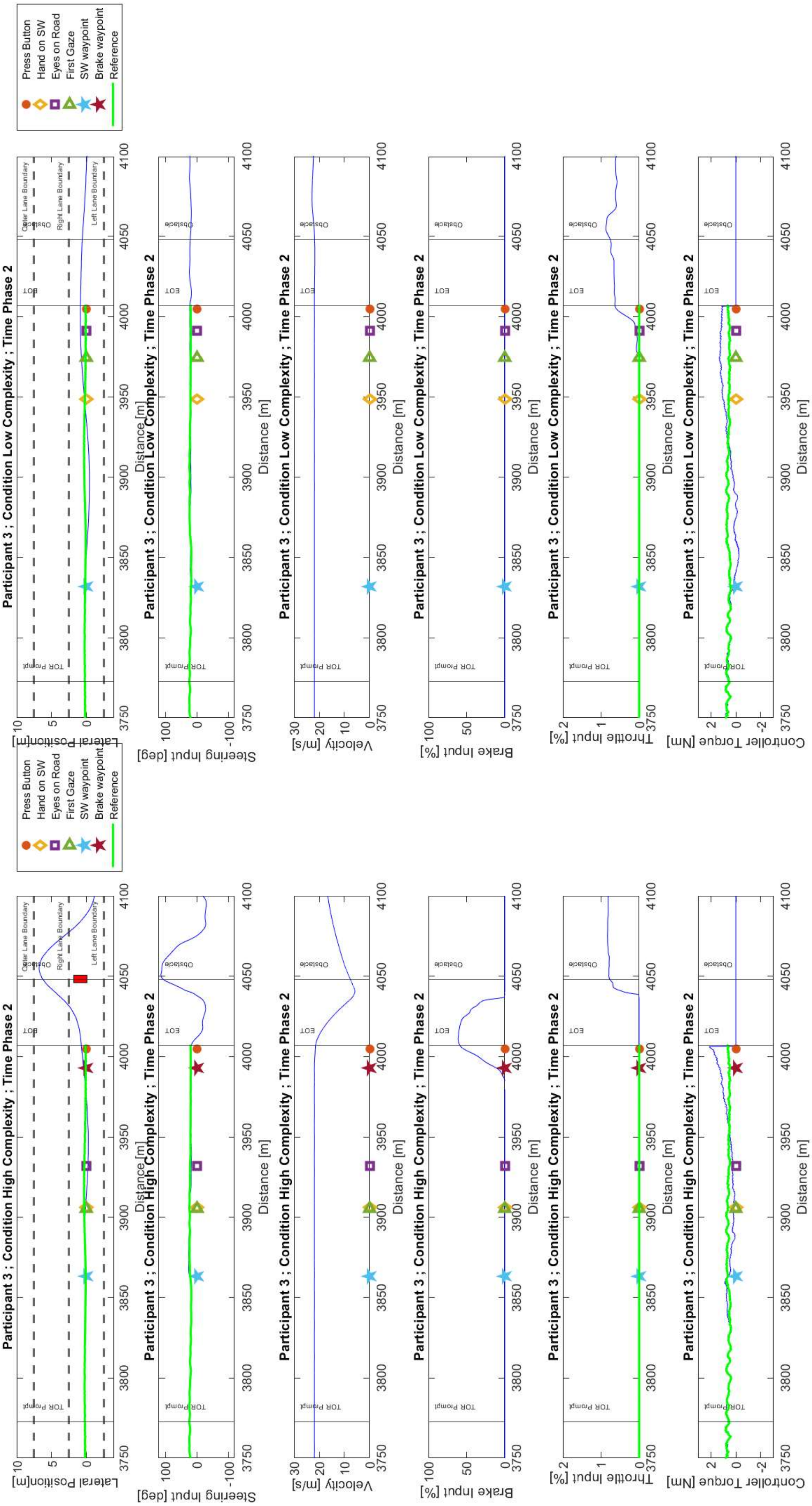

Participant 2 ; Condition High Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

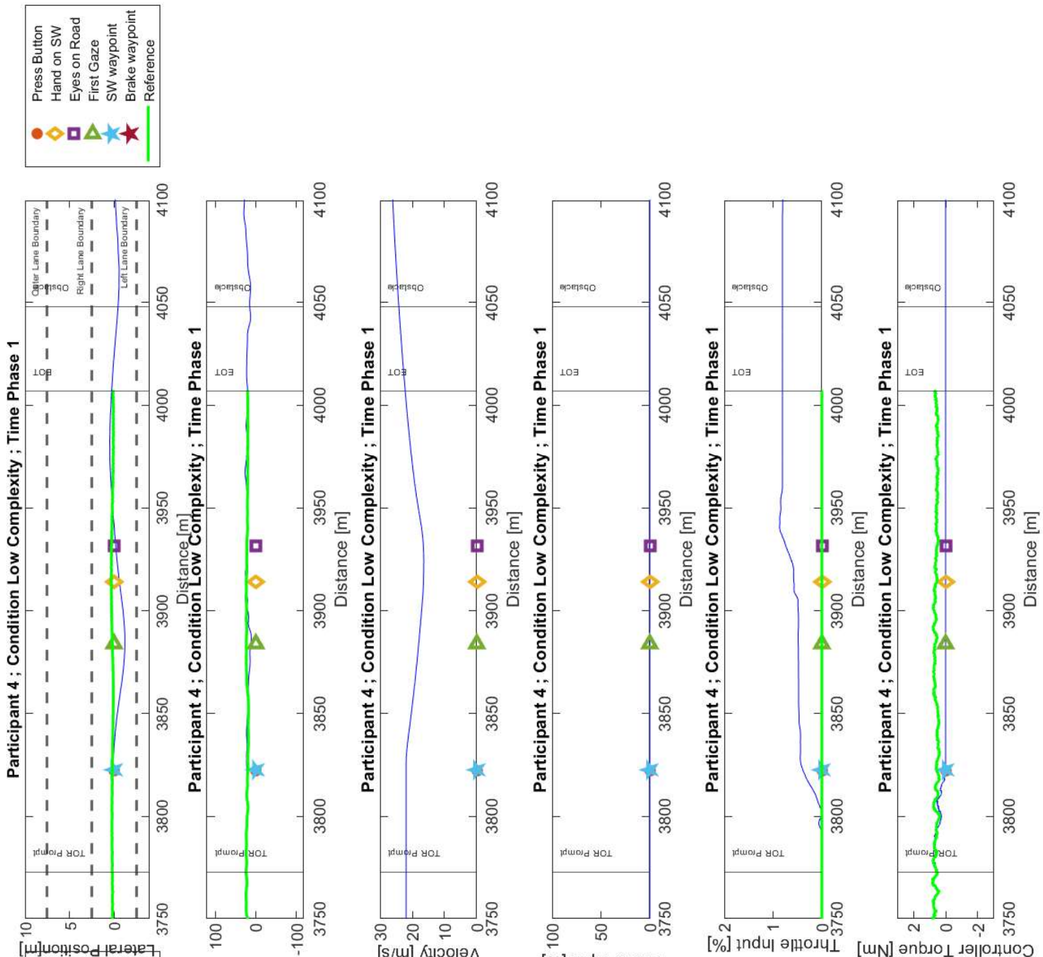

Participant 2 ; Condition Low Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

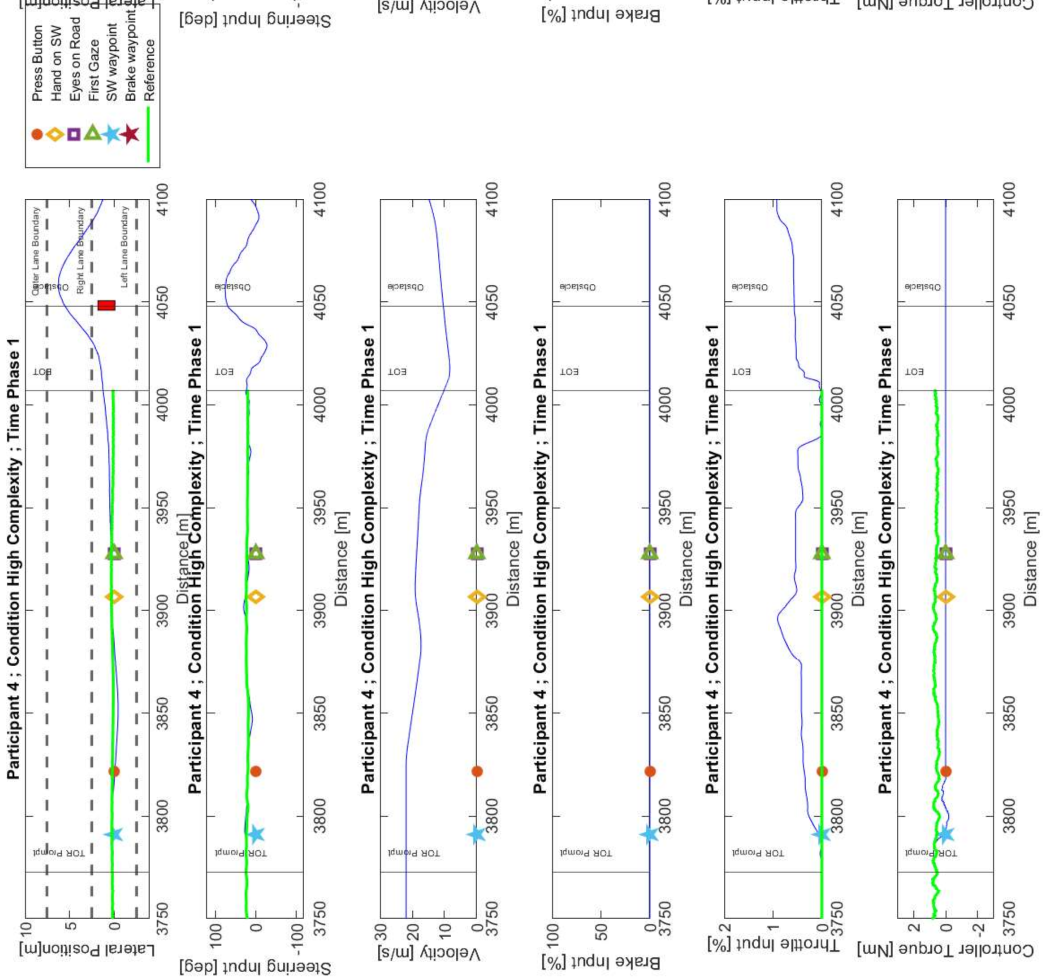

Participant 2 ; Condition High Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

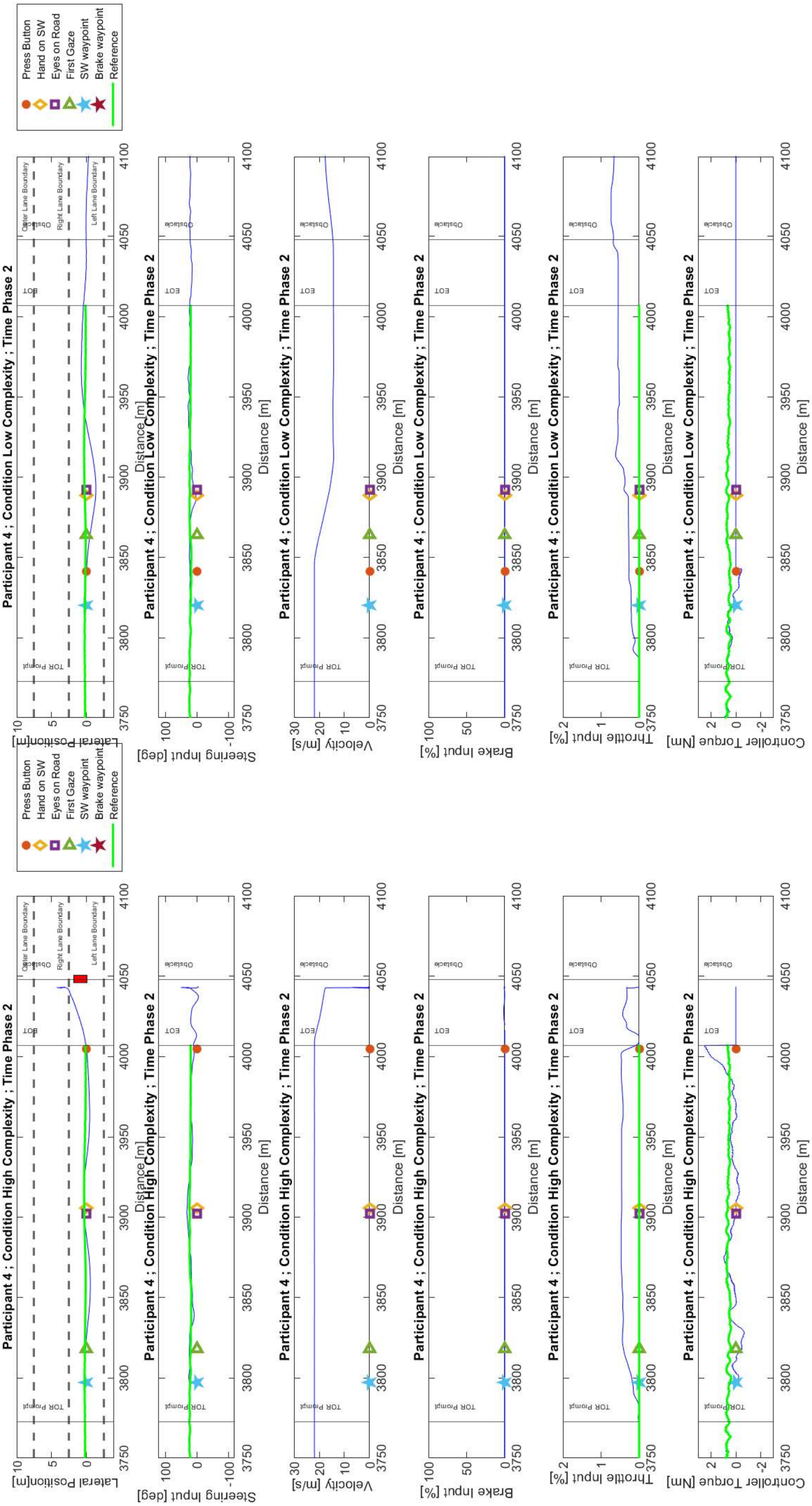

Participant 3 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

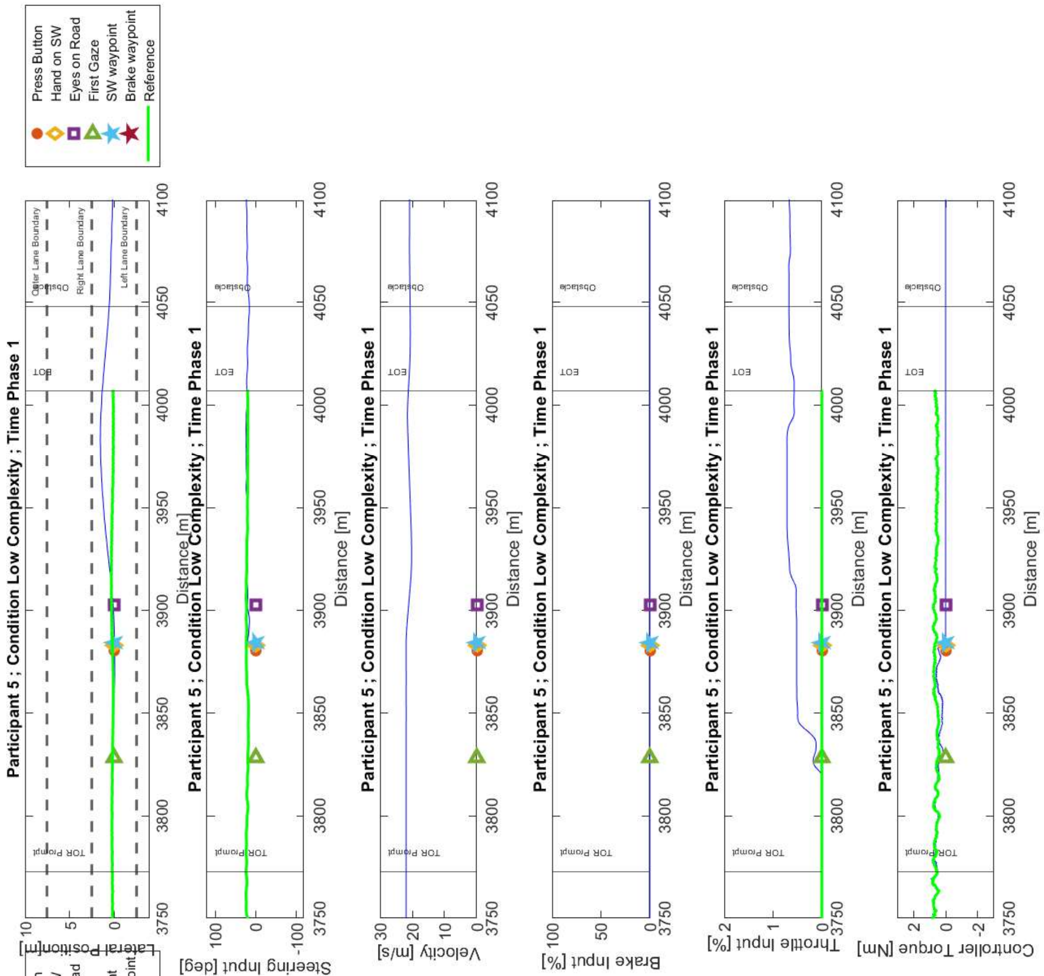

Participant 3 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary


Participant 3 ; Condition High Complexity ; Time Phase 2
Participant 3 ; Condition Low Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

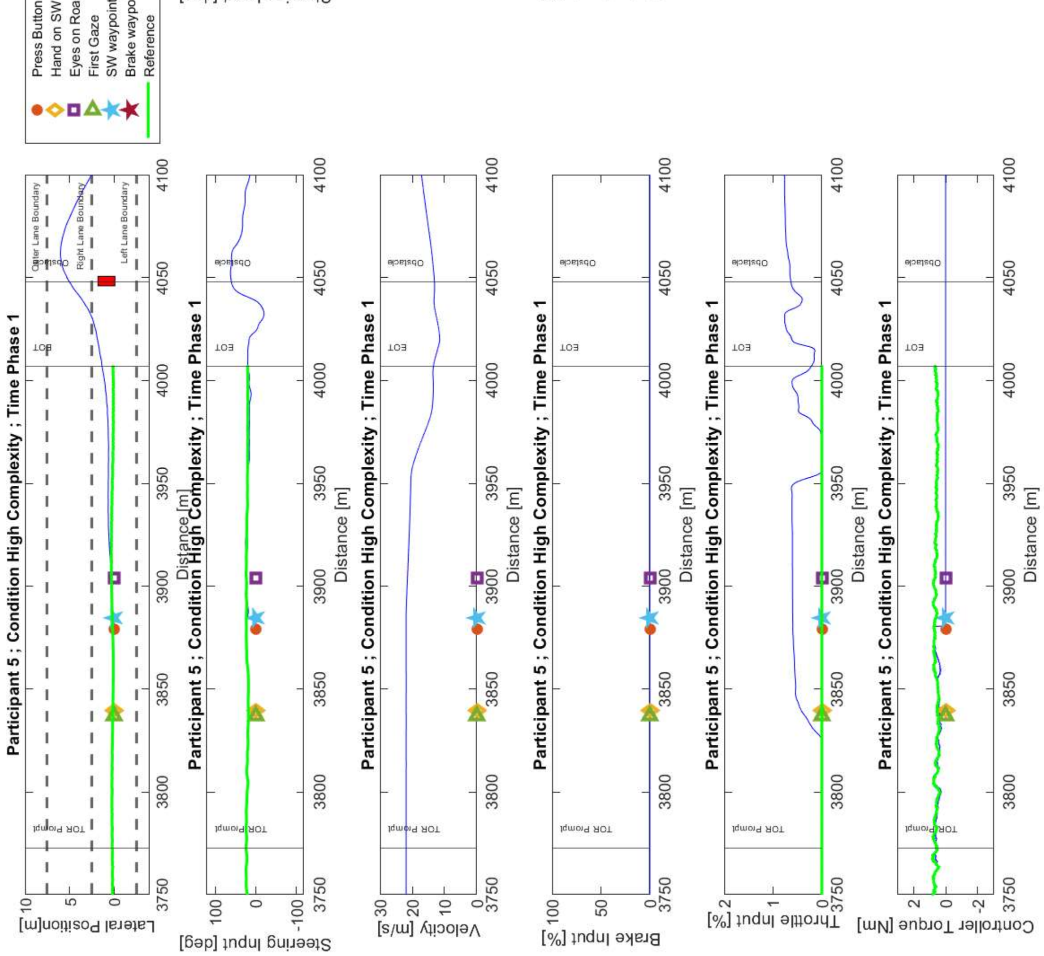

Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Participant 4 ; Condition Low Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary


Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Participant 4 ; Condition High Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

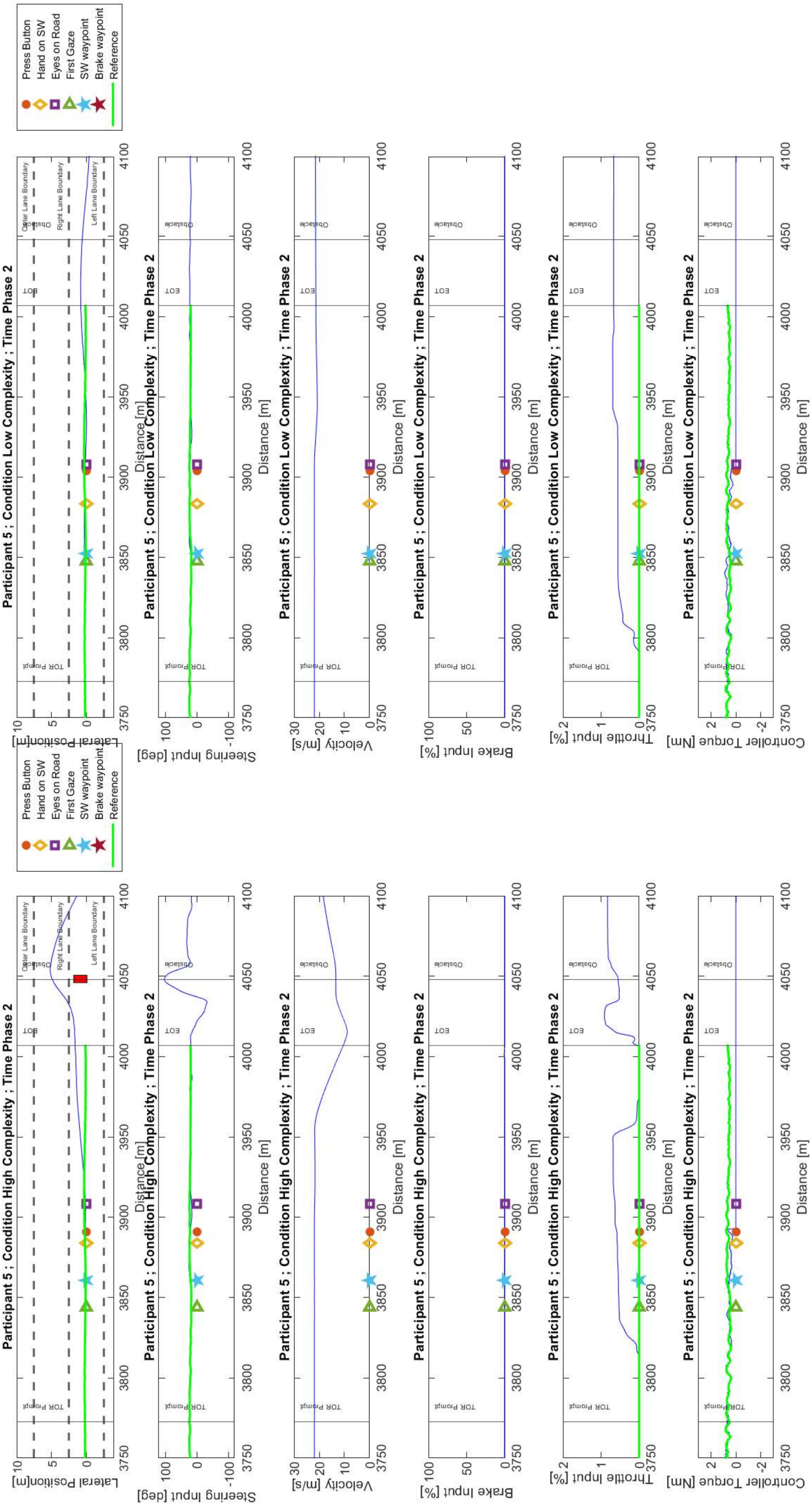

Participant 4 ; Condition High Complexity ; Time Phase 2
Participant 4 ; Condition Low Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

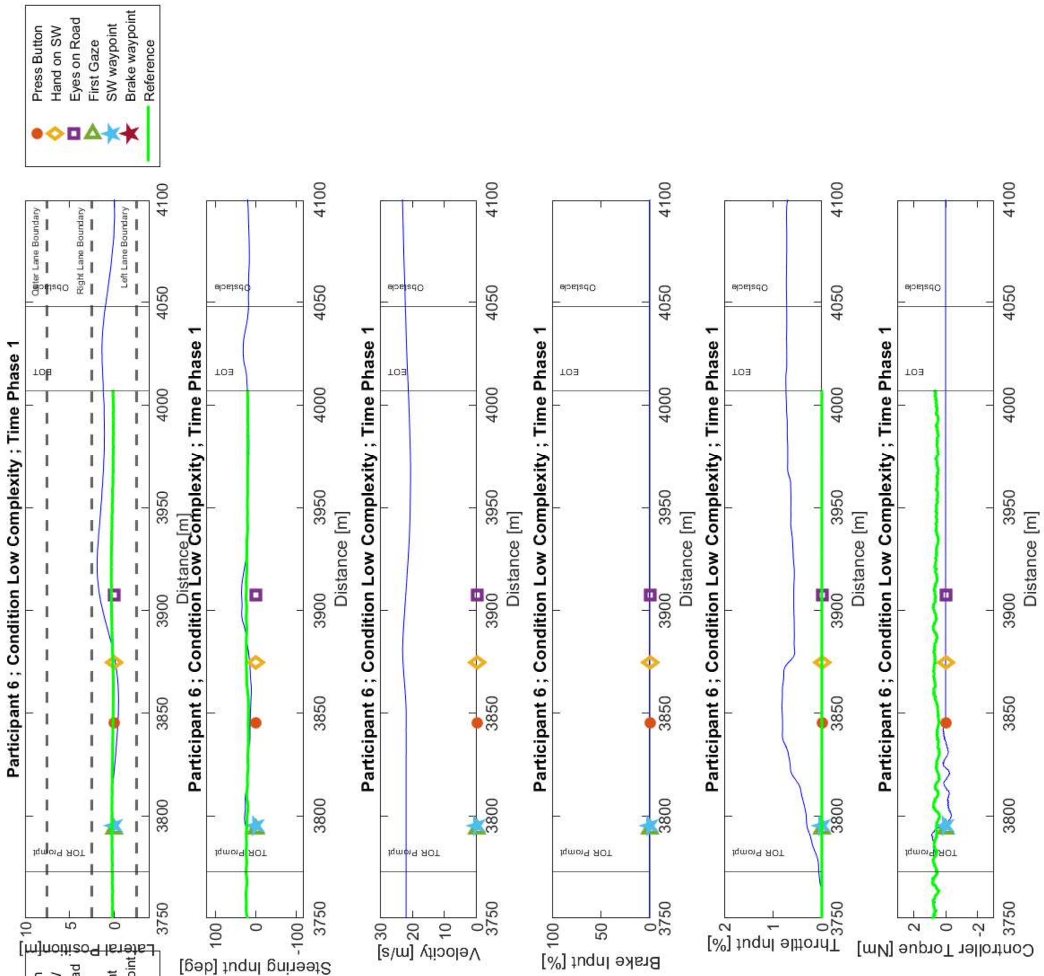


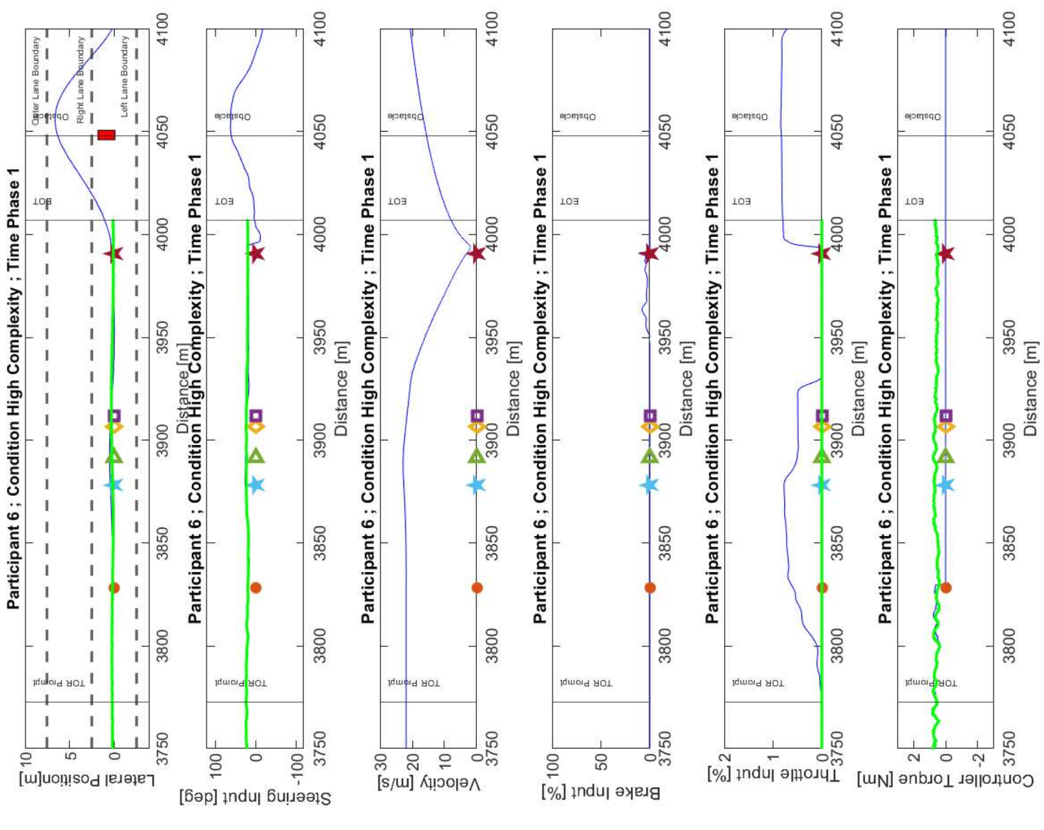
Participant 5 ; Condition Low Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

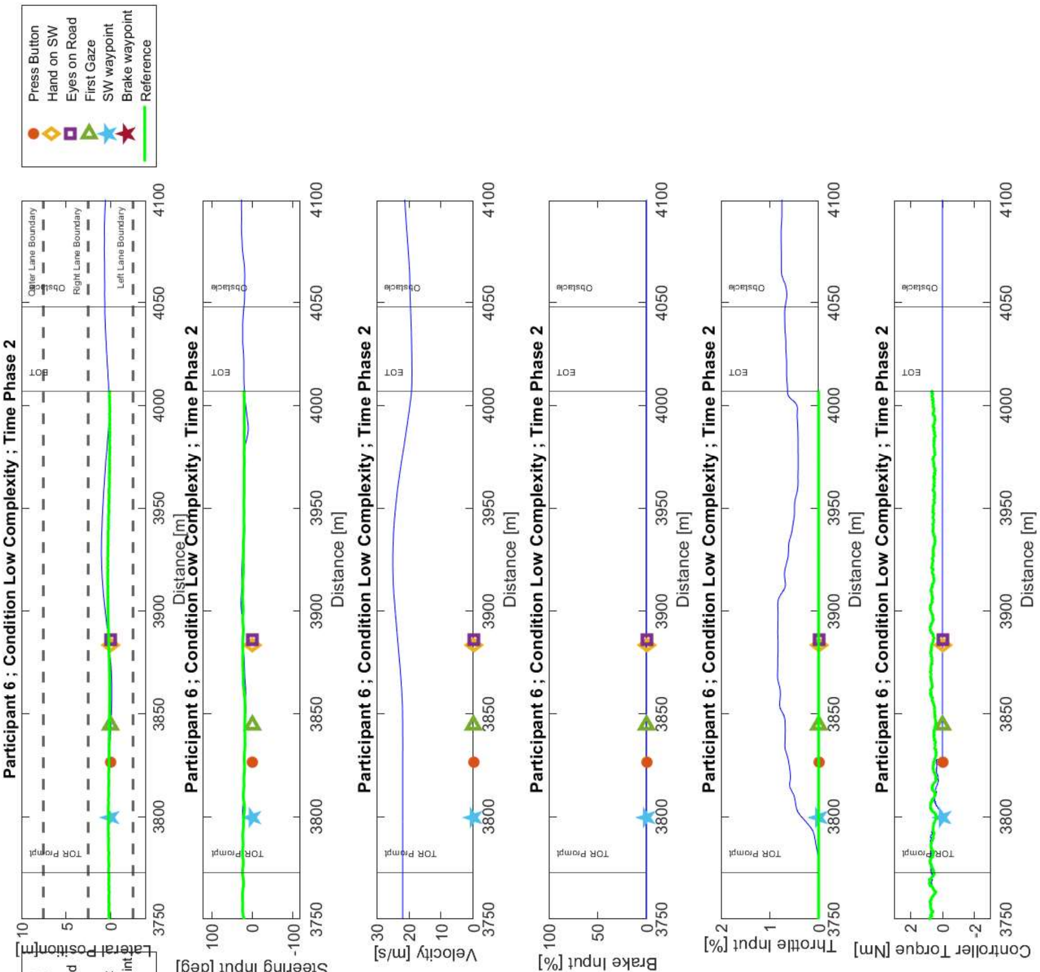


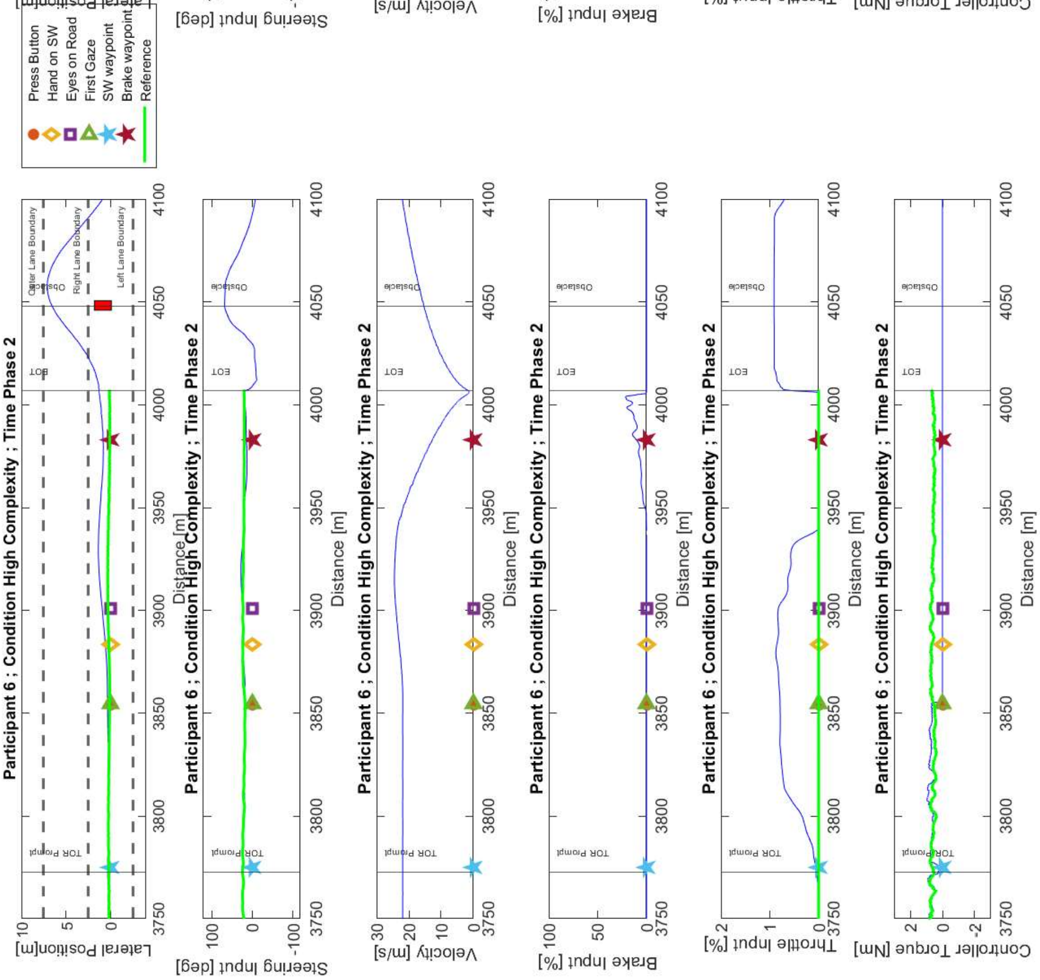
Participant 5 ; Condition High Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

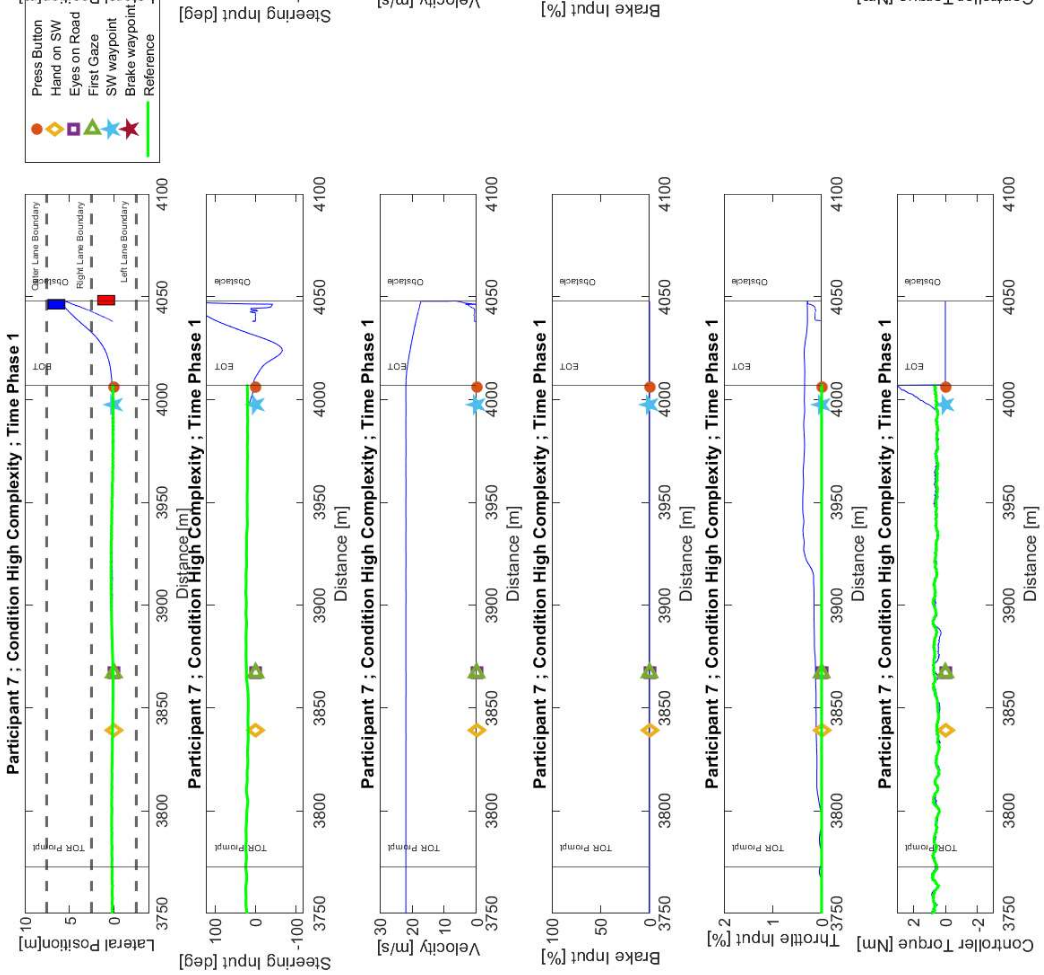

Participant 5 ; Condition Low Complexity ; Time Phase 2
Participant 5 ; Condition High Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

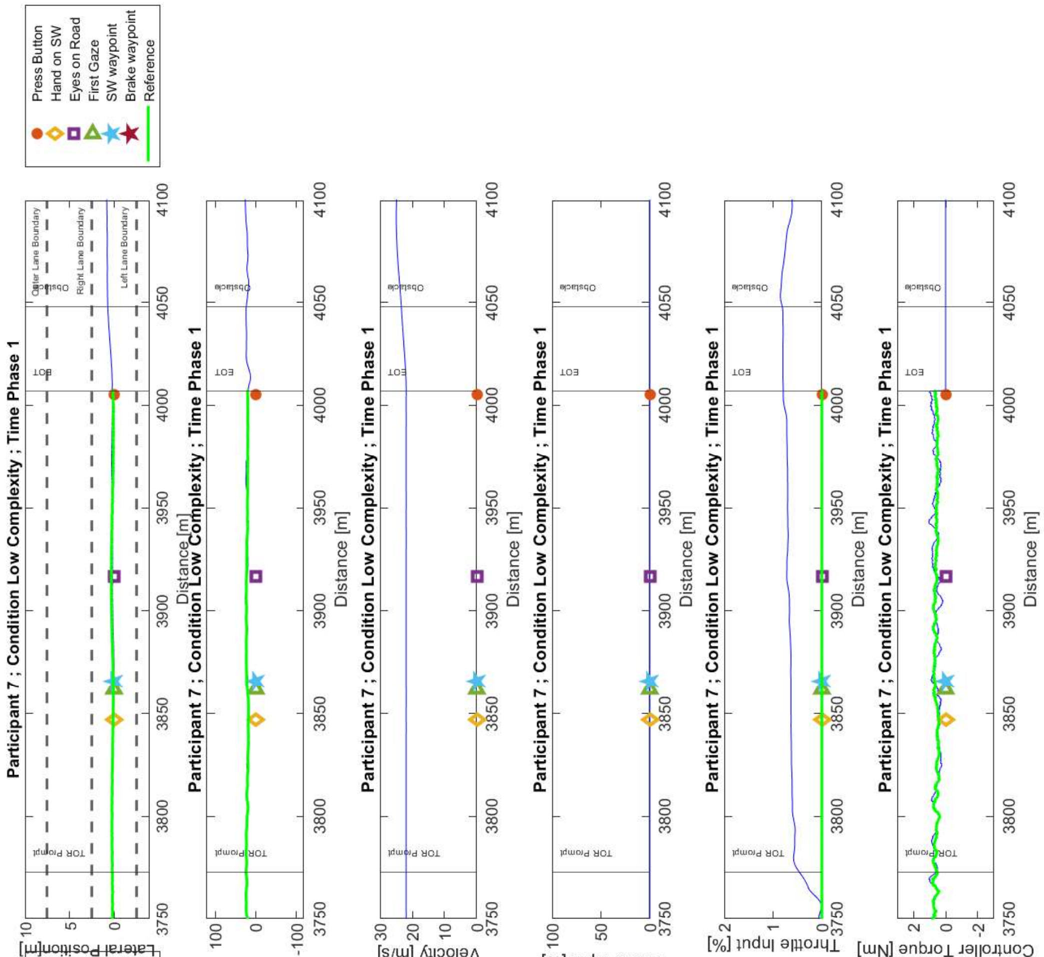

Participant 6 ; Condition Low Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

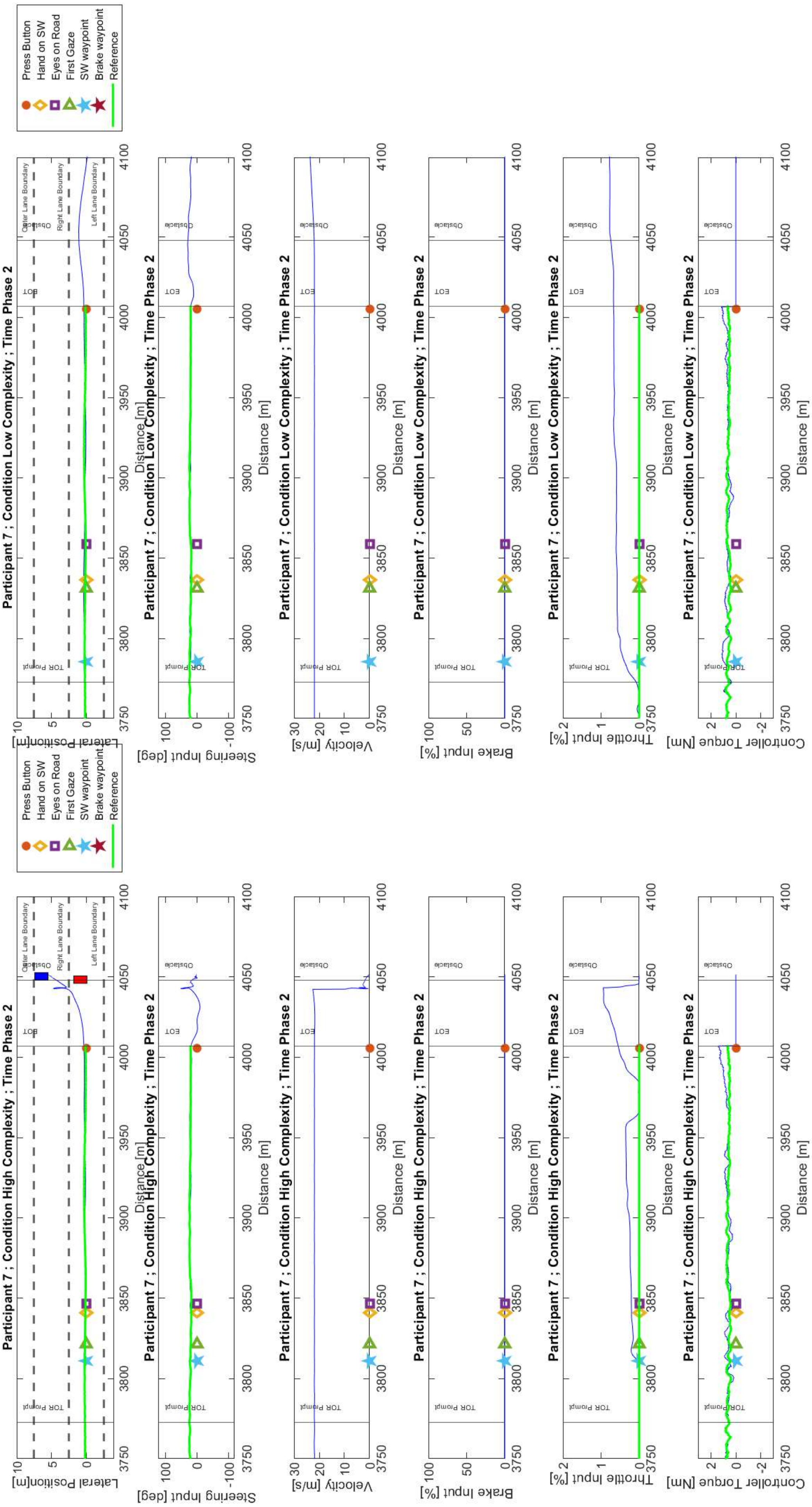

Participant 6 ; Condition High Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

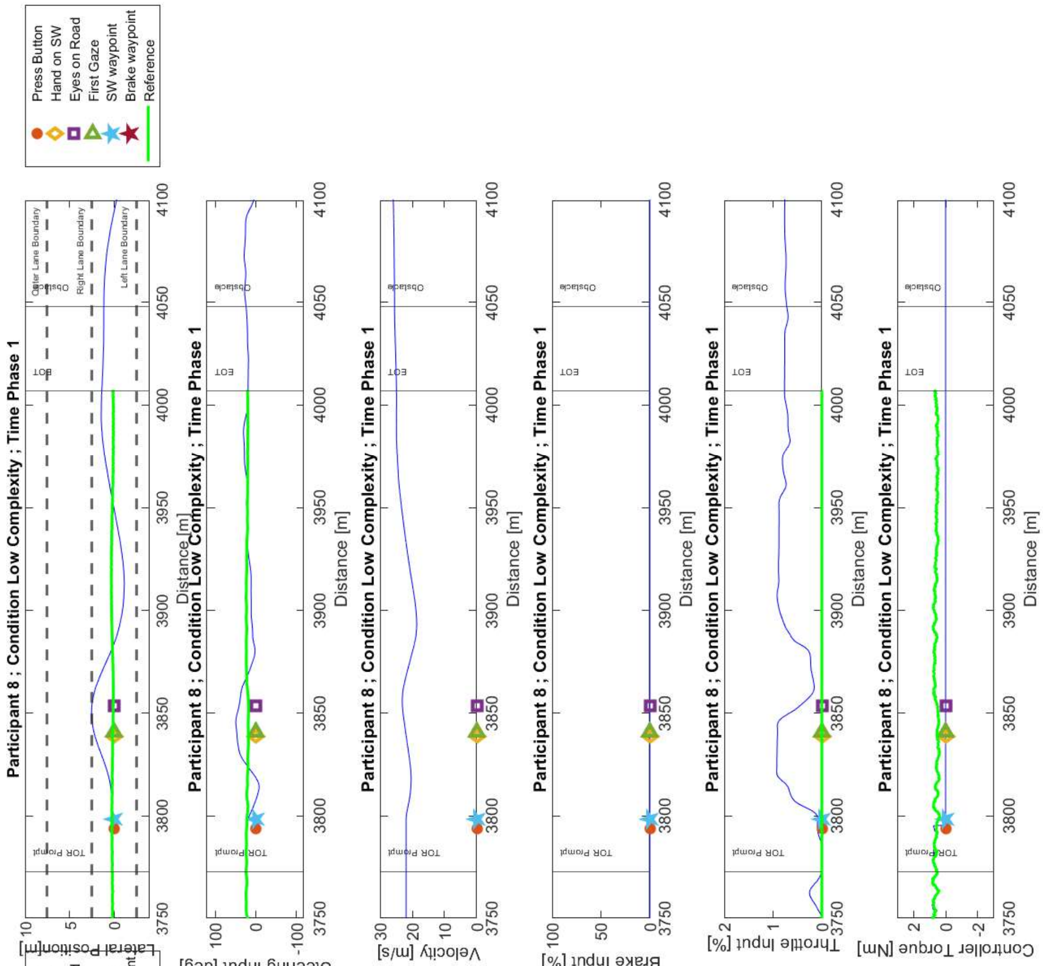

Participant 6 ; Condition Low Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]

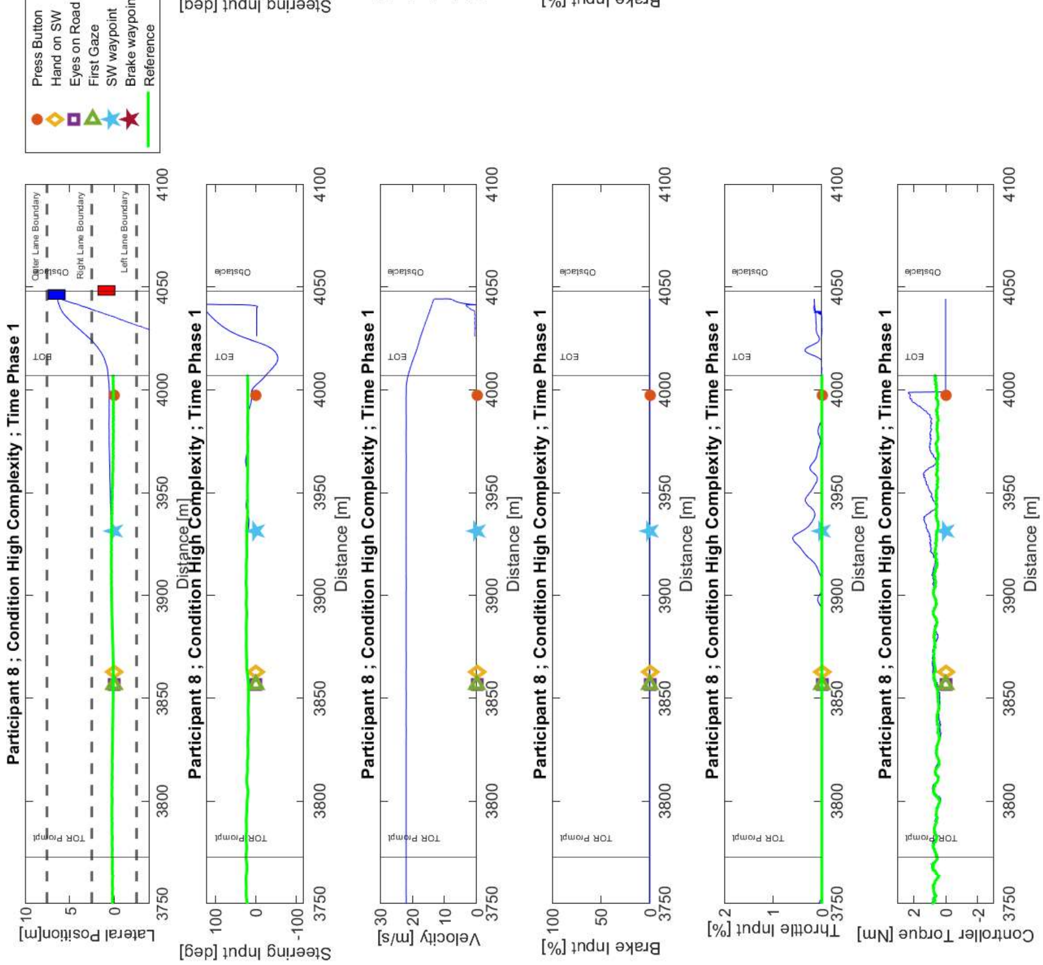

Participant 6 ; Condition High Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]

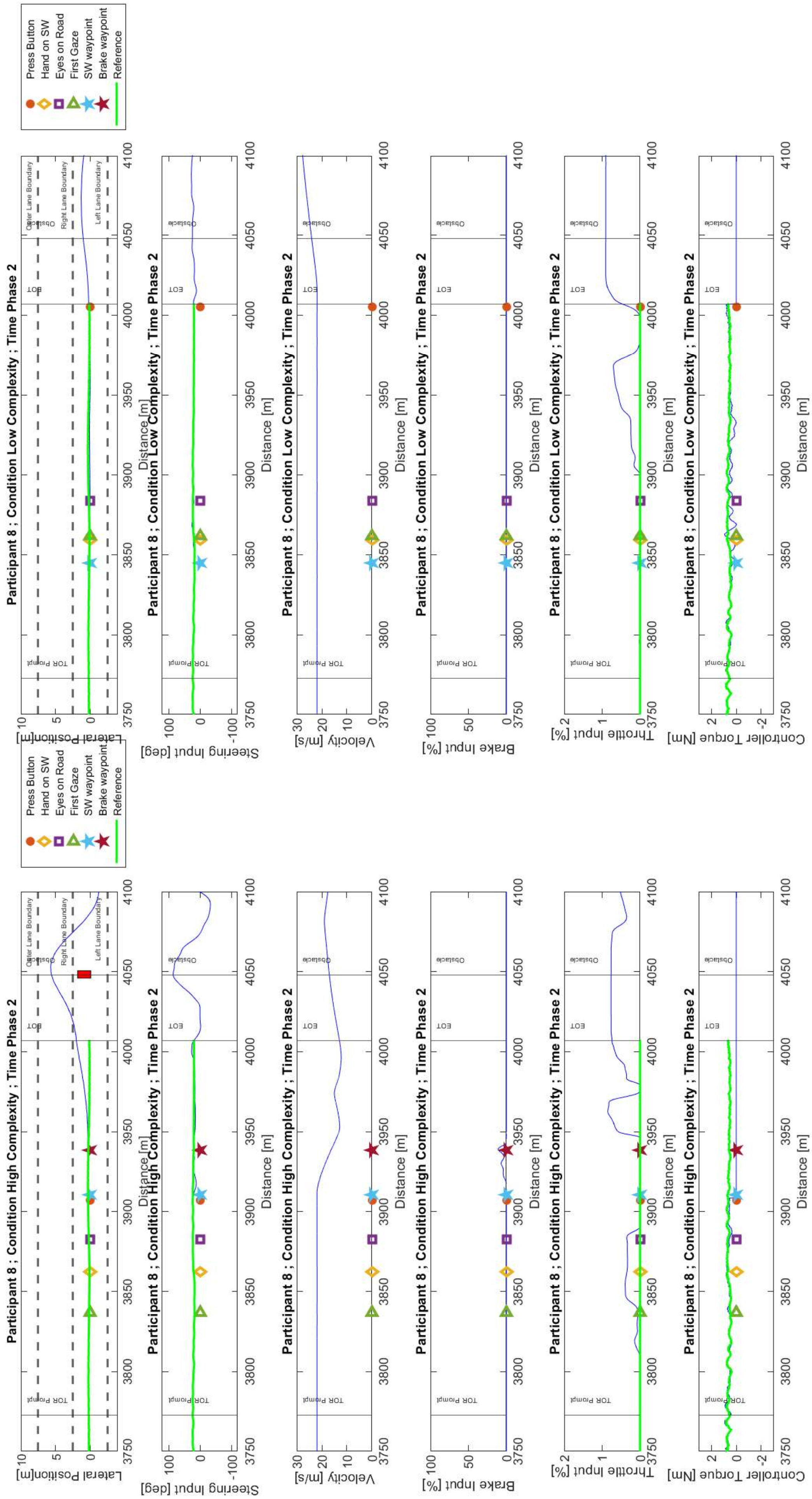

Participant 7 ; Condition High Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference


Participant 7 ; Condition Low Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

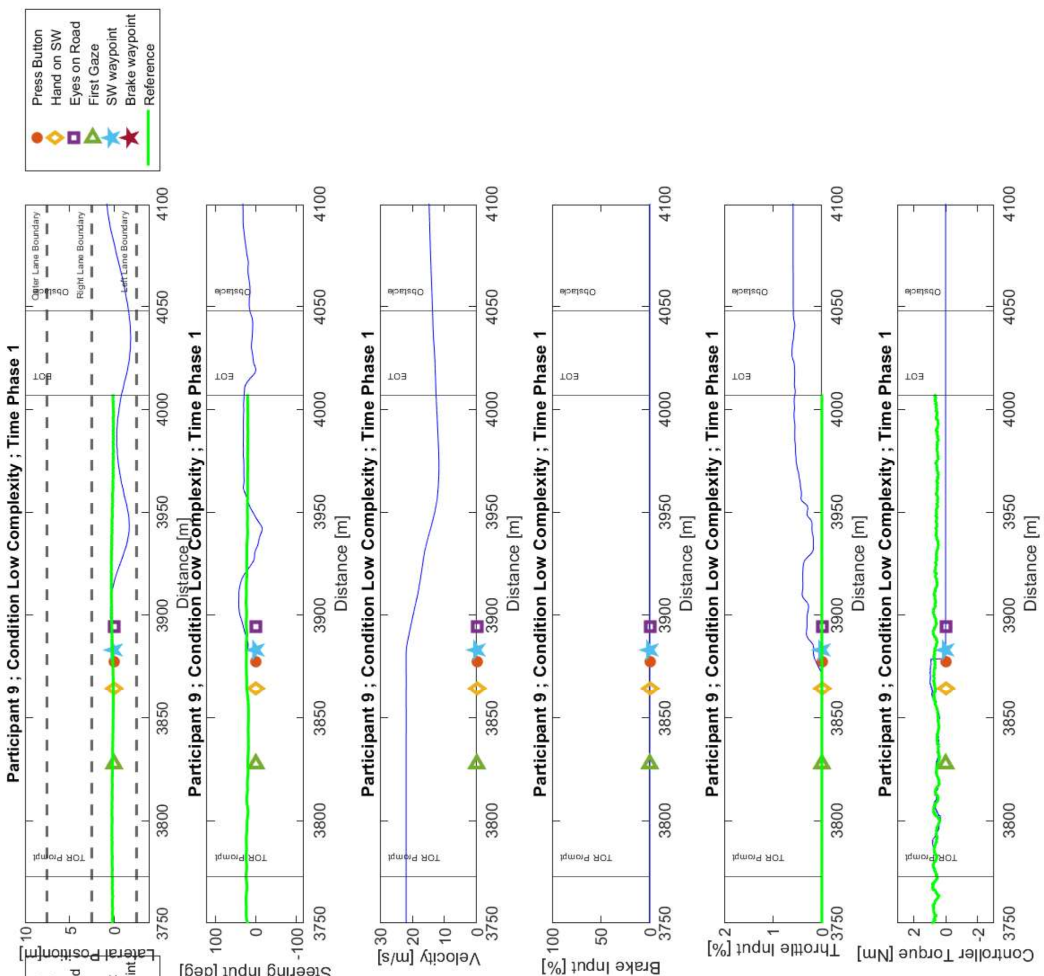

Participant 7 ; Condition Low Complexity ; Time Phase 2
Participant 7 ; Condition High Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]

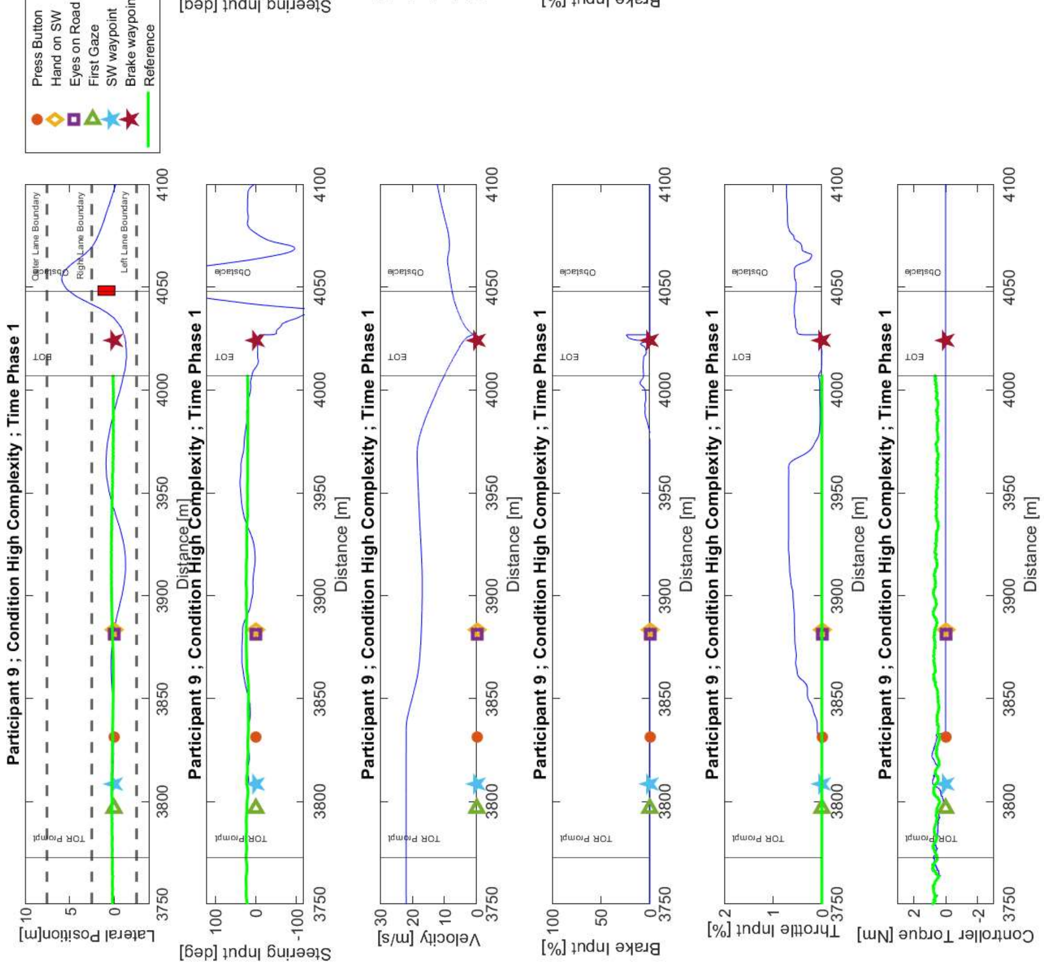

Participant 8 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

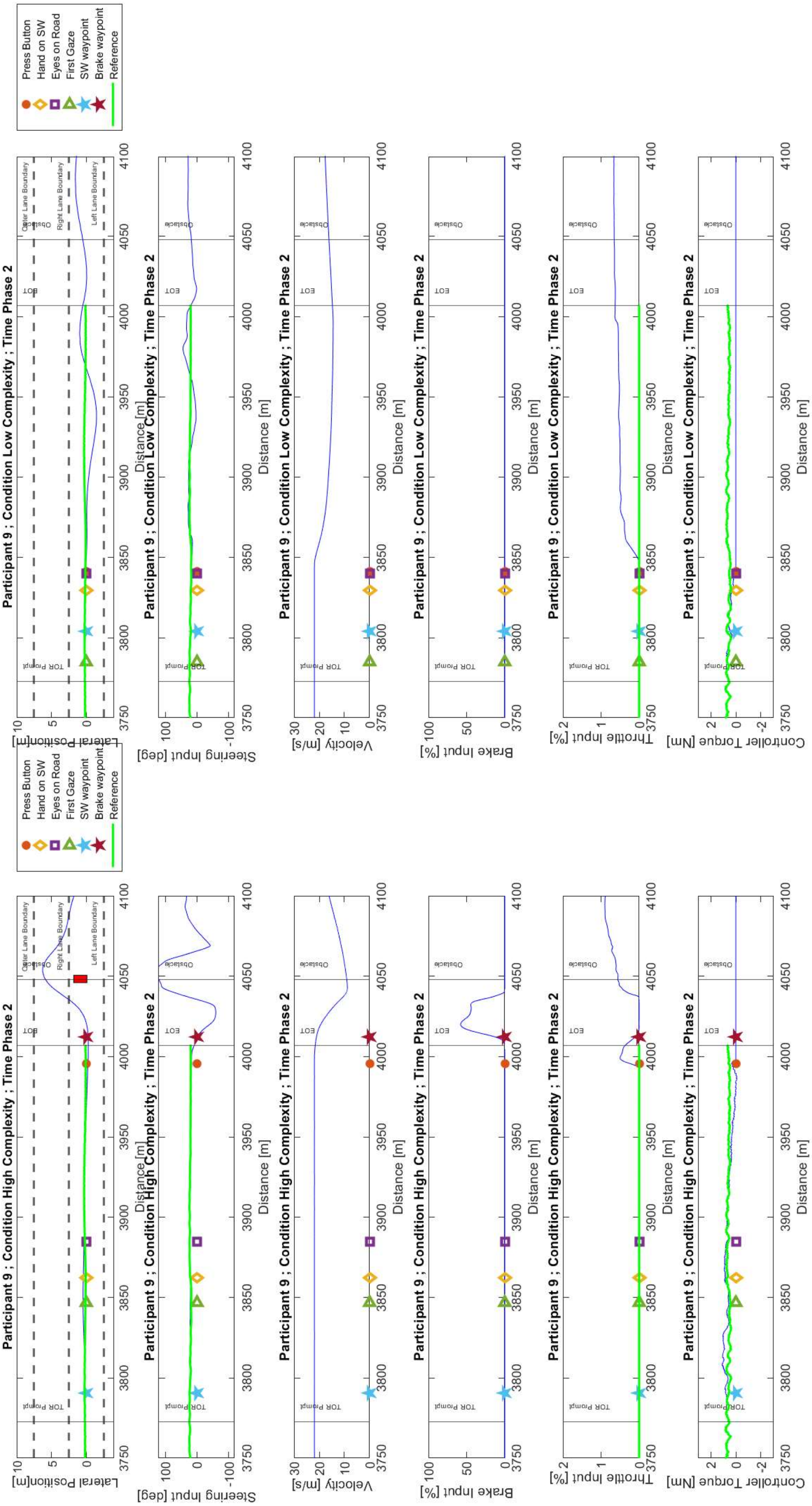

Participant 8 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary



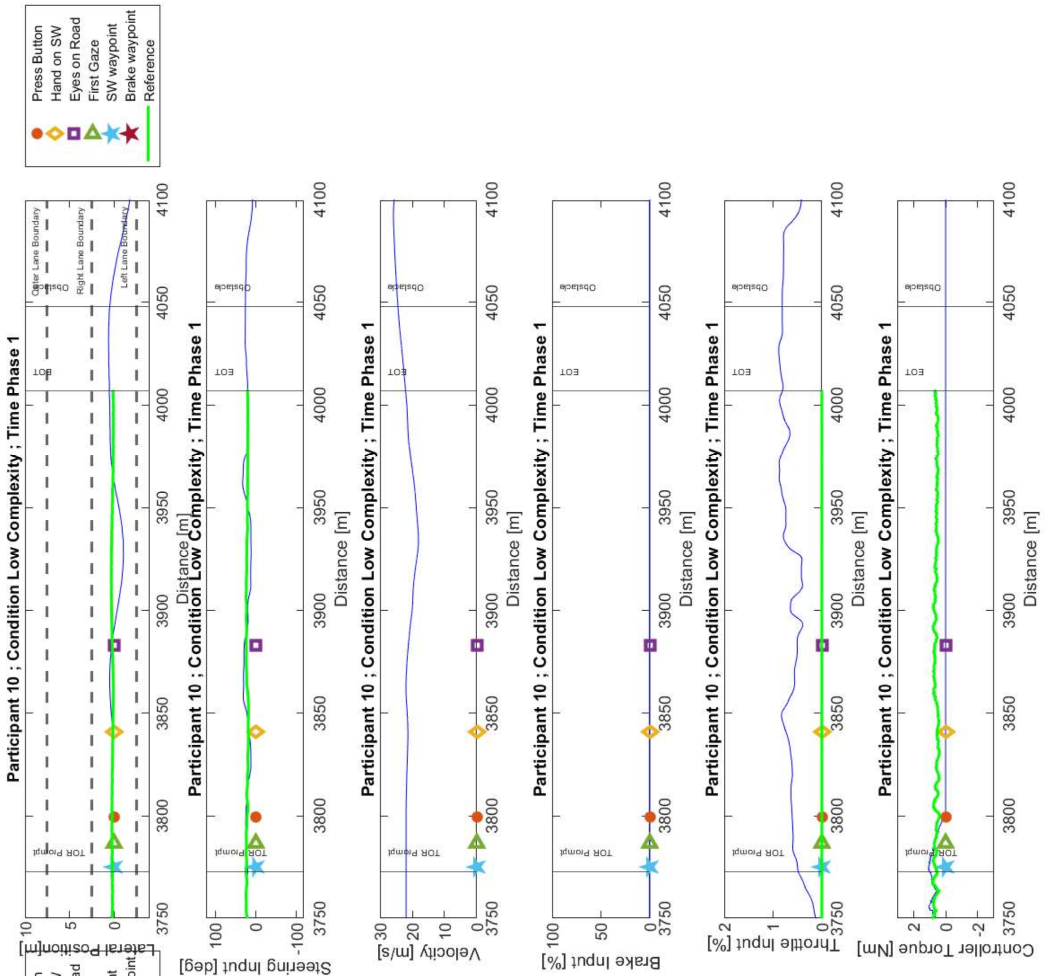
Participant 8 ; Condition Low Complexity ; Time Phase 2
Participant 8 ; Condition High Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
TOR Prompt
EOT
Obstacle
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]


Participant 9 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

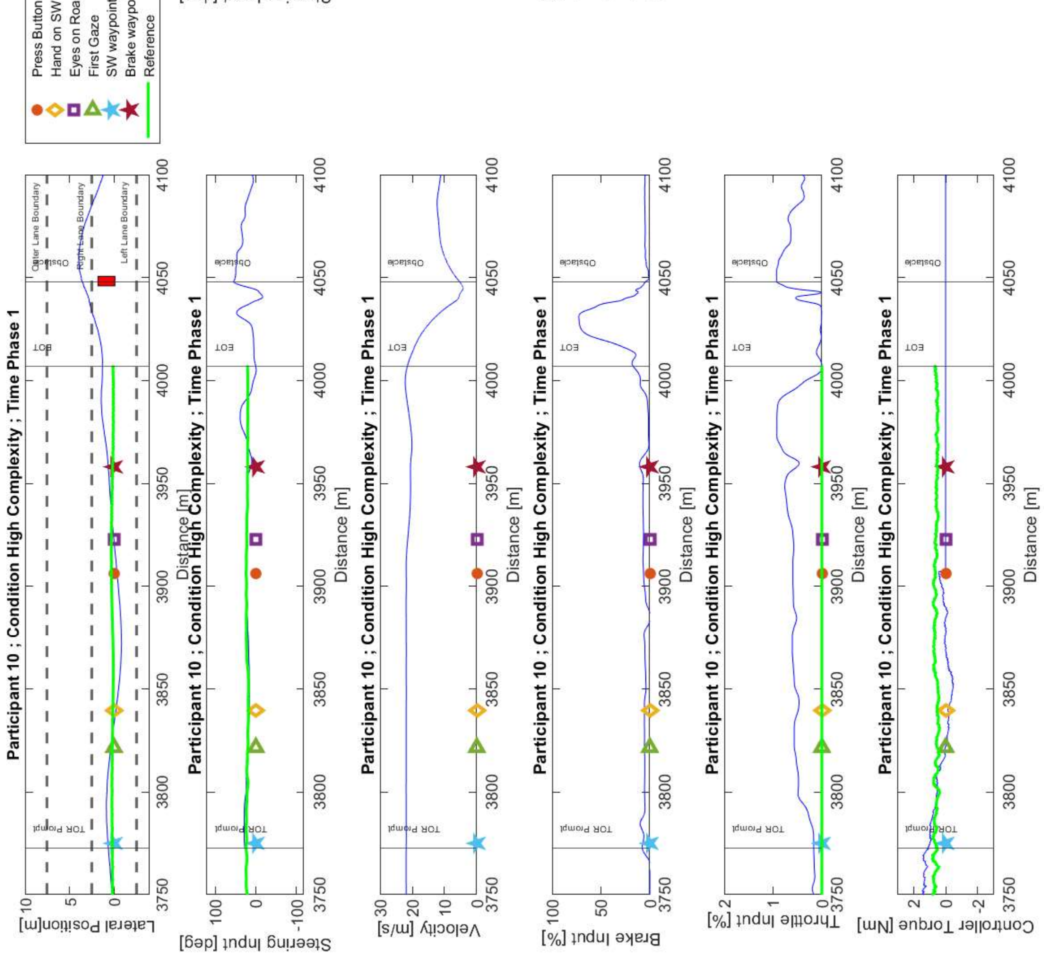

Participant 9 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary



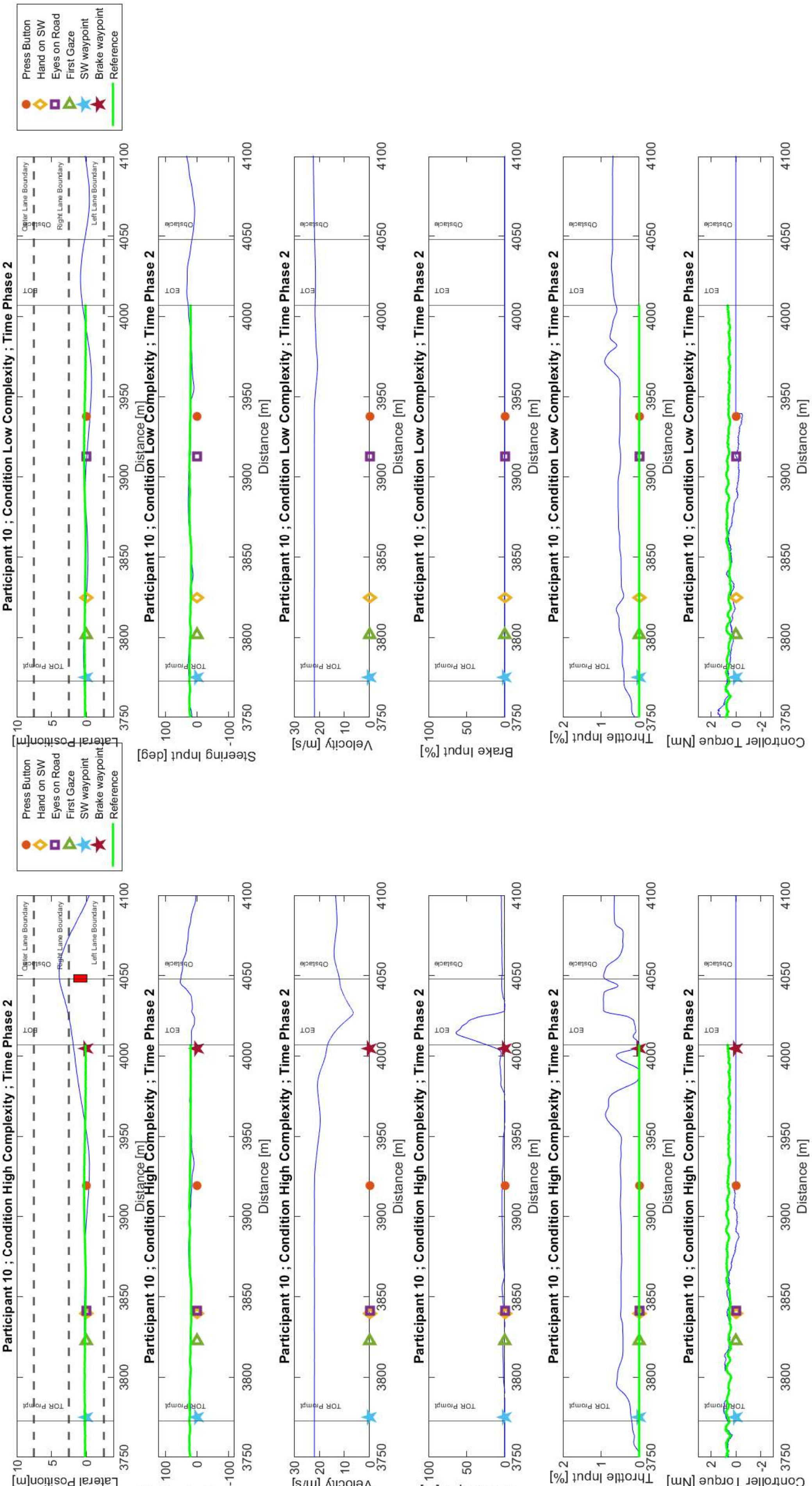
Participant 9 ; Condition High Complexity ; Time Phase 2
Participant 9 ; Condition Low Complexity ; Time Phase 2
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

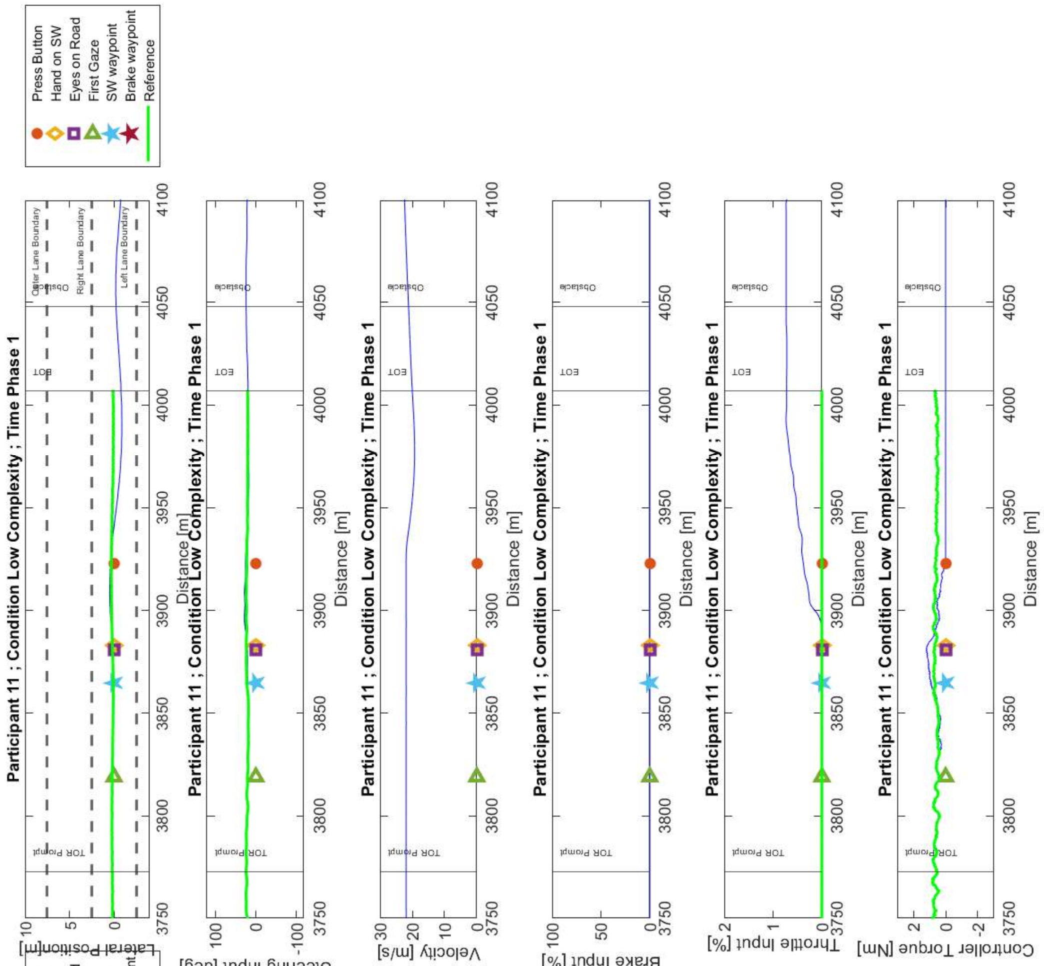


Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Participant 10 ; Condition Low Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

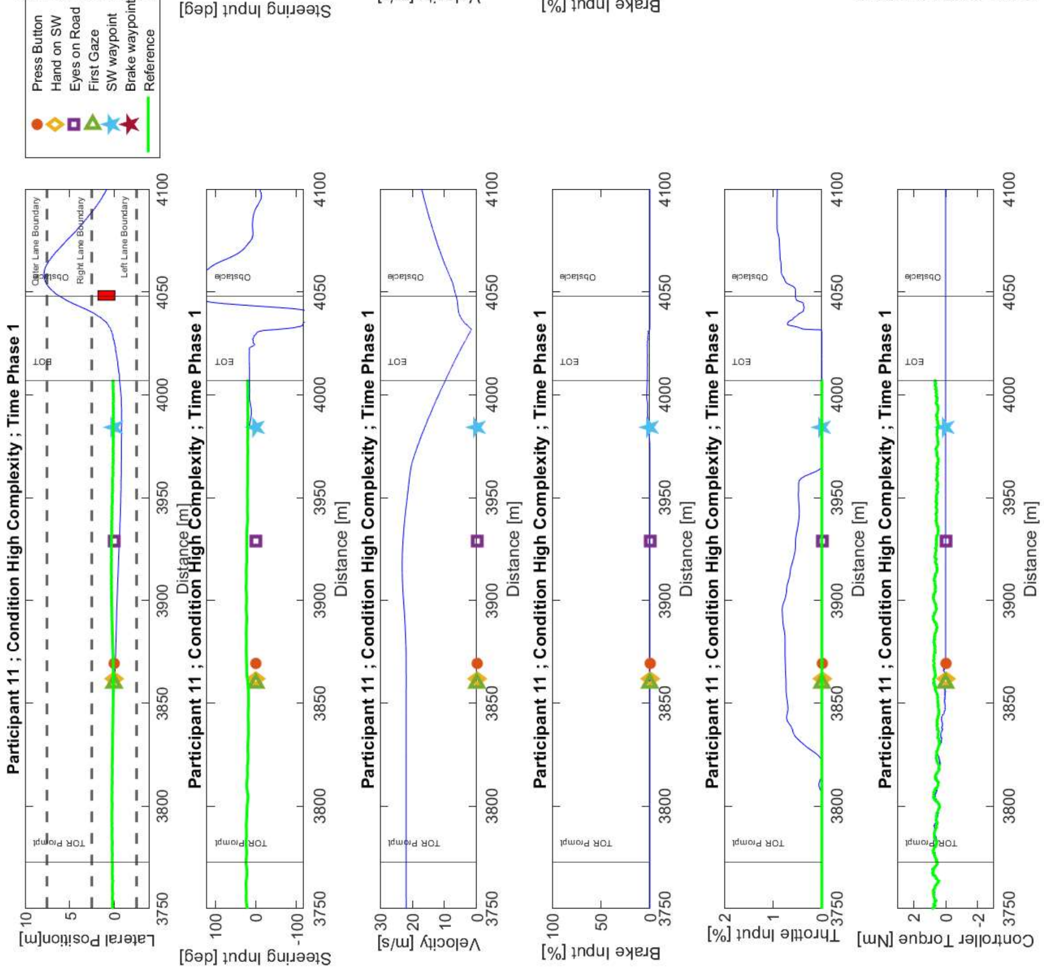


Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Participant 10 ; Condition High Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

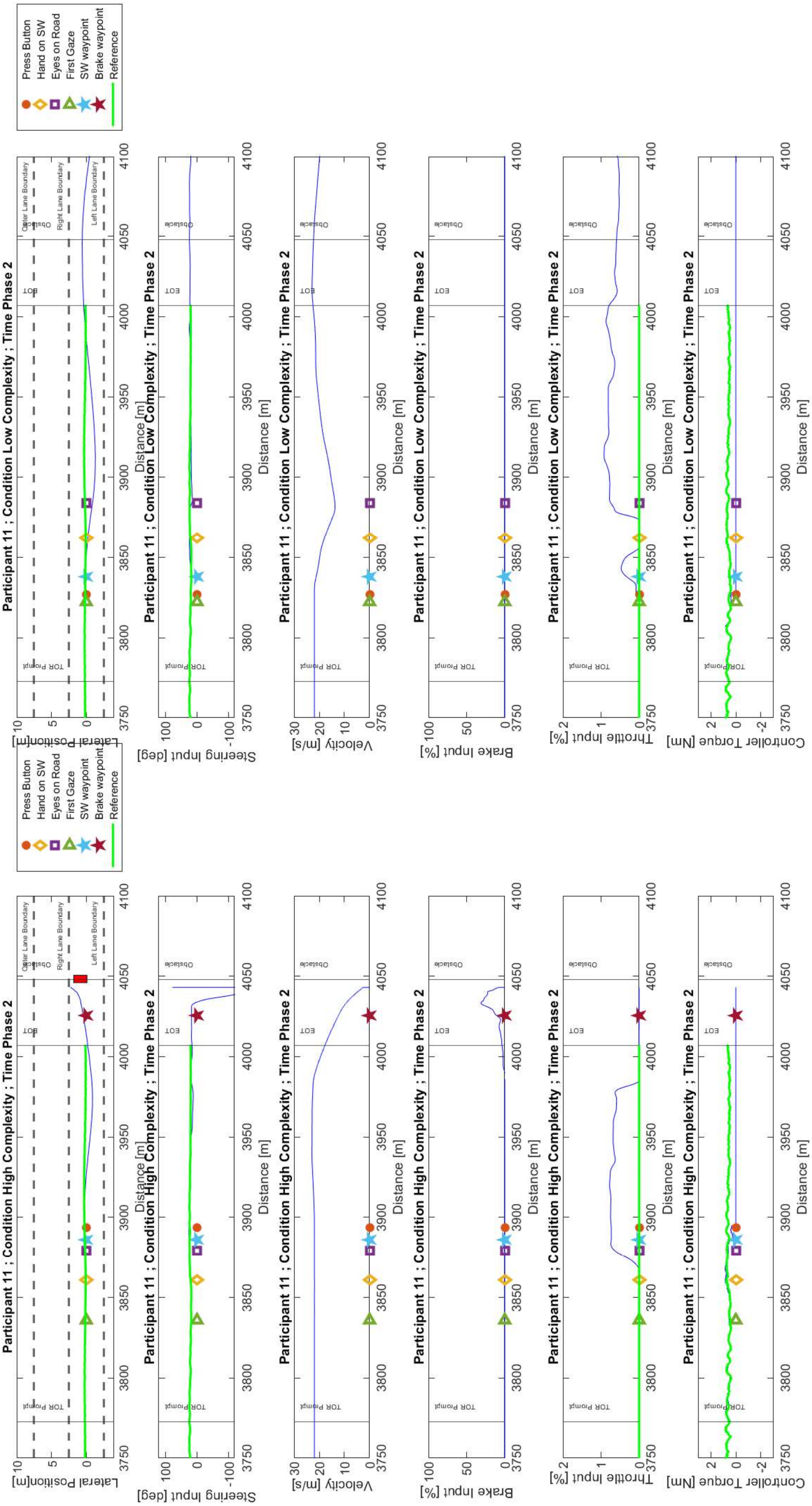

Participant 10 ; Condition High Complexity ; Time Phase 2
Participant 10 ; Condition Low Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

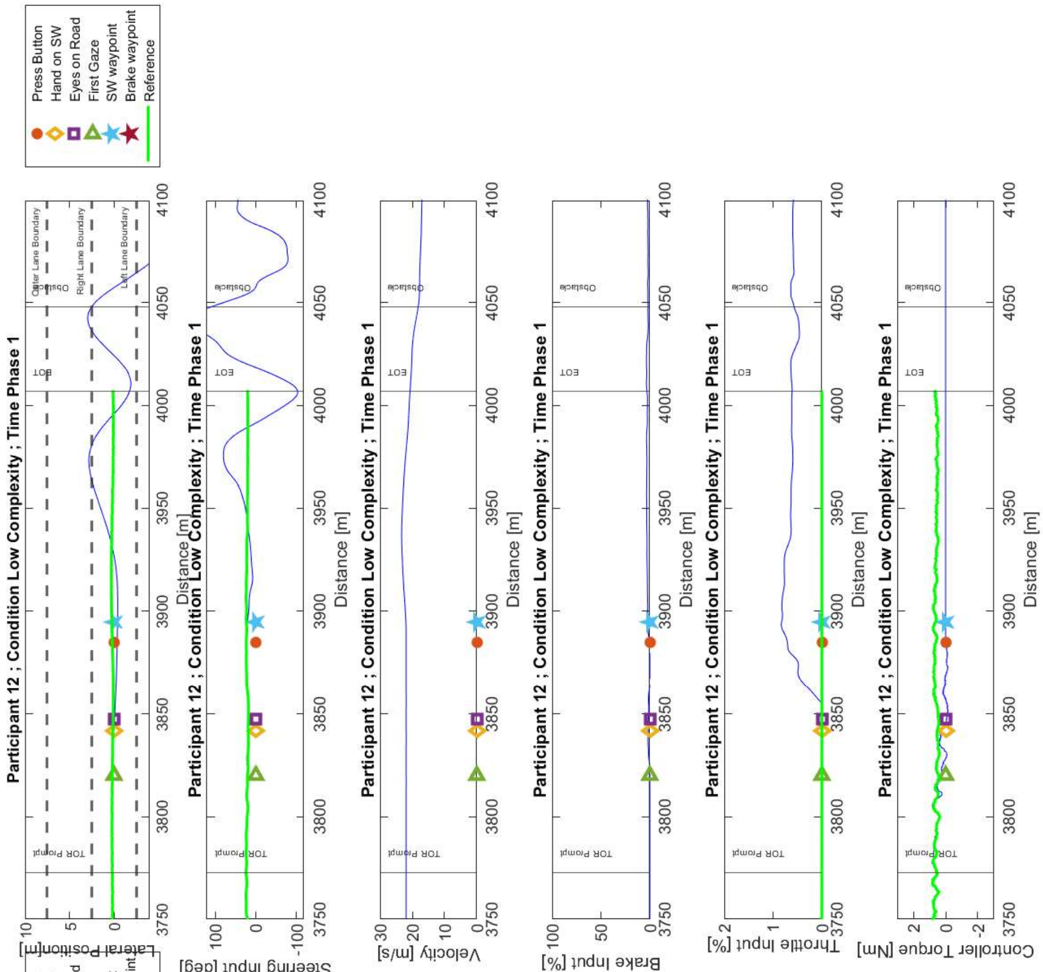


Participant 11 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

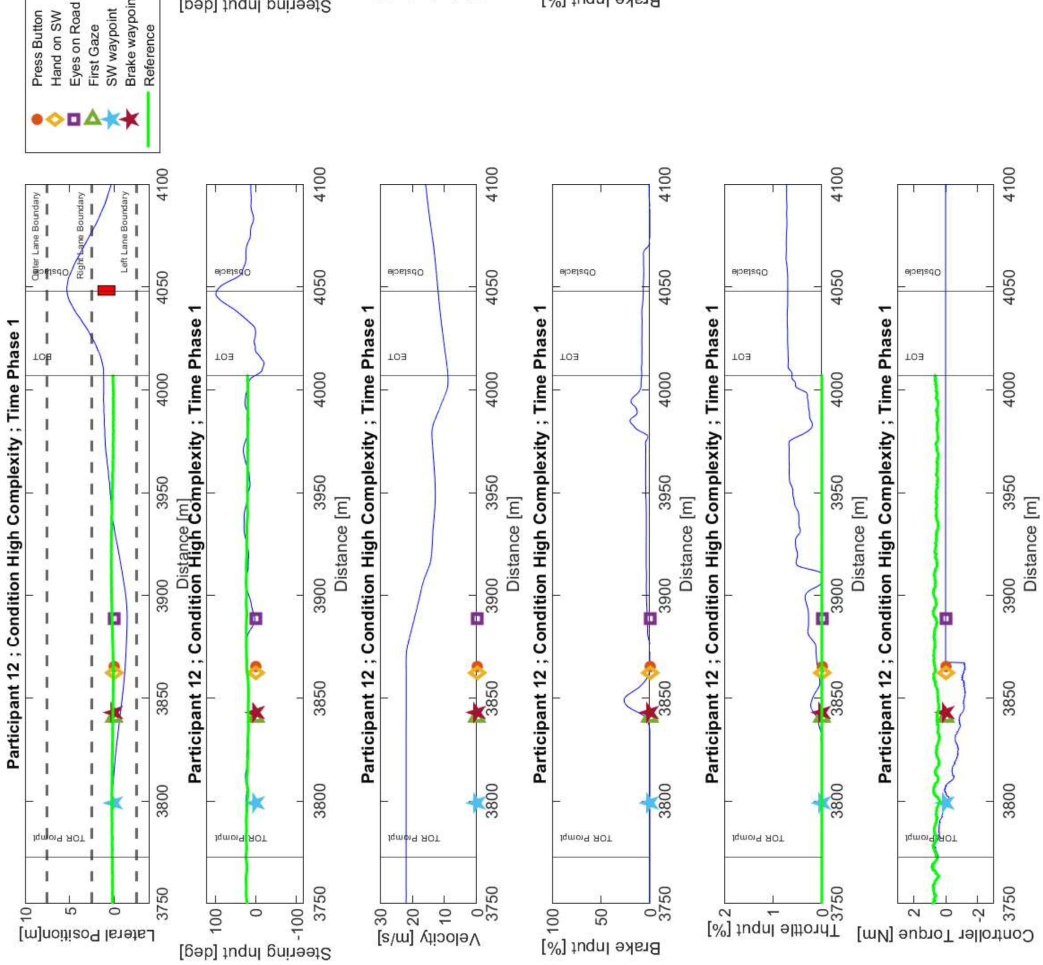


Participant 11 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

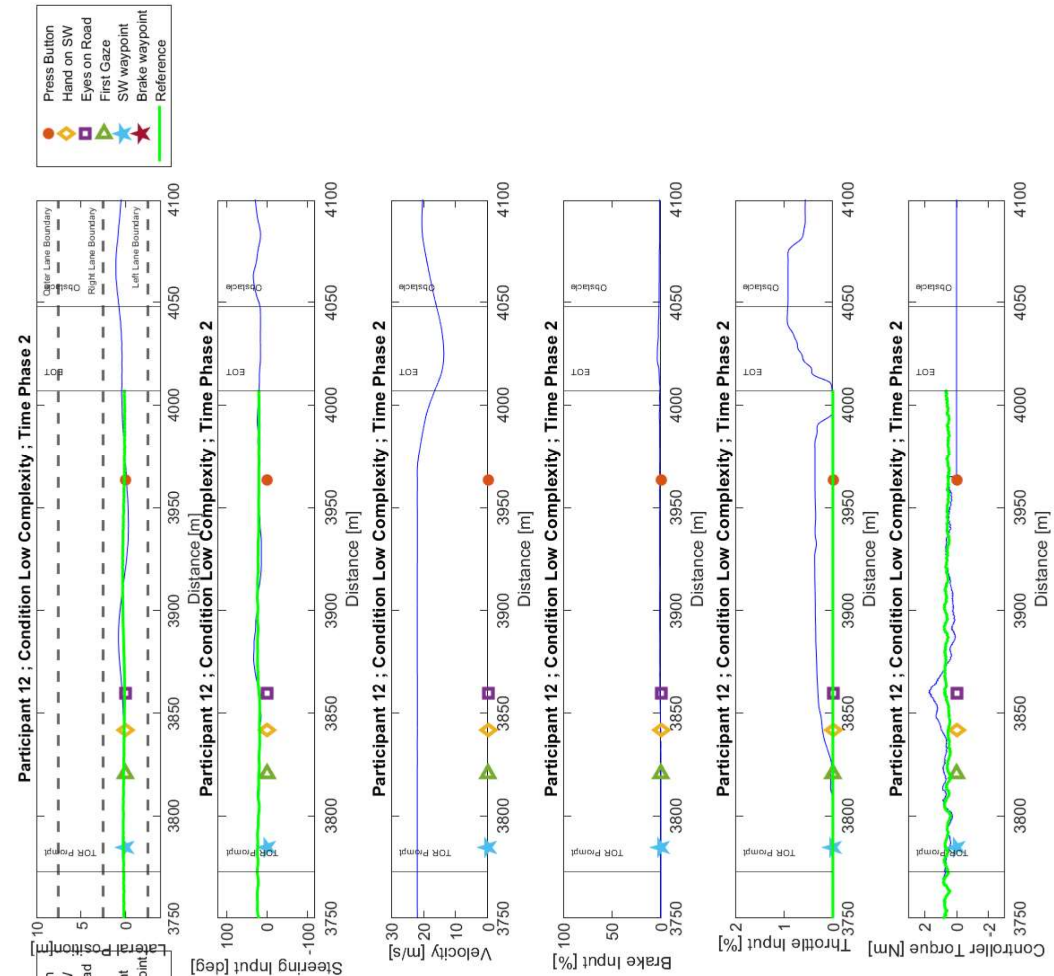

Participant 11 ; Condition High Complexity ; Time Phase 2
Participant 11 ; Condition Low Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

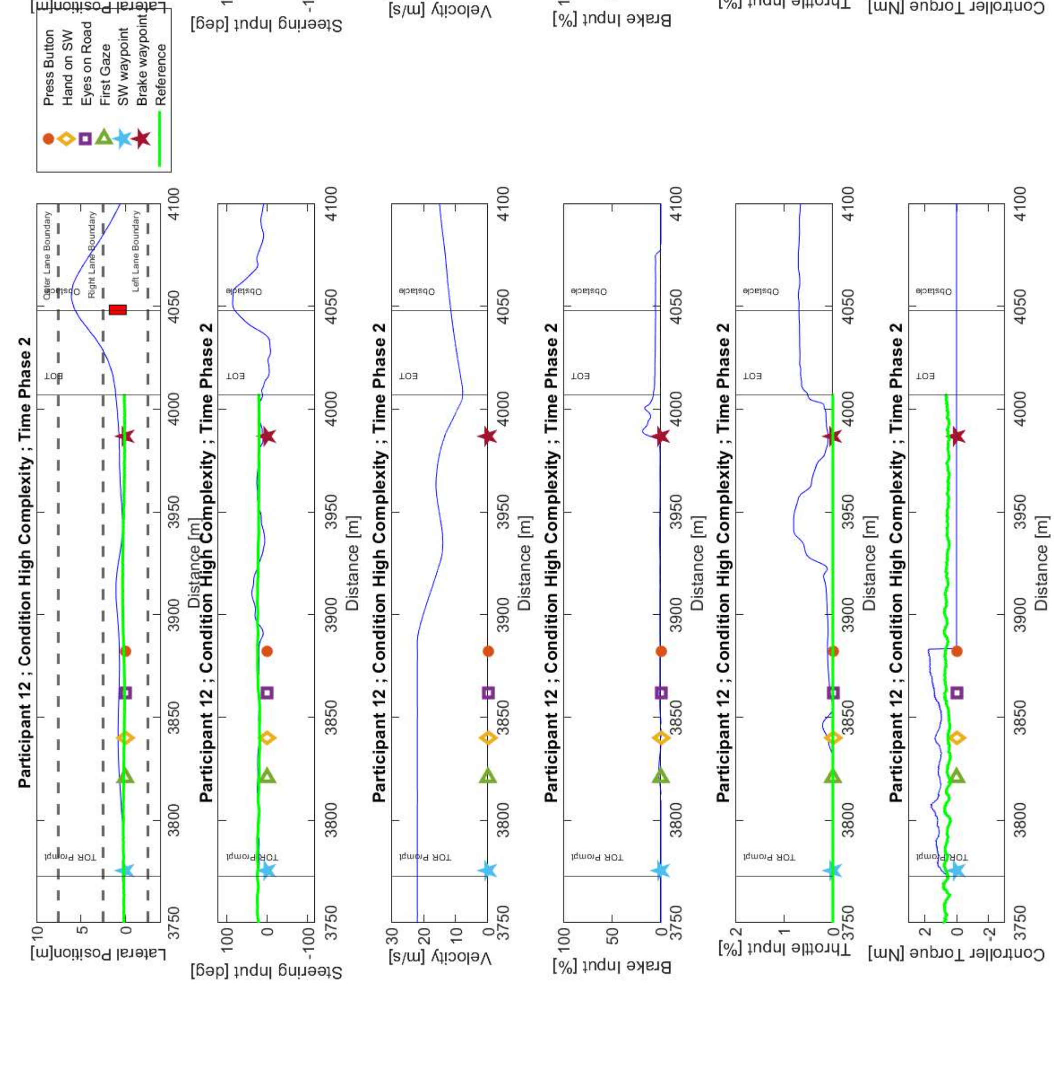


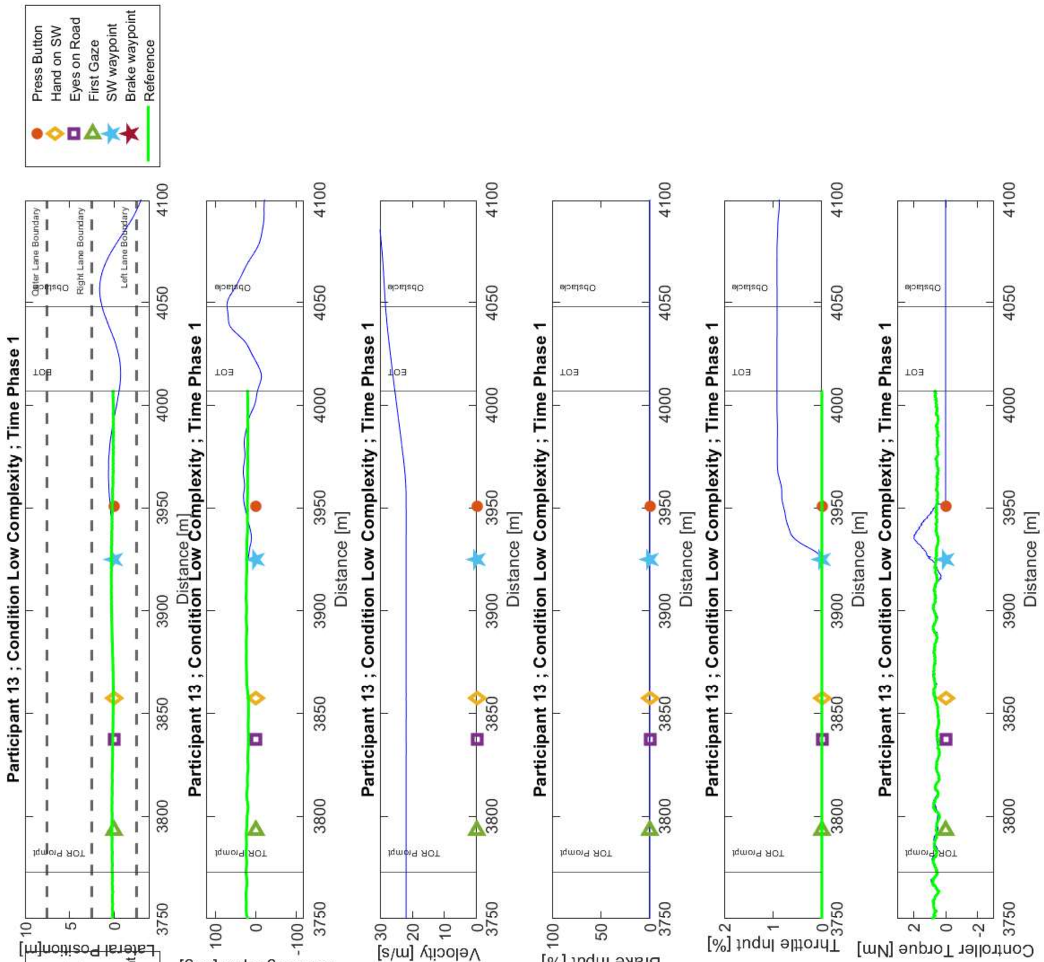
Participant 12 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]

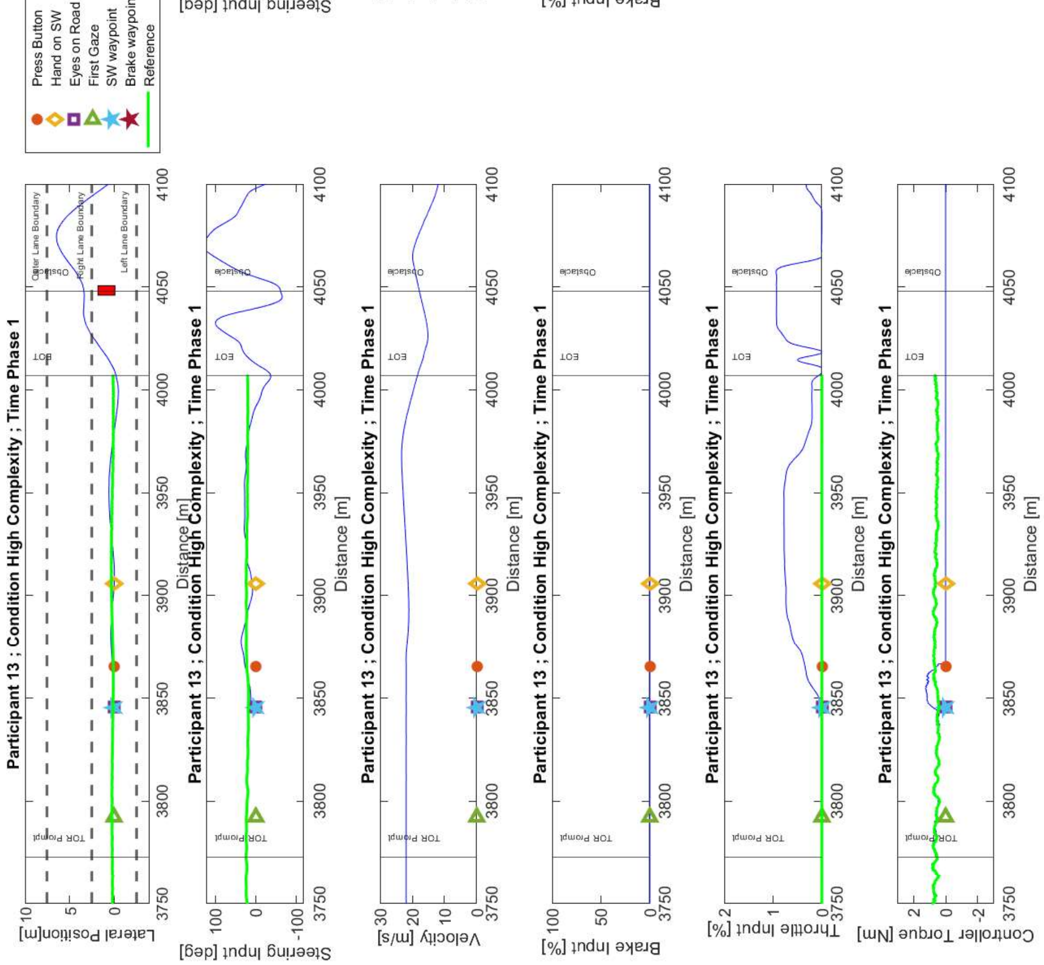


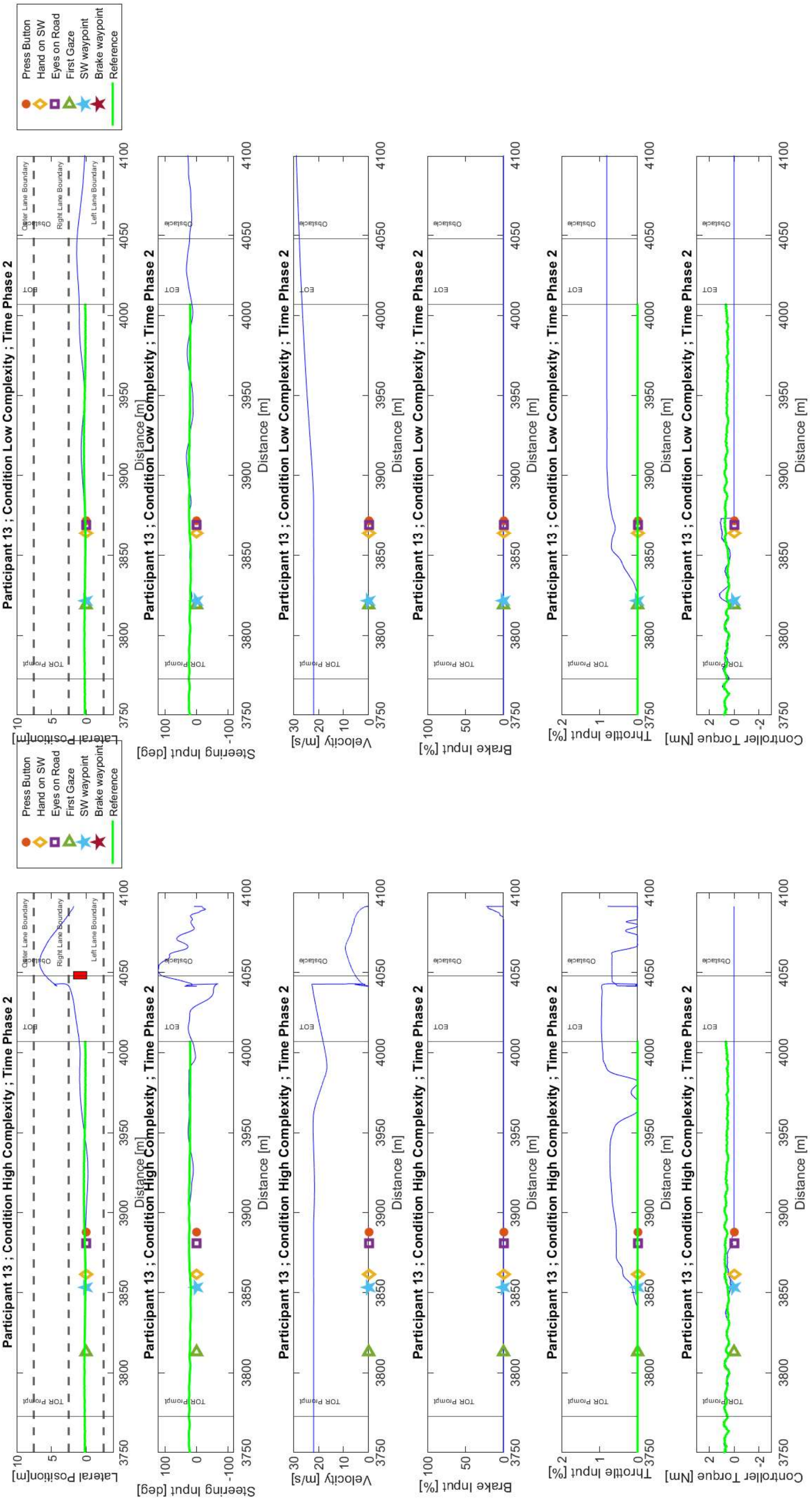
Participant 12 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]

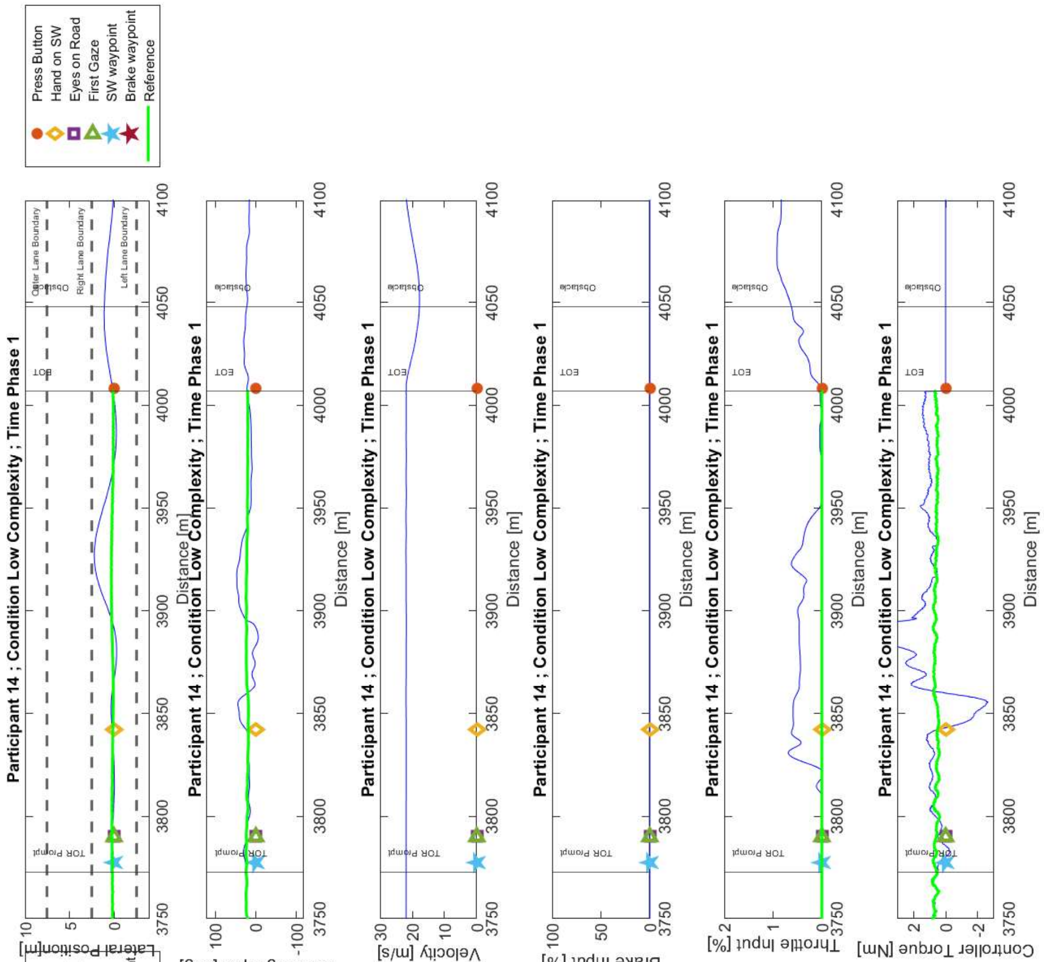

Participant 12 ; Condition Low Complexity ; Time Phase 2
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

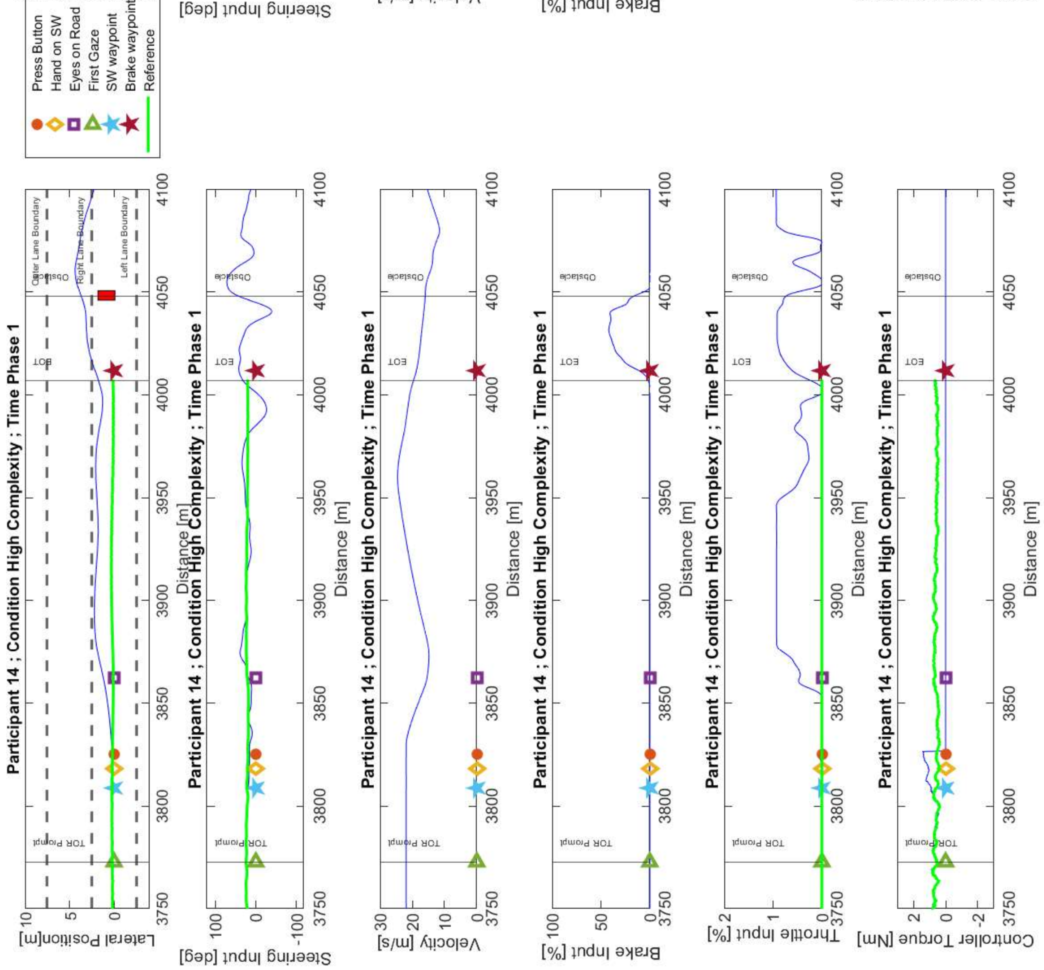

Participant 12 ; Condition High Complexity ; Time Phase 2
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

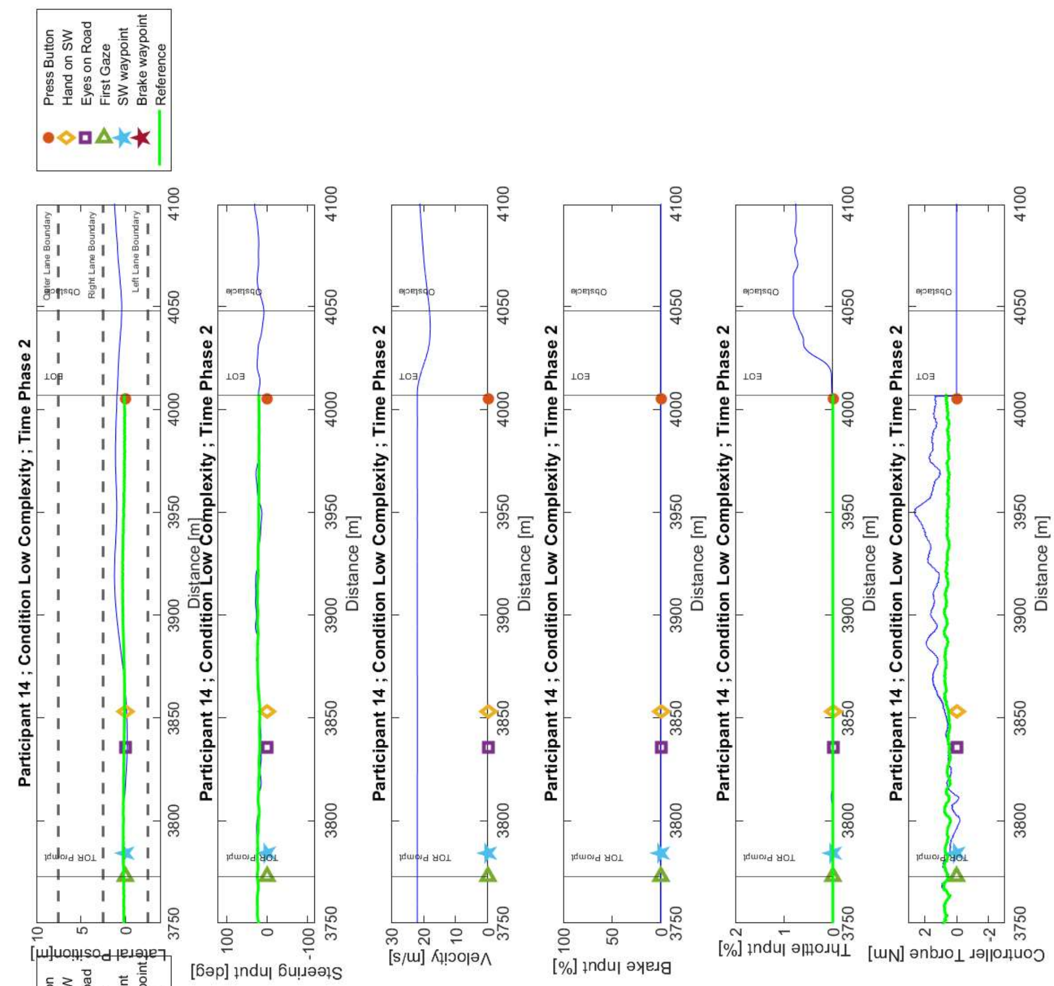

Participant 13 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

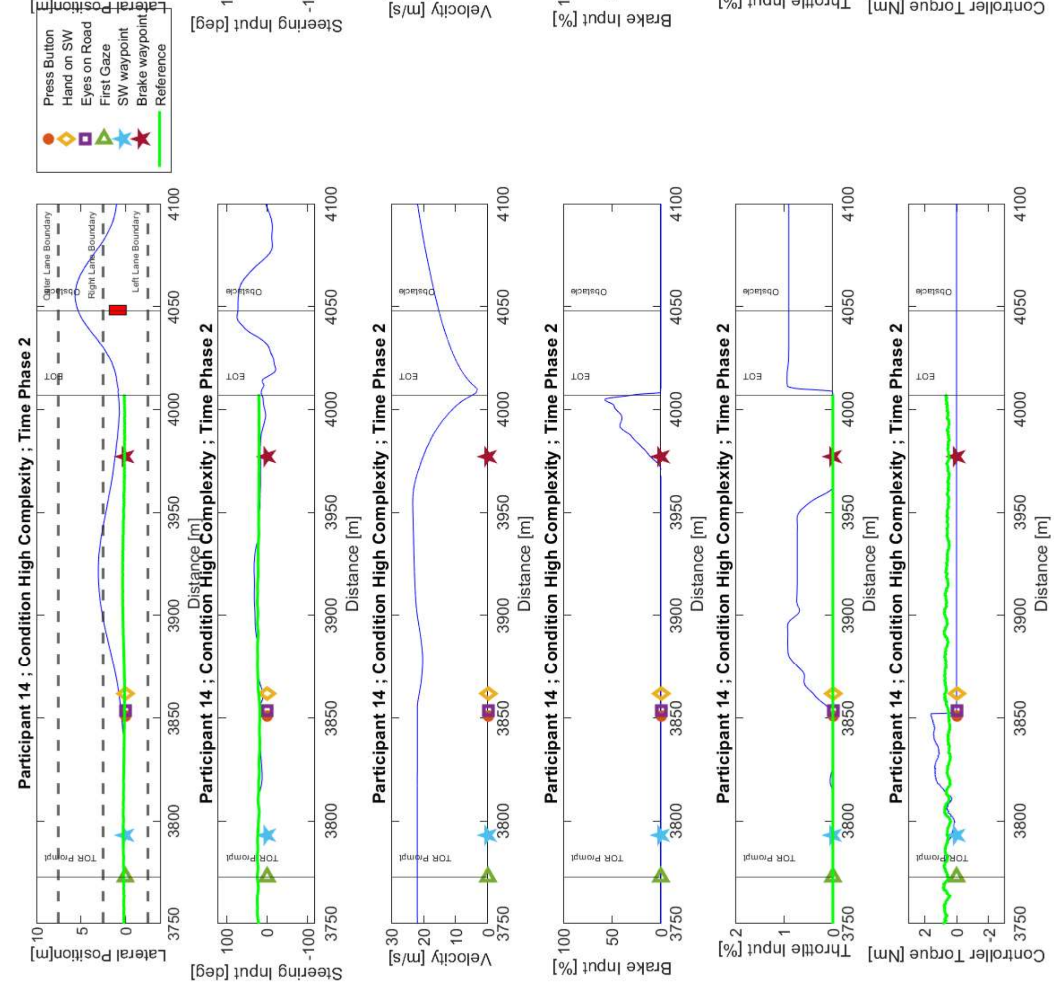

Participant 13 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

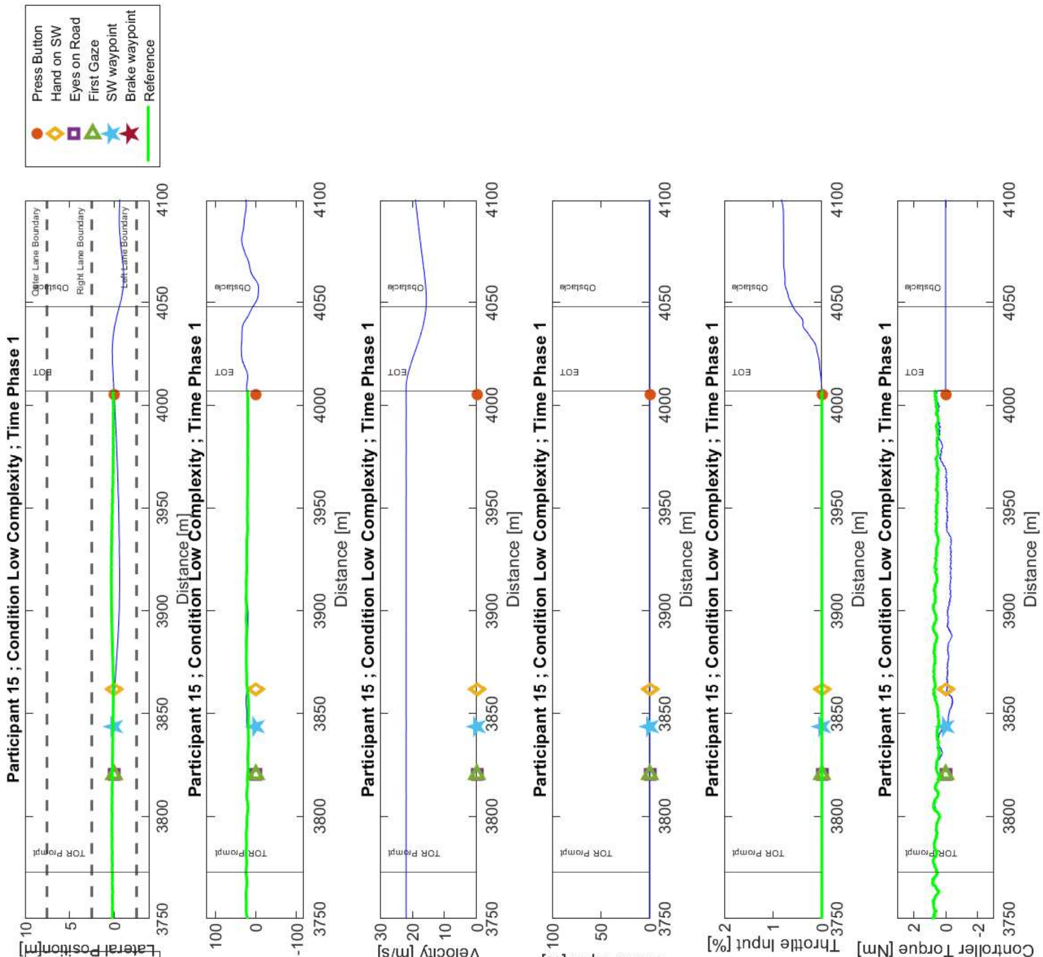

Participant 13 ; Condition High Complexity ; Time Phase 2
Participant 13 ; Condition Low Complexity ; Time Phase 2
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

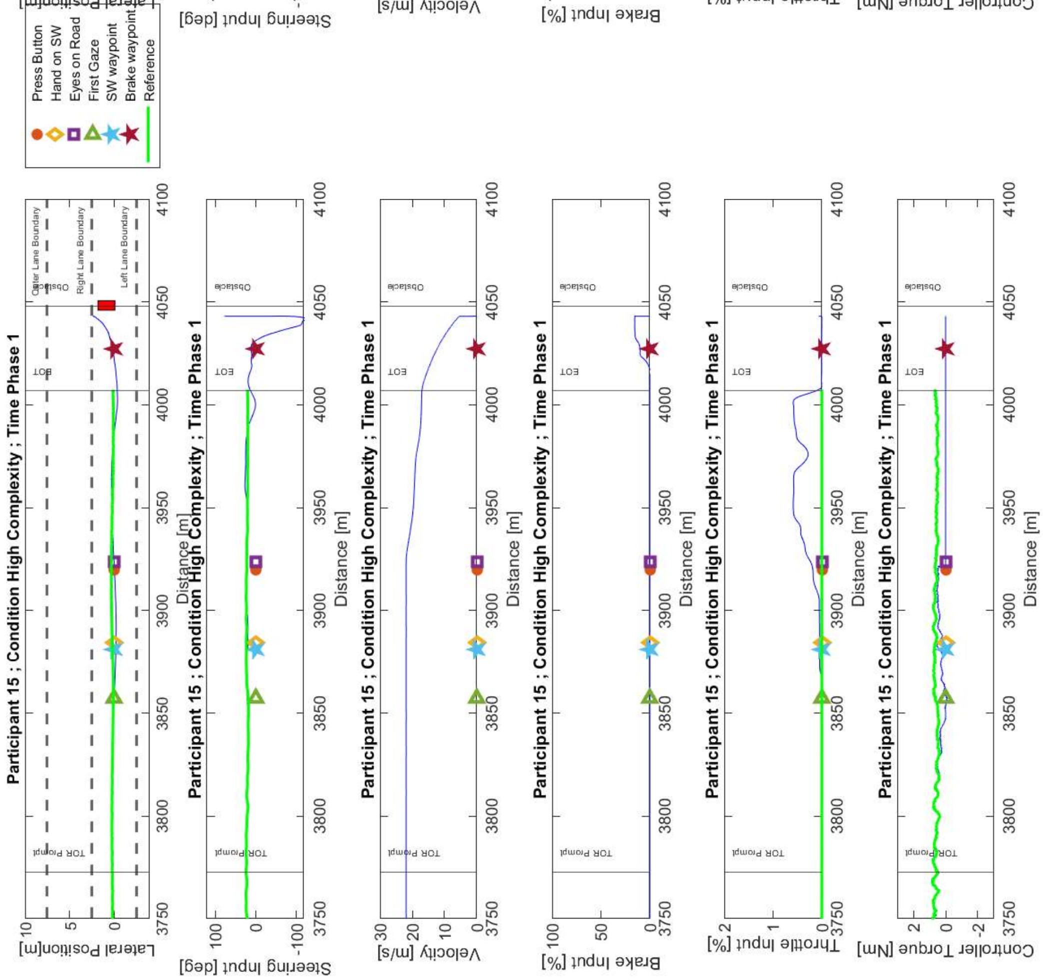

Participant 14 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

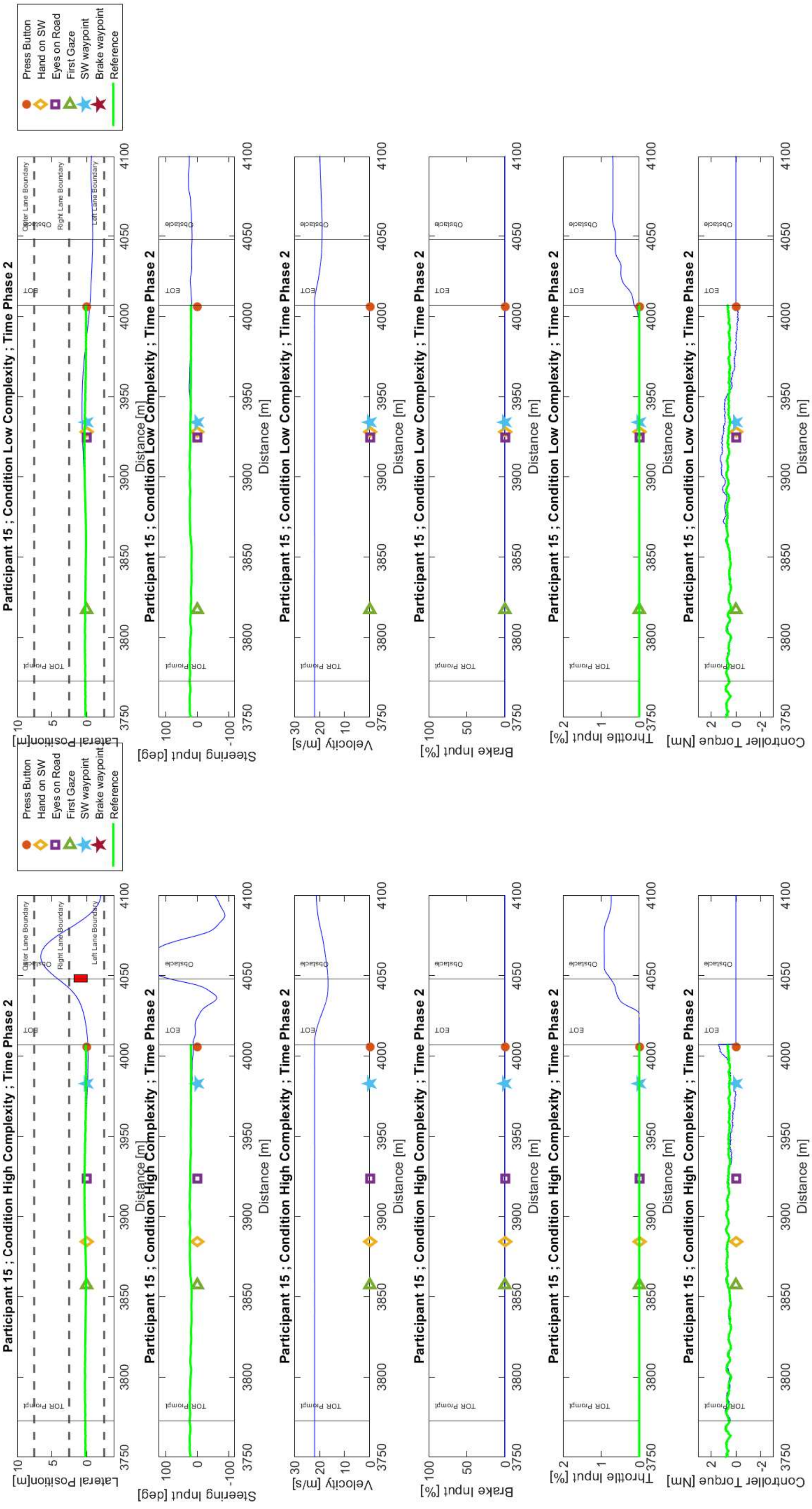

Participant 14 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary


Participant 14 ; Condition Low Complexity ; Time Phase 2
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

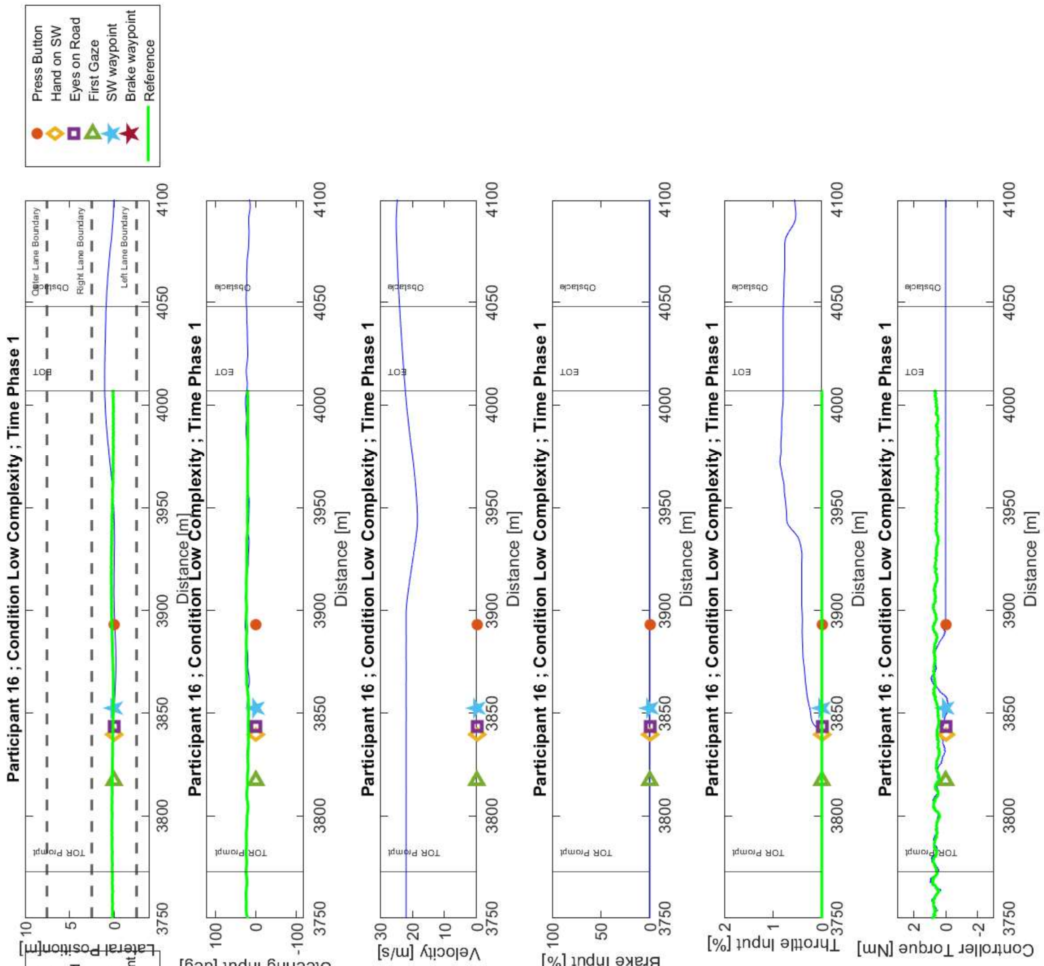

Participant 14 ; Condition High Complexity ; Time Phase 2
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

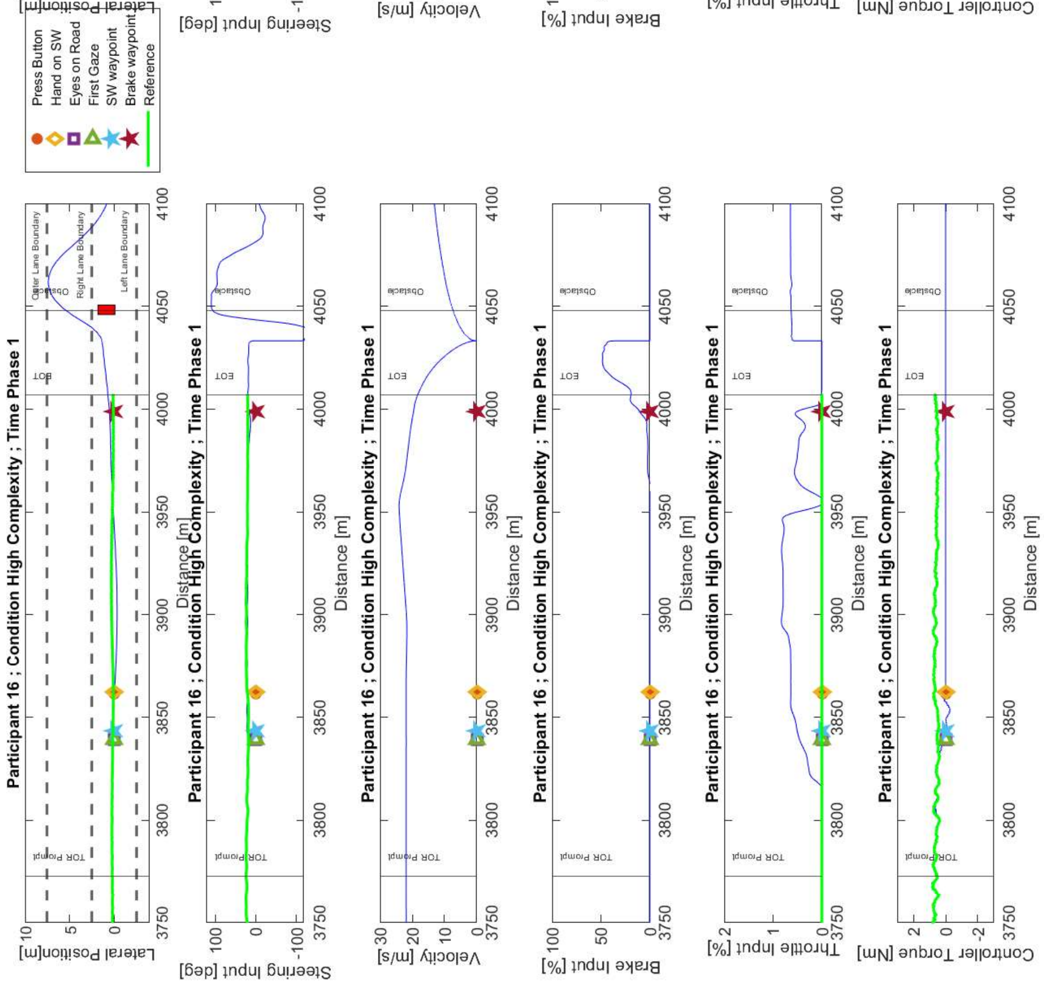

Participant 15 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

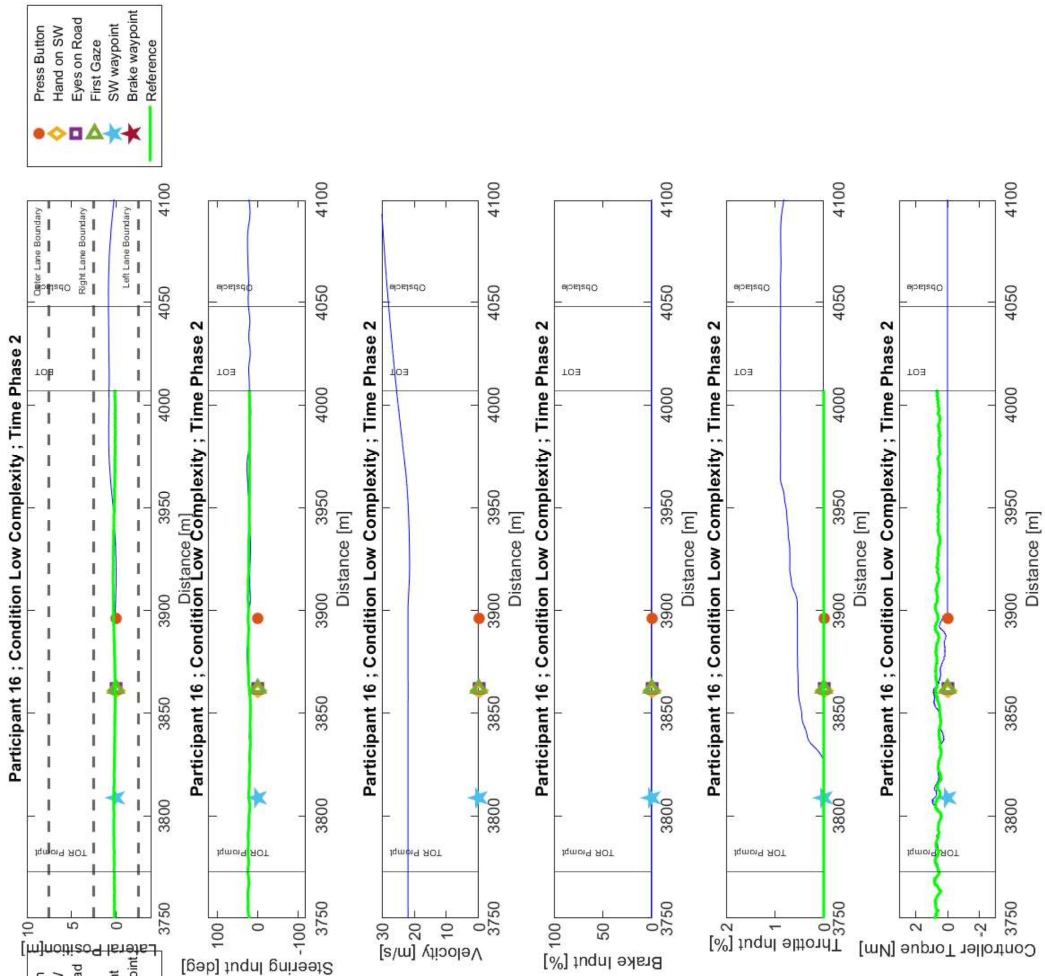

Participant 15 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

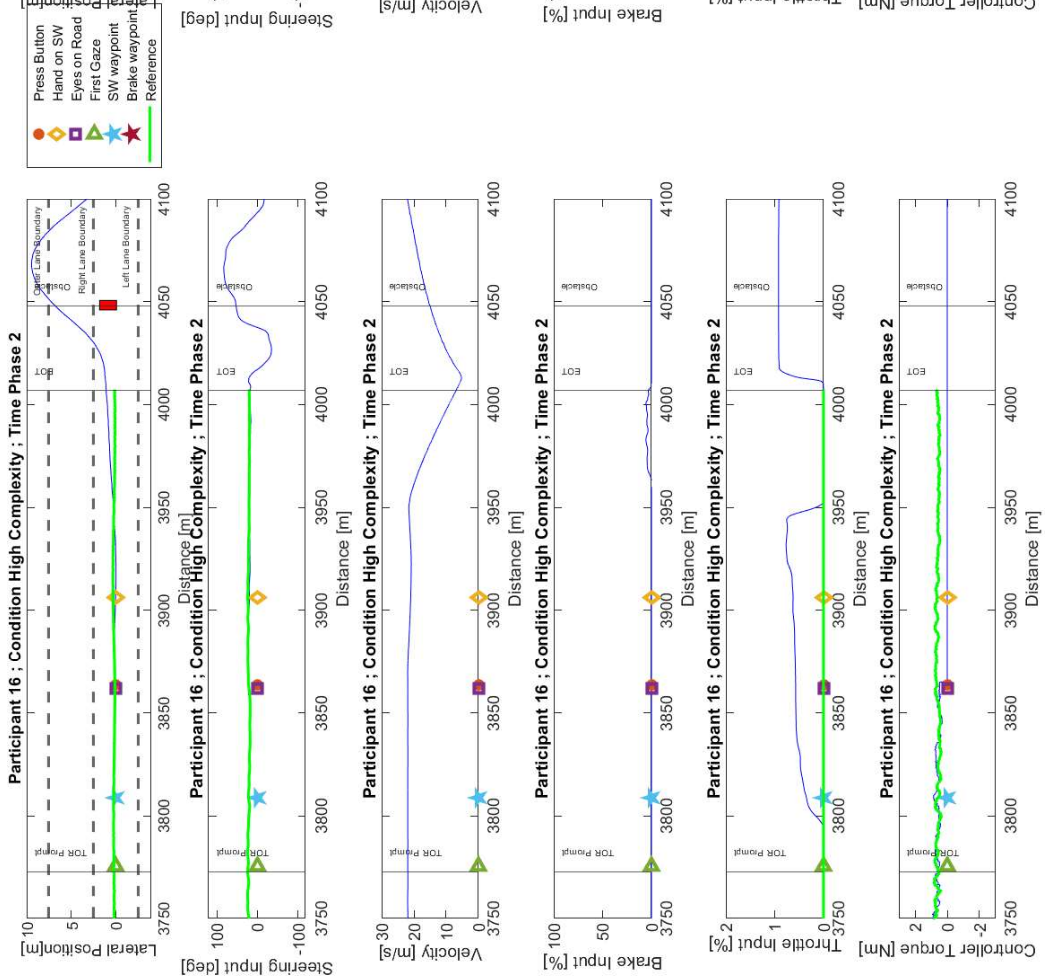


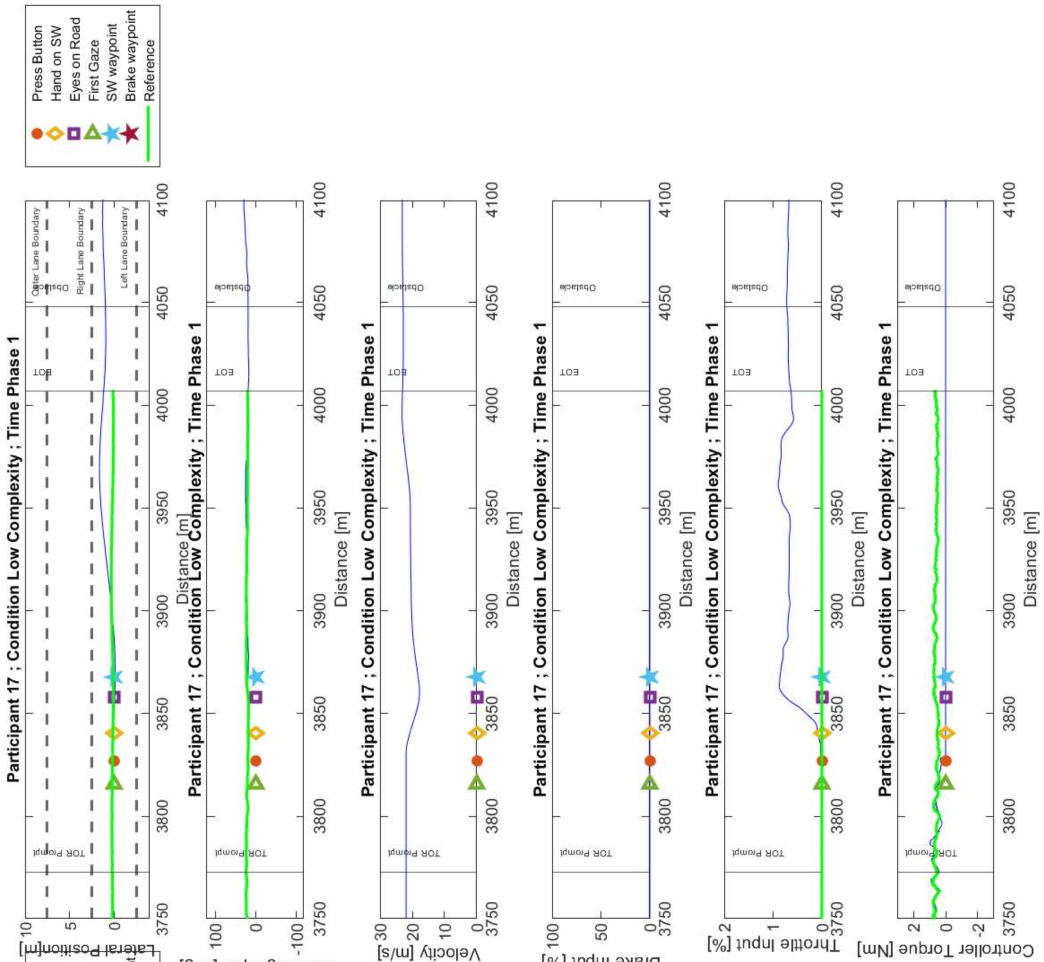
Participant 15 ; Condition High Complexity ; Time Phase 2
Participant 15 ; Condition Low Complexity ; Time Phase 2
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

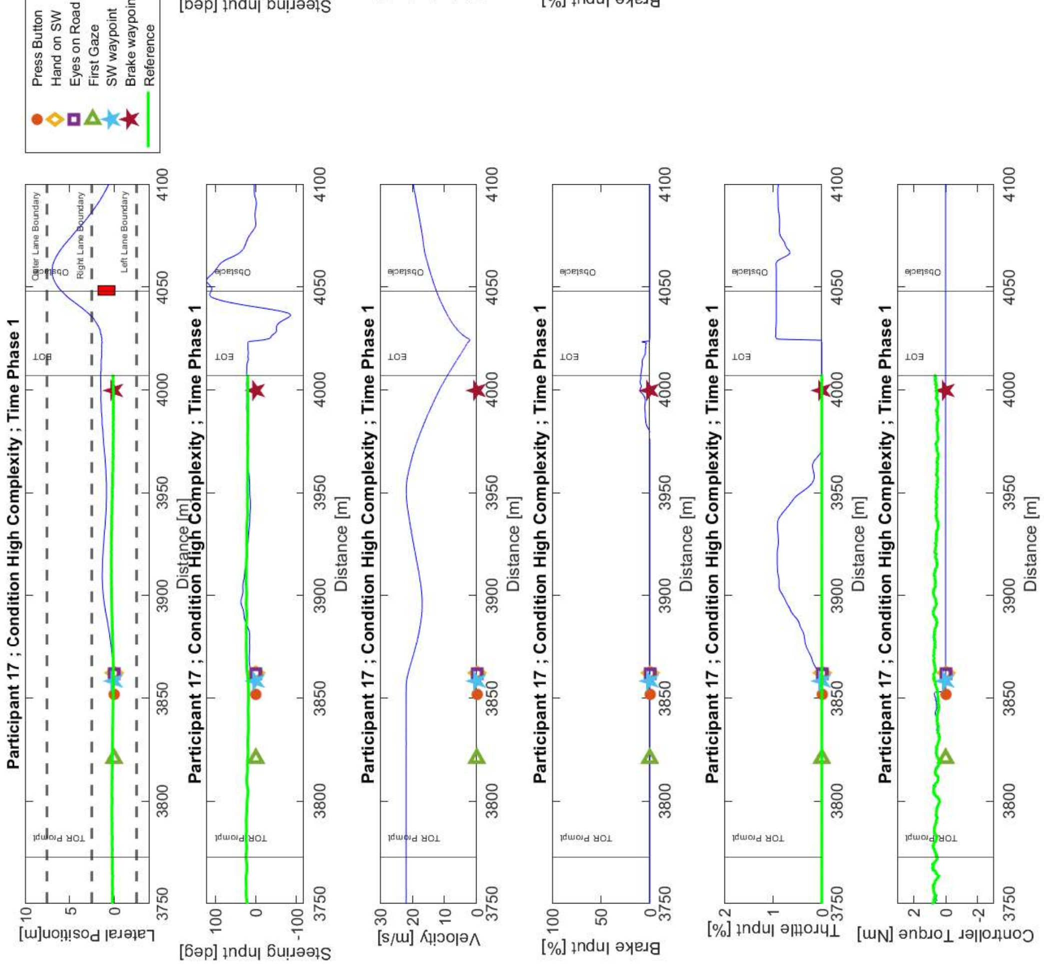

Participant 16 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

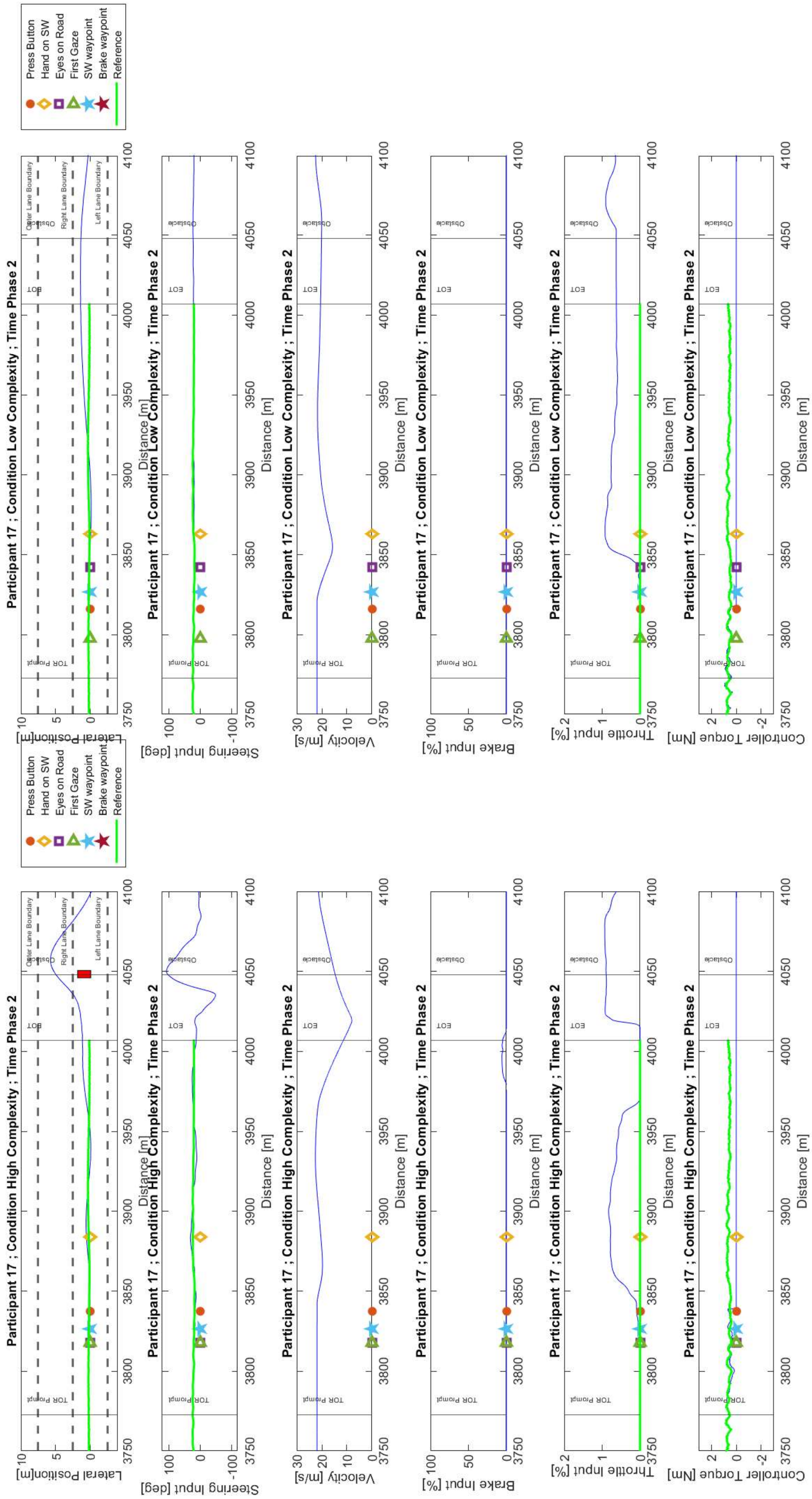

Participant 16 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary


Participant 16 ; Condition Low Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

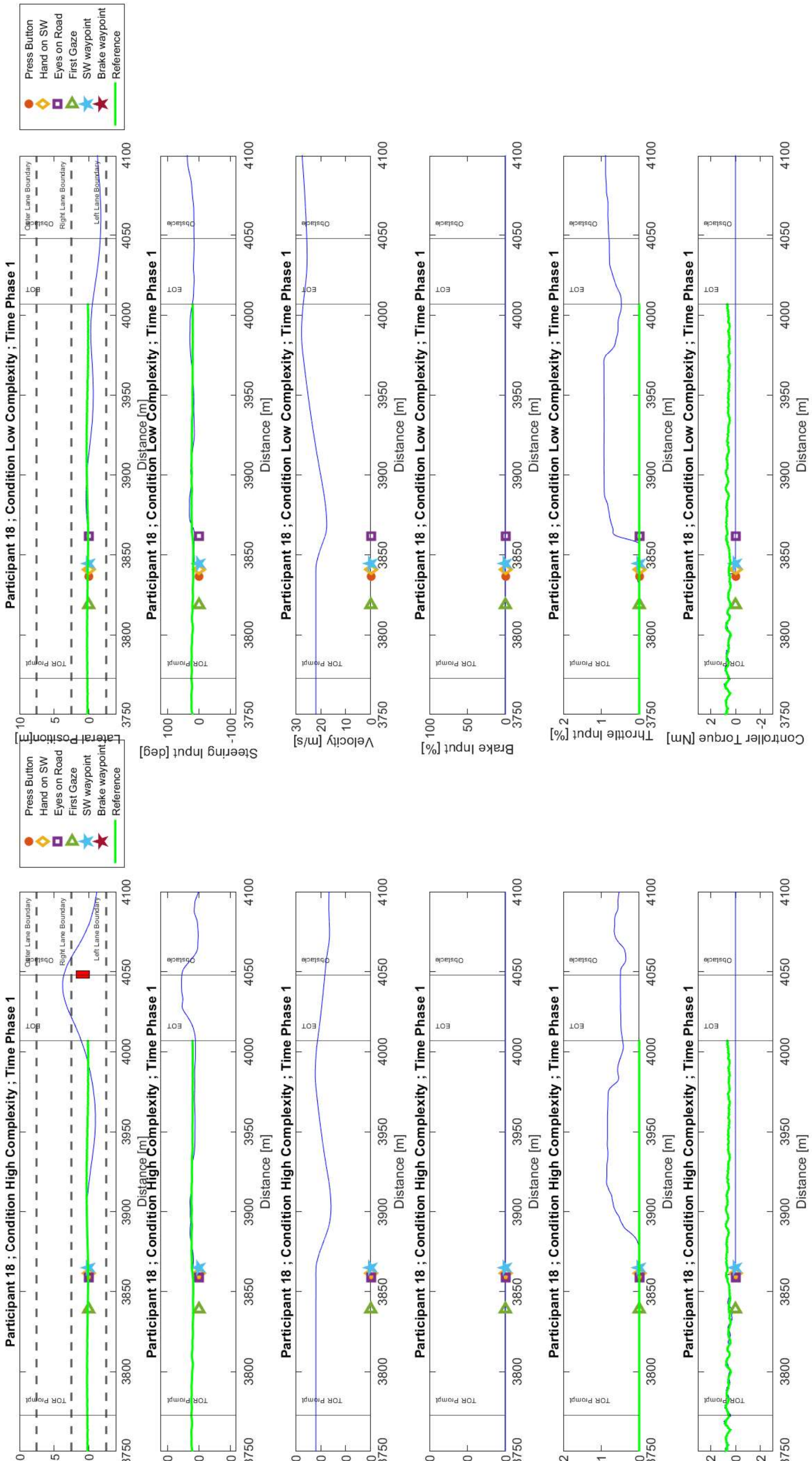

Participant 16 ; Condition High Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

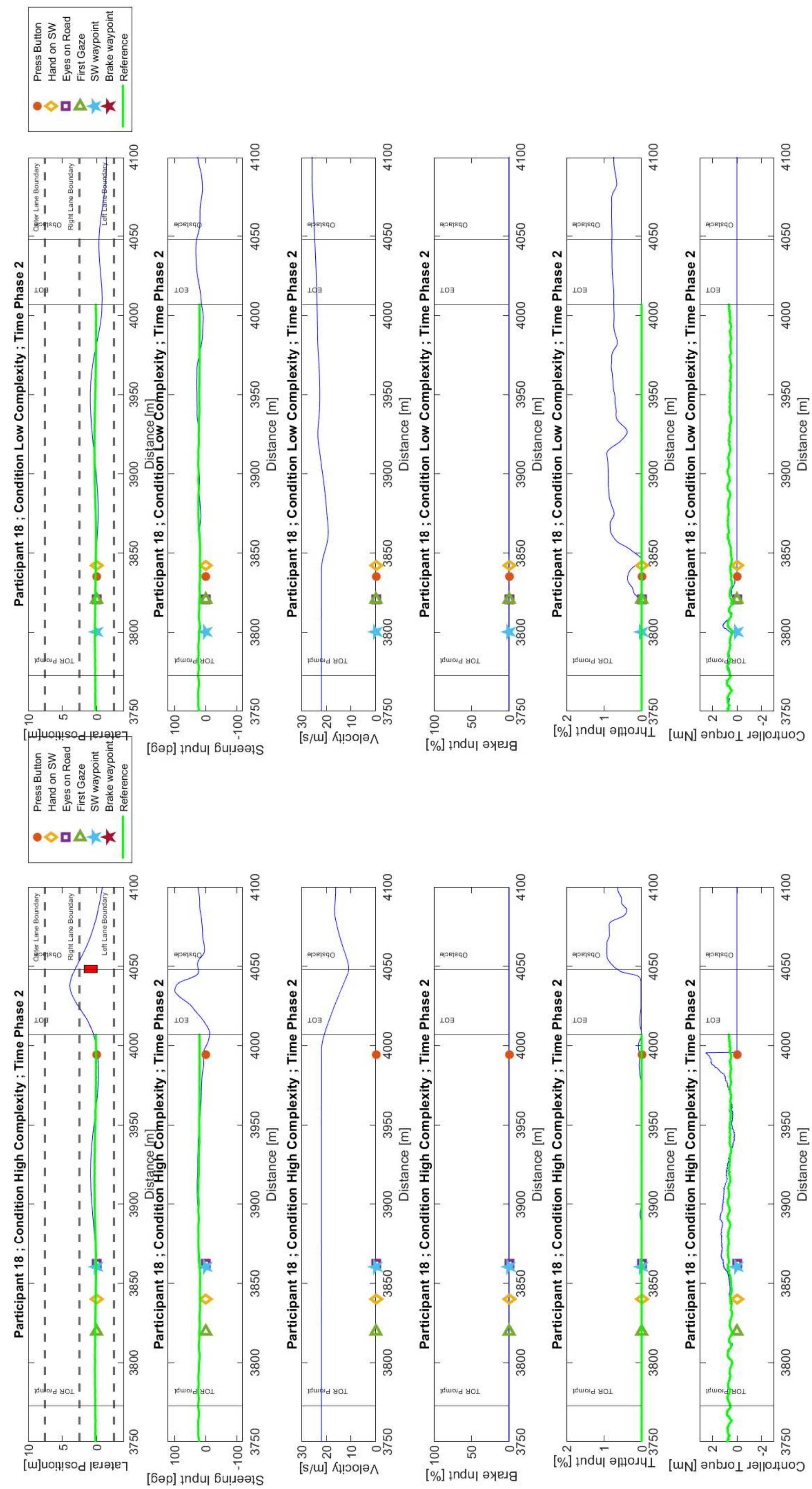

Participant 17 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary


Participant 17 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

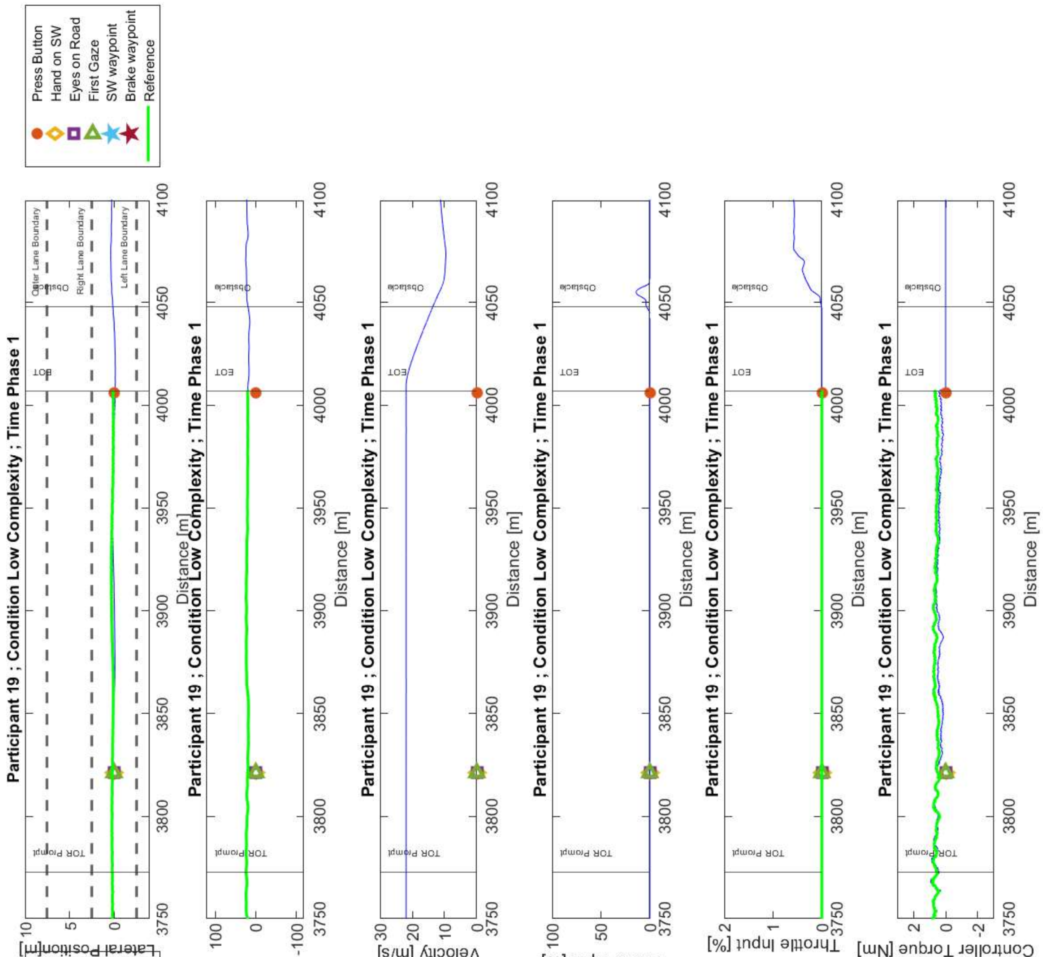


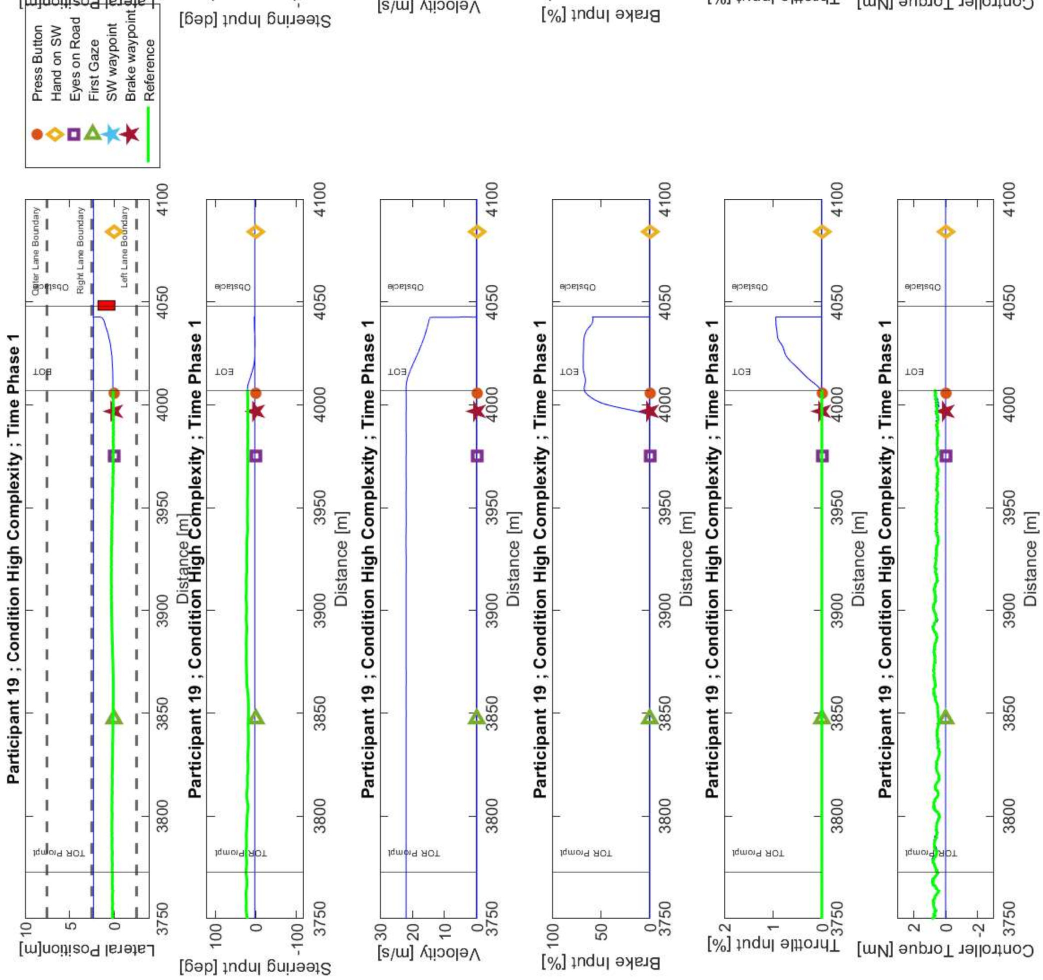
Participant 17 ; Condition Low Complexity ; Time Phase 2
Participant 17 ; Condition High Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

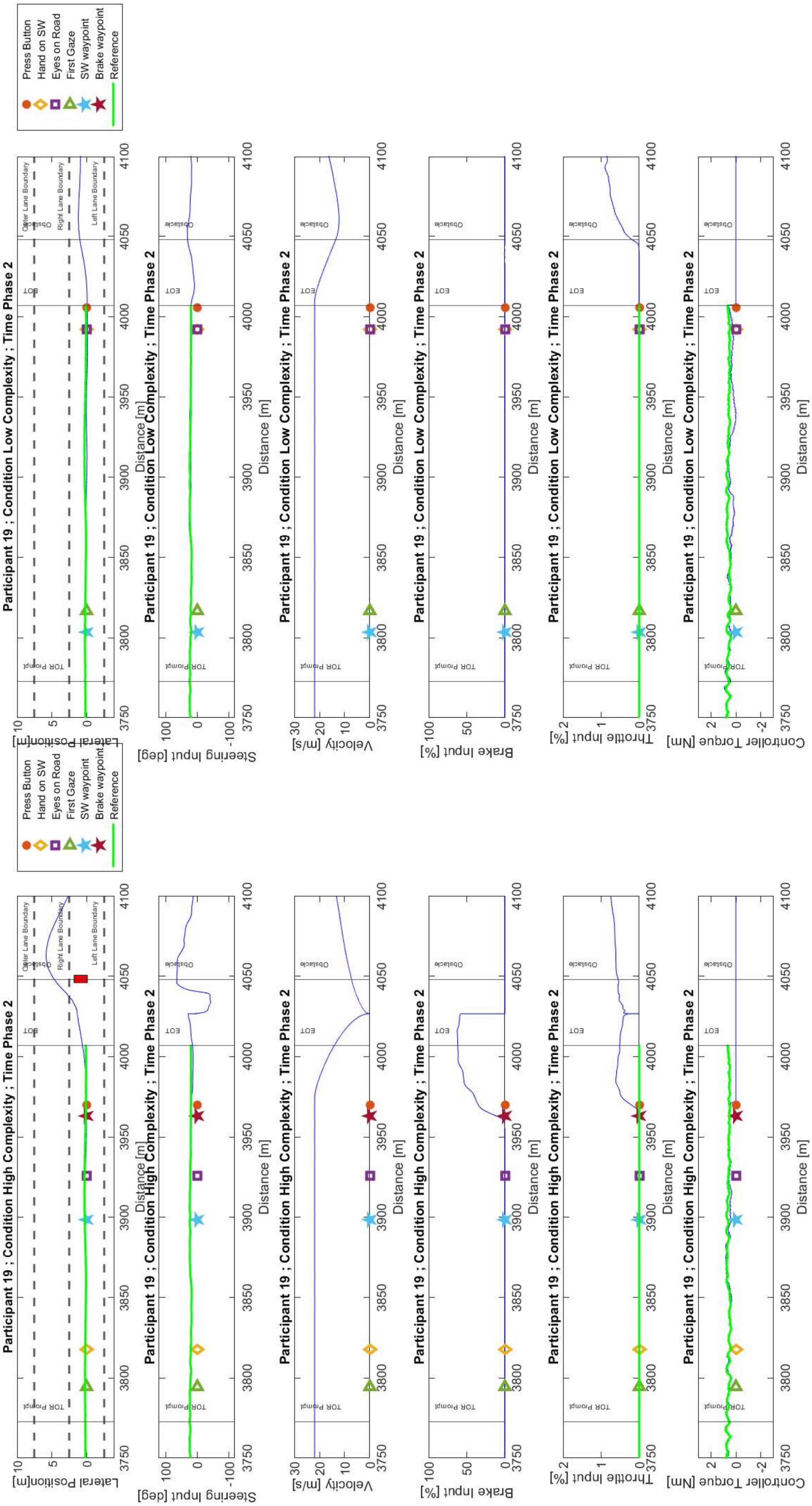

Participant 18 ; Condition Low Complexity ; Time Phase 1
Participant 18 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

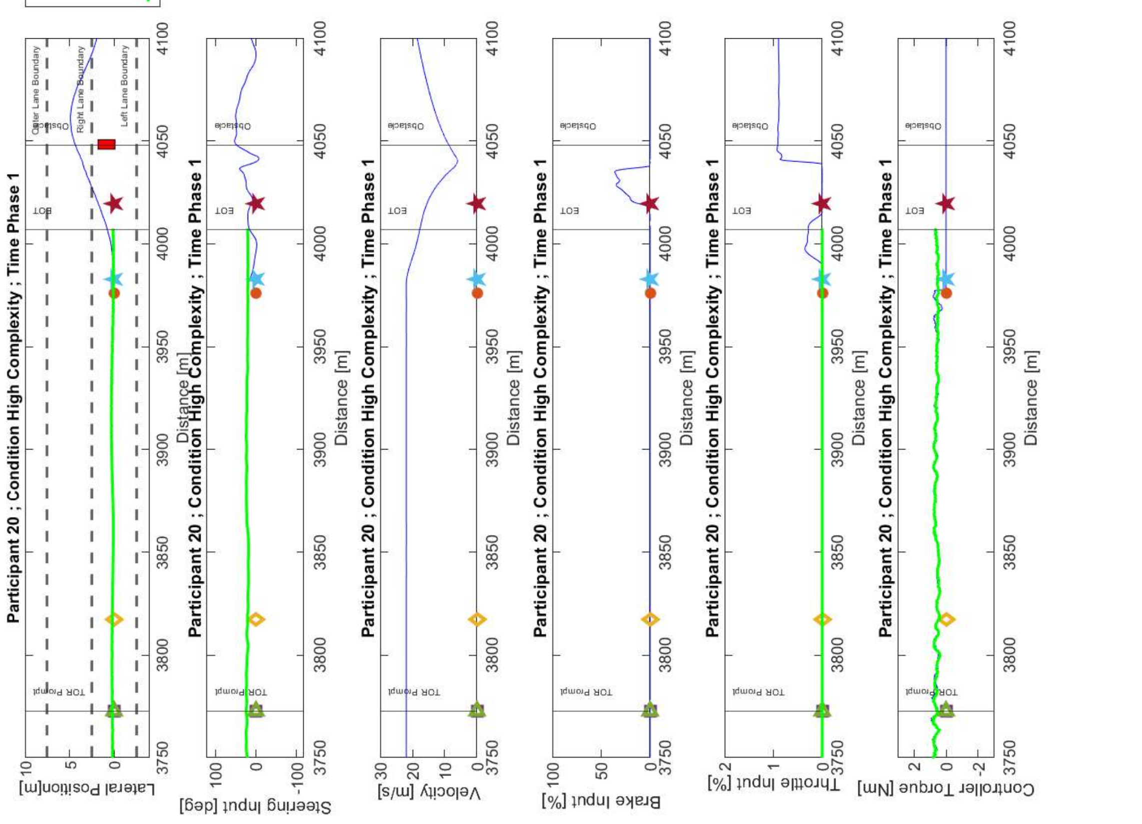


Participant 18 ; Condition High Complexity ; Time Phase 2
Participant 18 ; Condition Low Complexity ; Time Phase 2
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

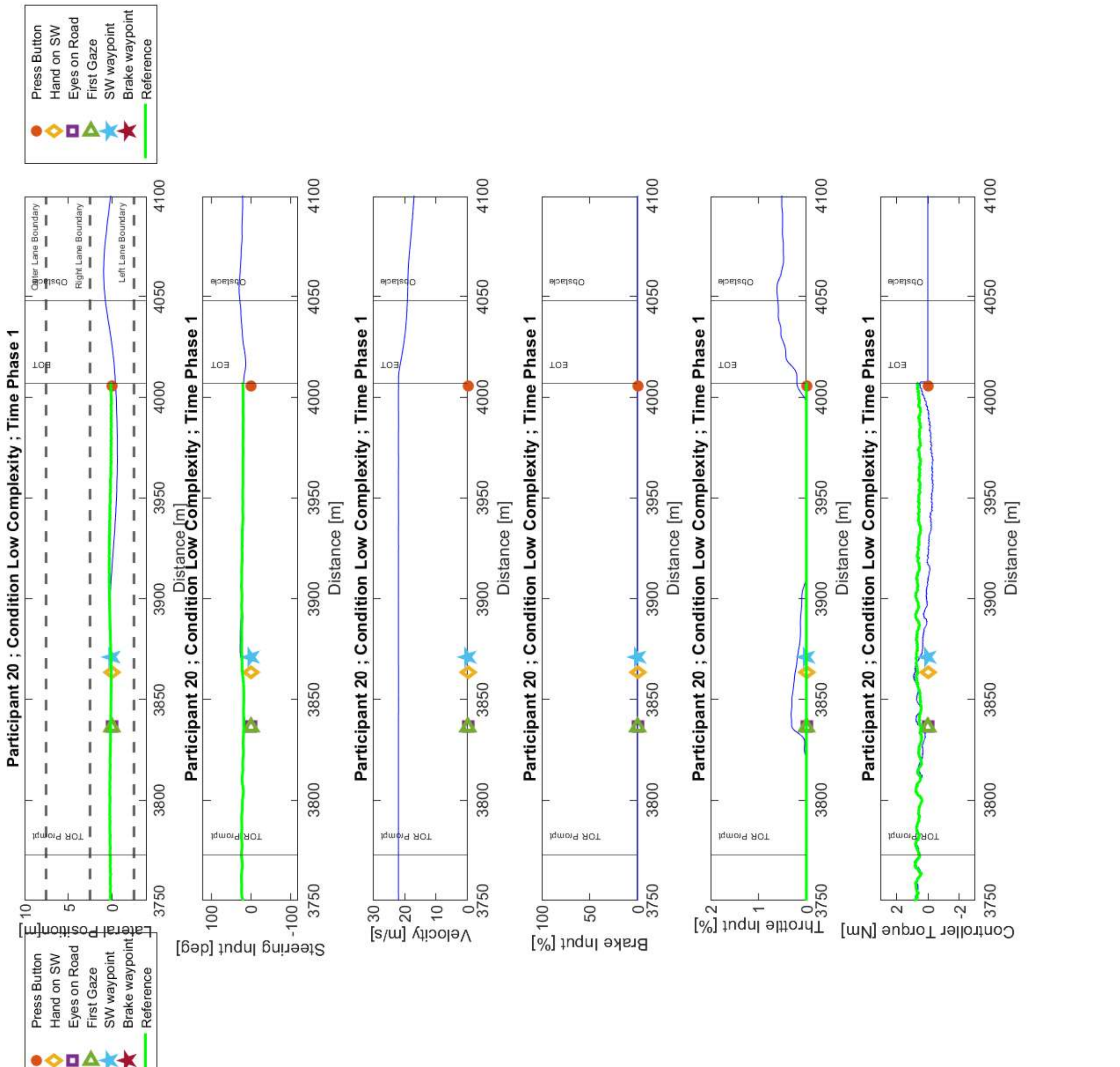

Participant 19 ; Condition Low Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference


Participant 19 ; Condition High Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference

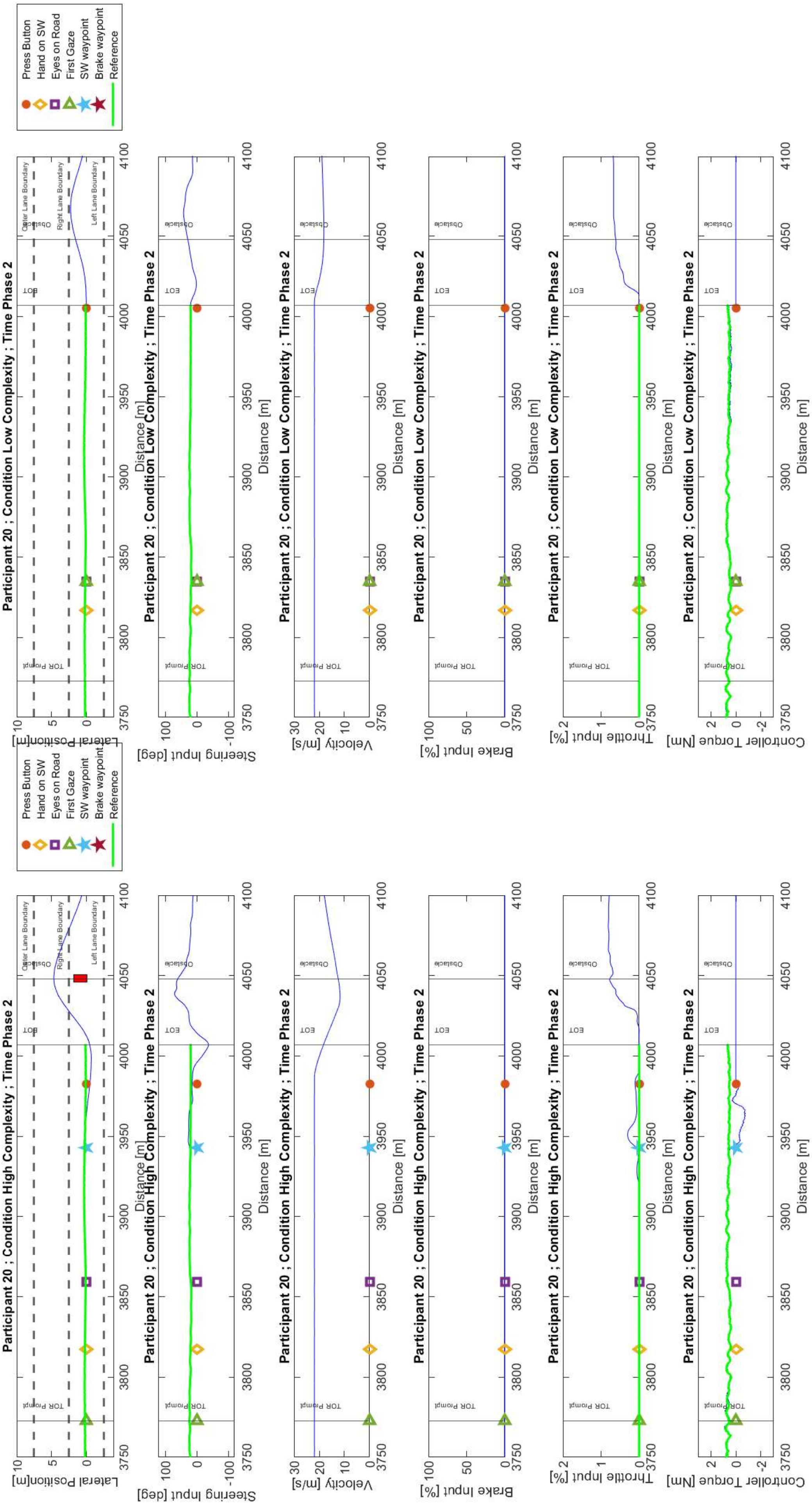

Participant 19 ; Condition High Complexity ; Time Phase 2
Participant 19 ; Condition Low Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary



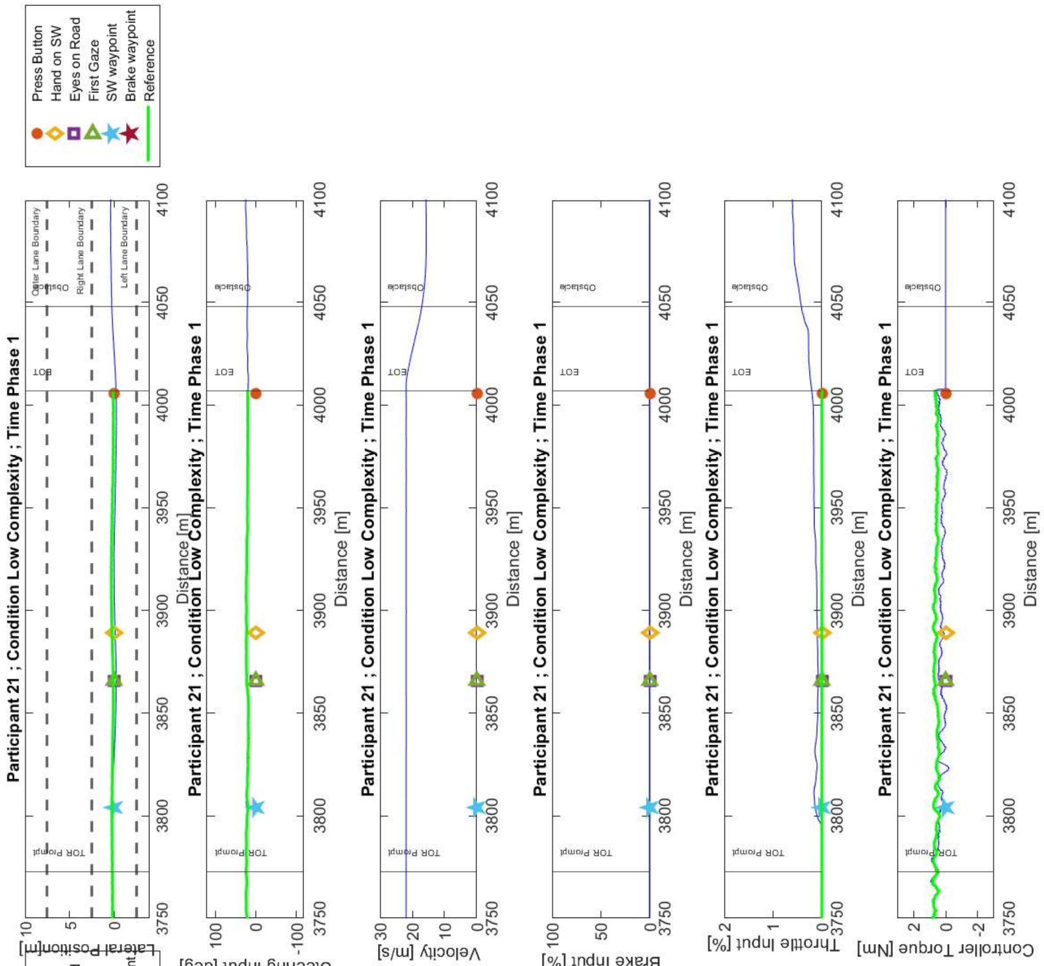
Participant 20 ; Condition High Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference



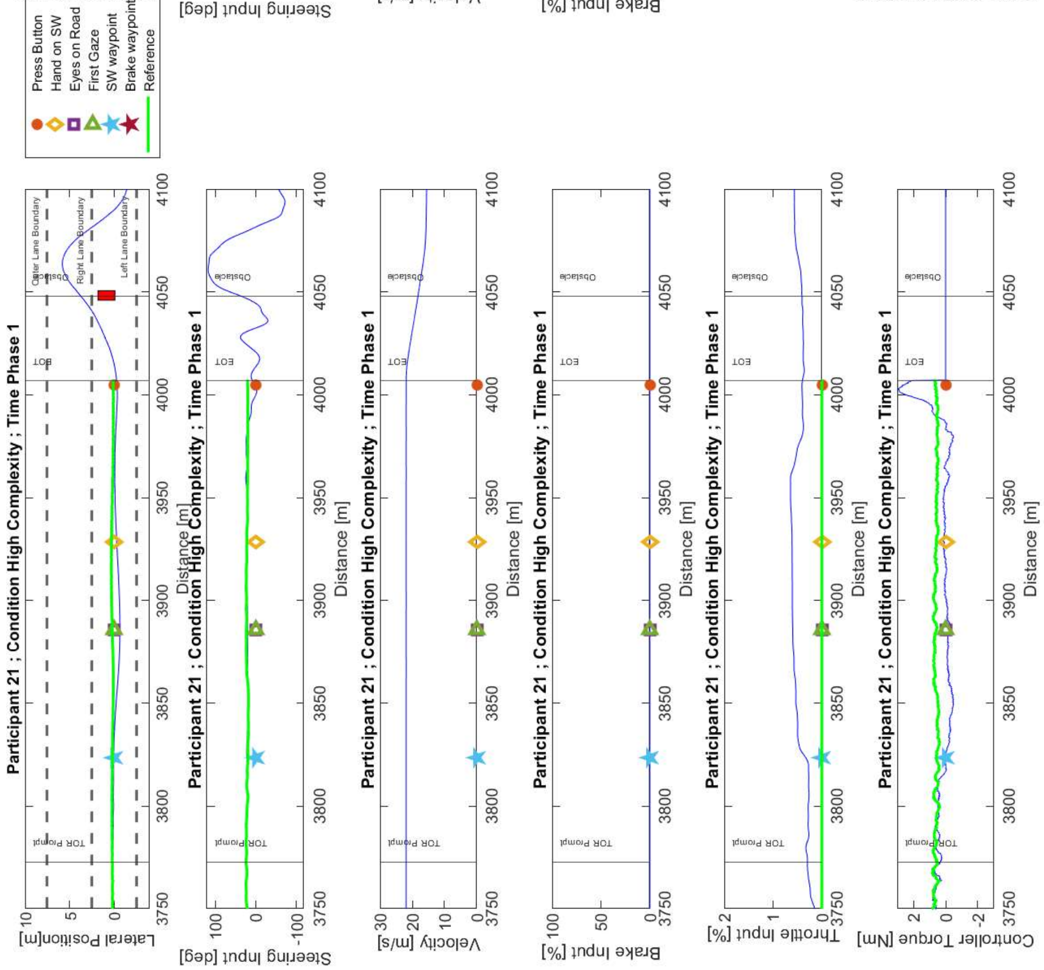
Participant 20 ; Condition Low Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference



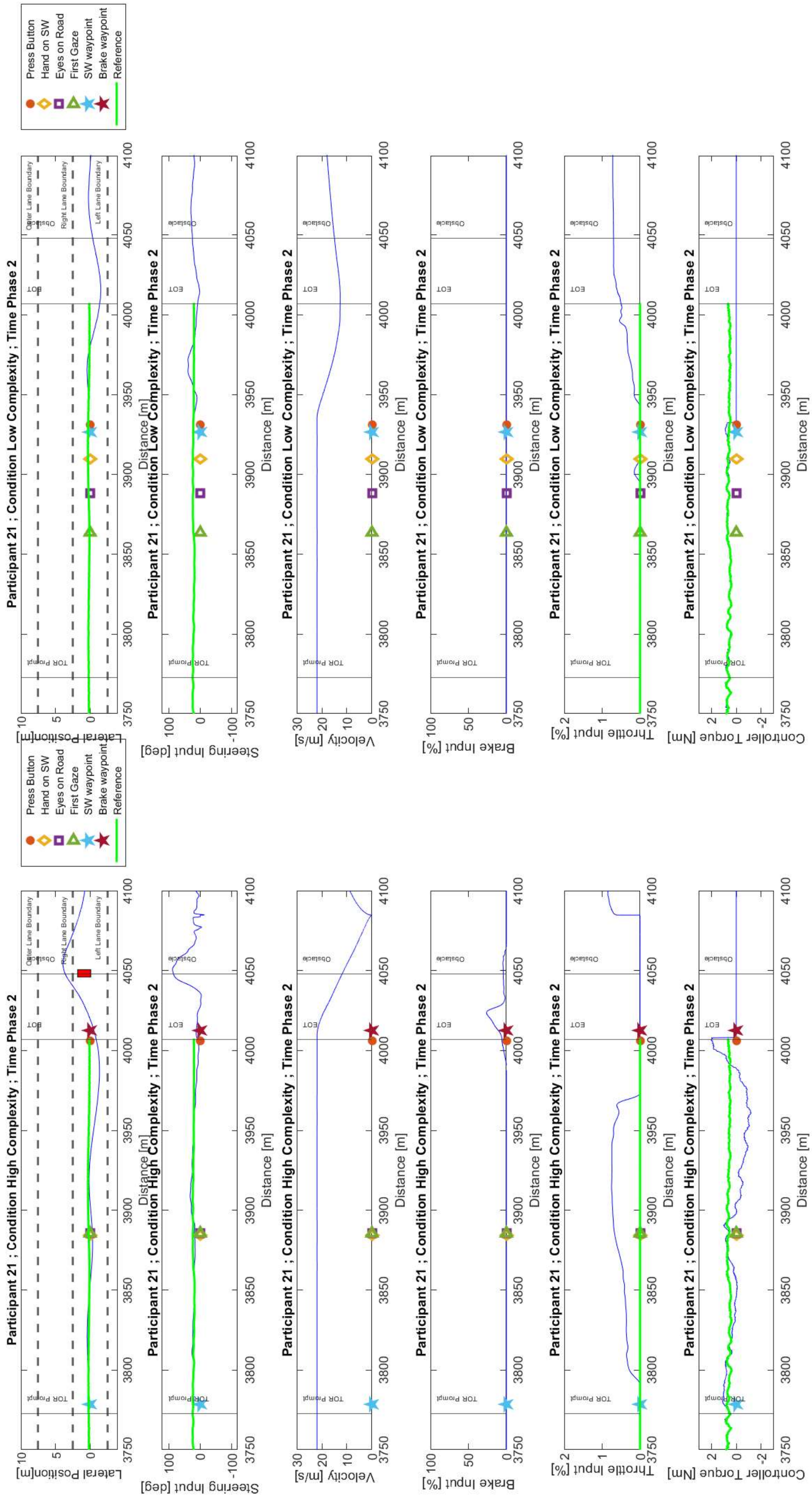
Participant 20 ; Condition High Complexity ; Time Phase 2
Participant 20 ; Condition Low Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary



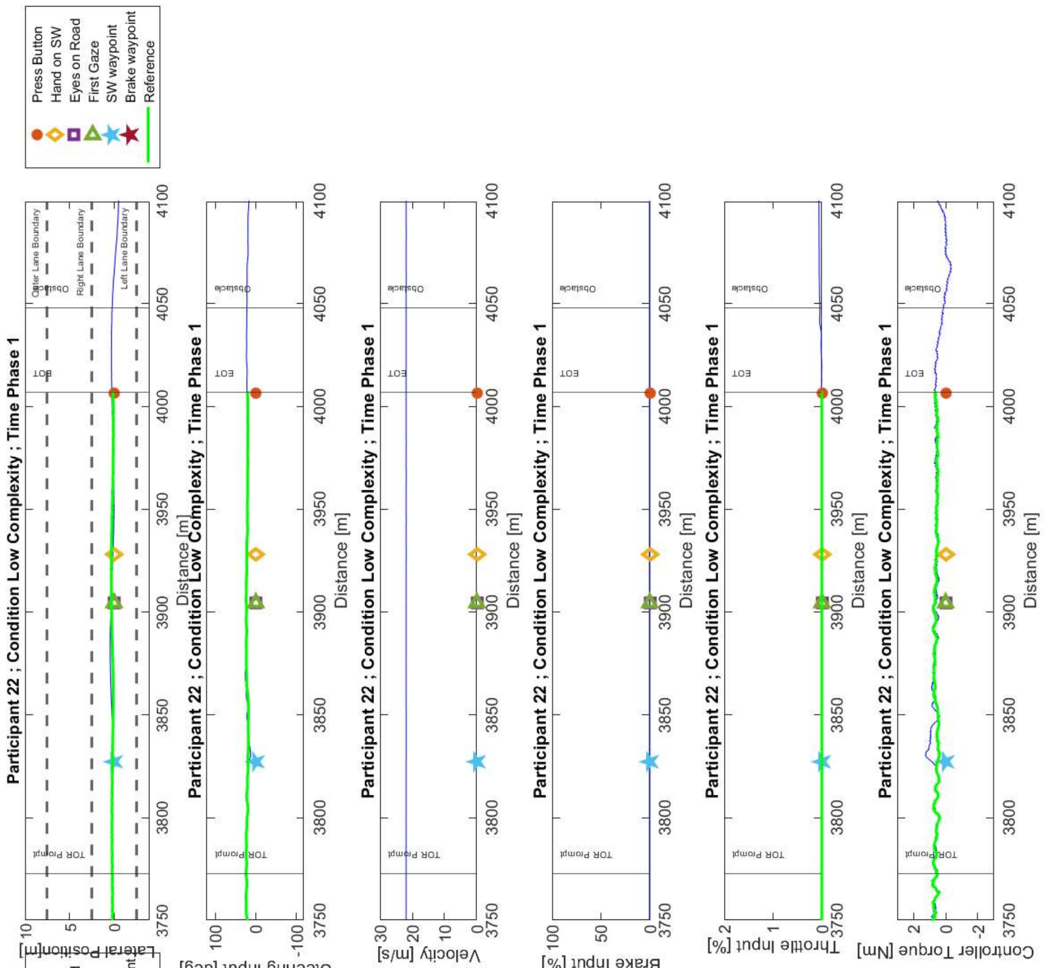
Participant 21 ; Condition Low Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference



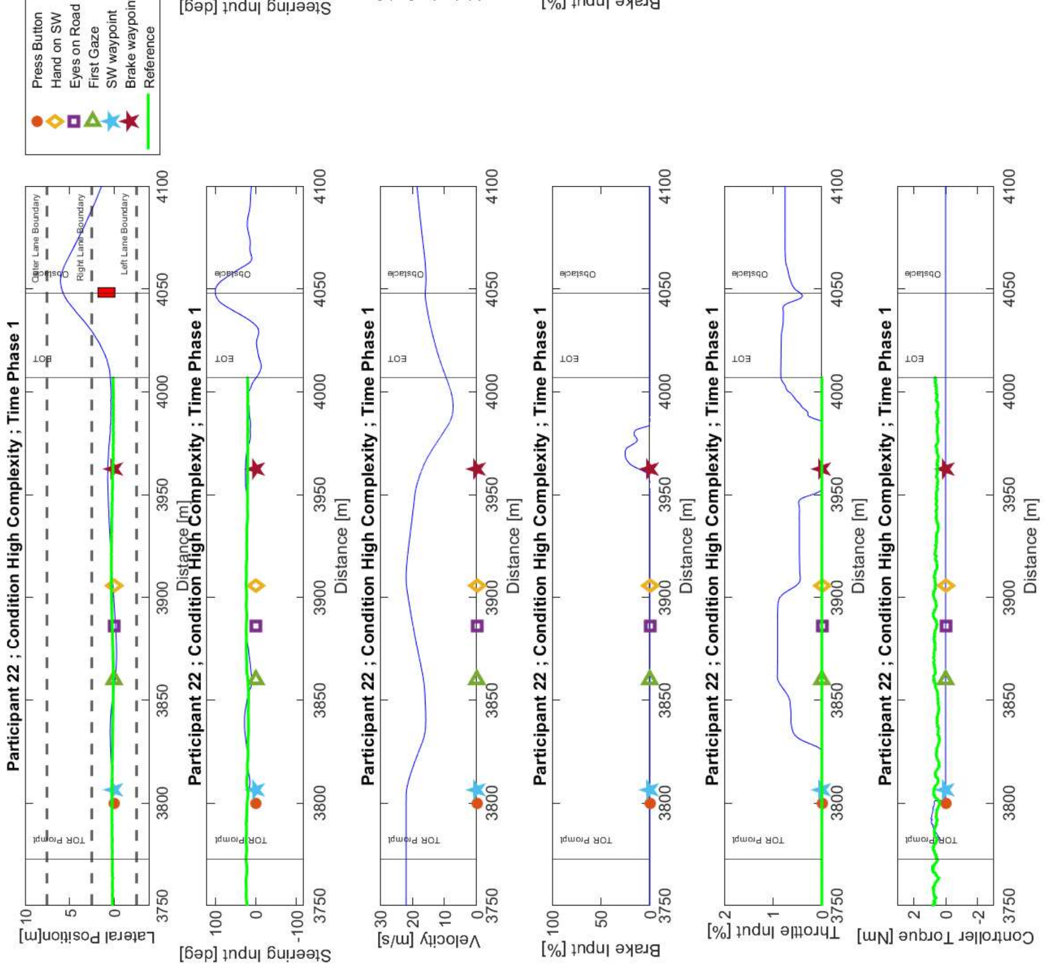
Participant 21 ; Condition High Complexity ; Time Phase 1
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference



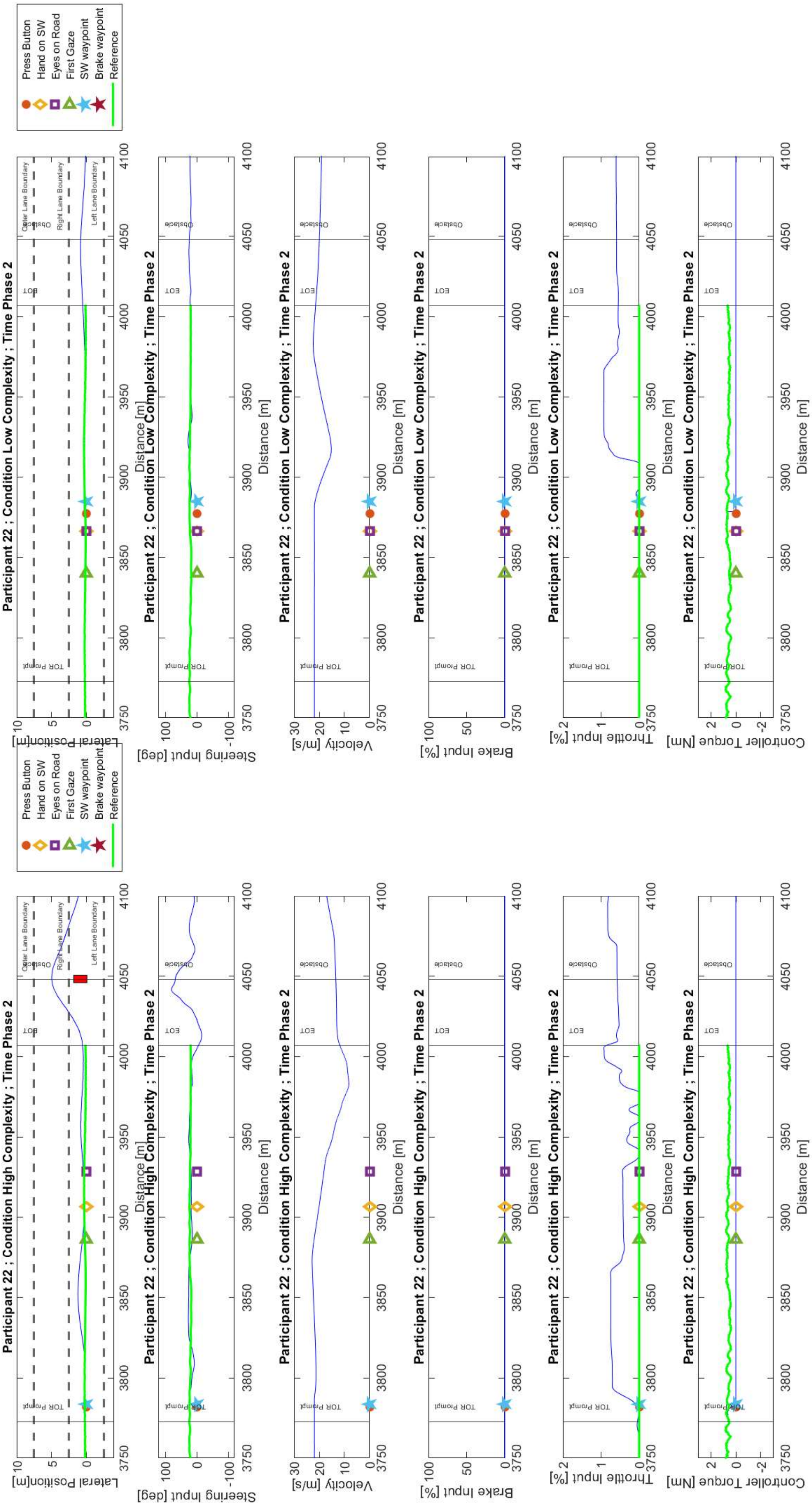
Participant 21 ; Condition High Complexity ; Time Phase 2
Participant 21 ; Condition Low Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

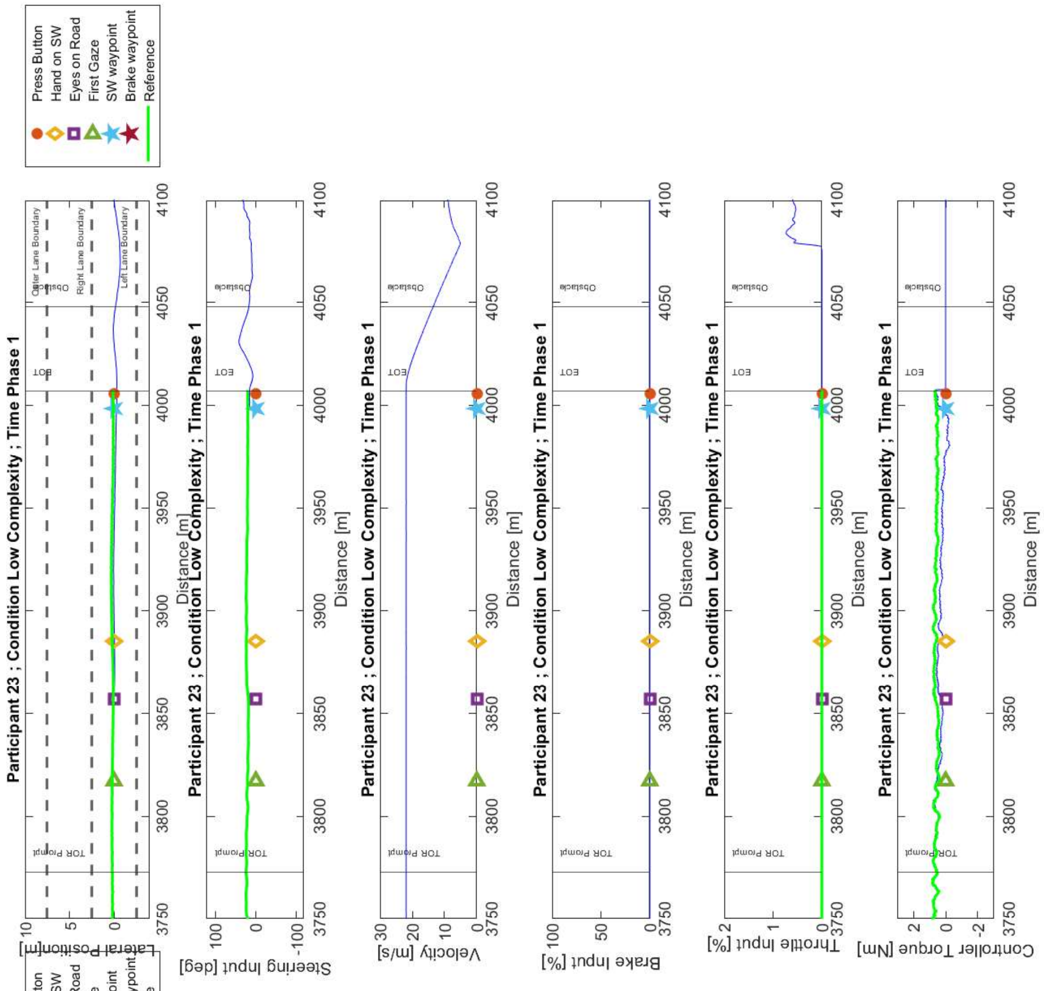


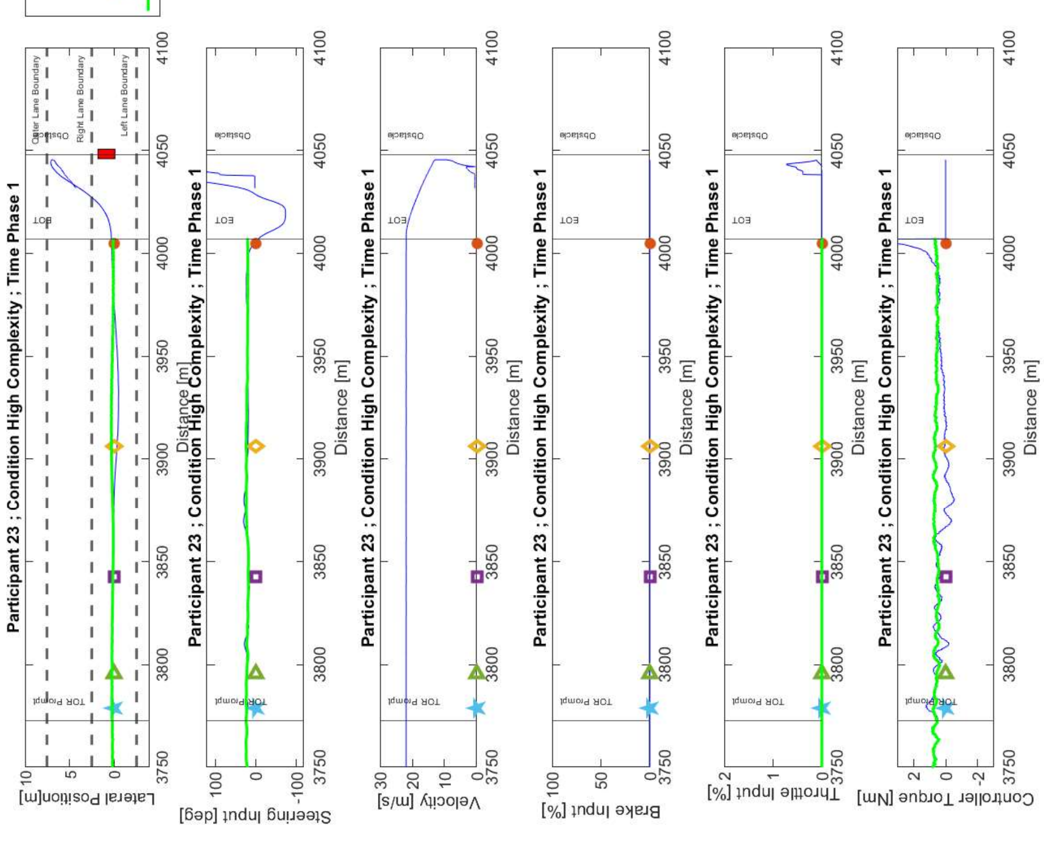
Participant 22 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

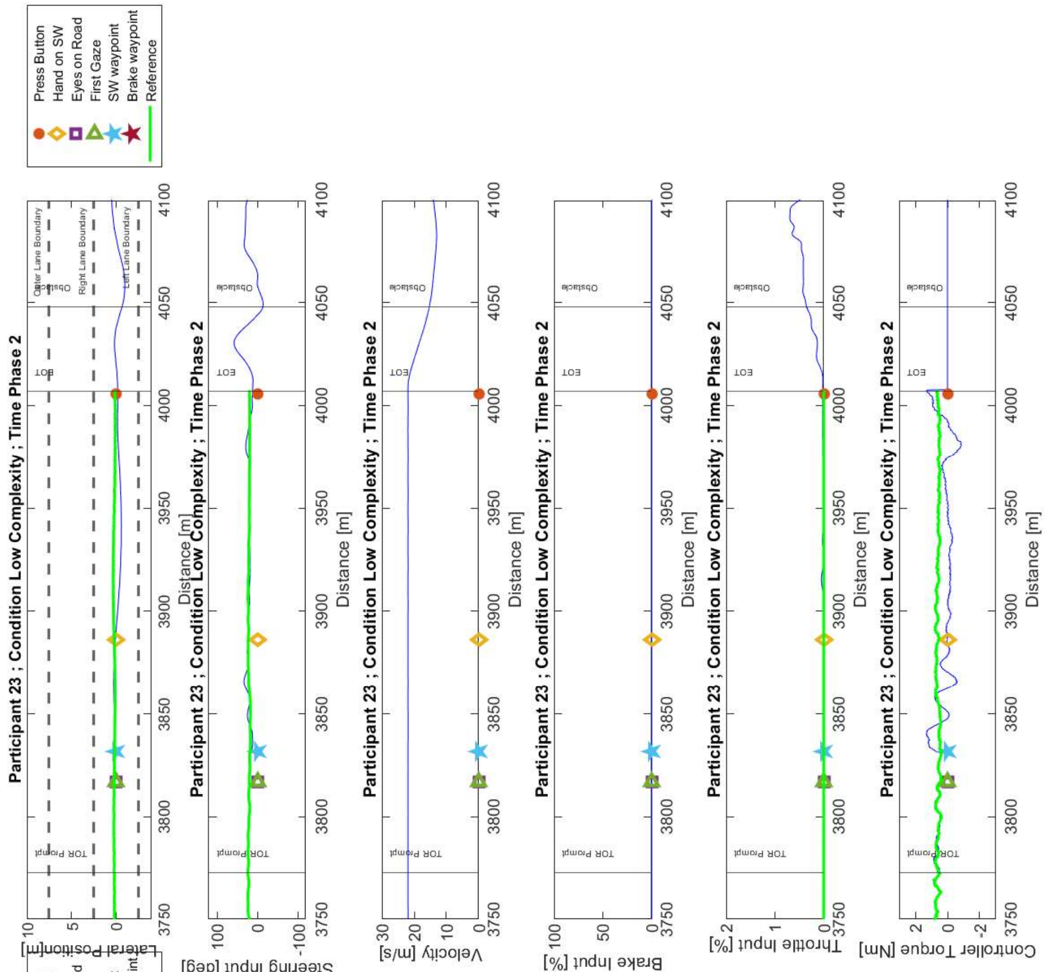


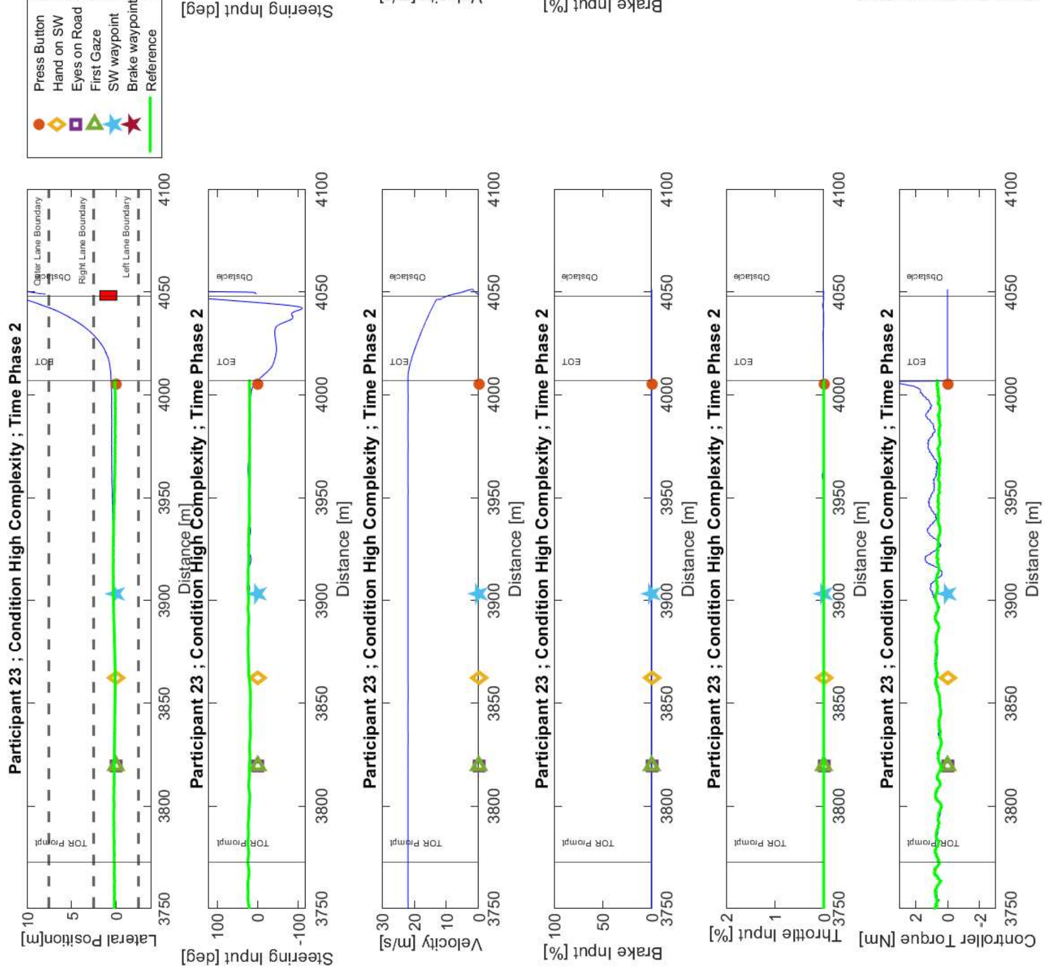
Participant 22 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

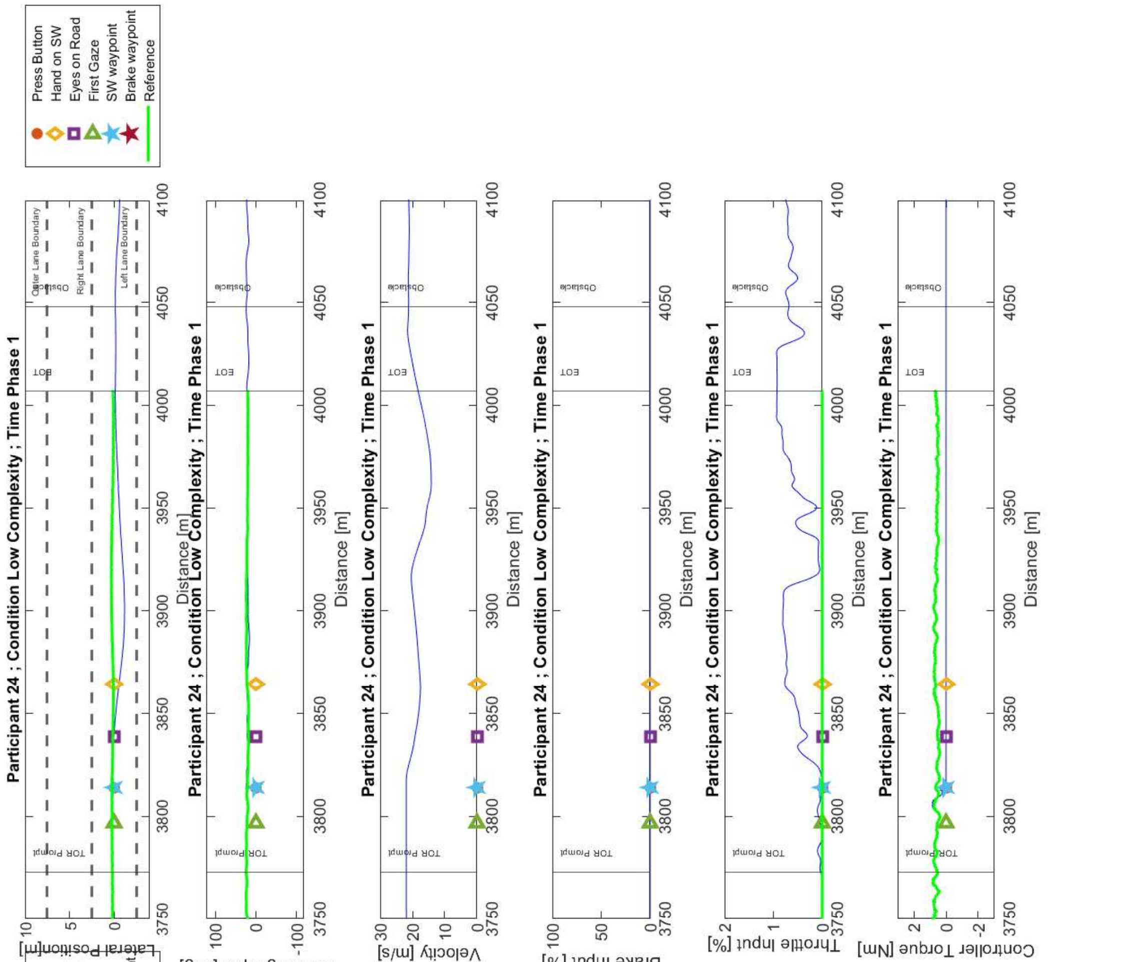

Participant 22 ; Condition High Complexity ; Time Phase 2
Participant 22 ; Condition Low Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

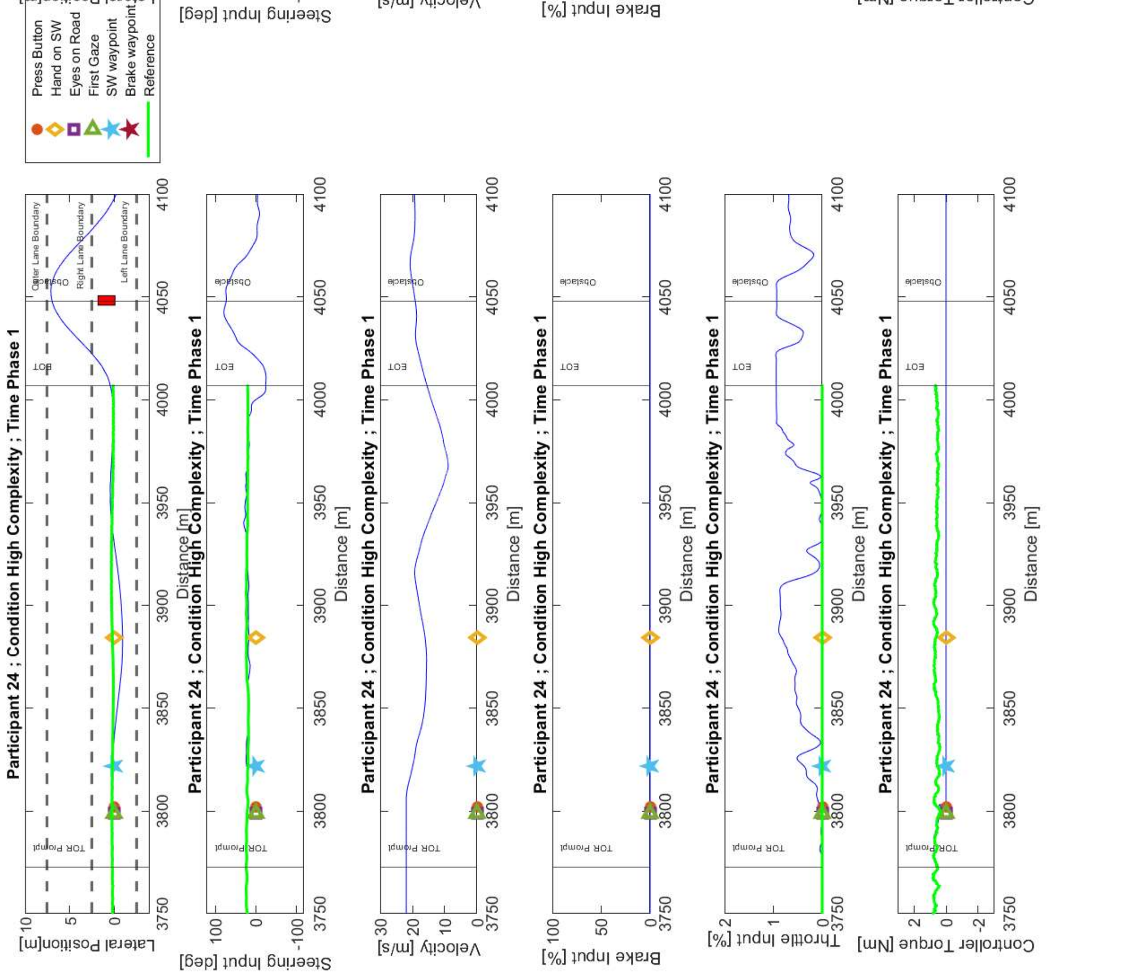

Participant 23 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

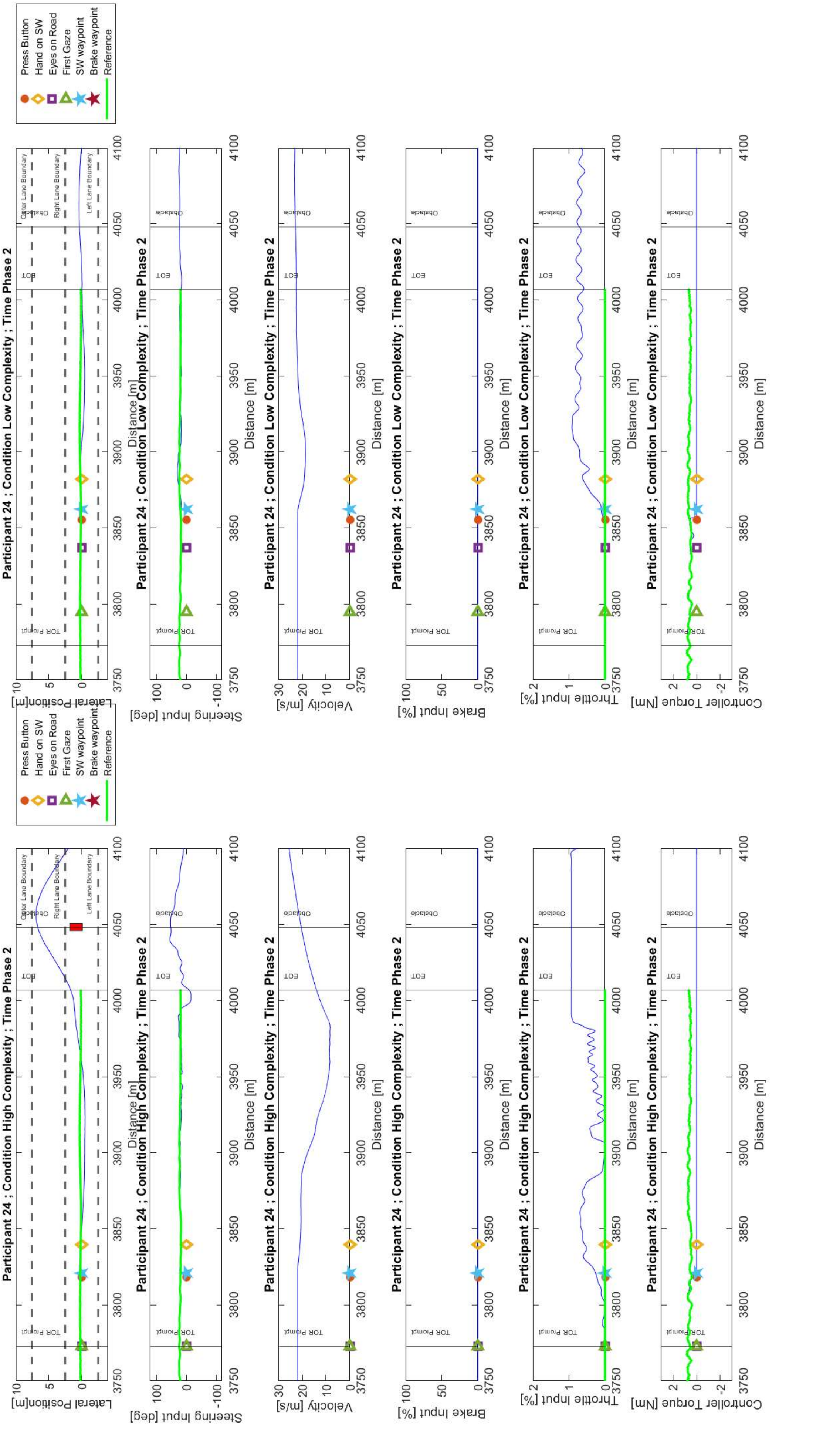

Participant 23 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary


Participant 23 ; Condition Low Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
TOR Prompt
EOT
Obstacle
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]


Participant 23 ; Condition High Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary
TOR Prompt
EOT
Obstacle
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]


Participant 24 ; Condition Low Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary


Participant 24 ; Condition High Complexity ; Time Phase 1
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary


Participant 24 ; Condition High Complexity ; Time Phase 2
Participant 24 ; Condition Low Complexity ; Time Phase 2
Press Button
Hand on SW
Eyes on Road
First Gaze
SW waypoint
Brake waypoint
Reference
Lateral Position[m]
Steering Input [deg]
Velocity [m/s]
Brake Input [%]
Throttle Input [%]
Controller Torque [Nm]
Distance [m]
TOR Prompt
EOT
Obstacle
Outer Lane Boundary
Right Lane Boundary
Left Lane Boundary

C

Experiment Design, Forms and Questionnaire

C.1. Experiment Design

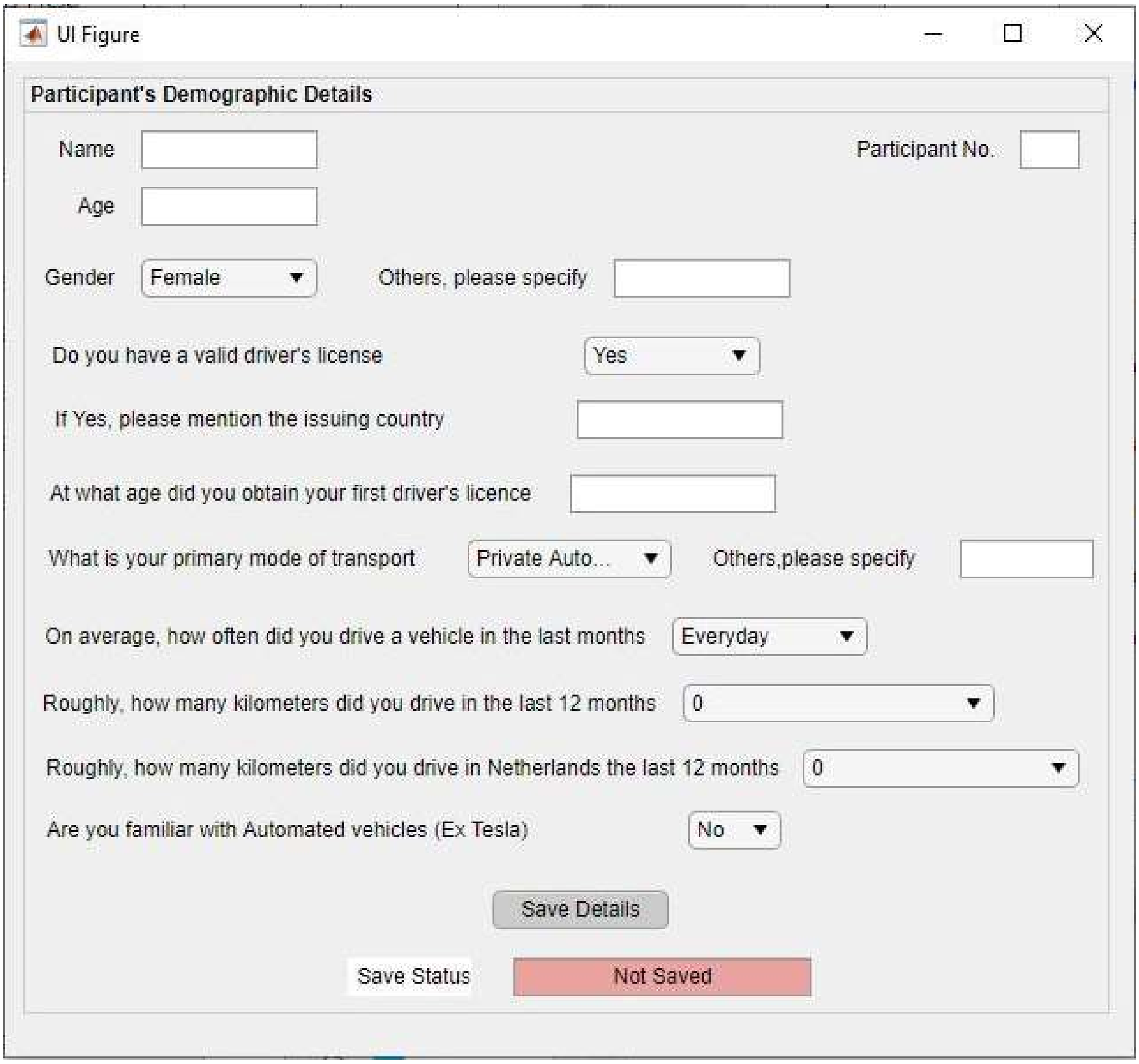
	Run	Particpants								
		1	2	3	4		5	6	7	8
Trial-1	1	TC-NC	HSC-C	TC-NC	HSC-C		TC-C	HSC-NC	TC-C	HSC-NC
	2	TC-C	HSC-NC	TC-C	HSC-NC		TC-NC	HSC-C	TC-NC	HSC-C
	3	TC-C	HSC-NC	TC-C	HSC-NC		TC-NC	HSC-C	TC-NC	HSC-C
	4	TC-NC	HSC-C	TC-NC	HSC-C		TC-C	HSC-NC	TC-C	HSC-NC
		Break for 10 mins								
Trial-2	1	HSC-C	TC-NC	HSC-C	TC-NC		HSC-NC	TC-C	HSC-NC	TC-C
	2	HSC-NC	TC-C	HSC-NC	TC-C		HSC-C	TC-NC	HSC-C	TC-NC
	3	HSC-NC	TC-C	HSC-NC	TC-C		HSC-C	TC-NC	HSC-C	TC-NC
	4	HSC-C	TC-NC	HSC-C	TC-NC		HSC-NC	TC-C	HSC-NC	TC-C

Figure C.1: For this study, a repeated measures within-subject experiment was designed with one within-subject factor: situation complexity. C represents critical (high situational complexity condition) and NC represents Non-Critical (Low situational complexity condition). TC stands for traded control wherea as HSC for Haptic Shared Control. As the experiment was originally designed for both the transitions approaches, the above table shows the four randomized conditions for two trials.

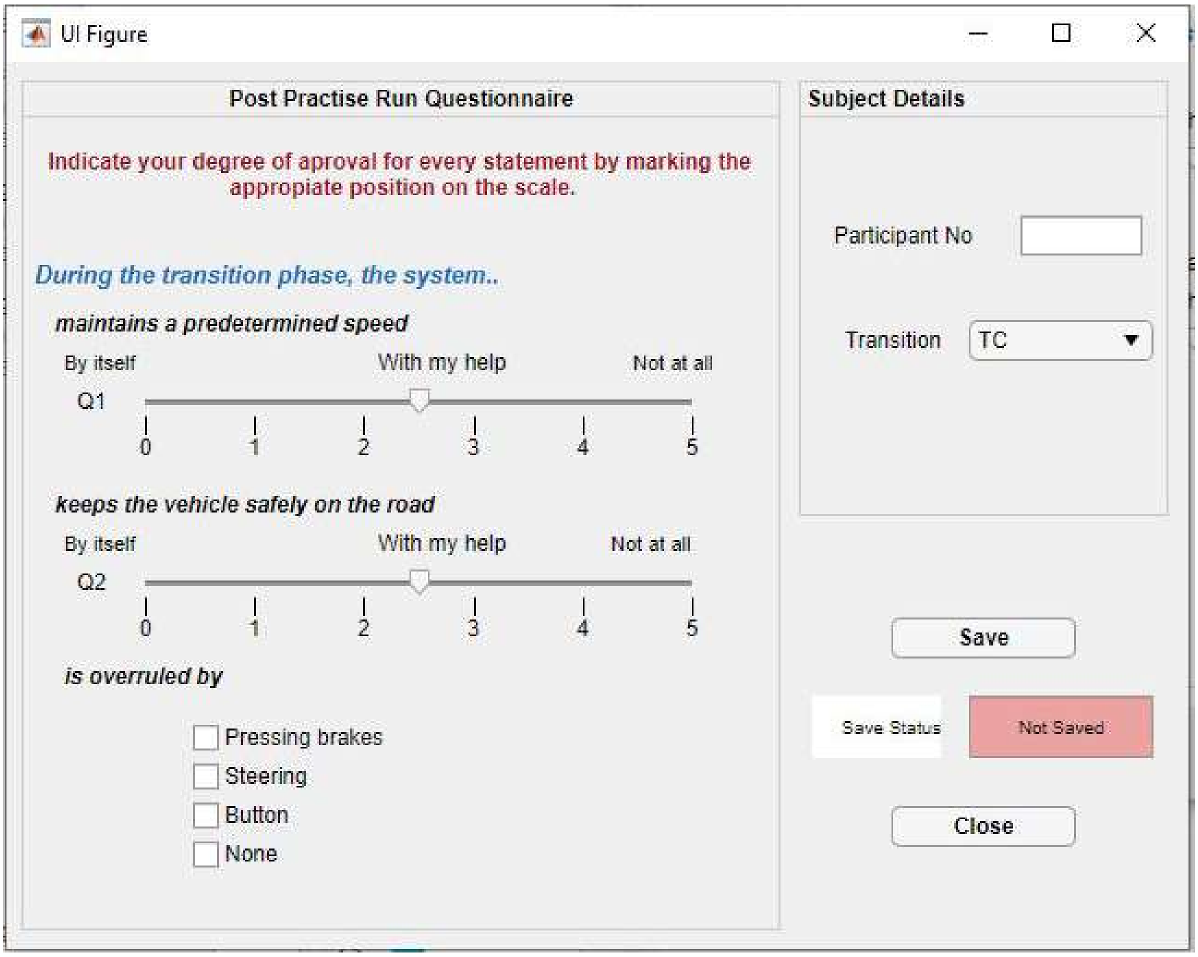
C.2. Informed Consent Form

Consent Form for Automation initiated driver in control authority transition in highly automated driving (SAE 3) using Haptic Shared Control		
Please tick the appropiate boxes	**Yes**	**No**
Taking part in the study		
I have read and understood the study information dated 24/02/2020, or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	O	O
I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	O	O
I understand that taking part in the study involves collection of data through demographic questions, video recording, subjective questionnaires and observation on my behaviour will be scored into metrics of performance.	O	O
I furthermore understand that video recordings are required to analyse the driving performance and these recordings will be kept for retention period of 10 years.	O	O
Risks associated with participating in the study		
<u>I understand that taking part in the study involves the following risks</u>: Virtual environments like driving simulators can cause motion sickness, due to a difference between actual and expected motion. Symptoms commonly include nausea, vomiting, cold sweat, headache, sleepiness, yawning, loss of appetite, and increased salivation. Risk factors include pregnancy, migraines, and Meniere’s disease. Behavioural measures to decrease motion sickness include holding the head still and lying on the back	O	O
Use of the information in the study		
I understand that information I provide will be used for analysing driver behaviour and performance in autonomous vehicles which will contribute towards the development of safer driver assistance system. I understand that it is not the purpose of this experiment of this experiment to highlight any individual’s performance and the results of this study will be published in possible future scientific publications.	O	O
I understand that personal information collected about me that can identify me, such as [e.g. my name or where I live], will not be shared beyond the study team.	O	O
Future use and reuse of the information by others		
I give permission for the driving behaviour and performance data that I provide to be or age, will not be shared beyond the study team. The collected data in this experiment is kept confidential and will be used for research purposes only. The data will also be anonymised i.e. you will be identified by a subject number.	O	O
I furthermore understand that the raw and anonymous data will be made publicly available for peer review, re-creation of the experiment, or used in other analyses.	O	O
I give permission for the anonymous data that I provide to be archived in the 4TU.Centre for Research Data so it can be used for future research and learning, including third parties	O	O
I give permission that this informed consent form will also be stored in the 4TU.Center for Research Data but will not be publicly available. I also understand that this informed consent form will be the only carrier of my personalised data and will be digitalized, after which this physical version will be destroyed, until which it will be stored out of reach for anyone.	O	O
Signatures		
Name of the participants ______________________ Signature _____________________ Date ________________________		
I have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting. Tarbiya Khanam _________________ ____________ Researcher name Signature Date		
Study contact details for further information: Tarbiya Khanam*, 0613098095, t.khanam@student.tudelft.nl*		

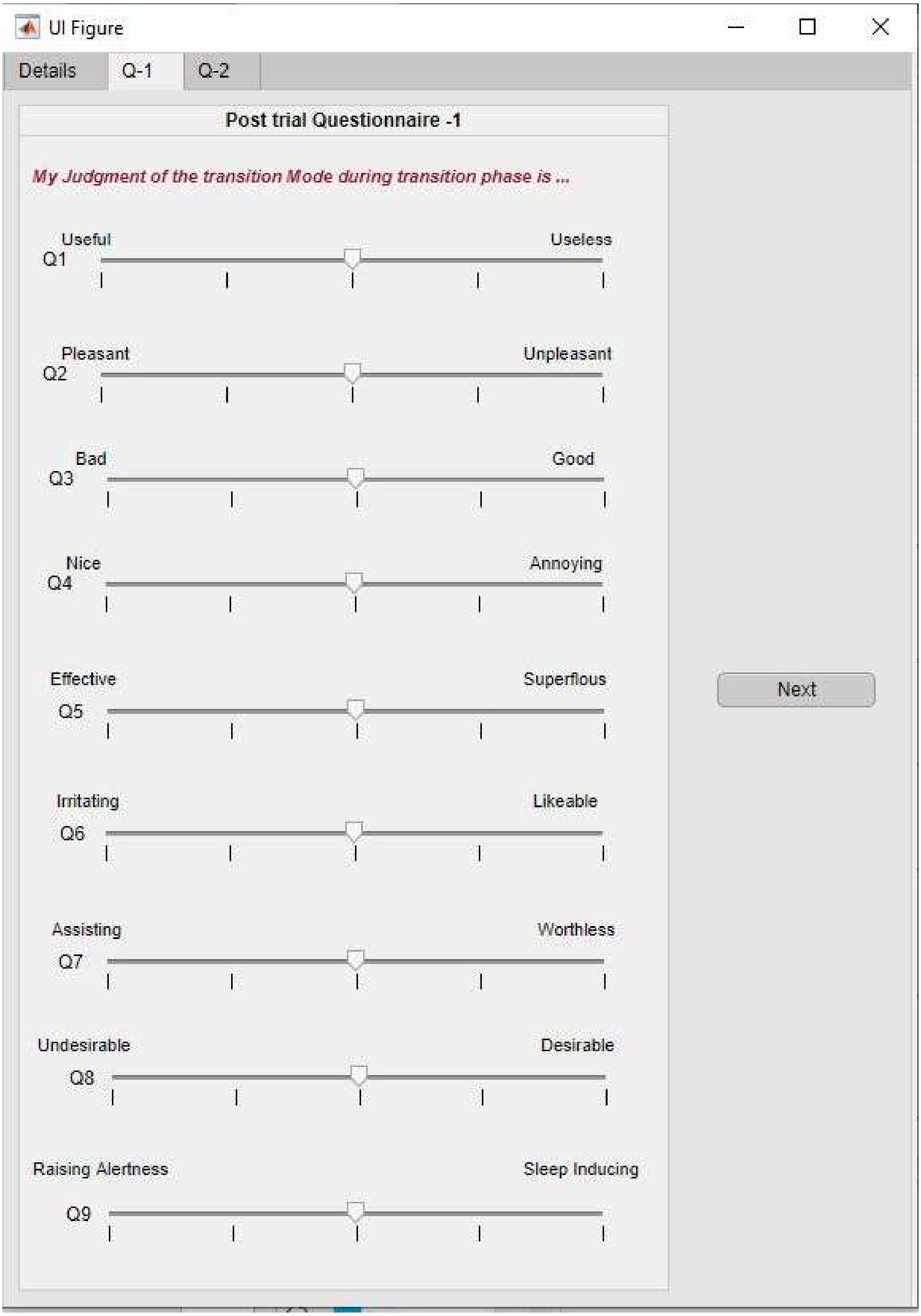
C.3. Demographic Questionnaire



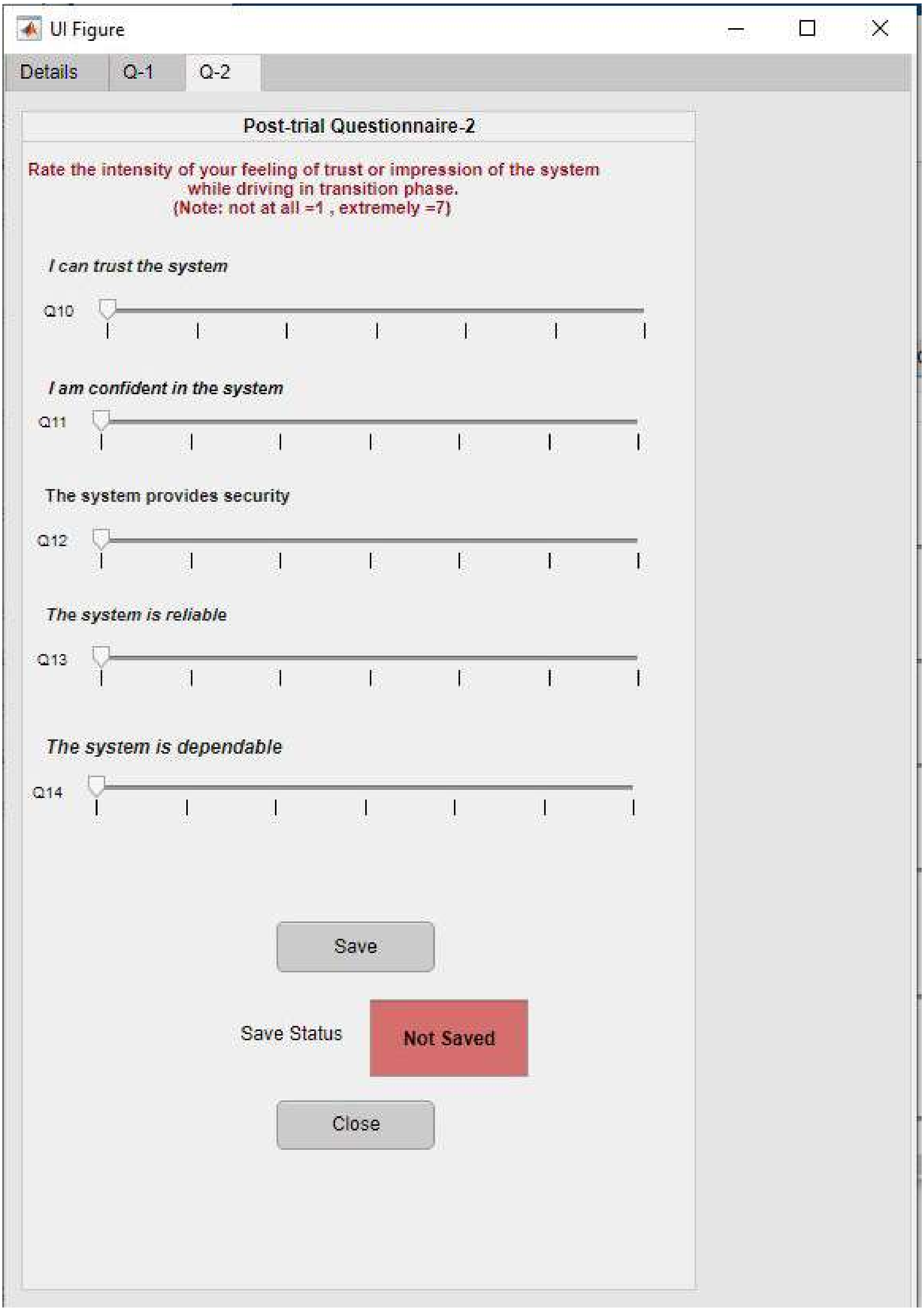
C.4. Mode Awareness Questionnaire



C.5. Van der Laan System Acceptance Questionnaire



C.6. Trust in Automation Questionnaire



C.7. Results

C.7.1. Mode awareness

Participant	Q1	Q2	Q3	Q4	Q5	Q6
1	0	0	0	0	1	0
2	0	1	0	0	1	0
3	0	0	0	0	1	0
4	3	1	0	1	1	0
5	0	0	0	0	1	0
6	0	0	0	0	1	0
7	0	0	0	0	1	0
8	0	0	0	0	1	0
9	0	0	0	0	1	0
10	2	1	0	0	1	0
11	0	0	0	0	0	1
12	0	0	0	0	1	0
13	0	0	0	0	1	0
14	0	0	0	0	1	0
15	0	0	0	0	1	0
16	0	1	0	0	1	0
17	0	1	0	1	1	0
18	1	1	0	0	1	0
19	0	0	0	0	1	0
20	0	0	0	0	1	0
21	1	1	0	0	1	0
22	0	0	0	0	0	1
23	2	2	0	0	1	0
24	0	0	0	0	1	0

Table C.1: Results from Mode awareness Questionnaire containing 6 questions. 0 means false and 1 means true

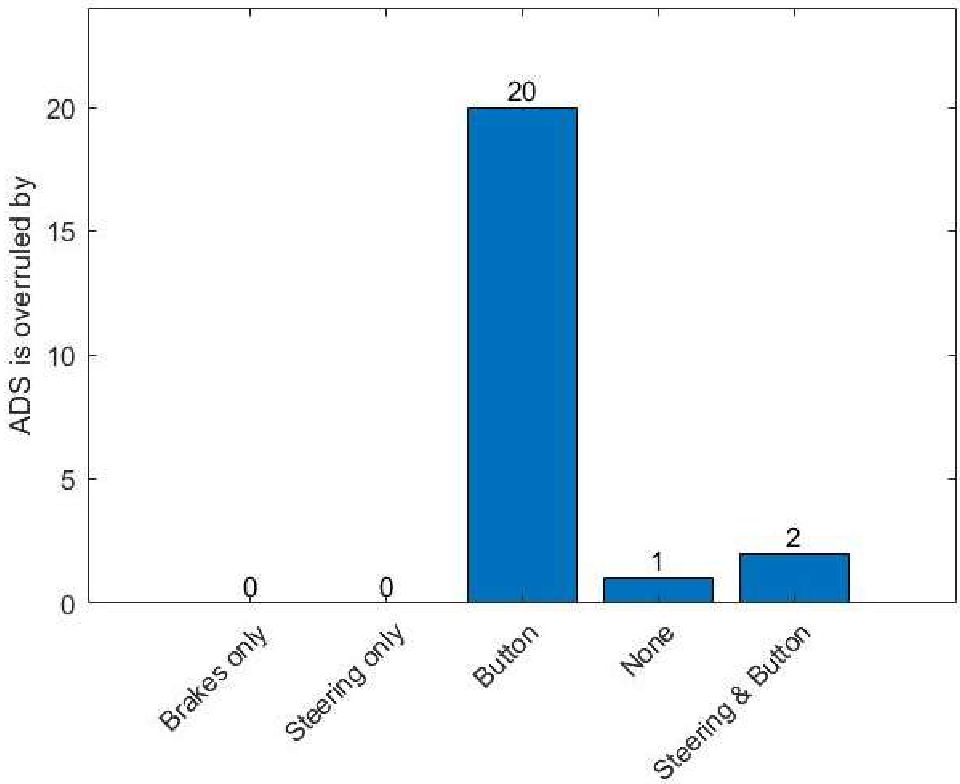


Figure C.2: Participant response to mode awareness questionnaire. Three participants had mode confusion regarding the ADS

C.7.2. Van der laan Questionnaire

	High Complexity Situation								
Participants	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
1	1	1	-2	2	1	0	2	-2	2
2	-1	-1	1	0	0	0	-1	1	0
3	2	2	-1	2	2	-2	2	-2	2
4	1	0	-1	0	1	0	0	0	1
5	2	2	-2	2	2	-2	2	-2	1
6	1	1	-1	1	1	-1	1	-1	2
7	-1	-1	1	-1	-2	1	-1	1	-1
8	-1	-2	1	0	-1	2	-1	2	2
9	2	0	-1	1	2	0	2	-2	2
10	1	2	-2	2	2	-1	1	-2	2
11	-2	-1	1	0	-1	1	0	0	1
12	-2	-1	0	1	-1	1	-1	1	2
13	0	-1	-1	-1	1	0	0	1	-1
14	2	2	-1	0	1	0	1	-1	2
15	-1	-1	1	-1	-1	0	0	1	1
16	2	2	-2	2	2	-2	2	-2	-1
17	1	1	-2	1	2	0	2	-2	2
18	1	1	-1	1	1	-1	1	0	1
19	2	0	-1	1	2	0	2	-1	2
20	-1	-1	0	-1	-2	0	-2	2	1
21	-1	-1	1	0	-1	2	1	-1	2
22	2	1	-1	2	1	-1	1	0	0
23	1	1	-1	-1	1	1	0	-1	1
24	1	-1	2	-2	-2	2	-2	2	1

Table C.2: Results of the Vander Laan Questionnaire containing ratings for each conditions per participants for high complexity scenario

	Low Complexity Situation								
Participants	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
1	2	2	-1	1	2	-1	2	-1	2
2	1	2	-2	1	2	-2	1	-2	1
3	0	1	-1	1	1	-1	1	-1	2
4	1	1	-1	0	1	0	1	0	1
5	2	2	-2	2	2	-2	2	-2	1
6	1	1	-1	1	0	-1	0	0	1
7	-1	-1	2	-2	-2	2	-1	2	0
8	2	2	-1	1	1	-1	0	0	-1
9	-1	0	0	-1	-1	1	0	0	1
10	1	2	-1	2	2	-1	0	-1	2
11	1	1	-1	1	1	0	1	-1	0
12	-1	-1	0	-1	1	1	-1	1	2
13	1	1	-1	1	1	-1	-1	-1	-1
14	2	2	-2	1	1	-1	2	-1	1
15	1	1	0	0	1	0	1	0	1
16	2	2	-2	2	2	-2	2	-2	-2
17	1	1	-1	1	1	0	1	-1	2
18	1	1	-1	1	1	-1	1	-1	1
19	1	1	0	1	1	1	1	-2	2
20	2	2	-1	1	1	-1	0	1	-1
21	1	1	-1	1	1	-1	2	-1	2
22	2	2	-1	1	2	0	1	-1	0
23	2	2	-2	2	2	-2	1	-2	1
24	-2	-2	0	-1	-2	1	-2	2	1

Table C.3: Results of the Vander Laan Questionnaire containing ratings for each conditions per participants for low complexity scenario

C.7.3. Trust in Automation Questionnaire

	High situational complexity					Low situational complexity				
Participants	Q10	Q11	Q12	Q13	Q14	Q10	Q11	Q12	Q13	Q14
1	4	3	4	4	6	3	3	4	3	2
2	2	3	3	3	2	2	2	2	2	2
3	5	4	4	4	4	5	4	4	4	4
4	5	5	5	5	6	5	5	5	5	6
5	5	5	5	5	5	5	5	6	5	5
6	5	5	5	4	5	5	5	4	5	6
7	2	2	2	2	2	7	3	3	6	6
8	1	1	4	3	3	5	5	5	5	5
9	5	5	5	5	5	5	4	6	4	4
10	6	5	4	6	5	6	5	4	6	6
11	6	6	1	6	6	7	7	6	7	7
12	2	2	2	2	2	2	2	2	2	2
13	6	7	6	6	2	6	6	6	7	2
14	6	6	5	7	6	7	7	6	7	7
15	5	4	4	5	4	5	5	6	5	5
16	7	7	7	7	7	7	7	7	7	7
17	7	6	7	6	6	7	6	7	6	6
18	5	5	5	5	5	6	6	6	6	6
19	3	3	1	3	4	7	7	6	7	7
20	1	1	1	1	1	5	6	6	6	6
21	4	4	5	5	4	4	4	4	4	4
22	6	6	6	6	7	6	7	6	6	2
23	2	2	2	3	5	5	4	5	5	4
24	5	5	6	5	5	6	6	6	6	6

Table C.4: Result of the trust in automation questionnaire containing ratings of 5 likert items for each participant