Does personality affect responses to auditory take-over requests? Validating a simulator experiment setup through a N=1-study

Master Thesis report

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Does personality affect responses to auditory take-over requests? Validating a simulator experiment setup through a N=1-study

Master Thesis

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Summary

Automated vehicles (AV) and other automated driving systems (ADS) are becoming more common. Current vehicles on the consumer market are capable of reaching SAE level 2, or partial automation (SAE International, 2018), when fitted with various high-tech systems such as adaptive cruise control (ACC) and/or lane keeping assistant (LKA). While driving a level 2 automated vehicle, the driver is still required to monitor the environment and the state of the vehicle, and needs to be ready at all times to take-over control of the vehicle whenever necessary. Human-machine interfaces (HMI) are implemented to help the human driver to interact with the vehicle, by providing either information to, or monitor the state of the driver.

HMIs are widely ranging in modality, type of feedback, and the application of it. Still, there is much to learn about the effects of certain HMIs on the driver in terms of behaviour. Visual stimuli are predominantly used for gathering information, whereas auditory stimuli have some advantages over visual stimuli, namely that it is not visually distracting and that it yields the most increase in situation awareness (Walker et al., 2006). Auditory feedback can be perceived differently, depending on its pitch, duration, loudness, timbre, texture, as well as direction (Burton, 2015). Moreover, an auditory take-over request (TOR) can be perceived differently by the driver, depending on, for example, the urgency, which can lead to different behavioural responses to the request (e.g., Bazilinskyy et al., 2018).

While it is known that different people respond differently to certain events in traffic such as speeding, tailgating, or crashing (Taubman-Ben-Ari & Yehiel, 2012), the effect personality has on driving with an AV is not yet researched. Eriksson and Stanton (2017) found that the difference between the response time of a driver on a TOR varies between 2 and 26 seconds, which clearly illustrates the individual differences between drivers.

These differences in drivers have not only an effect on their behaviour, but also the environment such as the road infrastructure has an effect on how people drive their vehicles. The lane width for example, has an effect on their position on the lane and steering ability (Mechery et al., 2017). How this translates to the take-over performance in an AV is still unknown.

In this research, an experimental setup for a large-scale simulator experiment towards the effects of personality on an auditory TOR is being validated through a N=1-study. Already over 100 participants were recruited, based on their personality trait using the Big Five Inventory (BFI) model by John et al. (1991), to subject them to a simulated drive in a SAE level 3 (conditional automation) vehicle with an auditory take-over request. However, due to the COVID-19 pandemic, human participation in experiments was restricted in the period of this research and therefore, this experiment was changed to an N=1-study whereby the lead researcher subjected himself to this experiment in order to optimize and validate variables used for a larger experiment. The main research question that is answered is: *What is the ideal setup of a simulator experiment that investigates the effects of personality on an auditory take-over request in conditional driving automation?* The scope lies into a highway scenario with human drivers, selected by their personality trait of the BFI model by John et al. (1991), with a woman's speech-based auditory TOR. The 'ideal' setup will be explained by the most efficient and valuable research variables with their levels for using them in a larger experiment, even as the setup in terms of hard- and software.

By means of a 3*3*3*3=81 variations intrapersonal counterbalanced experimental setup, the main research question is answered and suggestions are made to optimize the setup of a large-scale driving simulator experiment to investigate the effects the personality trait has on the take-over quality from a speech-based auditory TOR.

Four variables were chosen to vary in levels to find their influence on the TOR. The four variables were alternated in three ways:

(1) The take-over type, varying between non-urgent TOR (NTR), semi-urgent TOR (STR), and urgent TOR (UTR);
(2) The take-over speech rate, varying between its normal setting with -10, 0 and +10, whereby the normal settings are: +0 (100% of normal duration) for the NTR variable, +25 (87% of the

normal duration) for the STR variable, and the fastest for the UTR variable +50 (78% of normal duration);
(3) The take-over syntax, varying between three different signal words for each take-over type (cf. Hellier et al., 2002). For the NTR variable, the signal words "Note", "Risky", and "Hazard" were used. "Warning", "Attention", and "Caution" for the NTR variable, and the signal words "Danger", "Deadly", and "Beware" were used for the UTR variable. Each of these signal words were part of a standard sentence for each type, namely for the NTR "[…], take-over at your earliest convenience", for STR "[…], take-over as soon as possible", and for the UTR "[…], take-over immediately";
(4) The lane width, varying between 2.5, 3.0, and 3.5 metres.

Table 1 presents an overview of these variables and their variation of levels.

Table 1

Overview of the variables and their levels

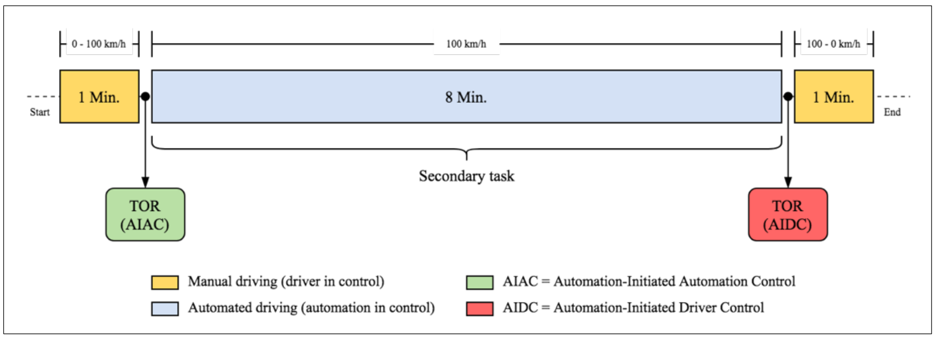
Variable	Levels
Take-over type	*NTR* *STR* *UTR*
Take-over speech-rate *(varying between -10, 0, and +10)*	*(NTR) -10, 0, +10* *(STR) +15, +25, +35* *(UTR) +40, +50, +60*
Take-over syntax	*(NTR) Note, Risky, or Hazard* *(STR) Warning, Attention, or Caution* *(UTR) Danger, Deadly, or Beware*
Lane width	*2.5 metres* *3.0 metres* *3.5 metres*

The experiment was performed in a static driving simulator, displaying a typical Dutch two-lane highway with a maximum speed of 100 km/h. Each run lasted approximately 10 minutes in total, with 1 minute of manual driving before taking over by the vehicle, whereafter approximately 8 minutes the ADS was in control till the TOR was executed as shown in Figure 1. When the ADS of the vehicle was in control, the driver was asked to play the game Tetris on a tablet to distract him from the driving task and environment. With the use of a three-camera setup, recording the eyes, the hands and the feet of the human driver, the take-over times (TOT) were measured. Moreover, screen recording was used to record and measure the lateral deviation (LD).

Three full working days in total were used to perform the 81 experimental runs. Overall, each run took approximately 15 minutes, with a break after every 4 to 7 runs to avoid fatigue. After the experiments, the results were analysed with different camera and screen recording images combined together to reveal the TOT and the LD of each run. For all variables together, and per variable, a descriptive analysis was performed with testing the differences between the conditions for significance.

Figure 1

Design and timeline of each run



It was found that the mean TOT for all tests combined amounts 3.08 seconds, whereas throughout the 81 tests, the TOT ranges between 1.80 and 5.23 seconds. The difference between the take-over types were significant, which shows a decrease in the mean TOT if urgency increases, meaning the slowest mean TOT for NTR and the quickest mean for the UTR. For the speech-rate nuances, no significance was found between the levels for each of the urgency types. The difference between the urgency types in terms of the syntax was significant at the .05 level, which indicates that the sentences and signal words fits the meaning of the urgency. Moreover, for each type of urgency, only the STR and UTR have significant differences within their variation of signal words, whereas the NTR have no significant difference between the three signal words.

The lane width and thus the LD between the different types of urgency is not significant for a significance level of .05 used in this study, whereas for .1 it is significant. Overall, the highest relative mean LD is found for the UTR (8.117%), the smallest for the NTR (5.432%) and between these the STR (5.678%). This supports the finding of Politis et al. (2015) and Gray (2011) that accuracy is at the expense of higher urgency. Furthermore, within each urgency, the lane width differs between 2.5, 3.0 and 3.5 metres. This experiment shows that for the STR and UTR, the differences between these lane widths are significant, whereas for the NTR this is not. For the NTR, a learning curve was found, due to the fact that in the first tests, the LD was large but after a few tests stabilizes around a lower LD.

By means of exploratory research, it was found that the accuracy of the foot placement when taking over the vehicle differs between the urgency levels. The UTR has in 56% of the tests an error (pressing both the accelerator and brake pedal), and the NTR and STR only in 22% of the tests. Regarding the day part in which the tests were performed, divided into early morning (EM), late morning (LM), early afternoon (EA) and late afternoon (LA), no significant difference was found. Finally, the influence of the game was measured relative to the TOT, but no significant difference was found either.

From the results, several conclusions can be drawn. This research proves that a few variables and their given levels are significant and thus influence the TOT. This means that validation of variables and their levels are useful before implementing them in a large experiment. For example, significant difference was found in the type of take-over (NTR, STR, UTR) used, the syntax in means of signal words and lane-width for the STR and UTR urgency types. From these results, an efficient design of variables and their levels can be defined for use in a larger experiment.

In this experiment, three types of urgencies are defined (NTR, STR, UTR) that as standard varied relative to each other by means of speech-rate and syntax. Furthermore, significant differences are found between the levels of urgency in terms of TOT, and these different levels of urgency influence the human errors such as the LD and foot placement when taking over the driving task. A higher urgency is found to incorporate less accuracy when taking over the driving task by the driver compared to a lower urgency.

The speech-rate was varied in three steps, namely -10, 0, and +10, with respect to the standard given speech-rate per urgency type (NTR: 0; STR: +25; UTR: +50). The variation in speech-rates did not provide significant differences in terms of the TOT. However, the speech-rate is still relevant for indicating a certain urgency by their standard given speech-rate.

The syntax, or signal words, were varied for each take-over type in three levels. The words were chosen on basis of the research of Hellier et al. (2002) and were assigned as is shown in table 1. Significant words were found for the STR and UTR, but not for the NTR. Still, the findings are useful for the design of the variables and their levels for a larger experiment. For the final design of the variables and their levels, it is chosen that the TOT between the three urgency levels are widespread, which means that the urgency level is more recognisable for the driver. For the syntax, this means that for the low urgency (NTR), the signal word with the highest mean TOT is chosen, which is “Hazard”. For the middle urgency (STR), the signal word with the middle mean TOT is “Caution”, whereas the highest urgency level (UTR) is chosen to have the signal word with the quickest TOT, which is “Deadly”.

The lane width influences the LD when the driver takes over the vehicle. A narrower lane width has less LD than a wider lane. This means that the driver is consciously or unconsciously aware of the capacity it has to deviate the vehicle on the lane. Overall, a narrow lane means less LD, which is the preferred option to choose in all cases.

A final design for the variables, varying in levels for each urgency, are presented in Table 2 and can be used for testing the influence of the personality trait against these variables in a larger experiment.

Table 2

Final design of the variables for each type of urgency

Urgency	Type	Speech-rate	Syntax	Lane width
Low	*NTR*	*+0*	*"Hazard, take-over at your earliest convenience"*	*2.5*
Middle	*STR*	*+25*	*"Caution, take-over as soon as possible"*	*2.5*
High	*UTR*	*+50*	*"Deadly, take-over immediately"*	*2.5*

Relating the research findings to literature, additional conclusions can be made, and findings can be validated. From literature (e.g., Bazilinskyy & de Winter, 2017; Politis et al., 2014) urgency levels can be made clearly distinguishable by a certain speech-rate, which was done in this research by giving each take-over type a standard speech-rate that differs relative to each other. Furthermore, the signal words, found by Hellier et al. (2002) who indicate these signal words in terms of urgency, are used in this research for varying the different types of urgency. As found by this experiment, some of these words do indeed indicate the urgency level, especially the words used for the STR and UTR variables. The lane width in relation to the LD was found to be significant for higher urgencies, which supports the findings of Politis et al. (2013). The finding of a learning curve for keeping in the lane are not found exactly in literature, but some tend to remark them in their research (e.g., De Groot et al., 2011; Van Leeuwen et al., 2011).

This N=1-study shows that validating variables and their levels are useful for larger experiments. However, the personality trait could not be tested in this N=1-study. Therefore, more participants are needed in order to measure the influence of the personality trait on a speech-based auditory TOR. Overall, this N=1-study proves that validating variables and their levels are interesting and useful for in a larger experiment. Even more, the setup in terms of hard- and software can be tested beforehand, errors could be solved, and indications about certain results could already be made. Furthermore, this shows that this unique N=1-study, which is never performed before in this field of research, shows the importance and meaningfulness for a research.

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Acronyms

ADS: Automated Driving Systems
AIAC: Automation-Initiated Automation Control
AIDC: Automation-Initiated Driver Control
ATM: Automation to Manual
AV: Automated Vehicle
DIAC: Driver-Initiated Automation Control
DIDC: Driver-Initiated Driver Control
EA: Early Afternoon
EM: Early Morning
EOR: Eyes On Road
FOP: Foot On Pedal
FOV: Field Of View
FPE: Foot Placement Error
HMI: Human Machine Interface
HOW: Hands On Wheel
LA: Late Afternoon
LD: Lateral Deviation
LM: Late Morning
MTA: Manual to Automation
NTR: Non-urgent Take-over Request
ODD: Operational Design Domain
STR: Semi-urgent Take-over Request
TAM: Take-over Automation to Manual
THI: Take-over time Human after Initiation
TOR: Take-Over Request
UX: User Experience
UI: User Interface
UTR: Urgent Take-over Request

Preface

Dear reader,

In the upcoming years, automated vehicles (AVs) are becoming more common in our daily lives. Using our own AV for transportation to our work location or sharing an AV for going to school could be one of the possibilities. These kind of innovations in transportation purposes are essential in keeping society running and transferring our environment towards an accident-free future. At the same time, it should not be forgotten that this transfer has some large bridges to build before this future becomes reality. Especially the small features in this transition are important, such as the different kind of people using these innovations, and their interaction with these machines.

With the opportunity to dive into this topic for several months, I found the personality trait of human drivers in relation to the time to take-over an AV in emergency situations very interesting. Especially testing potential factors who influence this take-over time is important for further testing, researching and implementing of AVs. The exploratory discussions with Daniël Heikoop and Jan Anne Annema helped me guiding through the stages of my thesis, and finally led to this research as presented in this report. Thank you for your continued support throughout the process, with special gratitude to Daniël as my daily supervisor for continuously keeping me motivated and reviewing my research and writing style. I would also like to thank my professor Marjan Hagenzieker for challenging me in our meetings and bringing this research towards a whole new level, especially after the COVID-19 pandemic started and the original thesis research was not possible to be conducted. Especially the positiveness and energy of you all motivated me to finish this research. Thank you!

A special word of appreciation goes to my family and friends for their continues support throughout my years of studying, not only for their positiveness, but also for their stimulation to finish my study.

Enjoy reading this research!

Thijs Ebbers

October 2020

Chapter 1

Introduction

This chapter starts (1.1) with background information about automated vehicles (AV) together with the involved automated driving systems (ADS) and the function of human machine interfaces (HMI) in it. Furthermore, problems are shown why this research is started in the first place and how the research has changed due to COVID-19. In the following paragraphs, this chapter will define the problem, goal, and scope of this research (1.2). Paragraph 1.3 contains the research questions, whereas the outline of this research is given in paragraph 1.4.

COVID-19
Two months after the start of this research, the outbreak of COVID-19 in the Netherlands started. At the 10th of March 2020, the TU Delft closed her doors for students and staff members until further notice. The last week of March until the end of April 2020 was planned for receiving more than 100 participants to take part in the simulator study of which the original research consisted. Due to the fact this was not possible at that moment, and also had no perspective in the future, the aim of the research was changed in consultation with my supervisors. Instead of researching the influence of the personality trait of a human driver with the time to take-over an automated vehicle with N=100, the research changed to a N=1 experiment, whereby the researcher took part in his own experiment. The researcher subjected himself to all combinations of take-over requests, varying by three variables related to the take-over request design and one to the lane width, to validate these in this experiment. The outcome of this research will therefore change from a large-scale simulator experiment, researching the relationship between personality trait and the take-over time in AVs, to validating this experimental setup through a N=1 study.

1.1 Background

These days, an increasing number of vehicles are on the market that are equipped with longitudinal and lateral automated control support up to SAE level 2 or partial automation (SAE International, 2018). However, the driver still needs to monitor the automation and is responsible for the driving task. Conditional automation (level 3) and high automation (level 4) are expected to be introduced on the road in the upcoming years (EU Commission, 2018). The standards used for indicating the level of automation are found by the Society of Automotive Engineers (SAE), an organization that provides a taxonomy with definitions for six levels of driving automation. These levels range, in the context of motorized vehicles, from no driving automation (level 0) to full driving automation (level 5), whereby an increase in level means an increase in the autonomy of the vehicle and the role of the human driver shifts from a controlling function to a supervisory function.

It can be assumed that the human driver will be attracted by secondary tasks or is getting drowsy while the automated vehicle (AV) is taking over their driving task (Collet & Musicant, 2019). It is especially the case when automation level 3 or higher is implemented, in which the human driver task is only to take-over control when the AV is requesting it (Wu et al., 2019). This take-over request (TOR) from the AV to the human driver has some concerns. The first concern is how the AV could inform the human driver in a way that the driver can take-over the driving task of the AV in a safe manner (Carsten & Martens, 2019). The second concern is that human drivers differ between each other and respond differently to certain events in traffic (Naujoks et al., 2019), which could influence the way that drivers initiate the TORs.

For the first concern, namely the information exchange between the AV and the human driver, Human Machine Interfaces (HMIs) are used to inform the human driver to take-over control of the vehicle. There already exists extensive research in the field of HMIs and their effect on TORs from the AV to the human driver (e.g., Dogan et al., 2019; Eriksson & Stanton, 2017; Gold et al., 2018). Some of these TORs are investigated with the aid of driving simulators to find out which HMIs are the most effective in terms of reaction times, safety, and driver behaviour strategies (Melcher, 2015).

When driving manually, the human driver has all kinds of information available through visual displays, the speed of the vehicle, and also auditory feedback from road strip rumbles, horns and noise of the road. Auditory and vibrotactile (vibrating steering wheel or chair) feedback have advantages over visual displays due to the fact the information is available without having the eye off the road (Meng & Spence, 2015). Due to the fact that the human driver is resorted to performing a non-driving task in highly AVs, auditory or vibrotactile feedback are expected to be better options than visual displays (Bazilinskyy & de Winter, 2015). Moreover, the effectiveness of HMIs is a combination of several factors, which include the combination of the secondary task, trust in the vehicle, and the fatigue of the human driver (Naujoks et al., 2018). As Bazilinskyy and de Winter (2015) found out, the use of auditory feedback in AVs is highly recommended. In their article, they further stated that the use of a female voice was the most preferred feedback type for a TOR in a highly automated vehicle. Notably, the speech-based output instead of generic auditory output leads to a decrease in self-reported visual workload and reduced interference with non-driving tasks (Forster et al., 2017; Naujoks et al., 2016). This gives the driver an idea of the situation in advance and leads to less stress (Bazilinskyy et al., 2016). Ultimately, Naujoks et al., (2016) and Bazilinskyy and de Winter (2015) both concluded that auditory feedback is one of the most promising HMI in terms of TORs.

The second concern is that human drivers differ between each other in terms of personality and react differently on certain events and requests. Furthermore, this effect of personality on driving metrics with AVs has not yet been researched. The reaction time of a driver on a take-over request from an ADS varies between 2 and 26 seconds (Eriksson & Stanton, 2017). Attention strategies, levels of trust towards, and acceptance of ADS are widespread (Hartwith et al., 2018; Körber & Bengler, 2014; Kyriakidis et al., 2017), which shows the individual differences the domain of automated driving needs to address.

1.2 Problem definition

A large variety of studies are conducted that are researching the field of HMIs and its use in AVs. HMIs are, for example, used to warn human drivers to take-over control of a vehicle when the automation recognizes that it is unable to handle a particular traffic situation (Brandenburg & Chuang, 2019). Although most of the HMIs are designed for getting the attention of the human driver, it is still unclear which HMI or combination of HMI works the best for a specific human driver (Naujoks et al., 2019). Some car manufacturers are investing greatly in getting AVs on the road and are criticized by their use of HMIs in their vehicles as being unsafe, since it is easy to fool and the only use of auditory and visual feedback (Carsten & Martens, 2019). Using, for example, speech-based auditory feedback to get the attention of the driver as stated earlier could be one of the solutions.

Furthermore, drivers differ between each other in terms of driving style and personality (e.g., Taubman-Ben-Ari et al., 2002; Poó & Ledesma, 2013; Miller & Taubman-Ben-Ari, 2010), which could influence the performance of a certain TOR. This could even lead to an HMI design that fits none, based on the personality of the driver, and therefore being not as effective as it could be, while having also an effect on the safety of their own and others on the road.

Research in the field of personality traits and their effect on TORs in AVs are relatively new. However, these focus mainly on the most effective HMI system to reduce the take-over time (e.g. Dogan et al., 2019; Gold et al., 2018; Wu et al., 2019). Furthermore, no HMI study looked into the fact that the human drivers differ from each other in terms of personality, which could lead to a difference between drivers in terms of take-over time or reaction time on HMIs. The scientific gap, to what extent the personality trait of the human driver influences the time to take-over an AV, could give many insights for future designs of HMIs in AVs. Furthermore, if there is a link between the drivers' reaction time to an HMI and their personality, HMIs may be implemented in a different way as known today.

For this research, speech-based auditory feedback is used as HMI as it is found as the most promising HMI for AVs (e.g., Naujoks et al., 2016; Bazilinskyy & de Winter, 2015). Moreover, only SAE level 3 (conditional driving automation) (SAE, 2018) is used, due to the fact this is the next step in the direction of fully AVs after the, already driving on the road, level 2 AVs.

A large-scale simulator study towards the effects of personality and HMI design has never been designed and optimized in terms of the variables. Therefore, the researcher of this thesis subjected himself to his own experiment in a so-called N=1-study in order to optimize and validate the variables used for his study.

1.3 Research questions

In this thesis, an experimental setup for a large-scale simulator study towards the effects of personality on an auditory take-over request is being validated through a N=1-study. The N=1-study focuses on optimizing and validating the variables used for N=100 study. The research question for this thesis therefore is:

What is the ideal setup of a simulator experiment that investigates the effects of personality on an auditory take-over request in conditional driving automation?

An ideal setup in this research is defined in terms of variables and their level, which incorporates the most suitable design for a large experiment. Furthermore, the setup of data measuring methods will be tested and verified, even as the driving environment software, questionnaires and legal documents.

A few variables were identified that are expected to have large effects on the efficiency of this research, namely the take-over type in terms of urgency (e.g., Baldwin, 2011; Baldwin & Moore, 2002; Politis et al., 2013, 2015a), the speech-rate (e.g., Bazilinskyy & de Winter, 2017; Edworthy et al., 2003), syntax (e.g., Hellier et al., 2002; Politis et al., 2014; Politis et al., 2015b), and lane width (Farah et al., 2018; Politis et al., 2015a).

For reaching a valid conclusion, the answer to this research question will be supported by the following sub-questions.

SQ1: *To what extent does a different level of urgency of an auditory take-over request affect the take-over quality of the driver in a SAE level 3 automated vehicle?*

SQ2: *To what extent does the speech-rate of an auditory take-over request influence the take-over speed?*

SQ3: *How will the message conveyed to the driver influence the perceived urgency of an auditory take-over request?*

SQ4: *How does the lane width relate to the take-over quality during different levels of urgency of an auditory take-over request?*

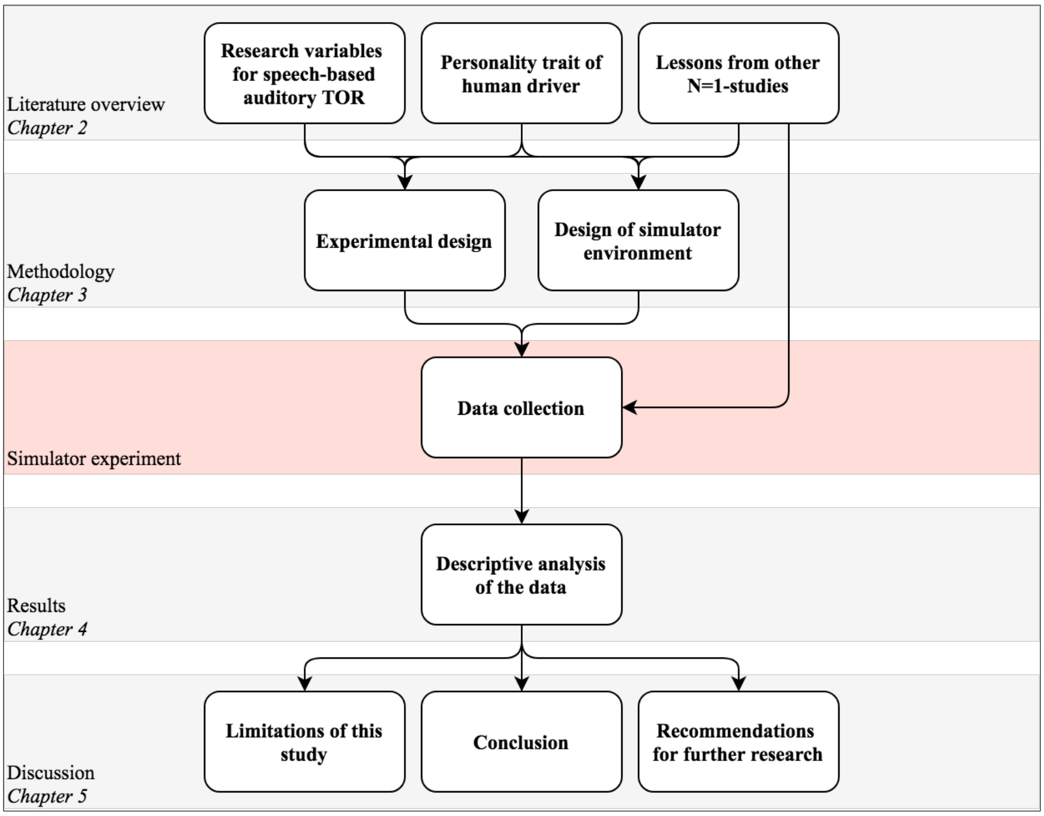
1.4 Thesis outline

With the use of an interpersonal counterbalanced experimental setup with 3*3*3*3=81 variations, the abovementioned research questions will be answered, and suggestions will be made to optimize the setup of a large-scale driving simulator experiment to investigate the effects personality has on the take-over quality from an auditory take-over request.

To demonstrate the process towards the conclusion and recommendations for the research questions, this thesis is constructed by several chapters to guide the reader through the process. In Figure 2, the thesis outline is shown, and the following paragraphs will explain per chapter how this thesis is constructed.

Figure 2

Thesis structure



1.4.1 Literature Overview

The first understanding of HMIs and personality traits from literature are discussed already in paragraph 1.1 and will be further discussed in the literature overview in chapter 2. This literature overview will start from the beginning by explaining AVs (2.1) and the known issues with the transition of control (2.1.2). Furthermore, it identifies all the problems in the literature about the design of the HMI (2.2), the use of speech-based auditory feedback (2.3), the influence of personality traits of the human driver (2.4), and which lessons can be learned from other N=1 studies (2.5). From the literature review, several assumptions will be derived which will be summarized and compared later to the results found in this research (2.6).

1.4.2 Methodology

In the methodology (chapter 3), the experiment will be explained in terms of methods used for this research by explaining what and how it is executed. First, the participants (3.1) and apparatus (3.2) are explained in detail, the environment in terms of important factors (3.3), the design of the environment (3.3.2) and how the take-over request is designed (3.4). Secondly, the experimental design is clarified with the chosen variables and secondary task (3.5), followed by the procedure (3.6), indicating the duration and location of the experiment, and as final the used methods of analysing the data (3.7).

1.4.3 Results

Chapter 4 presents the results from the data gathered from the driving simulator experiment. The data is first presented in tables (some of them supported by charts) and analysed in a descriptive way per variable. Statistical techniques in SPSS will be used for measuring the statistical significance of the variables. Further statistical investigation was not needed due to the fact the results were already informative and due to the fact, this is a N=1 experiment, further investigation with statistical tools makes no sense.

1.4.4 Discussion

A discussion is built upon the results from the driving experiment, first the limitations of this study are addressed (5.1), the key findings from the results (5.2), the conclusion (5.3), and recommendations (5.4) for further research are given.

This chapter will first answer sub question 1 to 4 and from these insights, answer the main research question of this thesis.

Chapter 2

Literature Overview

This chapter describes the literature related to AVs, human machine interfaces (HMI), type of feedback, modalities, and driver personality. The first paragraph defines what an AV is and how it can be categorized. Furthermore, it explains what can be expected from a transition from manual driving to automated driving in terms of take-over time and the influence of the driver's personality. The subsequent paragraphs cover the HMIs, speech-based auditory feedback, and the personality traits of human driver. A final paragraph will summarize the findings and will give some assumptions based on this literature.

2.1 Automated vehicles

Vehicles equipped with technologies that assist the human driver in the longitudinal and lateral driving tasks are more common now due to the fact that car manufacturers are introducing new vehicles on the market that have adaptive cruise control (ACC) and lane-keeping assistance (LKA). These systems will change the role of the driver from actively to passively controlling the actions of the automation. Fully AVs on the road would still take a considerable number of years, and due to this, vehicle automation is introduced in stages (Milakis et al., 2017). The commonly used staged autonomy levels are introduced by the Society of Automotive Engineers (SAE) (2018), whereby each level is designed for specific conditions in terms of geographical, environmental, road geometry, traffic, and speed dimensions, also called the Operational Design Domain (ODD). The ODD is for most of the levels differently and in combination with other dimensions such as Dynamic Driving Task (DDT), it allows to classify the automation levels. Conditional driving automation (level 3, see paragraph 2.1.1) is one of the most promising automation type to date whereby most of the vehicles today are automated till level 2 and thus level 3 is the next step. Furthermore, level 3 equipped vehicles have an important change in the DDT fallback type, whereas the driver becomes a fallback-ready user of the vehicle instead of the driver being the fallback at all times (SAE, 2018).

2.1.1 Levels of automation

The levels of automation, which includes completely manual to fully autonomous and driverless driving have been classified by the SAE (2018). Nowadays, these levels are known as the standard in defining the level of automation:

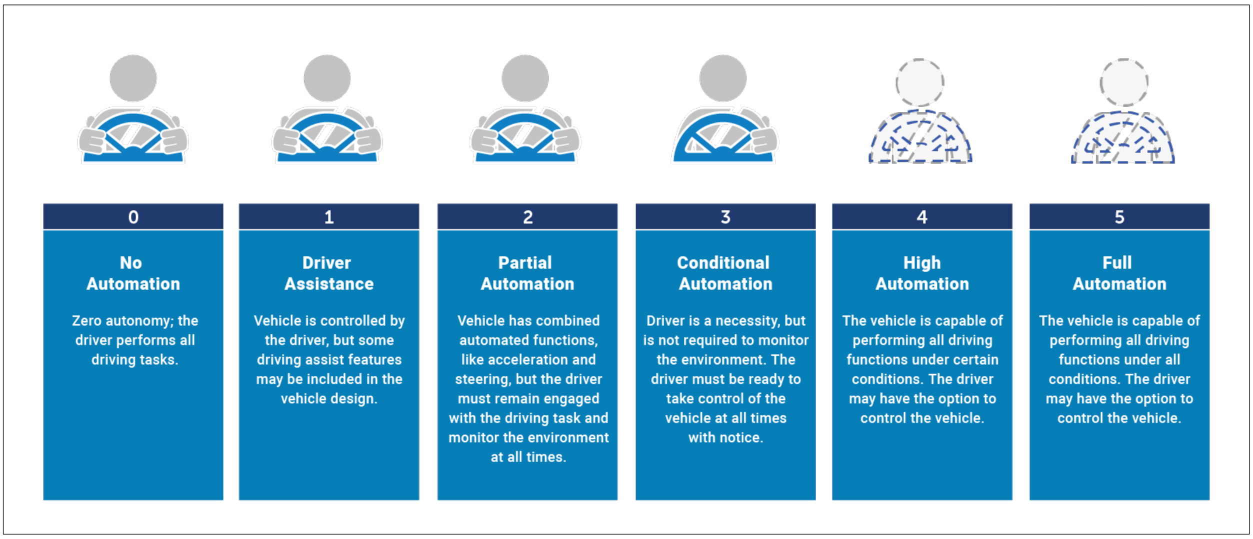
- *Level 0. No driving automation*: "The performance by the driver of the entire DDT, even when enhanced by active safety systems"
- *Level 1. Driver assistance*: "The sustained and ODD-specific execution by a driving automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT"
- *Level 2. Partial driving automation:* "The sustained and ODD-specific execution by a driving automation system of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the OEDR (Object, Event Detection, and Response) subtask and supervises the driving automation system"
- *Level 3. Conditional driving automation:* "The sustained and ODD-specific performance by an ADS (Automated Driving System) of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems, and will respond appropriately"
- *Level 4. High driving automation:* "The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene"

- *Level 5. Full driving automation:* "The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene"

In this research, the level of automation will be identified by the levels of SAE. Today, most vehicles on the Dutch road network have a level 2 or lower automation (Onderzoeksraad voor Veiligheid, 2019). In Figure 3, the taxonomy and definitions of automated driving by SAE are shown.

Figure 3

SAE levels automated driving (SAE International, 2018)



2.1.2 Transition of control

A well-researched problem in SAE level 3 vehicles is the fact that the driver is still responsible for the fallback operation if the vehicle is requesting to, also called the authority transition (see e.g., Banks & Stanton, 2015,2016; Eriksson & Stanton, 2017; Lu & de Winter, 2015). The driver is responsible for the take-over of the control from the automation system to drive the vehicle in a safe way further. If this transition of control is not clear or takes to long for the driver to take over the vehicle, it can cause accidents (Roche & Brandenburg, 2018). The transition of control is therefore an essential part of level 3 equipped vehicles and needs to be designed in such a way that the transition is clear for the driver and takes as little time as possible (Brandenburg & Chuang, 2019).

A mismatch in the communication between the vehicle and the driver can happen if the driver does not understand or is not aware of the TOR of the vehicle (e.g., Casner et al., 2016; Jamson et al., 2013). Moreover, an increase in reaction time becomes problematic when the driver is expected to regain control when systems limits are exceeded when automation fails (Eriksson & Stanton, 2017). To successfully re-enter the driving task, drivers need to receive appropriate feedback (e.g., Cranor, 2008; Eriksson & Stanton, 2016). If the TOR is explicit for the driver, this introduces trust towards the automation, and the driver is able to take-over the automation in an efficient and safe way (Elyasi-Pour, 2015).

2.1.3 Secondary tasks

In level 3 or higher vehicles, the driver will be distracted by, or is able to do secondary tasks (Merat et al., 2014). Such tasks could be reading a newspaper, making phone calls, answering an e-mail on a laptop or even playing smartphone games (Banks et al., 2018; Lin et al., 2018). This engagement in secondary tasks was found not to be detrimental in case the driving conditions were clear (e.g., in a quiet highway environment), but when the traffic density increases, the attention of the driver towards the driving situation also increase in manual driving (Jamson et al., 2013). Jamson et al. (2013) also stated that this behaviour is merely caused by the fact that driver is expecting that something can happen due to the increase of traffic (e.g. road accident) and that he/she is ready to intervene as fast as possible. In an AV, this behaviour is not as normal, due to the fact that the driver could be distracted by a secondary task and is not aware of a certain situation or change of situation. This type of distraction by a secondary task and even more important the time it takes to switch to the driving task is one of the main issues to overcome in an AV (Merat et al., 2014).

2.2 Human Machine Interfaces

Interaction with machines is commonly done with the use of an interface, whereby HMI can stand for Human Machine Interaction but is in general known as Human Machine Interface. This definition describes how humans interact with machines, whereby a machine can be any mechanical or electrical device that transmits or modifies energy to perform or assist in the performance of human tasks (Cannan & Hu, 2011). The main goal of an HMI is to reduce the risk of injuries, fatigue, error and discomfort while improving the productivity and the quality of the interaction. Systems who neglect ergonomics in HMI leading to more operating errors or accidents (Flaspöler et al., 2009).

2.2.1 Categorisation and learning curve

HMIs can be subdivided in five categories, namely acoustic (sound), optics (light), bionics, motion and tactile (touch) (Cannan & Hu, 2011) Acoustic based technology are technologies such as voice recognition like e.g. Apple Siri or Google Assistant, and in-car entertainment systems (Tashev et al., 2009). Optics are technologies such as cameras who recognize interaction by motions and gestures whereas bionics is a technology were biology, robotics and computer science are combined to perform a function (e.g., Exoskeleton). Motion are technologies such as gyroscopes or accelerometers and tactile is technology whereby the user needs to physically touch something, such as a keyboard, touchscreen or button (Cannan & Hu, 2011).

The use of HMIs is widely accepted and due to the use of smartphones with their multi-touch displays for example, the learning curve is high. Learning at a younger age how to use a device such as a computer, television or even driving a vehicle, pushed the learning time of other comparable devices down (Gellatly et al., 2010). With increasing age, learning new skills can be difficult (Craik & Jacoby, 1996), and older drivers need to have more time to change and getting used to new technologies. Most HMIs are designed to guide the user through the process of communication with the device (Young et al., 2017).

2.2.2 HMI interface in AVs

An HMI is used in a vehicle to allow human drivers to interact with the vehicle (Carsten & Martens, 2019). Moreover, the task of the HMI is to process and present information optimally towards the human driver (Jamson et al., 2013). The system is designed to support the driver and should do this in a way which is not hazardous for him/her and the environment of the vehicle (Jiménez, 2016). HMIs are already widely used in vehicles in which the main areas for the HMI placement are the instrument cluster, central console, steering wheel. Supplementary devices such as auditory feedback by means of beeps or speech-based sentences or visualization devices such as head-up displays (HUD) are becoming more common in vehicles (Politis et al., 2015a).

Visualization feedback such as a head-up displays (HUD) and auditory feedback such as bleeps or speech-based sentences are interesting types of HMIs, whereby both systems do not require the driver to move his/her eyes from the road situation (Politis et al., 2015a). Auditory feedback provides even information without visual distraction. Furthermore, the reaction time is shorter than for the visual feedback type (Salvendy, 2012). However, auditory feedback needs to respect also some criteria, which are a clear and understandable voice or other sound, and a short information level (Large & Burnett, 2013). Furthermore, the volume of the sound, and the distinguishability of the feedback from other sources are also important to assess. Regarding the volume, this needs to have a proper level of urgency without creating irritation, while the feedback distinguishability can be affected by other informing sounds, as well as the environmental sounds from and around the vehicle (e.g., Bazilinskyy & de Winter, 2015, 2017).

As mentioned above, auditory feedback has several affecting factors. Likewise, HMIs in general have affecting factors that influence the effectivity thereof. Apart from the factors mentioned in relation to auditory feedback, several other affecting factors are known. The following section will discuss those.

2.2.3 Factors affecting the performance of HMIs in relation to AVs

The performance in terms of understanding and reaction time depends heavily on the communication between the HMI and the driver. To get a better understanding in the design of the HMI, factors influencing the performance would help to reduce the misunderstanding and reaction time between the driver and the HMI. As stated by Calvert et al. (2020), driver core components of control in ADS are driver, vehicle, infrastructure, and environment.

Driver

The driver is still one of most important factors in an AV till automation level 3 (SAE, 2018). The driver remains the fallback option in level 3 and needs to take over control of the automation when automation fails or request a take-over. The characteristics of the driver could influence this take-over time, due to their level of distraction or speed of interpretation of the situation (Miller & Taubman-Ben-Ari 2010). The difference in characteristics can be identified by the personality trait of the driver such as the BFI model by John et al. (1991) and used to differentiate the drivers. Moreover, the personality trait of the driver could be influencing the understandings between the HMI and the driver, and the effectiveness of a certain HMI in terms of trust and time could be influenced (e.g., Borojeni et al., 2016; Braun et al., 2019, Casner et al., 2016; Roche et al., 2018). Overall, the effectiveness of HMIs in AVs can be seen as in which time span the human driver is able to retrieve control of the vehicle and to avoid any obstacles (cf. Brandenburg & Chuang, 2019; Casner et al., 2016).

Vehicle

The AV can affect the performance of the HMI in terms of other sources of distraction such as flickering displays or tire/wind rustle or even multiple HMI sources such as a navigation system with spoken instructions, as these instructions or tones could be resembling feedback tones which can be confusing for the driver. Moreover, vehicle noise coming from wind, engine, or tires could influence the audibility of feedback which could be prevented by speed-based volume adjustments (Bazilinskyy & de Winter, 2017). In this way, the feedback can be clearly distinguishable from other sound sources (Bazilinskyy & de Winter, 2015).

Infrastructure

The road infrastructure components are part of the increasing digitalisation of society, whereby two components can be distinguished (Farah et al., 2018). The digital infrastructure that refers to hard- and software information systems, and the physical infrastructure which is the traditional infrastructure (e.g. Calvert et al., 2020, SAE, 2018). Physical infrastructure such as number of lanes, lane width, intersections, barriers and signs (e.g. road, lane or traffic signs) can influence the way HMIs are interpret and how the driver react on it (Naujoks et al., 2014). Digital infrastructure is data mapping, sensing such as cameras, GPS and induction loop, services like in-car signage, traffic information and navigations and communication channels like WIFI-P (Sanchez et al., 2016). These digital services are expected to be further developed and will become a crucial component in AVs to ensure safety and proper operation of the vehicle (Calvert et al., 2020).

Environment

The environment in terms of the situation in which the vehicle is driving is important. Urban areas, characterized by its high complexity due to different type of road users, a variety of static and dynamic objects, and the high density of information (Götze et al., 2015) is found to have a lower reaction time than when driving on a highway environment (Dixit et al., 2016). The complexity and high information density of urban area and are known for distracting the driver (Horberry et al., 2006; Kountouriotis & Merat, 2016). Due to drivers limited cognitive information processing, being aware of the traffic situation and to anticipate on it demands a lot from the driver (Lev et al., 2007; Banks et al., 2017). Systems who intervene should thus be designed in a way to minimize the conflict between the complexity of the traffic situation and the drivers limited cognitive information processing (Drüke, 2018).

2.3 HMI: Auditory feedback

Auditory feedback is common in industries like aviation, medicine machines (e.g., AED), voice assistants (e.g., Google Assistant, Amazon Alexa, Apple Siri) and cars. In our daily life, voice assistants become a tool for interaction (Porcheron et al., 2018), and a similar trend is visible in the automotive industry with the user interfaces (UI) used for in-car instructions (Riener et al., 2017). They are not only used for improving the performance and safety due to less distraction during manual driving (Hellier et al., 2002), but auditory, and definitely speech-based interfaces, offer a more natural way of user experience compared to the existing conventional user interfaces in cars (Braun et al., 2019). Moreover, due to this positive side of using auditory speech-based systems in automotive UIs, it can be a promising feedback type for future technologies in vehicles and AVs (Alvarez et al., 2011).

Auditory feedback in AVs can be varied in terms of speech-rate, semantics, and syntax, which makes it distinguishable in terms of meaning (Hellier et al., 2002). Variation in feedback is part of creating a suitable instruction for a situation in order to accomplish a certain request (Carsten & Martens, 2018). Situations on the road can change within seconds, whereby a certain urgency is required in taking over the vehicle. These situations can be differentiated in terms of perceived urgency, which can be determined by the variables such as earlier mentioned, speech-rate, semantics and syntax. Speech-rate influences the perceived importance for a TOR, a higher rate creating a more important request (Bazilinkskyy & de Winter, 2017). Semantics is the relation between signifiers, like words, phrases, signs and symbols, and what they stand for in reality. As Hellier et al., 2002 stated; semantics are important in urgency perception by the concept of arousal strength. Part of arousal strength can be the syntax of the sentence in terms of signal words that give higher importance than others such as the word 'danger' instead as 'note' (Edwordthy et al., 2003).

2.3.1 Speech-based auditory feedback

A study by Bazilinskyy and De Winter (2015) investigated the opinion of people towards auditory interfaces in existing vehicles and their willingness to be informed by this auditory feedback in AVs. The results of the internet-based survey are promising towards the use of auditory feedback, where the speech-based female voice was the most preferred feedback type in AVs. In addition, the use of speech-based cues was found to improve the recognition of the urgency level and the perceived effectiveness of the TOR (Politis et al., 2014). By comparing language-based messages to abstract ones, the performance and driving metrics (lateral deviation and steering angle) of the take-over improve when using speech-based instructions (Politis et al., 2015b). Sterkenburg et al., (2016) found that the driving performance and eye glance behaviour improved with the use of auditory feedback, and that it was positively affecting the perceived workload. In terms of driver distraction by in-vehicle visual interfaces, speech-based auditory feedback reduces the distraction of the human driver and raises the driver situation awareness (Larsson, 2016). From these researches, it can be concluded that speech-based auditory feedback is a promising method for the interaction between vehicle and human driver.

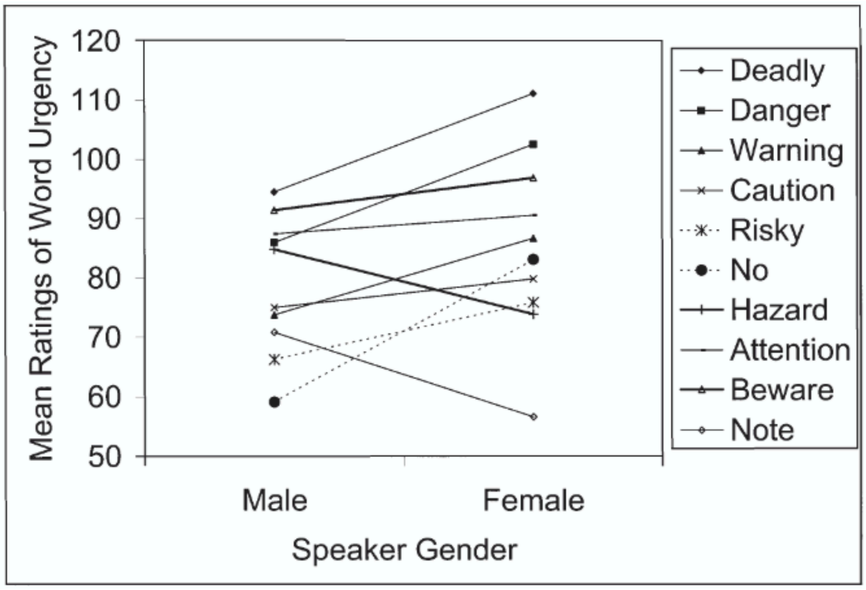
2.3.2 Urgency in speech-based auditory feedback

TORs may convey different types of urgencies depending on the design. Several driving simulator studies indicated that a higher perceived urgency leads to faster reactions, lower accuracy and higher lateral deviation (e.g., Baldwin, 2011; Baldwin & Moore, 2002; Politis et al., 2013, 2015a). Variables within the TOR design influences the perceived urgency, such as the speaking style of a speech message (Hellier et al., 2002) or used words (Bazilinskyy & de Winter, 2017; Politis et al., 2014). Furthermore, higher speech rates are perceived as more commanding and urgent than lower speech rates (Bazilinskyy & de Winter, 2017; Edworthy et al., 2003).

Hellier et al. (2002) found that urgency perception of a sentence can be varied by signal words. By using different signal words to alert the driver, it influences the way the driver perceives the urgency. Signal words such as "Danger" are more urgent than "Warning", but both are also perceived more urgent than "Notice" (Politis et al., 2014; Politis et al., 2015b). Signal words create higher urgency ratings compared to a monotone style and from Hellier et al. (2002), signal words "Deadly", "Danger", and "Beware" can be seen as most urgent from a female gender speaker, whereas "Note", "Risky" and "Hazard" can be seen as less urgent (Figure 4). Taking into account that words such as "Danger" leads to higher lateral deviations (Politis et al., 2015a), lane width can be used to indicate this lateral deviation.

Figure 4

Urgency of signal word per gender (from Hellier et al., 2002)



2.3.3 Lane width

Farah et al., 2018 mentions that narrowing the lanes with the introduction of AVs would open up new possibilities. Furthermore, it would lead to an increase in the capacity of existing roads. This is the case when the AVs have level 4 or higher (SAE, 2018), where the human driver is out of the loop and the AV drives without intervention needed. As in level 3 vehicles the driver is still needed to take-over in difficult situations, the lateral position of the vehicle on the lane is important to address and whether this differentiate between different urgency levels (Farah et al., 2018). When the lane width increases, drivers tend to stay more in the middle of the lane (Liu et al., 2016) but also when the visibility is poor or trees are close to the side of the lane (Calvi, 2015; Mollu et al., 2018). Difference between lateral deviation and the personality of the human driver has been researched by Linkov et al. (2018), who found that drivers with extraversion drive more on the right side of the road, whereas other personalities drive more to the centre of the road. The personality of the driver influences the driving performance and is interesting to include when researching driving metrics (Ge et al., 2014; Taubman-Ben Ari & Yehiel, 2012).

2.4 Personality trait of the human driver

The influence of the personality trait of a human driver on their driving performance in AVs in general has not yet been researched extensively. This sub-chapter gives an overview of a commonly used model and how this model classified humans. Moreover, how this personality trait model can be connected to the human driver and their driving style will be researched and explained.

2.4.1 Personality trait by Goldberg

It is commonly accepted that human beings do differ between each other in terms of personality. For several years, researchers are trying to identify and to classify personalities. One of the most successful, best accepted, and most commonly used models to identify personality traits of humans in academic psychology is developed by Goldberg (1992). Goldberg (1992) found that the personality traits can be structured into five factors. This result was a robust, comprehensive, and meaningful taxonomy for describing the personality traits that illustrates variance across human behaviour (Wallace & Vodanovich, 2003). These factors are labelled as follows; Openness to experience, Conscientiousness, Extraversion, Agreeableness and Neuroticism. These five personality traits factors are called the Big Five personality traits, the Five-Factor Model (FFM) or the OCEAN model (Costa & McCrae, 1992). The definition of these personality traits is given as follows:

- *Openness to experience* are humans who are curious, open to emotion and sensitive to beauty as well trying out new things. Moreover, they are more aware of their feelings and creative compared to other humans. Lack of focus and more likely to engage in risky behaviour are also characteristics of this trait.
- *Conscientiousness* humans are more careful and diligent. They take their work or task seriously and want to perform well, are dependable and are structured and planned. Deliberation is also one of their main characteristics, which is the tendency to think carefully before acting (Thompson, 2008).
- *Extraversion* is a characteristic which encounters enthusiasm, assertive, gregarious and talkative. Human who are extravert do like social gatherings and do work well in groups. However, spending time alone is not what they like to do.
- *Agreeableness* humans are perceived as considerate, cooperative, sympathetic and kind. They tend to be altruistic and empathetic and is sometimes called the superior trait.
- *Neuroticism,* which is a characteristic whereby the human has feelings like anger, fear, worry, guilt jealousy, anxiety and is more often than average moody. Moreover, they see small frustrations as difficult and ordinary situations as threatening (Thompson, 2008).

John et al. (1991) invented the Big Five Inventory model, which is a tool to indicate the personality trait of a person by the same taxonomy as Goldberg.

Evidence is found that some of the factors are significant predictors of accident risk and attitude to traffic safety (e.g., Chen, 2009; Ehsani et al., 2015; Machin & Sankey, 2008). This connection between personality and driving characteristics can be interesting in terms of behaviour and attitude towards TORs.

2.4.2 Personality connected to driving characteristics

Several studies into personality connected to the drivers' driving style found that a certain driving style is associated to a set of sociodemographic, personality and motivational factors (e.g., Taubman-Ben-Ari et al., 2002; Poó & Ledesma, 2013; Miller & Taubman-Ben-Ari, 2010). Furthermore, men and even mostly younger drivers, within the extraversion group, do have more angry and reckless driving styles (Machin & Sankey, 2007). Even higher educated drivers, who tend to be more annoyed and controlled, have an angry driving style (Taubman-Ben-Ari & Yehiel, 2012). Anxious driving styles are more endorsed by woman and drivers who are in a lower range of conscientiousness and in the higher range of neuroticism (Jovanovic et al., 2011). As personality has been researched by Goldberg (1992) and explained in the previous paragraph, driving characteristics can be connected to this taxonomy.

Openness to experience

In the Big Five literature about accidents, this personality trait has received the least amount of result out of all. As this factor consists of sensitive, broad-minded, and tolerant individuals (high in openness), it increases the likelihood that these drivers are more willing to make realistic and situationally based views (e.g., " The driver in front of me does not know the maximum speed") as opposed to angry views (e.g., "The slow driver in front of me is a bad driver") (Dahlen et al., 2012). This personality trait implies that even their own errors are not their fault and out of their control, and are likely to point to others, which leads to fewer hostile reactions and peaceful driving characteristics (Dahlen & White, 2006).

Conscientiousness

Planned, responsible and carefulness are some traits from this personality, and is positively related to workplace safety (Wallace & Vodanovich, 2003). This personality trait is related to self-reported vehicle crashes and non-aggressive driving characteristics. Furthermore, they are responsive to rules, and comply with driving laws (Arthur & Graziano, 1996). Booth-Kewley and Vickers (1994) conclude that conscientiousness drivers are negatively related to high-risk driving, and significantly related to accident control. This personality is also positively related to the careful driving style, especially endorsed more by women. Younger conscientiousness drivers have a higher level of pleasure when driving compared to others, and are lower thrill seeking or worrying about damaging their vehicle while driving (Taubman-Ben-Ari & Yehiel, 2012).

Extraversion
This trait is positively associated with traffic fatalities as found by Lajunen (2001), road departure errors (Verwey & Zaidel, 2000) and violations in traffic (Lev et al., 2008). It is related to aggressive driving due to their impulsive and active behaviour and because aggressive driving behaviours appear to be impulsive, it is expected from extravert drivers to have a high level of aggressiveness in their driving habitat (Dahlen et al., 2012). Speeding is found to be connected with extraversion, which is correlated with excitement seeking, normlessness and anger (e.g., Machin & Sankey, 2008; Tao et al., 2017). This personality can be best described as reckless driving (Renner & Ander, 2000).

Agreeableness
This trait is associated with forgiving, tolerant and maintaining positive relations. It is therefore not related to an aggressive driving style due to the fact they do not seek provocation, but rather cooperation and block negative emotions (Cellar et al., 2000). Loss of vehicle control is also negatively related with this trait due to the fact there are known as considerate (Dahlen & White, 2006). Due to the fact they inclined to trust others, are likely to forgive, tolerant and gentle, they have a low level of aggressiveness when driving (Benfield et al., 2006). The agreeableness drivers have a careful driving style, and those drivers with a higher level of education are more anxious when comparing them to the lower level of education drivers (Taubman-Ben-Ari & Yehiel, 2012).

Neuroticism
The relationship between this trait and their driving metrics is that they perceive more stress, and due to this less emotionally stable, easily angered and insecure feeling, they have a larger risk of acting aggressively behind the steering wheel (Barsky et al., 2004). Impatient, anxious, and irritated are reasons that they have a higher risk of being involved in an accident with their risky and aggressive driving style (Bone & Mowen, 2006; Dahlen & White, 2006). Furthermore, the number of car accidents, mortality and the dislike of driving confirms this higher risk of an accident (Kirkcaldy & Furnham, 2000). Driver's anger found to be the main factor of the aggressive driving behaviour of neurotic drivers (Jovanovic et al., 2011).

2.5 N=1 studies

During this research into the field of TORs, varying in urgency, and the relation with personality, COVID-19 became a global problem whereby the original setup of this research with N=100 was not feasible. Due to time reasons and the uncertainty of the end of this global problem, this research is changed to a N=1 study. This chapter is added to this literature review in order to know what N=1 studies are, which problems can occur and how to get unbiased results.

Several N=1, n-of-1, or Proof of Concept (PoC) studies have been conducted whereby several lessons are learned and can be taken into account for this research beforehand. While this N=1 study is unique in its research gap, some general lessons can be taken into account from other N=1 studies. For example, Endsley (2017) conducted a naturalistic study with a Tesla Model S in order to derive new insights into semi-autonomous driving systems and set considerations and guidelines as well as recommendations for improving driver situation awareness in autonomous vehicles. One of the findings is that the driver is being adapted to the automation and knows what it could or could not do whereby the workload was decreasing over time (learning effect). Furthermore, over-time a significant increase in non-driving behaviour is expected when automation is in control.

N=1 experiments are sometimes told to be useless or have low statistical power, but as found by Hanley et al. (2019), N=1 experiments can be highly informative. While scientists can falsify the results of their own self-experiments, they have little incentive to do so, and these motives tend to further down the line after commitment of resources. Still self-assessment errors and bias can occur but can be taken away by having designed the experiment by a double-blind, placebo controlled, or randomized controlled trial (Hanley et al., 2019; Huber et al., 2011). Self-experiments are quite common to test studies, but is often conducted secretly, as it is not always ethically responsible in some domains such as medical experiments (Hanley et al., 2019). Moving ahead in research is the most important, and that outweighs the research value (Weisse, 2012). The value of a research is impossible to know, until some decades later (Dresser, 2014; Sacks, 2012), but with the support of highly respected scientists, N=1 experiments can be seen as valuable and important (Hanley et al., 2019).

Nevertheless, bias in an N=1 experiment is difficult to obviate and thus important to address while performing a self-experiment. As stated by Huber et al. (2011), randomizing the tests is important for lowering bias, which can be done by throwing a die or using software such as Microsoft Excel or Ngene (ChoiceMetrics, 2018).

2.6 Conclusions from the literature overview

TORs are widely researched in all kind of ways, but not with auditory speech-based feedback in relation to the personality trait of the human driver. Furthermore, the performance, in terms of take-over time, of a driver receiving speech-based feedback, and the effect personality has on a driver's performance, has not been researched yet, despite the fact that SAE level 3 AVs will be introduced on the open roads in the coming years (Taylor, 2017). Therefore, the following conclusions can be made from literature and will be taken into account for this research. These assumptions will be used to classify some researchable factors or for information regarding the experiment.

- In conditional driving automation (SAE level 3) it is still required that the human driver is always ready to intervene if the AV is requesting for it (SAE, 2018). The driver is still responsible for the whole performance of the AV and thus a minimum time budget for taking over and successfully intervening is required.
- Human drivers need to have a full understanding of the TOR in order to fulfil the take-over in a safe and successive way, but also for getting trust towards the use of the AV (Lin et al., 2018). Cooperation between the automation and the manual task by the human driver is essential for getting trust (Elyasi-Pour, 2016).
- A TOR needs to be designed in such a way that it brings a clear message, is loud enough, and differentiates itself from other noise or warning signals (Hellier et al., 2002). Auditory speech-based TORs are the most promising methods to combine all these requirements (cf., Bazilinskyy & de Winter, 2017; Brandenburg & Chuang, 2019; Roche & Brandenburg, 2018). The information it needs to communicate needs to be short and the right information or instruction at the right time (e.g., Bazilinskyy & de Winter, 2015; Politis et al., 2014, 2015a, 2015b).
- Importance of the TOR can be introduced by levels of urgency. By varying for example, the speech-rate, volume level or tone of the speech, a certain level of urgency can be created (Hellier et al., 2002; Politis et al., 2014).
- Urgency can create different levels of lateral deviation, meaning take-over time and safety can be conflicting (Politis et al., 2015a).
- The personality trait model by John et al. (1991), which is known as the Big Five Inventory model, is commonly used in research, and together with the included questionnaire of this model, participants for an experiment can easily be selected by their personality.

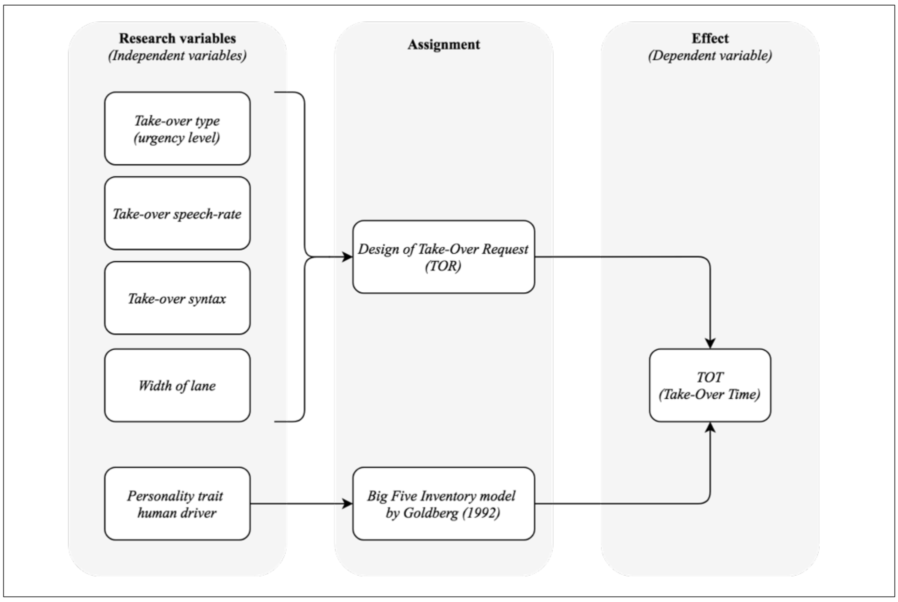
Important independent variables to take into account for measuring the dependent variable take-over time (TOT):

1. Type of take-over
2. Speech-rate
3. Syntax (signal words)
4. Lane width (measuring lateral deviation (LD))

These variables and their influence are presented in Figure 5.

Figure 5

Conceptual framework of this research



Chapter 3

Methodology

This chapter gives a complete overview of the methodology used for this research. First, the participants of this study will be explained, then the apparatus used for this experiment, the environment in which participants will be tested, and the design of the take-over request, and, as a final part, the procedure of the test.

3.1 Participants

Comprising a N=1 study, only one participant took part in the experiment, namely the lead researcher of this research. The male participant is 29 years old and has ten years of driving experience. His average mileage of driving is 1400 kilometres per year. After having completed the Big Five Inventory test by John et al. (1991), he is not classified with one 'pure' personality, but scores high on Extraversion and Agreeableness. If the personality score is used with the written software, which use an algorithm to select participants on their personality and classify them into one personality group which fits their BFI score at best, his classification is Agreeableness.

The increasing awareness and concern for the ethical impact of human research led to a formation of a commission for maintaining ethical protections for participants in a research study. On the TU Delft, the Human Research Ethics Committee (HREC) examines the research which involves humans. For this research, which involves participants, this examination by the HREC is mandatory.
The experiment was approved under the ethics application number: 1051. The Data Management Plan (DMP) and the approvement by the HREC can be found in Appendix B.

3.2 Apparatus

Several apparati are needed in the driving simulator for deriving information, such as body movements (eye, hands, foot), and for simulating a certain behaviour (working on laptop/tablet) to be distracted from the driving task. Figure 6 gives an overview of the set-up of the simulator, including the placement of equipment.

Figure 6

Layout of the driving simulator

3.2.1 Driving simulator

The research will be held in a driving simulator to simulate a driving environment which looks almost as identical as a real-life environment. The simulator of the faculty of Civil Engineering and Geosciences (CiTG) in Delft, the Netherlands, will be used for this research. The simulator is a fixed-based driving simulator (Figure 6) and uses the software package Unity 5.5.2 for the software driving environment. The simulator itself is equipped with an adjustable (and able to vibrate) car seat with seatbelt, three Full-HD LCD screens presenting the highway scenario in an almost 180-degree field of view (FOV) assisted by a Fanatec haptic steering wheel with a three-pedal (clutch, brake and accelerator) setup and gear lever in front of the human driver.

3.2.2 Camera

Three cameras in total will be used in order to derive the results out of the simulator test. One camera is targeting the driving pedals, to indicate when the foot of the driver presses the accelerator/brake. A second camera is set towards the steering wheel to indicate if the driver has his hands on the wheel. The third camera is used set right above in the middle of the centre screen of the simulator focused on the head/eyes of the driver. This camera image will be used for eye-tracking to indicate whether the driver is looking towards the driving environment or towards the secondary task (tablet).

The camera equipment consists of two Logitech HD Pro C920 (1920*1080 resolution), aimed at the driver' head and the steering wheel, and one Microsoft LifeCam HD-3000 (1280*720 resolution) targeting the driving pedals.

For recording the screen (what the driver sees in the environment and how the vehicle behaves) a screen recording program is used during the driving simulator test, namely Microsoft Xbox Game Bar (Standard included in Microsoft Windows 10). This program allows to record the centre screen in full HD resolution.

3.2.3 Sound

The speakers, which simulate the driving environment even further with the vehicle engine noise, traffic noise and audible take-over request, are set on a volume of 75 dB(A) (on the Windows 10 environment in the simulator set to volume 80), set-up in stereo.

The speakers used for this research are Trust Soundwave 240 dual loudspeakers.

3.2.4 Tablet

A tablet was used in order to distract the driver from the driving task by getting his/her full attention. The simulator is not designed to equip a tablet; therefore, a tablet stand is made specifically for this simulator on the right side of the driving position.

The tablet used for this research is an Apple iPad 10.2 inch (5th generation) with iOS 13.4.5 installed. On this tablet, the popular game of Tetris is played during the test. The scores were written down for every test in order to combine it with the results of the TOR.

3.3 Environment

The driving scenario is based on a typical Dutch highway environment whereby several important factors stated in paragraph 3.3.1 are included in the design.

3.3.1 Important factors

Several factors were taken into account to make the driving environment like a real scenario based on a highway environment in the Netherlands. These factors were extracted from literature (e.g., Swart, 2006) and from the design of the highway A12, and are the following:

Important factors from research

- Varying lane marking types
- Several on- and off-ramps along the route
- Sufficient curves

- Different types of landscapes along the route
- Available emergency lane
- Presence of guardrails
- Streetlights and road signs
- Length of route and cycle time of TORs

General factors chosen by researcher
- 500 m straight lane on the route (for executing the TOR)
- Two lane highway for the whole route
- Typical Dutch highway environment (trees, grassland, horizon view)

All the factors are applied in the final design of the simulator environment as explained in the following chapter.

3.3.2 Design

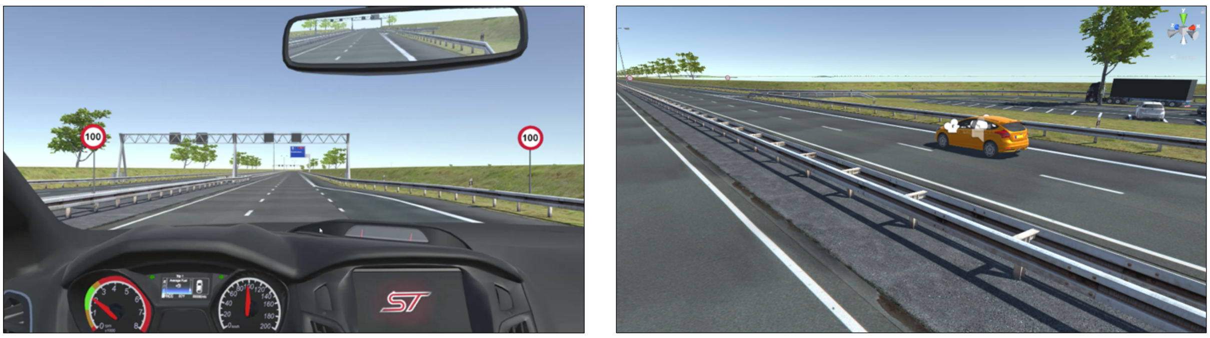
A maximum speed of 100 km/h is chosen due to the fact the new Dutch regulations, valid from March 2020, is a maximum speed on highways of 100 km/h to decrease the amount of nitrogen emissions (Schouten et al., 2019). The speed represents not only a real-life scenario, but also with a speed of 100 km/h, in comparison with 120/130 km/h, the driving simulator is running more fluently (the driving simulator computer was able to keep up with the graphics). The design of the road network is not only one straight road, but with several bland corners (max 15 degrees) and curvature in a straight road to counteract fatigue. For a realistic view, the road (asphalt, lineation, colour), signage, guardrail and street lights are designed by using the Dutch road construction manual of the Ministry of Infrastructure and Waterways (Swart, 2006) together with the Dutch highway package within the Unity driving simulator software.

The horizon view behind the guardrails where designed on the basis of a Dutch highway, who is passing not only dense city areas, but also nature like forests and grasslands. In order to make it as realistic as much, buildings, trees, overpasses and even several exits to gas stations, parking lots and adjacent cities are implemented. Figure 7 shows a preview of the scenario with on both sides' forests and grasslands, matrix and street signs, together with the environment.

The lane width varied between 2.5 meters, 3.0 meters, and 3.5 meters depending on the research condition, varied as part of the validation study of this experiment. Each run lasted approximately 10 minutes, with 1 minute of manual driving and approximately 9 minutes of automated driving.

Figure 7

Driving scenario and environment of the simulator



3.4 Take-over request

The auditory feedback TOR is designed on the basis of the literature of Bazilinskyy & de Winter (2015) and will therefore use a woman's voice to pronounce the take-over as explained in Chapter 1 and 2. Moreover, there will be seven different kind of TORs, namely three different request varying in urgency for TORs from automation to manual and four normal request when automation is taking over the driver.

3.4.1 Definition & function of take-over requests

Before further researching the aim and performance of TORs, it is important to define a TOR. TORs can be separated in this research in two meanings, namely the TOR itself and the performance of the TOR.

Several definitions of take-over or TORs are found in dictionaries:

- *To assume control or possession and becoming dominant* (Merriam Webster Dictionary, 2020)
- *Try to get control of something* (Cambridge Dictionary, 2020)

Definition of performance:

- *How well a person, machine, etc., does a piece of work or an activity* (Cambridge Dictionary, 2020)
- *The execution of an action or something accomplished* (Merriam Webster Dictionary, 2020)

In this research, the definition of a TOR is defined in terms of the definitions from the dictionaries and a broader definition which allows to refer to it in a broader way:

- ***Take-over request performance*:** Taking over control of a vehicle in a minimum amount of time while taking into account efficiency and safety.

Efficiency is how well the TOR is executed in terms variables varied in this research, such as the given urgency level, combined with the syntax, speech-rate and lane width. This definition indicates that a TOR can have a wide implementation with several elements which are researchable and can therefore be optimized. The first element is the TOR itself, which can be separated into several categorizations as explained in Chapter 3.4.2 and the performance element, which can be measured in terms of time, efficiency and amount of errors.

As already explained in the Chapter 1 and 2, the TOR in this research will only interact with the human driver by a speech-based auditory feedback with the aid of a female voice. No other form of interaction will be used (e.g. displays, warning beeps or vibration). A TOR can be given bidirectionally, namely automation-initiated driver control (AIDC), automation-initiated automation control (AIAC), driver-initiated automation control (DIAC) or driver-initiated driver control (DIDC) (Lu & de Winter, 2015). In this research, a TOR will always be initiated by the AV and not by the driver, so AIDC or AIAC is used.

3.4.2 Categorisation of TORs

Many types of TORs exist, but only the most promising are included in this research. A clear categorization of TOR types with different types of variables is needed in order to fulfil this research. Therefore, the following three definitions apply in this research:

Non-urgent take-over request (NTR): *A clear voice, speaking with a standard speech-rate, while not chasing the human driver.*
The standard speech-rate and not chasing the hearer is what differentiates this TOR from the other two. It is more or less the same as a standard dual conversation where one says a kind of sentence towards the other one.

Semi-urgent take-over request (STR): *A clear voice but speaking with a higher speech-rate in order to get a direct reaction of the human driver.*
The higher speech-rate enables the importance of a certain request and feels more like e.g. a sentence which will be used for noticing someone on the street when his/her wallet falls on the ground.

Urgent take-over request (UTR): *A clear but fast speaking voice for getting direct attention of the human driver in order to intervene as fast as possible.*

The high speech-rate and the hastiness makes this feel like a very important message and is mostly used e.g. to warn someone like he/she wants to pass a street and a car is approaching.

These three definitions of the TOR categorise them and makes them a researchable object in terms of function.

3.5 Experimental design

As mentioned earlier, the lead researcher took part in his own experiment. Instead of using a certain number of participants, the researcher subjected himself to all combinations of TORs to be validated in this study. Four type of variables were varied in three different ways.

3.5.1 Chosen variables

The main focus of this research is the dependent variable, namely the TOR, varying in three levels of urgency (NTR, STR, UTR). Four variables are chosen from literature to optimize with this research. These were chosen due to the fact these found to be the most important and fitted this research and test procedure perfectly. The variables are take-over type, take-over syntax, take-over speech-rate and the width of the lane. An overview of all the variables are presented in Table 3, with the chosen variables being marked.

Table 3

Overview of the variables that are taken into account

Take-over performance variables
Take-over type
Take-over time
Take-over speech-rate
Take-over semantics
Take-over syntax
Take-over information
Environment
Weather
Traffic intensity
Traffic speed
Traffic user characteristics
Total number of lanes
Lane width
Crossing traffic
Vehicle characteristics
Obstacles on lane
Passengers
Electronic devices

More variables could be varied but in the amount of time available, a selection is made with the above-mentioned variables. A summary of the chosen variables and their levels are shown in Table 4 and explained in the next subchapters.

Table 4

Overview of the variables and their levels

Variable	Levels
Take-over type	*[0] NTR* *[1] STR* *[2] UTR*
Take-over speech-rate	*[0] -10* *[1] 0* *[2] +10*
Take-over syntax	*[0] TXT 1* *[1] TXT 2* *[2] TXT 3*
Lane width	*[0] 2.5 metres* *[1] 3.0 metres* *[2] 3.5 metres*

Take-over type

As mentioned earlier, the TOR is varied in three types or urgency, namely a non-urgent take-over request (NTR), semi-urgent take-over request (STR), and urgent take-over request (UTR). These take-over types will be randomized during the real driving experiment, which can be varied in 3! different orders. Each take-over type has as standard already given a certain speech-rate, fitted to the type of urgency. For the NTR, the speech rate is set to normal (+0). Similarly, for the STR the speech rate is set to +25 and the UTR speech rate is set to +50.

Due to the design of this test experiment, where only one take-over request will be tested in each scenario, the take-over type will be counterbalanced together with the other variables to counteract order effects.

Take-over speech-rate

The speech rate is important in a TOR when urgency is involved. For this research, the online tool Acapela-box (https://acapela-box.com) is used to reproduce natural speech-based phrases. Furthermore, this tool is used in some research into speech-based messages in automated vehicles such as Bazilinskyy, & de Winter (2017). The tool has a built-in feature to adjust the speech-rate, which in this case is useful to vary and to optimize. In the experiment, the speech-rate will be varied with -10, 0 or +10 below/above the standard given speech-rate in order to validate the variable. Table 5 presents an overview the take-over speech-rates.

Table 5

Take-over speech-rate variation

Type of urgency	Standard speech-rate	Variation	Speech-rate to test
NTR	*0*	*-10*	*-10*
		0	*0*
		+10	*+10*
STR	*+25*	*-10*	*+15*
		0	*+25*
		+10	*+35*
UTR	*+50*	*-10*	*+40*
		0	*+50*
		+10	*+60*

Take-over syntax

The phrase pronounced by the TOR is important in terms of wording such as the length of the sentence or the use of signal words. Several signal words are available for indicating a certain urgency which in this case will be varied to choose the most suitable belonging to the situation. The mean ratings of the urgency of signal words are researched by Hellier et al. (2002) in a research of speech warnings (as

stated in chapter 2). The outcome of this research is used to design these signal words and are used in this research for finding the optimal sentence for each TOR.
Table **6** presents an overview of the variation in syntax for each urgency type.

Table 6

Take-over syntax variation

Type of urgency	Standard speech-rate
NTR	*TXT 1. Note, take-over at your earliest convenience*
	TXT 2. Risky, take-over at your earliest convenience
	TXT 3. Hazard, take-over at your earliest convenience
STR	*TXT 1. Warning, take-over as soon as possible*
	TXT 2. Attention, take-over as soon as possible
	TXT 3. Caution, take-over as soon as possible
UTR	*TXT 1. Danger, take-over immediately*
	TXT 2. Deadly, take-over immediately
	TXT 3. Beware, take-over immediately

Lane width
The width of the lane is an interesting variable due to the aim of this study, namely the research of the take-over performance. In this take-over performance, lateral deviation (LD) depends on the lane width which can be adjusted in the scenario. In Europe, the lane width varies between 2.5 and 3.5 meters (Ministry I&W, 2007).

In the experiment, the lane width will be varied between 2.5 meters, 3.0 meters, and 3.5 meters wide in order to optimize the lane width concerning the LD of the driver. In the Unity software, this lane width is adjusted by scaling the vehicle.

3.5.2 Counterbalanced design

To perform a valid experiment, the design of the experiment needs to be counterbalanced to evaluate the performance through the test conditions. Otherwise this confounding influence will affect the accuracy of the results of the experiment. Counterbalancing is a method to arrange the test conditions in a different order for each group (Reese, 1997). This group could be a certain group of participants but will in this case only be one participant. A counterbalanced design could be made with help of statistics or by hand calculation. The software Ngene (Version 1.2.1) can do this counterbalancing automatically and guarantees in this way that the design is optimized with no correlations (Appendix C2).

Due to the fact that four types of variables are used where each of them varies in three levels, the order in which the kind of level of the certain variable is given in the TOR is important. This is also known as the permutation of the levels, rather in how many positions the levels can be placed. Every urgency level (NTR, STR, UTR) has three levels, which lead to 81 variations of order so 81 tests in the experiment.

3.5.3 Secondary task

The secondary task in the driver simulator experiment is made in order to distract the human driver from the driving task for measuring the time to take-over control. For this secondary task, the driver needs to be distracted by another task such as a mobile device or a book, which is expected to become a secondary task when AVs are introduced, and the driver is allowed to do (e.g., Banks et al., 2018; Casner et al., 2016; Lin et al., 2017; 2019). Games on a mobile phone or tablet is promising for distracting the driver (Lin et al., 2018). The game Tetris is chosen due to the fact it is understandable and widely known, is easy to use and due to the increasing rapidity of the game it will gain all the attention of the driver. A tablet (as stated in chapter 3.2.4) is chosen to use in the simulator experiment, because it has a larger screen which is easier to use and gives a better visibility. Moreover, it could simulate also a laptop or in-car screen which are getting bigger in new and future vehicles and do have more functionalities (Carsten & Martens, 2019).

3.6 Procedure

Several builds of the driving simulator software will be tested whereby each build contains certain variables with their own dedicated level, randomized by software. Each test contains only one TOR in order have the same scenario for all tests.

3.6.1 Duration

Several pre-tests were conducted in order to find out the time it took before the human driver has no idea anymore of the driving time and was totally focused into the game. It was found that after four minutes the driver's attention was at the game in a comfortable and restful way. This led to the conclusion that a duration between 5 to 10 minutes was necessary to minimalize errors and bias.

In the chosen route for the N=1 test, the TOR was initiated at a straight stretch of road after approximately 8 minutes of driving. After the take-over takes place, a minute is chosen for manual driving until the test ends. Therefore, the duration of each N=1 test is chosen to be 10 minutes in total (1-minute manual driving, 8-minutes automated driving and again 1-minute manual driving). The total time of each experimental run took approximately around 15 minutes due to equipment setup time and saving of the data. After 4 to 7 runs, a break was taken to avoid fatigue.

3.6.2 Date & time

Five days were available to execute the pilot tests. These five days were separated with one day off between each day and without the use of weekend days, starting at the end of April 2020 and finishing at the beginning of May (28 April – 11 May), each day from 9 am to 17 pm. This time budget could be increased from 8 am – 18 pm if necessary.

3.6.3 Location

After 8 minutes of automated driving, the TOR will be issued, and the driver is taking over. Figure 8 shows the timeline of the experiment with the given take-over moments. The location of the TOR is based on several criteria, namely being on a straight road with a normal highway appearance (road signs, streetlights, rural environment) without off- or on-ramps. This monotonous type of environment is an earlier stated criterion in chapter 3.3.1 when issuing a TOR. Figure 9 shows the take-over moment on the route map and the environment the driver sees when confronting with the TOR.

Figure 8

TOR timeline

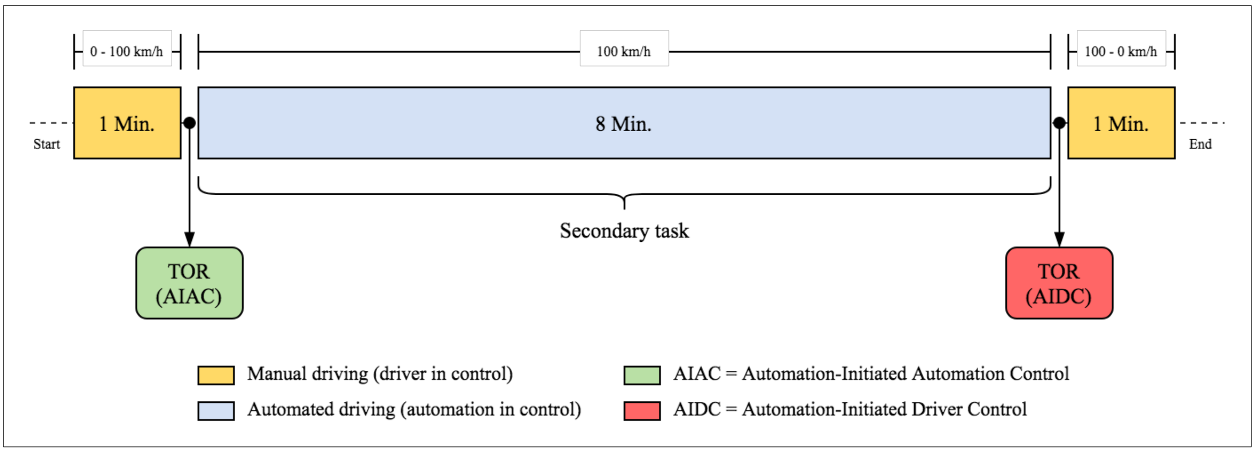


Figure 9

Take-over moment on the driving map and the environment the driver sees when the TOR is issued

3.7 Data collection

After five days of testing, the data needs to be obtained from all the camera images, log files of the Unity software and screen recording images of the test. All the data was directly composed in an Excel file to get an overview of every test (Appendix D). With these data, some graphs were made to make the data more insightful, and the result together with remarkable insights were extracted. In this paragraph, the measurement of how to get a certain output or how to evaluate a certain output will be discussed.

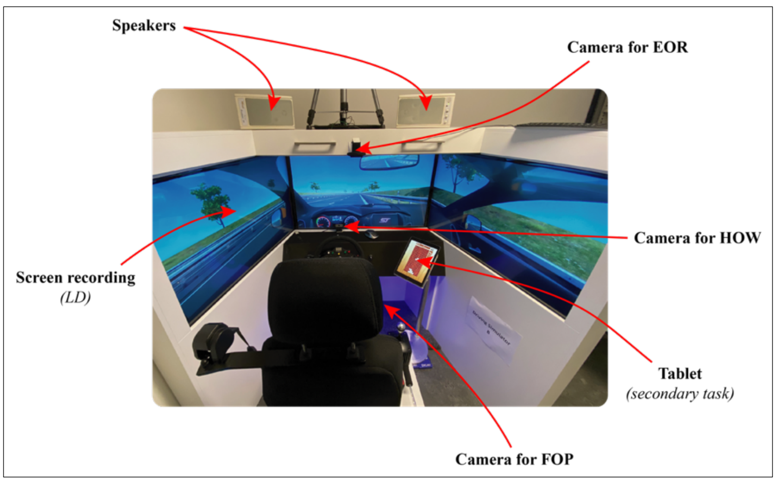
For deriving exact measurement out of camera images, the Apple software package Final Cut Pro X (Version 10.4.4) is used in order to separate camera images and sound to see the increase or decrease in dB(A) and exact time in milliseconds for sound as well the camera images.

Most of the data is obtained by camera images or by the screen recording image, which will be explained in detail of how the data is derived from these recordings. This chapter is divided into five subparagraphs, each of them consisting of a measurement device where the data is obtained from. The Foot On Pedal (FOP) is used to indicate the time between the TOR and the participant has his/her foot on the accelerator. Furthermore, the Hands On Wheel (HOW) is measured by the time when the participant has both hands on the steering wheel after the TOR. The Eyes On Road (EOR) for the time between the TOR and when the eyes of the participants are pointed towards the screen, and the screen recording of the driving scenario is used for measuring the lateral deviation (LD) after taking-over the vehicle. The FOP, HOW, and EOR together are used for defining the Take-Over Time (TOT) by taking the longest number of seconds needed of these three measurements to take-over the vehicle.

An overview of the placement of the cameras and devices such as the tablet and speakers are displayed in Figure 10.

Figure 10

Location of several measurement devices and support devices



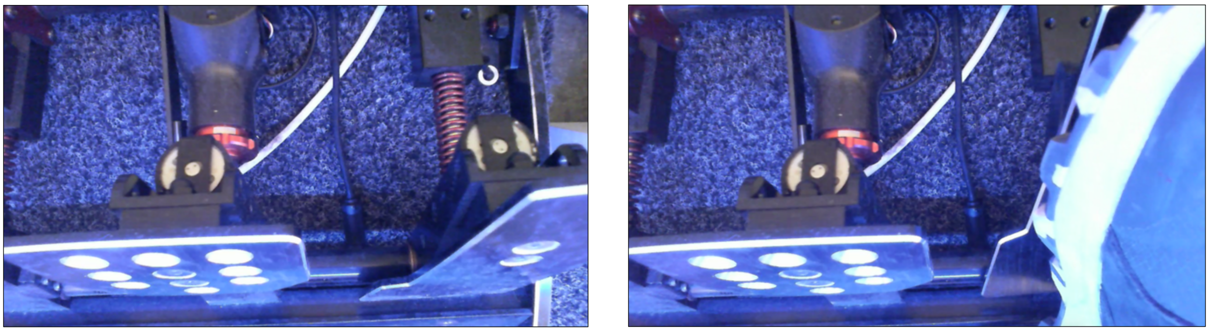
3.7.1 Foot On Pedal (FOP)

Camera 1 is focused on the driving pedals and through the camera images the time it took to put the foot on the pedal (in this case the accelerator) is clear and usable for investigation. The data from the camera consists not only of recording images but also surrounding sound. Via the video editing software (Final Cut Pro X), the level of dB(A) increase can be found easily and used to indicate the Take-over Automation to Manual (TAM) and timestamp of when the human driver presses the pedal (FOP). Subtracting these values, the Take-over time of the Human driver after Initiation (THI) can be found. In calculation form: THI = FOP - TAM. The TAM was found by indicating the increase in sound, whereas the FOP was indicated by when the foot presses the pedal (moment when pedal moves).

Figure 11 shows on the left picture the pedals when the automation is in control, whereas on the right picture the pedals are shown when the driver take-over the automation.

Figure 11

Pedals without (left) and with foot placement



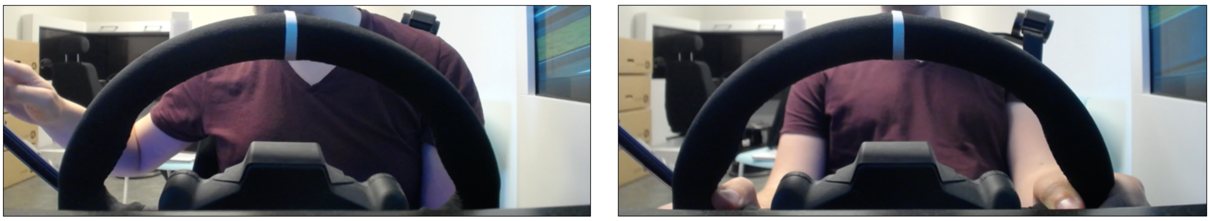
3.7.2 Hands On Wheel (HOW)

Camera 2 is focused on the steering wheel and thus pointed on the human driver's hands. Through this, the TOT of the driver is calculated when he/she is taking over the driving task. The hands on the wheel (HOW) is extracted the same way as for the FOP, namely by looking at when TAM takes place of the vehicle (voice of woman initiating the take-over process), and the time it takes when the human driver has his hands on the steering wheel (TOT = HOW – TAM). It is chosen to take into account the time it takes when **both** hands of the human driver are on the steering wheel due to the fact sometimes one hand is placed earlier than the other on the steering wheel.

Figure 12 indicates on the left image when the automation is in control and the driver is performing a secondary task on a tablet, whereas on in the right image the driver is in control by having both hands on the steering wheel.

Figure 12

Without (left) and with hands on the steering wheel



3.7.3 Eyes On Road (EOR)

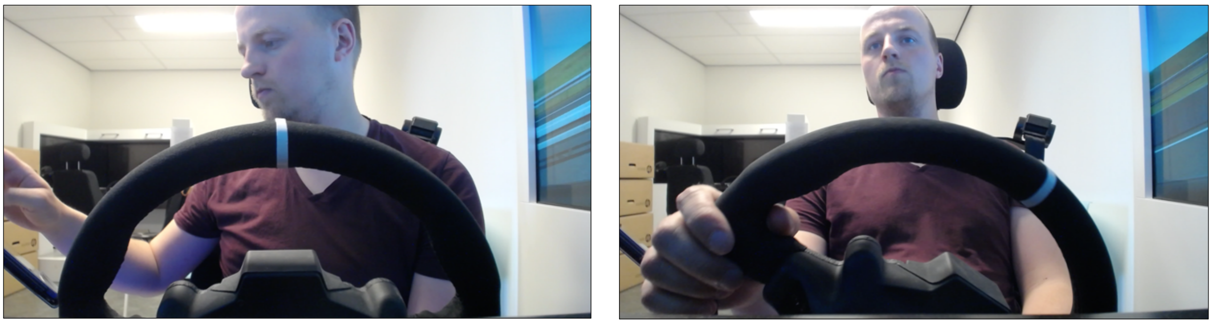
The third camera is focused above the centre of the screen and points directly on the head of the human driver. In this way, the eye-movements of the human are visible and are able to be tracked manually or for example by eye tracking software. For this N=1 experiment, manually eye tracking was executed.

The moment of TAM was found in the same way as in the previous paragraphs, and the movement of the eyes were easily to see due to the fact the human driver was looking at the tablet on the right side. When the TAM takes place, the human is turning his/her head in the direction of the screens and moves the eyes from bottom right (in the camera images bottom left) towards the centre. Due to this eye movement, the timestamp of having their eyes on the screen was indicated as EOR. In calculation: TOT = EOR – TAM.

In Figure 13, the eye direction of the driver can be seen when he is looking at the tablet on his right side, and when he is looking at the driving environment (right picture).

Figure 13

Eyes off (left) and on the road



3.7.4 Lateral Deviation (LD)

The lateral deviation (LD) is found by measuring the deviation of the lane from the point when the automation is asking the driving to take-over, and the point where the driver takes over by having his hands on the steering wheel. This lateral deviation is calculated in percentage of lateral deviation in order to get a more detailed view of how large this deviation is. This means its measured as a relative LD.

Figure 14 shows how this LD is measured, by having a built-in ruler inside a program (Ruler for macOS version 2.0.2) that checks several important aspects, such as having the same screen ratio, in order to have no bias in the measurements.

Figure 14

Measuring lateral deviation

3.7.5 More measurements

The main measurements for the experiment are explained in the previous paragraphs, but additional measurements have been registered, such as the score of the game Tetris for each of the 81 tests, the day and the time each test is performed, and the foot placement on the driving pedals. Several measurements are registered by Unity itself, such as the coordinates of the vehicle, the speed, acceleration and rpm. A selection was made of results which are relevant to this research and those are, together with the FOP, HOW and EOR, discussed in the following chapter.

Chapter 4

Results

This chapter points out the results from the simulator experiment as collected and measured given the conditions stated in chapter 3. It will examine the results on basis of descriptive analysis. First, descriptive statistics are given for four variables, divided by paragraphs, that give insights in the data. Based on these data, conclusions and recommendations are made which can be found in chapter 5.
The overview of all the data, and the calculations per variable and variable level can be found in Appendix D.

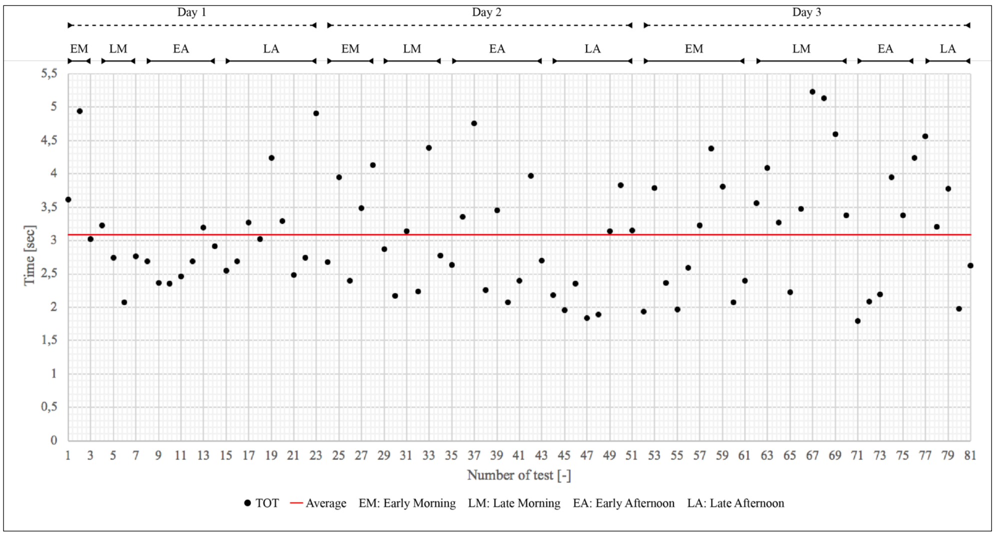
The experiment consisted of 81 TOR tests that are analysed in a descriptive way. The analysis of the data is based on combining the data in a table, some with the aid of a graph with, for example, a linear or polynomial trendline. When data fluctuates, a polynomial trendline is useful to analyse gains and losses over a data set, by using a curvilinear relation between variables that may not be shown when using linear or logarithmic regression (Mendenhall & Beaver, 1994).

Figure 15 presents an overview of all the results of the simulator experiment, based on the take-over time (TOT) of the 81 tests. The mean of these 81 tests (3,083) is given by a horizontal red line to show the deviation of each individual test from the mean. The maximum TOT (5,230) is test 67 (NTR, -10, *"Note"*, 3.5), whereas the minimum TOT (1,800) is test 71 (UTR, +50, "*Deadly"*, 2.5). Furthermore, the experiment is divided over three days with coffee- and lunch breaks in between. Days are divided into parts, namely early morning (EM), late morning (LM), early afternoon (EA), and late afternoon (LA). The maximum TOT (test 76) was performed in daypart LM, that includes most of the TOT above the mean on day 2 and 3. The minimum TOT (test 71) was performed in daypart EA, that has on all three days the lowest average TOT (2,893). Day 1 has the least spread in the TOT, with test 2, 19, and 23 as outliers, whereby 65.2% of the tests have a TOT below the average. Moreover, the TOT is on average the lowest in daypart EA (2,893), whereas EM has the highest (3,350). Day 2 has a more scattered data but on average the lowest TOT (2,968), whereby day 1 (3,118) and day 3 (3,228) incorporate longer TOTs.

The data will be analysed more thoroughly in the next paragraphs, based on the given variables in chapter 3.5.1.

Figure 15

Overview of TOT for all tests per part of day



4.1 Take-over type

The TOT is being researched for the take-over type (type of urgency) individually and showed together in one graph to indicate the relationship to each other. Each take-over type consisted of 27 tests, which makes 3*27 is 81 tests in total. As can be seen in Figure 16, the urgent take-over request (UTR) has the lowest TOT for almost all tests, whereas the non-urgent take-over request (NTR) has the longest TOT. After around five tests, it can be seen that each type distinguishes it from the others by having their own more or less linear line. Notable is that by the increase of the number of tests, the TOT of the UTR becomes quicker, whereas the TOT of the NTR and STR becomes slower. This type of behaviour indicates that the driver consciously or unconsciously knows the difference between the urgency levels and reacts on this in a way it is designed by the researcher. This could be a context effect, in which being tested in one condition can change the way how the driver perceive stimuli or interpret their task in later conditions, due to the fact after five tests, there is a clear difference between the type of urgency related to the TOT.

Table 7 shows a summary of the TOT per take-over type. This data, whereby the mean is given, together with the standard deviation, shows that there is a relationship between the take-over types, whereby the NTR has the longest TOT, the UTR the shortest, and the semi-urgent take-over request (STR) in between them. Furthermore, a One-Way ANOVA test was performed to test for significance between these take-over types, whereby $p < .001$.

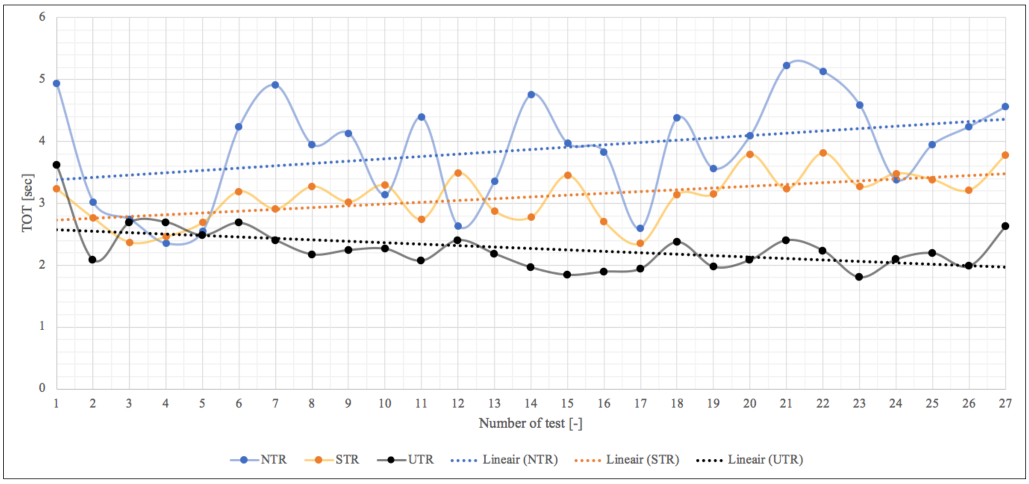
Table 7

Average TOT per take-over type

Type of take-over	M(SD) [sec]
NTR	3.87(0.85)
STR	3.10(0.41)
UTR	2.27(0.37)

Figure 16

TOT for every take-over type individually



4.2 Speech-rate

The speech-rate in the experiment was, as explained in chapter 3.5.1, varied in three ways for each level of urgency, namely -10, 0, and +10. In this paragraph, the speech-rate in relation to the three urgency levels are analysed. For each of the urgency levels, 27 experiments are performed. Table 8 shows an overview of the mean TOT and their SD. The NTR has the highest TOT (4.06) and the UTR the lowest (2.16). For the NTR, there is no clear difference between the speech-rate and the mean TOT, whereas for the STR there is a decrease for the mean TOT for each increase in speech-rate. The UTR has also no clear difference in the relationship between TOT and speech-rate.

A more profound analysis of each speech-rate per urgency level can be found in the next paragraphs.

Table 8

Average TOT for each speech-rate, per urgency level

Type of urgency	Speech-rate	M(SD) [sec]
NTR	*-10*	3.84(1.12)
	0	4.06(0.50)
	+10	3.72(0.88)
STR	*+15*	3.28(0.40)
	+25	3.08(0.44)
	+35	2.95(0.35)
UTR	*+40*	2.27(0.29)
	+50	2.38(0.28)
	+60	2.16(0.26)

4.2.1 NTR

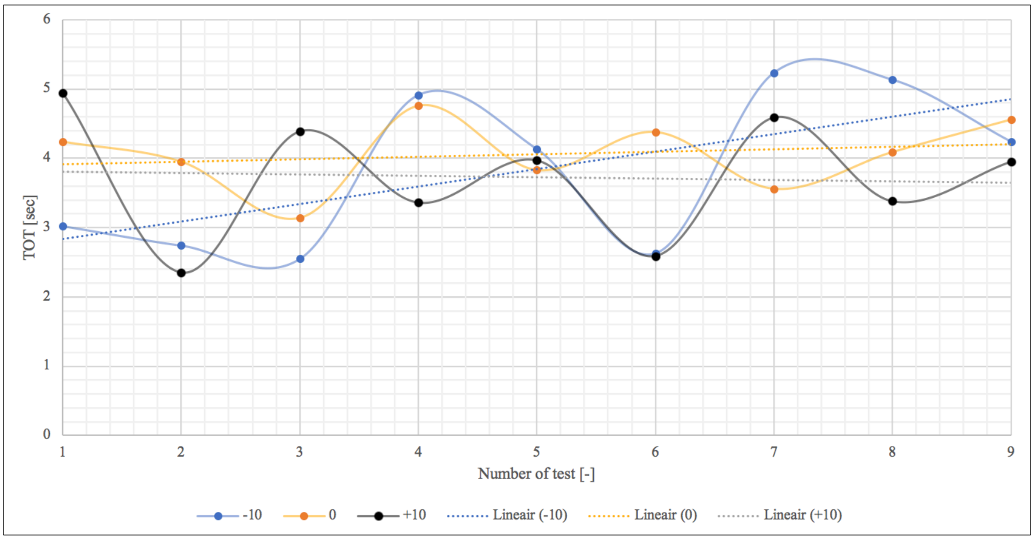
The NTR has a speech-rate of 0 as standard, which can be seen as a normal speech-rate (100%). Therefore, this urgency level varies between -10, 0, and +10.

As can be seen in Figure 17, the TOTs of speech-rate -10 and +10 are fluctuating a lot, whereas the TOT of 0 is more stable. On average, the TOT is the quickest for the +10 speech-rate level, as can be expected, as an increase in speech-rate results in an increase of perceived urgency (Bazilinskyy & de Winter, 2017). This does also apply to -10 and 0, whereby the TOT of -10 is on average lower than 0. The TOT of -10 is slightly increasing with the number of tests as can be seen in Figure 17, which could be explained by the fact the -10 speech-rate feels unnaturally slow and is easily perceived, relative to the others, as the least urgent TOR

Overall, the difference between these three speech-rates for the NTR is not significant ($p = 0.718$, $p > .05$).

Figure 17

TOT for NTR, based on speech-rate



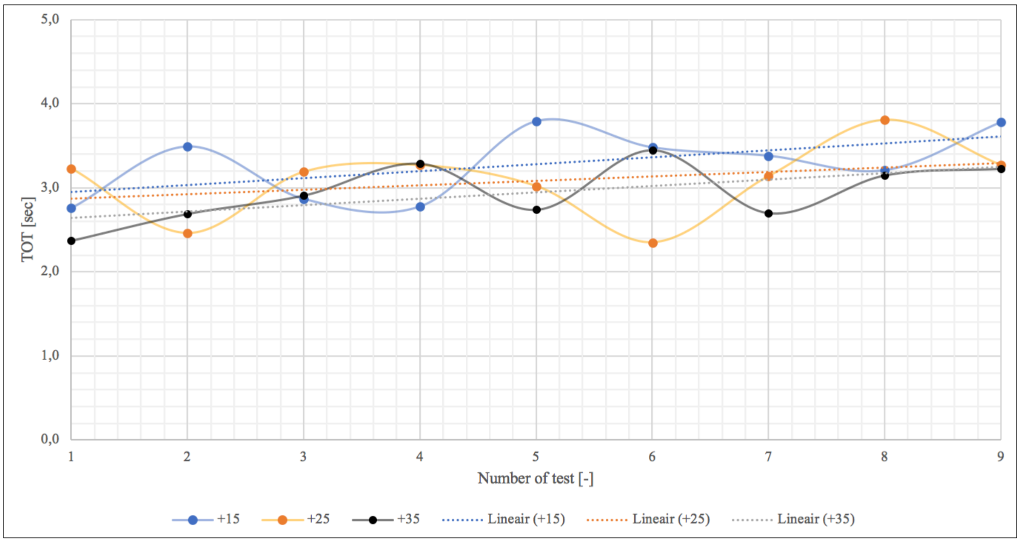
4.2.2 STR

The STR has a speech-rate of +25 as standard, or 86% duration compared to the normal duration (NTR). Hence, this urgency level varies between +15, +25, and +35 (Table 8).

The TOT for the STR as shown in Figure 18 has, in contrast to the NTR, less fluctuations, whereby the highest speech-rate (+35) has the lowest TOT (2.95) on average. The standard speech-rate (+25) has for two tests a lower TOT relative to the highest speech-rate, but no significant difference (p >.05) between the speech-rates is found.

Figure 18

TOT for STR, based on speech-rate



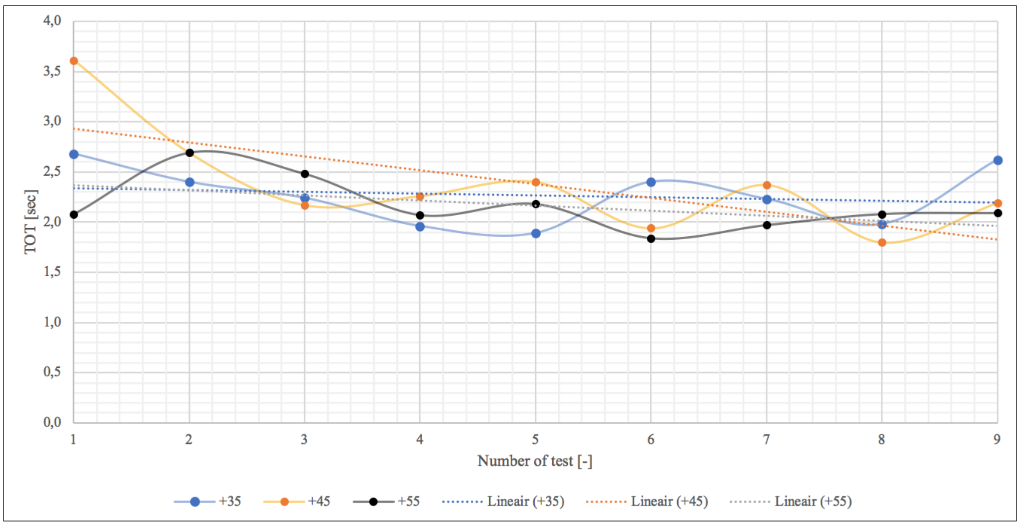
4.2.3 UTR

The UTR has a speech-rate of +50 as standard, meaning a 78% duration compared to the normal duration (NTR). This urgency level varied in the experiment between +40, +50, and +60.

Figure 19 shows the TOT of the UTR based on the speech-rate, that shows that for most of the experiments the TOT did not differ that much. In the first tests, the speech-rate of +50 has the highest TOT (3.61), but that decreases over the number of tests towards a more stable TOT around the average (2.38). The high TOT for the first test of the +50 speech-rate can be explained by the fact that this test was the first of all 81 tests in the simulator. Overall, the difference found in the TOT between the speech-rates are not significant (p >.05).

Figure 19

TOT for UTR, based on speech-rate



4.3 Syntax

As explained in subchapter 3.5.1, the syntax in terms of signal words were for each urgency level varied in three different ways. For the NTR, the signal words "Note", "Risky", and "Hazard" were used in the sentence "[…], take-over at your earliest convenience". The words "Warning", "Attention", and "Caution" are used for the STR in the sentence "[…], take-over as soon as possible", and the words "Danger", "Deadly", and "Beware" for the UTR in the sentence "[…], take-over immediately". The difference between the syntax of these three urgency levels is significant at .01 level ($p = 8.089*10^{-15}$).

Table 9 shows an overview of the average TOT for each type of urgency and their used syntax.

Table 9

Average TOT for each syntax, per urgency level

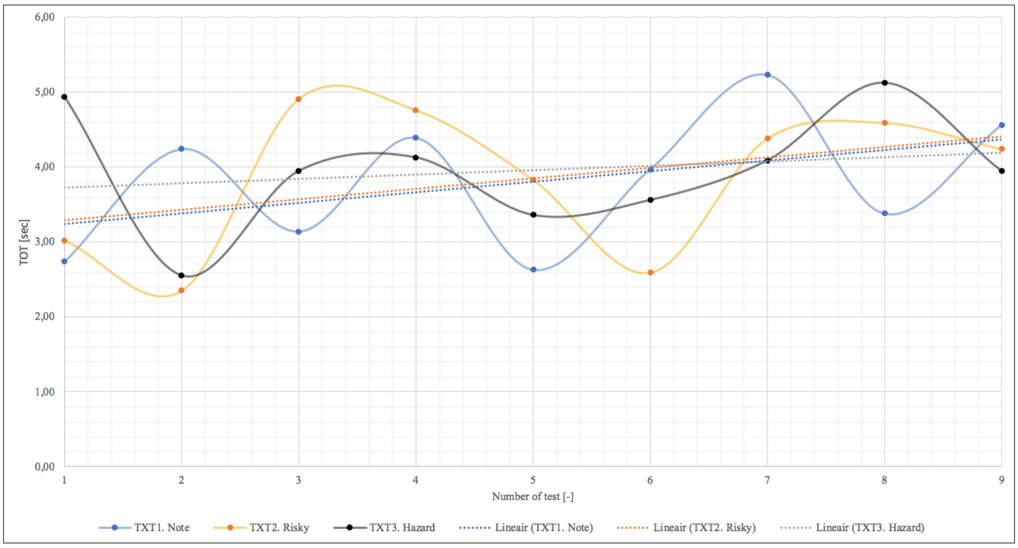
Type of urgency	Syntax	M(SD) [sec]
NTR	*TXT 1. Note, […]*	3.81(0.89)
	TXT 2. Risky, […]	3.85(0.97)
	TXT 3. Hazard, […]	3.96(0.78)
STR	*TXT 1. Warning, […]*	2.81(0.40)
	TXT 2. Attention, […]	3.34(0.30)
	TXT 3. Caution, […]	3.16(0.37)
UTR	*TXT 1. Danger, […]*	2.37(0.29)
	TXT 2. Deadly, […]	2.02(0.13)
	TXT 3. Beware, […]	2.42(0.50)

4.3.1 NTR

As can be seen in Figure 20, the TOT between the different syntaxes are fluctuating and do not have a linear line. Text 2 'Risky' has the lowest TOT (2.35) at test 2, but at test 3 it goes up to 4.91 seconds. Text 1 'Note' and text 3 'Hazard' do not have a linear line either, and do also have peaks and valleys. Overall, the signal word 'Note' has the lowest mean TOT (3.81), even though this is with a small margin relative to 'Risky' (3.85). No significant effect is found between the three different syntaxes ($p = 0.931$, $p > .05$).

Figure 20

TOT for NTR, based on syntax



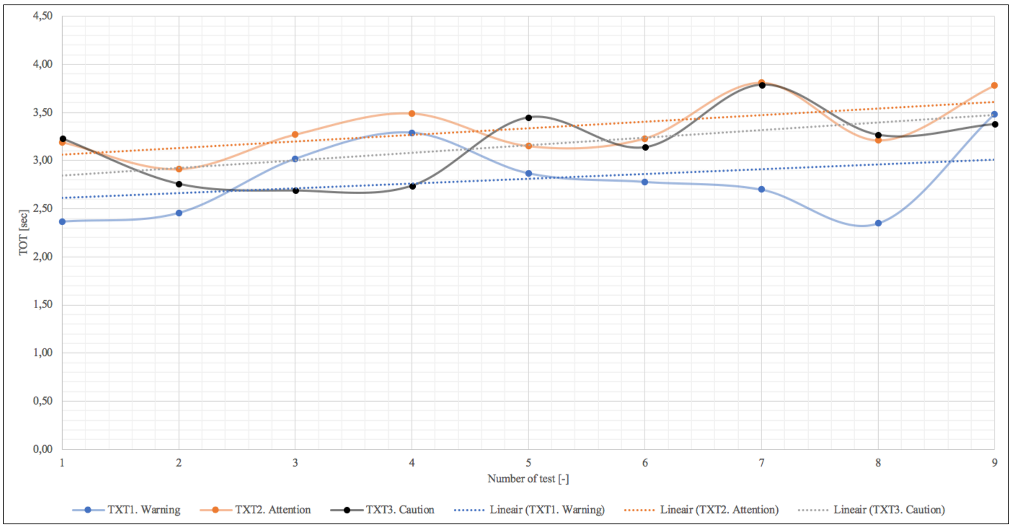
4.3.2 STR

As can be seen in Figure 21, the TOT of the STR when using different signal words were not as fluctuating as the NTR. Based on the trendline, text 2 'Attention' has a more stable TOT around 3.34 seconds and has the highest TOT of all three signal words. The TOT is on average the lowest for text 1 'Warning' (2.81), especially at test 1 and 2 and after test 4. Text 3 'Caution' has a slightly rising TOT through the tests.

A significant effect is found between the three different syntaxes for STR ($p = 0.015$, $p < .05$).

Figure 21

TOT for STR, based on syntax

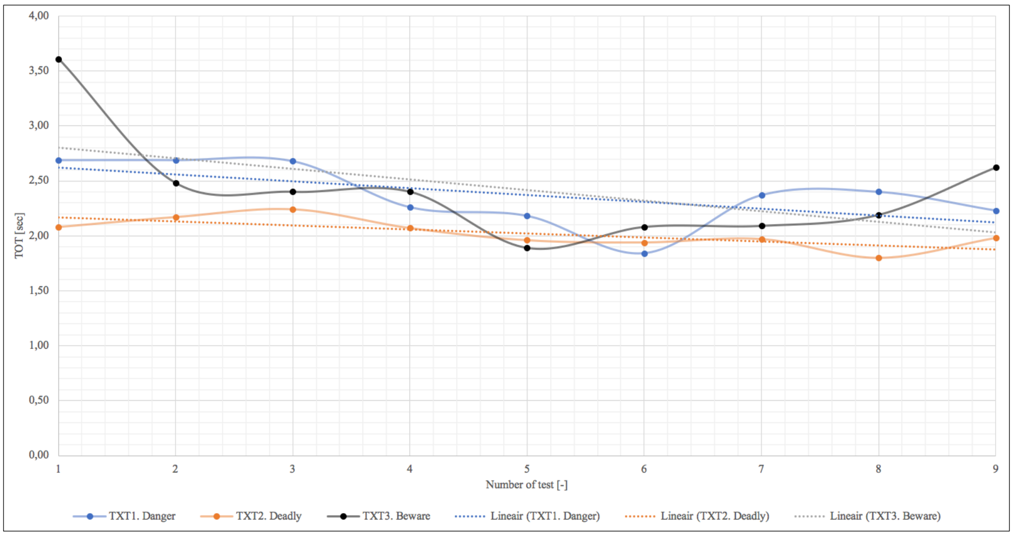


4.3.3 UTR

Figure 22 shows that the results of the TOT for the three signal words used for this urgency level are close together. In the first tests, a clear difference is shown whereby text 2 'Deadly' has the lowest TOT (2.08). In the tests later on, the difference becomes smaller as indicated by the trendline. 'Deadly' has overall the lowest TOT on average (2.02). Test 5 and 6 have for all signal words a lower TOT and are performed at the end of day 2 and some are the first tests of day 3. Furthermore, all tests have a declining trendline, which indicates that over the time span of the tests, the TOT becomes smaller. A significant effect is found between the three syntaxes ($p = 0.044$, $p < .05$).

Figure 22

TOT for UTR, based on syntax



4.4 Lane width

The lane width is varied in three ways, namely 2.5, 3.0, and 3.5 meters wide. This variable is used to indicate the lateral deviation (LD) when urgency varies. Table 10 shows an overview of the average lateral deviation relative to the lane width for each type of urgency. For each of the urgency type, 27 tests are performed, 9 tests per lane width.

What immediately stands out in Table 10 is that for the UTR condition, the lane width of 3.0 metres has the highest mean lateral deviation and a large SD. Subchapter 4.4.3 will go more into detail of this phenomena. Furthermore, for most of the lane widths, the larger the lane width, the more deviation occurs. There is no significant relationship between the three levels of urgency and the lane width ($p = 0.071$, $p > .05$) when using .05 significance level, for a 0.1 level it is significant. In this study, the p-value needs to be .05 or lower in order to be significant.

In the following subchapters, the LD per urgency level will be explained by means of graphs.

Table 10

Mean lane deviation (LD) for each lane width, per urgency level

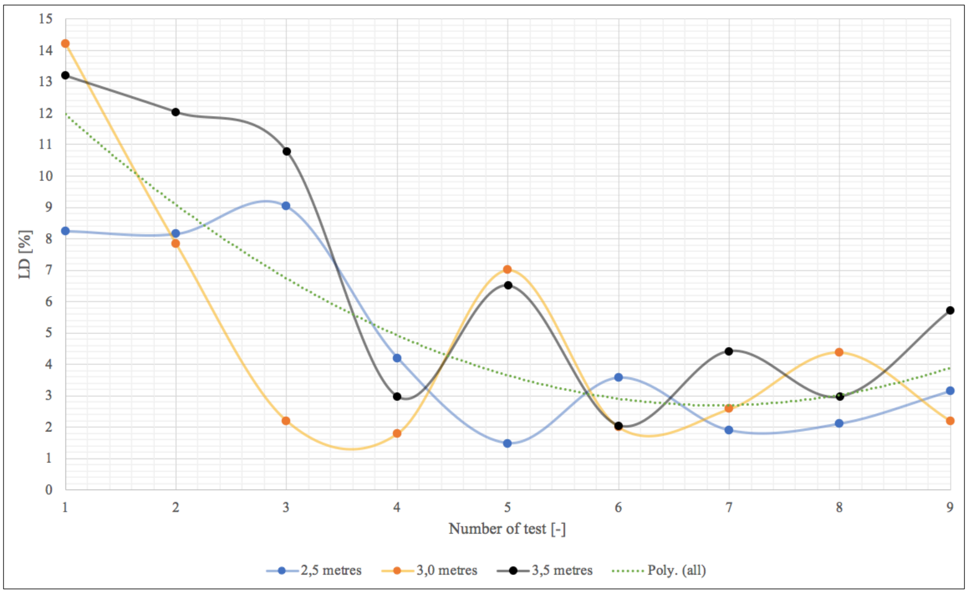
Type of urgency	Lane width [m]	M LD(SD) [%]
NTR	*2.5*	4.65(3.01)
	3.0	4.91(4.15)
	3.5	6.74(4.23)
STR	*2.5*	3.17(2.38)
	3.0	4.87(2.97)
	3.5	8.99(4.34)
UTR	*2.5*	4.81(1.89)
	3.0	11.71(7.60)
	3.5	7.83(4.89)

4.4.1 NTR

The lane width of 3.0 metres for the NTR condition has a steep curve in lateral deviation between the first three tests. This is a clear evidence of a learning curve. The polynomial trendline in Figure 23 shows this behaviour. The other two lane widths have the same behaviour. In the first number of tests, the lateral deviation is high, whereas in test 6 and later the deviation stabilizes into a smaller deviation. This can be recognized as a learning curve, whereafter a few tests, the deviation stabilizes at a certain lower point for the tests to come. Test 5 shows for the 3.0 metres as for the 3.5 metres width a hill, this could be the fact that both tests are performed in the early morning (EM). Furthermore, there is no significant difference between the three lane widths (p = 0.463, p > .05). The 2.5 lane width has over all the tests the lowest deviation and SD.

Figure 23

Lateral deviation compared to lane width for NTR

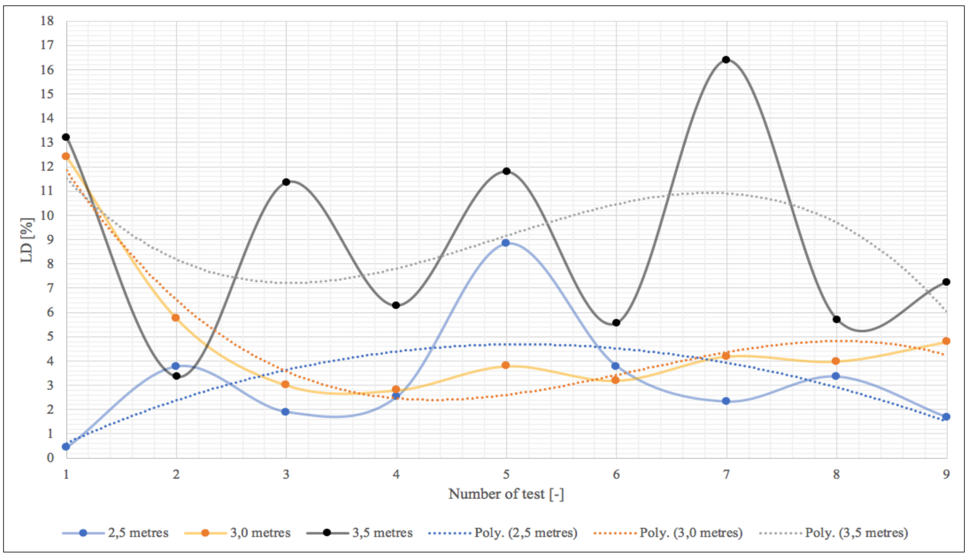


4.4.2 STR

The mean lateral deviation for the STR shows in Table 10 that it has the same structure as the NTR, namely that the smaller lane width has a lower lateral deviation. Comparing this average value with the values over the 9 tests of the STR, shown in Figure 24, the lateral deviation for the lane width of 2.5 and 3.0 metre are the most stable. The 3.5 metre lane width stands out with higher lateral deviation and more unstable behaviour. Between these lane widths for the STR, a significant difference is found (p = 0.003, p < .05).

Figure 24

Lateral deviation compared to lane width for STR



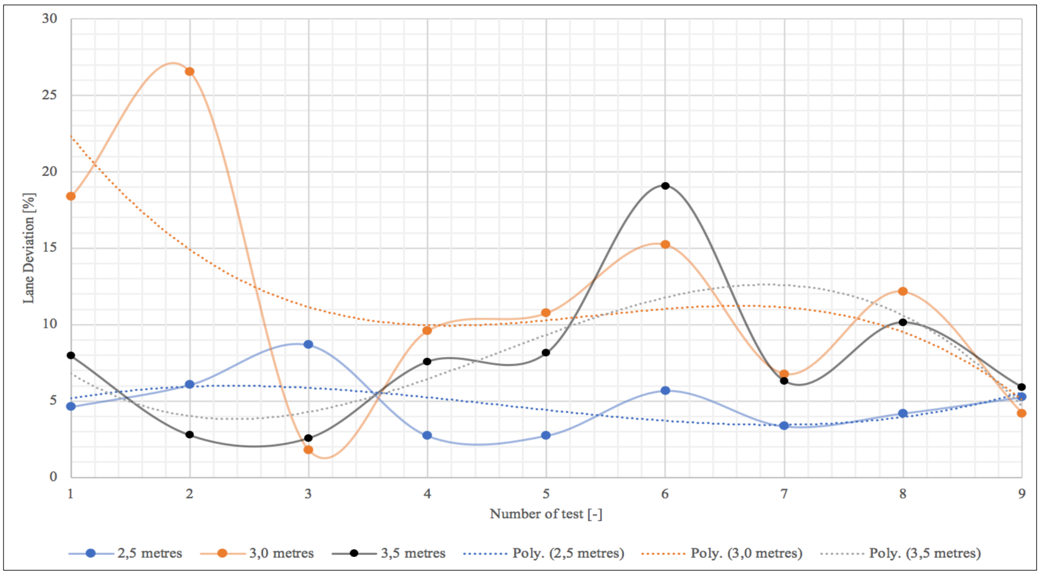
4.4.3 UTR

The overview of the means for the lane width in Table 10 shows that for the UTR, the 3.0 metre lane width has a large mean lateral deviation and SD. This large mean is due to the lateral deviation in test 2 and test 3 for the 3.0 metre lane width as can be seen in Figure 25. Test 2 is performed in the early morning, whereas test 3 after the morning coffee break. Furthermore, a hill at test 6 for the 3.5 and 3.0 metre lane width can be seen, and at test 9, all three lane widths are very close together. These latest tests (test 9) are performed at the end of the experiment, in the late afternoon at day 3.

A significant difference is found for the lane width ($p = 0.037$, $p < .05$).

Figure 25

Lateral deviation compared to lane width for UTR



4.5 Explorative research

When going through the data from the simulator experiment, other relevant data has been analysed. The data will be discussed below.

4.5.1 Foot placement error

Foot placement accuracy was often not perfectly on the pedal when taking over the vehicle (Figure 26). This placement error was registered together with the FOP as described in chapter 3.7.1. Table 11 indicates that the error was common for UTR in more than half of the tests, whereas NTR and STR only had it for approximately 1/5 of the tests.

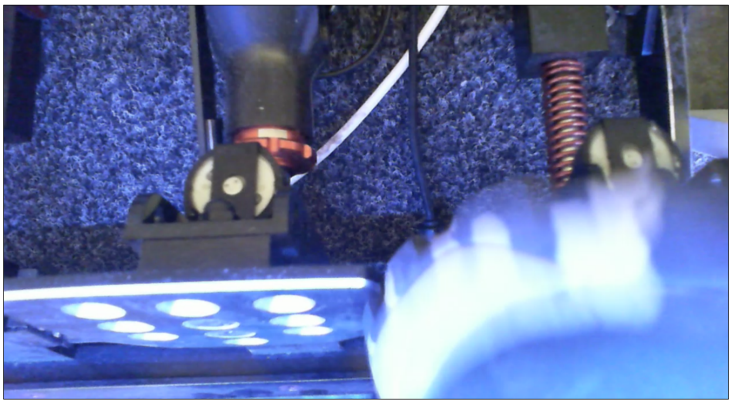
Table 11

Foot placement error

Type of urgency	Errors	Percentage(SD) [%]
NTR	*6*	0.22(0.42)
STR	*6*	0.22(0.42)
UTR	*15*	0.56(0.51)

Figure 26

Foot presses the brake pedal while pressing the accelerator

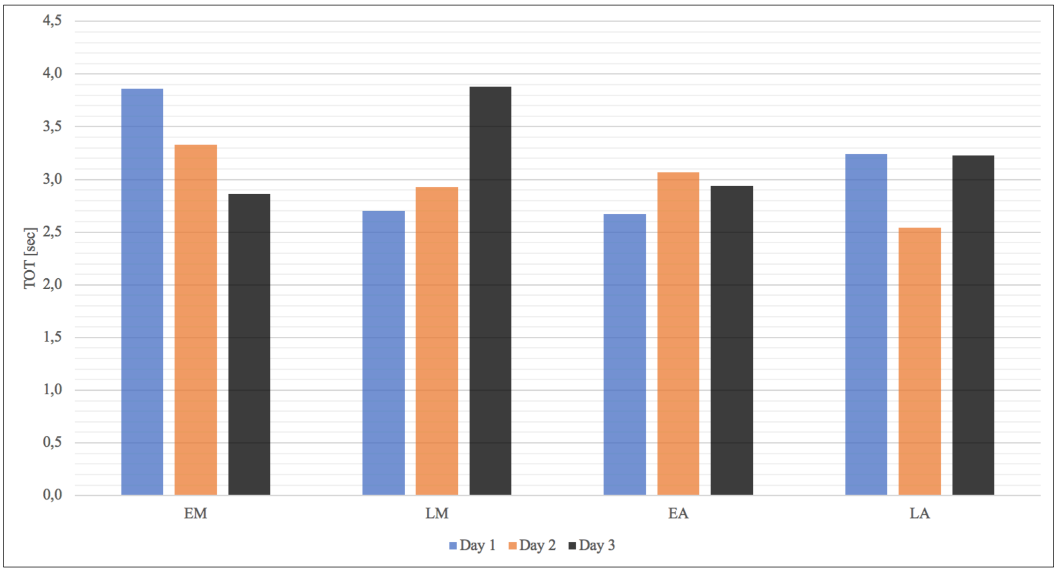


4.5.2 Time of day

As could already be seen in Figure 15, the experiment is performed over three days, from approximately 8:00 to 18:00. For the first and second day, the early morning (EM) tests do have on average a higher take-over time (TOT) (3.86 and 3.33) compared to the other half-days. Indicated by Figure 27, the average (trendline) over the three days shows that the TOT is higher in the morning tests, especially at the EM tests (3.35). Furthermore, the TOT in the late morning (LM) on day 2 shows the highest TOT (3.88), which does include some outliers of the TOT (4.59; 5.13; 5.23). A slight increase in the average TOT (3.00) can be seen for the late afternoon (LA) tests. Overall, the TOT is the lowest (2.89) for the tests in the early afternoon (EA) (after lunch) as indicated by the mean trendline. Furthermore, no significant differences are found for part of day ($p = 0.419$, $p > .05$) and between the three days, there is also no significant difference ($p = 0.404$, $p > .05$). These tests are based on a related one-tail t-test where two repeated conditions are tested by the same participant.

Figure 27

TOT per time of day



Coffee break between EM and LM

As can be seen in Figure 15, the tests are performed in the morning and are divided into EM and LM. Between these two dayparts in the morning, a coffee break is held by the participant. By observing the

TOT of the tests right before and after the coffee break, no significance could be found if coffee or a break influence the TOT relative to the test before the coffee break ($p = 0.363$, $p > .05$).

Lunch break between LM and EA

Between the test in the LM and the EA, the participant had a lunchbreak for around an hour. The food could give the participant a higher energy level or an after-dinner dip. For day 3, a difference in TOT can be seen clearly when looking at the values in Figure 15, where the TOT after the lunch (EA) are lower than before the lunch (LM). For day 1 and 2, this is not clearly visible. By comparing the TOT of the LM before and for the EA after the lunch, it is found that there is no significant difference ($p = 0.123$, $p > .05$).

Coffee break between EA and LA

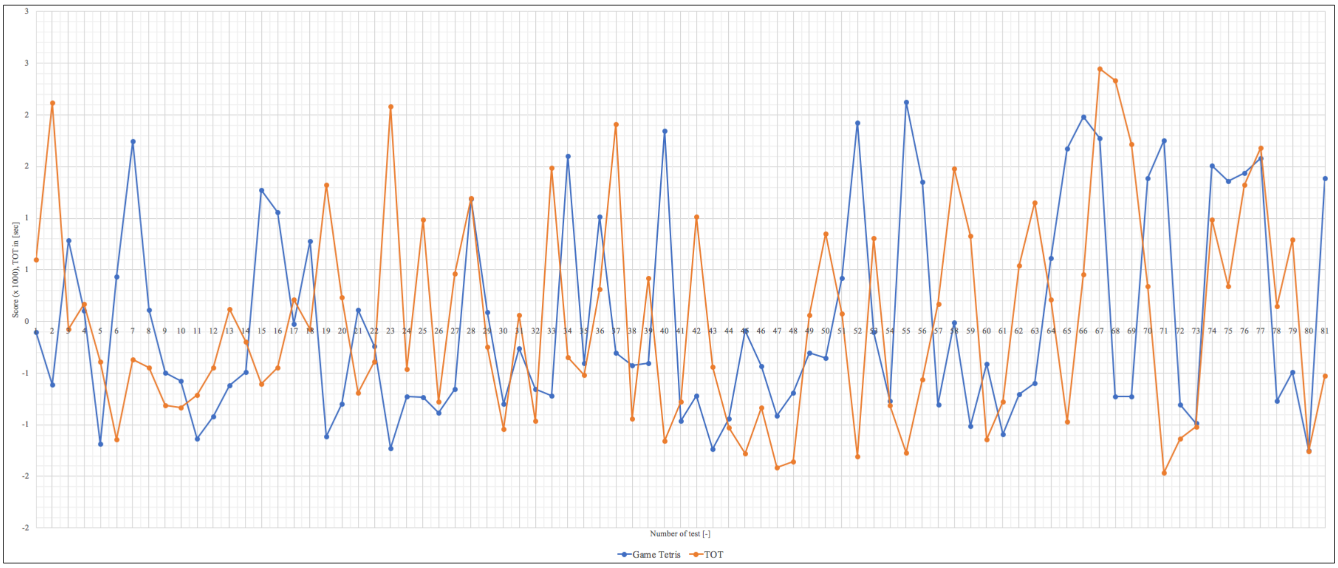
The coffee break in the afternoon, is for day 1 and 2 visible in a lower TOT for the first two tests right after this break (Figure 15). For day 3, this condition is visible because the first test after the break has a high TOT. When comparing the data of all three days, there is no significant effect ($p = 0.279$, $p > .05$).

4.5.3 Game (secondary task)

The secondary task, consisting of playing the game Tetris on a tablet, could influence the TOT of the TOR by finishing the game for a high score before taking over the vehicle. Or a high score could positively influence the TOT due to the fact the driver is energetic and attentive. Figure 28 shows the normalised score of the game compared to the normalised TOT per test. By observing the figure, the highest scores tend to have overall a low TOT in the first 65 tests, but later on, this observation seem less valid. No association between them is found (Pearson Product-Moment Correlation, $r = -.013$).

Figure 28

Game score compared to TOT (normalised)



Chapter 5

Discussion

The aim of this research is to investigate what the ideal setup of a driving simulator experiment is in order to research the effect of the personality trait of the human driver on a speech-based auditory take-over request (TOR). Some variables are found in literature who can have an effect on the take-over time (TOT) of the human driver when receiving a TOR. Four variables are chosen to vary in three levels for this research to find the effect on the TOT and to come up with recommendations regarding the driving simulator experiment. First, a counterbalanced design is made of all levels of variables to test in this experiment, whereby 81 were needed to validate these variables. Based on the number of tests, a schedule was made to test in the driving simulator. And second, the driving simulator environments was designed in terms of hard- and software. The experiment was performed comprising a N=1-study, meaning that only one participant, namely the lead researcher, partook in this experiment. The results of the experiment were registered by the simulator itself and by camera images, and explained by graphs, significance of the values and relationships within and between the variables.

This discussion chapter tries to explain and synthesise insights and results from the simulator experiment together with the assumptions from the literature review (chapter 2). The limitations of this study are discussed in subchapter 1, by acknowledging the decisions that had to be made for this research. In subchapter 2, the results are discussed in the light of the literature review in chapter 2 as new literature found based on the results. A conclusion is made, answering the main research question based on subchapter 1 and 2. As final, recommendations for further research are stated in chapter 3.

5.1 Limitations

Some decisions were made in this research for keeping this research manageable in the given time frame and to perform it regarding the resources that were available. These decisions that had to be made were well-thought but incorporate some shortcomings and thus limitations of this study.

The first limitation is that the influence of the personality trait of the human driver could not be measured with this study. For measuring the influence of the personality trait, more participant is needed in order to receive significant results and say something about the impact of the personality. The intention of this study was to include 100 participants, varying in five groups of personality, to test the influence on take-over performance. Due to the COVID-19 pandemic, the decision was made to change this study to a N=1-study with the limitation of not able to measure the impact of the driver's personality on the take-over performance. The positive side of this change is that this study gives a lot of insight in the hard- and software performance, the shortcomings and the expectations of this research when performing this set-up in the further with a large group of participants, while not having to test the set-up and know which kind of data can be expected.

Comprising a N=1-study, meaning that only one participant, namely the lead researcher, partook in this experiment, means that he knew beforehand what the experiment is about, which types of TORs in the experiment are given, and how the environment is designed. Knowing this beforehand can have an impact on the results of this experiment. Therefore, some measures were introduced to minimize this impact. For example, the length of automation in control till the TOR was issued took around 8 minutes, to take away time consciousness. Furthermore, the TORs were varied by four variables, each with three levels, which are counterbalanced for each test to arrange the test conditions in a different order. In this way, 81 tests were needed to incorporate all variations of TORs in randomized order, each indicated by a digit without further information of what kind of TOR and level was included. In this way, the results of the experiment are plausible and accurate to evaluate.

Only four variables are included in this experiment and their impact is measured by varying these variables in three levels. Due to several reasons, including time, the variety in this experiment is kept feasible to answer the main reasons in this research, namely, identifying the sensitivity for the variables, the design of hard- and software, and to test the setup, experience, and effects of the tests. For the goal of this research, the number of variables to vary were enough to measure, conclude, and answer the research questions.

The experiment is performed in a static driving simulator. This driving simulator makes use of a driving environment in which it is clear that it is not a real driving environment, even if it is designed to look exactly like a real one. This could influence the behaviour of the human driver relative to driving in a real-world vehicle and environment. Furthermore, the responsibility towards other road users or to their own safety is different than driving in a real-world scenario (Mullen et al., 2011). The aim of this study is to increase the safety in automated vehicles; therefore, this experiment helps to stimulate this with recommendations for further driving simulator experiments and real-life testing scenarios.

The same participant is subjected to more than one similar experiment in this study, which means that the participant 'knows' what can be expected in the follow up experiments after having finished a few of the same experiments. In this experiment, the participant has 81 tests of more or less similar designs, with only some changes in the levels of the variables. This problem, called practice effects, can be seen in the results whereby the TOT is on average decreasing when conducting more tests, even if the experiment is counterbalanced, this problem will arise with one participant. For this experiment, whereby the values of the variable which is the most effective is being researched and the whole setup is counterbalanced, this has a minimal impact.

5.2 Key findings

The main findings are based on the take-over time (TOT) of the take-over request (TOR) and are discussed based on the five sub research questions formulated in chapter 1.4 of this research. These sub questions will be answered in this section, each individually, and later on be combined together to answer the main research question of this research. The sub questions will be answered based on the literature (chapter 2), the results of the experiment (chapter 4), and new literature to support the findings in the experiment.

SQ1: *To what extent does a different level of urgency of an auditory take-over request affect the take-over quality of the driver in a SAE level 3 automated vehicle?*

For the different types of urgency, the variable take-over type, as proposed in the experiment, the TOT is found to be linearly decreasing with an increase in perceived urgency. In the first tests of the experiment, there was no clear evidence of significant differences between the take-over types, whereas after approximately six tests, the difference became significant. The mean TOT for the take-over type UTR (the most urgent type of TOR) was found to be 2.27 seconds, whereas for the non-urgent type NTR the TOT was 3.87 seconds. Together with the semi-urgent take-over request (STR), with a mean of 3.10 seconds, the differences between these take-over types was found significant at the .05 level.

The take-over quality of the driver can be defined in several ways. In this research, the lateral deviation as well as the TOT after the driver took over were evaluated as measures for the quality of the take-over (Merat et al., 2012; Radlmayr et al., 2014; Zeeb et al., 2016). Errors such as the foot placement error found by explorative research while measuring the foot on pedal (FOP), do have an impact in the quality of the take-over. As stated in chapter 4.5.1, the highest foot placement error was found with the UTR, with more than half (56%, 15 out of 27 tests) of the experiments where both the brake- and accelerator pedal was pressed instead of only the accelerator pedal. This can lead to dangerous situations whereas in the tests of NTR and STR only 22% (6 out of 27) of the tests this error occurred. Due to the pedal setup (close to each other), which is common in contemporary cars, a foot placement error is plausible, and this shows that this can be a serious problem in real life too.

The level of urgency appears to have an effect on lateral deviation as found in chapter 4.4. For the UTR, the lateral deviation has a mean of 8.12% relative to the lane width. For the NTR (5.43%) and STR (5.68%) this deviation is smaller. This validates the finding of Borojeni et al. (2018), Politis et al. (2013), and Roche & Brandenburg (2018), who found that a higher urgency means an overall lower accuracy. This finding is valid for the lateral deviation as for the foot placement in this experiment and answers the sub question in terms of quality for the different types of urgency. A higher urgency means a lower TOT, however, the take-over quality of the driver decreases.

SQ2: *To what extent does the speech-rate of an auditory take-over request influence the take-over speed?*

The speech-rate, varied among the different types of TORs, were varied in three steps, namely -10, 0 and +10 based on the standard given speech-rate per take-over type. The take-over speed in terms of TOT is the lowest for the UTR with speech-rate +60, namely 2.16 seconds. The highest TOT is for NTR with a speech-rate of +0, which is 4.06 seconds.

For the NTR (varying speech-rate of -10, 0, +10), the speech-rate of -10 has the highest TOT on average and the +10 the lowest as expected. But no significant difference between the speech-rates was found for this urgency type. For the STR and UTR, the same behaviour is found where still the highest speech-rate has the lowest TOT. Still, the difference between these speech-rates are not significant for all urgency types at the .05 level.

From the 81 tests, whereby for each urgency, 27 tests are performed consisting of three types of urgencies, it is found that there is no clear evidence for a lower TOT when increasing the speech-rate. The different types of urgencies have already as standard a different speech-rate relative to each other, whereas within the conditions, there does not appear to be a significant effect. It can be concluded that the difference in TOT between the conditions does not depend on speech-rate.

SQ3: *How will the message conveyed to the driver influence the perceived urgency of an auditory take-over request?*

The perceived urgency, based on the message, is measured in terms of TOT, and for each type of urgency, the message is changed by using three different signal words. The word 'Note' used for the NTR syntax has the fastest TOT (3.81) and this is still higher than all the mean TOTs of the STR which is a condition with a higher urgency and thus expected to have a faster TOT. For the STR, the word 'Warning' has the fastest TOT (2.82), which is slower than the mean TOT for UTR (2.02), where 'Deadly' has the quickest TOT.

As found in chapter 4.3, the perceived urgency between the three different types of signal words per urgency type was found to be significantly different ($p < .01$) from each other. For the NTR, there is no significant difference found between the three different signal words ($p = 0.930$, $p > .05$), so it is not certain if this urgency depends on the signal word, the speech-rate or the full syntax. For the STR ($p = 0.015$) and NTR ($p = 0.044$), there are significant differences found ($p < .05$) between the signal words, that does indicate that these have a significant difference in urgency between each of them. The message conveyed to the driver does indeed influence the perceived urgency of an auditory TOR, whereby different signal words assign a certain urgency to the message. For NTR messages, the message "Note, take-over at your earliest convenience" will convey a non-urgent message, "Warning, take-over as soon as possible" does indicate a semi-urgent message, and "Deadly, take-over immediately" has an urgent effect on the TOR.

SQ4: *How does the lane width relate to the take-over quality during different levels of urgency of an auditory take-over request?*

The lane width, varied in three levels for each type urgency type (2.5, 3.0, and 3.5 metres), are measured in percentage of lateral deviation (LD) when taking over the vehicle. From the results of the experiment, explained in chapter 4.4, the highest mean LD is found for the UTR (11.71%, 3m wide), while the lowest LD (3.17%, 2.5 m wide) was found for the STR. The high LD for the highest urgency is supported by Politis et al. (2013), who found that higher urgency incorporates lower accuracy. The difference between the three lane widths according to the level of urgency are significant at the .1 level, but not at the .05 level ($p = 0.072$). A higher urgency means a higher lateral deviation.

What was found in the NTR was that there is a learning curve involved, whereby the first tests (1 – 3) show a high LD, whereafter 4 tests it stabilizes around the mean. For the STR and UTR, a learning curve was less prominent but still visible in the first tests. For the NTR, there were no significant differences in LD based on the lane width ($p = 0.463$, $p > .05$), whereas excluding the outliers in the first test could give significant differences. For the STR ($p = 0.003$) and UTR ($p = 0.037$), differences between the lane width and lateral deviation are significant.

The take-over quality is defined by a relative LD, as with broader lane widths, there is more room to deviate. Overall, the smallest lane width (2.5) has the least LD. The driver is more accurate when driving on a smaller lane and this supports the idea that the take-over quality in terms of lane width improves when driving on a smaller and that the driver knows, consciously or unconsciously, that it needs to drive as close to the line the vehicle is driving when taking over the driving task (e.g., Brandenburg & Chuang, 2019; Liu et al., 2016; Politis et al., 2015).

5.3 Conclusion

After answering each of the sub research questions in the previous paragraph, the main research question can be answered. The main research question was defined as follows:

What is the ideal setup of a simulator experiment that investigates the effects of personality on a speech-based auditory take-over request in conditional driving automation?

The influence of the personality trait of the human driver could not be measured in this experiment, therefore the results of this N=1-study is used for finding the ideal setup in terms of the influence of varying the levels of the variables, the design of the hard- and software, and the experience of the experiment in terms of setup, lessons and improvements for a larger simulator experiment measuring the influence of personality on the TOT.

The ideal setup of a simulator experiment is found to be dependent on several factors. There are found significant differences within different values of the variables used in this experiment. Changing the values of some of the variables in the auditory take-over request does influence the take-over time (TOT). Different levels of speech-rate were not demonstrable influencing the TOT, however, it helps to distinguish the level of urgency with their standard given speech-rate. Overall, this indicates that the driver is sensitive to the other three variables and their varying levels, and thus the conceptual model, as proposed in chapter 2, corresponds partially with the outcome of the experiment. In Figure 29 an improved version of the conceptual model is showed.

The design of the driving environment and simulator setup as proposed in chapter 3.2 was already optimized by the test runs to validate the software. The design as proposed and used in this experiment is capable of processing a large number of participants. In this experiment, only a small section of the driving environment is used, whereas it could be enlarged to include three TORS and have a driving time up to 25 minutes. Still, some optimisations for future tests could be recommend, which are explained in chapter 5.4.

The ideal setup of a simulator environment that investigates the effects of personality on a speech-based auditory take-over request, varying in three types of urgency, in conditional driving automation, is formulated in Table 12 where a final design of the variables and their levels, based on the findings in this experiment, is given. For the variable speech-rate, the values do matter in terms of differentiating the urgency level, whereas the standard given speech-rate fulfilled these tasks already without changing them between -10 and 10 as in this experiment. The syntax for the STR and UTR were chosen based on the quickest TOT whereby the difference between the words were significant. However, for the NTR, this was not significant, and is chosen to use 'Note' as this word has the quickest mean TOT of all three. Moreover, the lane width is significant, and the least relative LD was found for the 2.5 metres for all urgency levels, which suits perfectly for a final design of the simulator study.

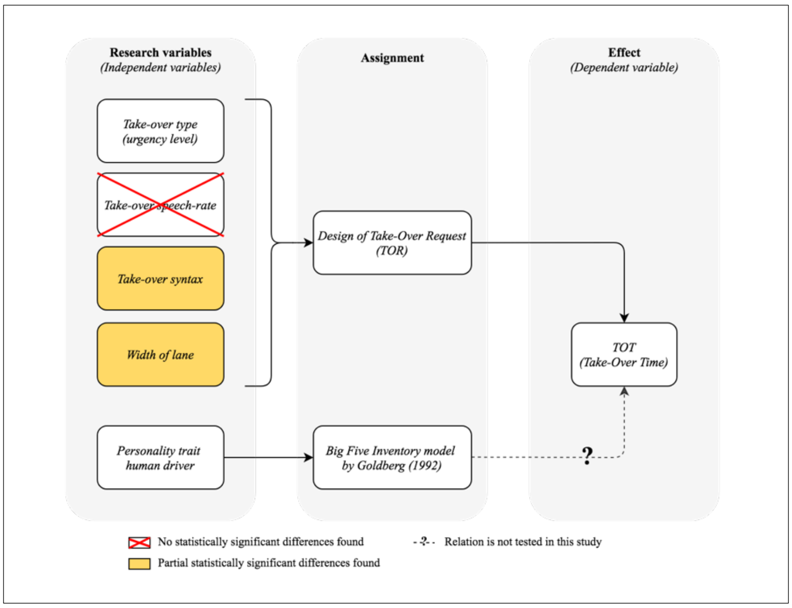
Table 12

Final speech-based auditory TOR design

Urgency	Type	Speech-rate	Syntax	Lane width
Low	*NTR*	*+0*	*"Hazard, take-over at your earliest convenience"*	*2.5*
Middle	*STR*	*+25*	*"Caution, take-over as soon as possible"*	*2.5*
High	*UTR*	*+50*	*"Deadly, take-over immediately"*	*2.5*

Figure 29

Revised conceptual framework



5.4 Recommendations

This paragraph provides (the reader) recommendations for further research investigating the effects of personality on an auditory take-over request in a conditionally automated vehicle.

This experiment was a N=1-study to find out if the human driver was sensitive of the variables, varying in levels, and to test the simulator setup and environment, which is fulfilled by this experiment. The only variable, discussed in this experiment but not able to test, is the personality trait of the driver (only one participant, one personality, took part of this experiment). Further research can include the personality trait of the driver, whereby the collection of participants (more than 100), grouped in their personality trait by a mathematical model (Appendix B.4) and other personal information, anonymized and ordered to be used for this large experiment. Although the effect of personality could mean that the ideal setup of the driving simulator environment could change, this is expected to have minimal effect on the hard- and software side, but larger effects on the sensitivity to the variables included in the experiment as other personalities could be more wait-and-see or energized (effect on the overall TOT), difference meaning of signal words, or be more precise and have less LD (e.g. Bazilinskyy & de Winter, 2017; Linkov et al., 2019; Taubman-Ben-Ari & Yehiel, 2012). This N=1-study tries to come up with one ideal setup incorporating the variables with their most effective level.

An effect which can have an influence on the experiment results are the practice effects. In this experiment, these effects could have played a role as the TOT was in later tests quicker than the first number of tests. These effects can be reduced by providing warm-up tests before the experiment begins. In this way, the participant knows what to expect and what to do. This means that the TOT is already quicker in the beginning and will thus over a number of tests not drop significantly but will be more stable. In the software, already made and finished for a larger experiment, a test-round is included for every participant before performing the experiment.

For recording the experiments, the driving simulator computer for this experiment was not able to keep up with the graphics of the driving scenario when at the same time recording the camera images to the hard disk. This problem was solved by using two external computers to record the images, while keeping the driving simulator computer only for two tasks, executing the driving scenario while registering the driver input, and recording the screen for the LD. This problem was specifically for this experiment a problem with the used driving simulator with older hardware (Intel i5 processor and AMD graphics 4gb, from 2014).

The tablet stand for the secondary task in the experiment was placed on the right-hand side of the driver. This placement is known when having a left-hand driving vehicle for having the on-board systems like navigation or radio. However, for long-term tasks, such as playing a game on the tablet, the participant may experience back or neck pain. A central display in front of the driver is therefore recommended.

The use of camera equipment who can automatically adjust itself for backlight or darkness, together with a high resolution (1080p, 1920*1080 pixels) or higher, and taking care of background light, does not only make the results more accurate, but will also help future software, such as eye tracking software (not implemented in this experiment due to software errors) who need to have a clear view on the eyes of the participant.

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Appendix A

A.1 Scientific paper

Does personality affect responses to auditory take-over requests? Validating a simulator experiment setup through a N=1-study

Abstract

Automated vehicles with conditional driving automation (SAE level 3 (SAE, 2018)) will request the human driver to intervene when reaching its system boundaries by issuing a take-over request (TOR). This study is investigating whether a speech-based auditory take-over request is influencing the time it takes from automated to manual driving, taking into account the personality trait of the human driver based on theory of Goldberg (1992). The audible warning is based on a woman's voice, varying in three levels of urgency, speech-rate and syntax, and incorporate a lateral deviation measurement by varying the lane width. Due to the COVID-19 pandemic, the experiment was changed to a N=1-study, meaning that only one participant, namely the lead researcher, partook in his own experiment. The driving experiment consisted of 81 runs, each having a TOR after approximately 8 minutes of automated driving. When the automated vehicle is in control, the human driver is asked to do a secondary task, namely the challenging game Tetris on a tablet to get distracted from the situation on the road. It was found that an increase in urgency (take-over type) means a decrease in take-over time (TOT). No significant differences were found for the speech-rate in relation to the TOT, whereas for the syntax, only the STR and UTR had significant differences. Lateral deviation was found to increase when urgency increases, which means that accuracy decreases with higher urgency. Overall, a final design is given based on the results of the N=1-study which could be used for a larger experiment including the personality trait.

Keywords: Automated vehicles, take-over request, driving simulator, personality trait, urgency

Introduction

Automated vehicles and other automated driving systems (ADS) are becoming increasingly commonplace. Fitted with various high-tech systems, such as adaptive cruise control (ACC) and/or lane keeping assist (LKA), current vehicles on the consumer market are capable of reaching SAE level 2, or Partial Automation (SAE International, 2018), meaning combined automated longitudinal and lateral control over the vehicle. While driving in level 2 automation, the driver is still required to monitor the environment and the state of the vehicle, and be ready to take-over control whenever necessary. To aid the driver in maintaining proper control over his/her vehicle, human-machine interfaces (HMI) are being implemented that provide either information to, or monitor the state of the driver.

With HMIs widely ranging in terms of modality (e.g., visual, auditory, or haptic), type of feedback (e.g., warning, state of the vehicle, or alerting), and purpose (providing feedback, monitoring the driver, or infotainment), the application of HMIs are seemingly endless. Consequentially, there is still much to know about the effect certain HMIs have on the driver in terms of behaviour.

Although it is commonly claimed that drivers predominantly use visual stimuli for gathering information (Sivak, 1996), auditory stimuli have some advantages over visual stimuli, namely that it is not visually distracting and that it yields the most increase in situation awareness (Walker, Stanton, & Young, 2006). Auditory feedback, or sound in general, can be perceived differently, depending on its pitch, duration, loudness, timbre, texture, as well as its direction (Burton, 2015). An auditory take-over request can therefore be perceived differently by the driver depending on, for example, how urgent this request sounds, which in turn can lead to different behavioural responses to the request (see e.g., Bazilinskyy et al., 2018).

While it is known that different people respond differently to certain events in traffic that result in, for instance, speeding, tailgating, or crash rates (e.g., Elander et al., 1993; Shinar, 1993; Taubman-Ben-

Ari & Yehiel, 2012), the effect personality has on driving with an automated vehicle is not yet researched. The time a driver responds to a take-over request from an ADS can vary anywhere between 2 and 26 seconds (Eriksson & Stanton, 2017), and attention strategies in, levels of trust towards, and general acceptance of ADS are similarly widespread (Hartwich et al., 2018; Körber & Bengler, 2014; Kyriakidis et al., 2017), which clearly illustrate the individual differences the automated driving domain needs to address.

Not only the differences between individuals have a clear, yet currently largely unknown, influence on drivers' behaviour, but also the road infrastructure has various effects on the way people drive their vehicles. For instance, the lane width has an effect on drivers' positioning and steering stability (Mechery et al., 2017). How this translates to the take-over performance from an ADS, however, remains unknown.

In this paper, an experimental setup for a large-scale simulator study towards the effects of personality on an auditory take-over request is being validated through a N=1-study. Initially, over 100 participants were intended to be recruited based on their personality (using the Big Five Inventory; John et al., 1991), and subjected to a simulated drive in a SAE level 3 or Conditional Automation vehicle with an auditory take-over request. However, due to the COVID-19 pandemic, human participation in experiments was restricted. Therefore, the lead researcher of this paper subjected himself to his own experiment in a so-called N=1-study in order to optimize and validate the variables used for his study. The research question posed in this paper therefore is fourfold:

(1) To what extent does a different level of urgency [of an auditory take-over-request] affect the take-over quality of the driver in a SAE level 3 automated vehicle?
(2) To what extent does the speech-rate [...] influence the take-over speed?
(3) How will the message conveyed to the driver influence the perceived urgency [...]?
(4) How does the lane width relate to the take-over quality during different levels of urgency [...]?

Via a 3*3*3*3=81 variations intrapersonal counterbalanced experimental setup, the abovementioned research questions will be answered, and suggestions will be made to optimize the setup of a large-scale driving simulator experiment to investigate the effects personality has on the take-over quality from an auditory take-over request.

Methods

Participants

Comprising a N=1-study, meaning that only one participant, namely the lead researcher, partook in his own experiment, the age of the (male) participant was 29, who had a driving experience of 10 years, with an average mileage of 1200 kilometres per year. After having completed the Big Five Inventory, he classified himself under the agreeableness trait.

Apparatus

The driving simulator used for this study comprised three screens offering 180° field of view, a Fanatec haptic steering wheel and clutch, brake and gas pedal, hand break, and car seat with seat belt (Figure 1). Unity software was used to design the scenarios for this experiment.

Figure 1

The Transport & Planning driving simulator

Two Logitech HD Pro C920 cameras with a resolution of 1920*1080 were directed towards the steering wheel and the driver's face, and one Microsoft LifeCam HD-3000 webcam with a resolution of 1280*720 was directed towards the pedals. These three cameras were used for the determination of the driver's take-over completion based on the driver's hand- and foot placements and movements as well as the eyes-on-road moment. Speakers were used to provide the auditory take-over request and ambient noise from the simulation.

A distractor task was implemented in the design of the study, using a 10.2 inch 5th generation Apple iPad on which the popular game of Tetris could be played.

Environment

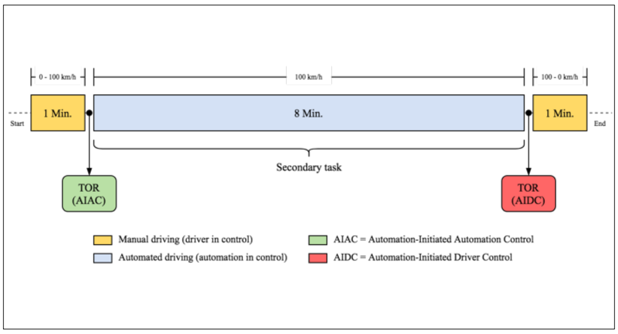
The scenario of the driving simulator study displayed a typical Dutch highway, as can also be seen in Figure 2. It consists of a 2-lane hard shoulder-separated two-way highway, with a maximum speed of 100 km/h, as per Dutch regulations since March 2020 (Schouten et al., 2019), and contains several easy curvatures (max. 15 degrees). Unity's Dutch highway package was used, containing Dutch signage, road markings, and asphalt colours, et cetera (see also Fig. 2). The lane width varied between 2.5 meters, 3.0 meters, and 3.5 meters depending on the condition, as this was part of the validation study of this experiment and was randomly and counterbalanced assigned to each run. Each run lasted approximately 10 minutes, with 1 minute of manual driving before automation took over, and 1 minute after TOR. The ADS was for approximately 8 minutes in the run as shown in Figure 3.

Figure 2

Still from the scenario used in this experiment, based on the A12 (Dutch highway)

Figure 3

Design of a run, including the manual driving before and after the automation is in control



Take-over request

The take-over request used in this experiment contained a women's voice (as that is considered to be the most appreciated type of feedback; see Bazilinskyy, & de Winter, 2015) uttering different sentences depending on the level of urgency. Three levels of urgency (non-urgent, semi-urgent, and urgent, in relation to the take-over request hereon forward called NTR, STR, UTR, respectively) are randomly and counterbalanced presented to the driver over the multiple runs, each run containing one take-over request. Furthermore, the take-over requests varied within their level of urgency in terms of syntax and speech rate, also in random counterbalanced order.

Experimental design

As mentioned above, the lead researcher partook in his own experiment. Therefore, instead of using a certain number of participants, the researcher subjected himself to all combinations to be validated in this study. Four variables were alternated in three ways:

(1) The take-over type, varied between a NTR, STR, and UTR. The NTR variable contained the female voice uttering "..., take over at your earliest convenience", the STR variable contained the female voice uttering "..., take over as soon as possible", and the UTR variable had the female voice saying "..., take over immediately".

(2) The take-over syntax, varied between three different signal words who had a similar loading per condition (cf. Hellier et al., 2002). For the NTR variable, the signal words "*Note*", "*Risky*", and "*Hazard*" were used, the STR variable used the signal words "*Warning*", "*Attention*", and "*Caution*", and for the UTR variable, the signal words "*Danger*", "*Deadly*", and "*Beware*" were varied. Two examples of complete take-over requests would thus be as follows:

"Danger, take-over immediately" (UTR), *or* "Attention, take-over as soon as possible" (STR).

(3) The take-over speech rate, varied between its normal setting (100% of normal duration (+0)) for the NTR variable, slightly faster for the NTR variable (87% of normal duration (+25)), and considerably faster for the UTR variable (78% of normal duration (+50)) with steps of -10, 0 or +10.

(4) The lane width, varied between 2.5 meters, 3.0 meters, and 3.5 meters, irrespective of the other variables.

Table 1 presents an overview of the variables and their variation levels within each variable.
Together, a total of 3 (NTR, STR or UTR take-over type) * 3 (NTR, STR or UTR take over syntax) * 3 (NTR, STR or UTR take-over speech rate) * 3 (2.5-, 3.0- or 3.5-meter lane width) = 81 different combinations were tested in this experiment.

Table 1

Experimental variables and their levels of variation within each variable

Variable	Level
Take-over type	NTR
	STR
	UTR
Take-over syntax	*-10*
	0
	+10
Take-over speech-rate	*Note, Risky, or Hazard* (NTR)
	Warning, Attention, or Caution (STR)
	Danger, Deadly, or Beware (UTR)
Lane width	2.5 meters
	3.0 meters
	3.5 meters

Procedure

The experiment took place between April 28th 2020 and May 11th 2020. In total, three full working days were used to perform the 81 experimental runs. Including setting up and closing off each separate run, each experimental run took approximately 15 minutes. After some runs (ranging between 4 to 7), a break was taken to avoid fatigue.

Results

After the experiments, the results were analysed with different camera and screen recording images combined together to reveal the take-over time (TOT) and the lateral deviation (LD) of each run. For all variables together, and per variable, a descriptive analysis was performed with testing the differences between the conditions for significance.

Figure 4

Overview of all tests with the take-over time (TOT) and daypart

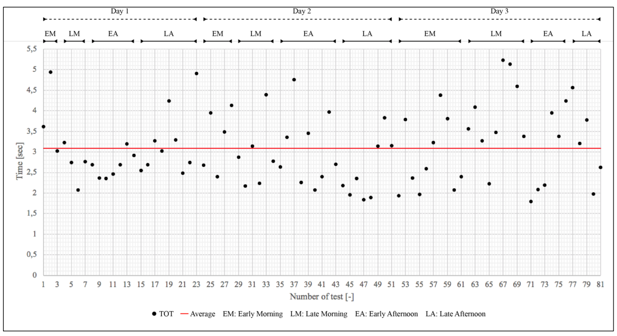
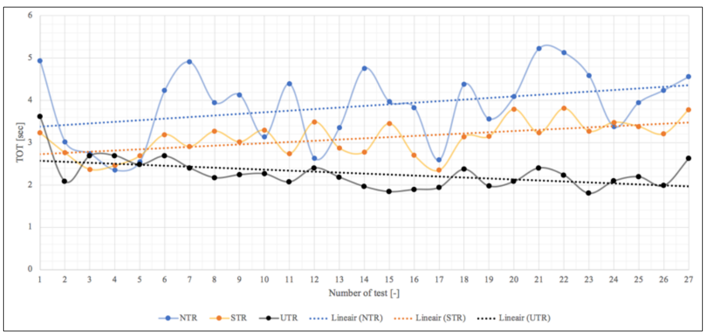


Figure 5

TOT for every take-over type individually



It was found that the mean TOT for all tests combined amounts 3.08 seconds (figure 4), whereas throughout the 81 tests, the TOT ranges between 1.80 and 5.23 seconds. The difference between the take-over types were significant, which shows a decrease in the mean TOT if urgency increases, meaning the slowest mean TOT for NTR and the quickest mean for the UTR (figure 5). For the speech-rate nuances, no significance is found between the levels for each of the urgency types. The difference between the urgency types in terms of the syntax is significant for even at the .01 level, which indicates that the sentences and signal words fits the meaning of the urgency. Moreover, for each type of urgency, only the STR and UTR have significant differences within their variation of signal words, whereas the NTR have no significant difference between the three signal words. While the syntax for NTR is not significant, yet one has been chosen for the final design, namely the word "Hazard" which has the slowest TOT and fits this type of urgency at best. For the STR the word "Caution" has been chosen, while for the UTR the word "Deadly" has the quickest mean TOT and thus chosen for this urgency type.

The lane width and thus the LD between the different types of urgency is significant. The highest relative mean LD is found for the UTR (8.117%), whereas the STR (5.678%) and NTR (5.432%) are smaller. This supports the finding of Politis et al. (2015) and Gray (2011) that accuracy is at the expense of higher urgency. Furthermore, within each urgency, the lane width differs between 2.5, 3.0 and 3.5 metres. In this experiment, for the STR and UTR the differences between the lane widths were found to be significant, whereas for the NTR this is not. For the NTR, a learning curve was found while by increasing the number of tests, the LD decreases rapidly after the first few tests, and then stabilizes.

By means of exploratory research, it was found that the accuracy of the foot placement when taking over the vehicle differ between the urgency levels, where the UTR has in 56% of the tests an error (pressing both the accelerator and brake pedal), and the NTR and STR only in 22% of the tests. The day part in which the tests were performed, divided by early morning (EM), late morning (LM), early afternoon (EA) and late afternoon (LA), no significant difference was found. Finally, the influence of the game was measured relative to the TOT but no significant difference was found.

Discussion

The influence of the personality trait of the human driver could not be measured in this study. For measuring the influence of the personality trait, more participants were needed and due to COVID-19 pandemic, this was not possible. The positive side of this change is that this study gives insight in the hard- and software performance of the driving simulator, the shortcomings and expectations of this research when performing this set-up with a large group of participants. Moreover, out of this N=1-study, validation of the variables and their levels are of importance and show that the participant is influenceable by variables and their difference in levels.

The lead researcher took part in his own experiment, which means that he knew beforehand what the experiment is about, which types of TORs he can expect, and how the environment is designed. To minimize the impact this has on the results, some measurements were introduced. The length of automation towards the TOR took approximately 8 minutes to take away time consciousness. Furthermore, all the tests, incorporating different levels of variables, are counterbalanced in randomized order. In this way, the researcher did not know when and what type of TOR he could expect.

Due to several reasons, including time, the number of variables is four, each varying in three levels. In this way, the sensitivity for the variables could be tested and recommendations could be given based on the results of these four variables.

Conclusion

From the results, several conclusions can be drawn. This research proves that a few variables and their given levels are significant and thus influence the TOT. This means that validation of variables and their levels are useful before implementing them in a large experiment. For example, significant different were found in the type of take-over (NTR, STR, UTR) used, the syntax in means of signal words and lane-width for the STR and UTR urgency types. From these results, an efficient design of variables and their levels can be defined for use in a larger experiment.

In this experiment, three types of urgencies are defined that as standard varied relative to each other by means of speech-rate and syntax. Furthermore, significant differences are found between the levels of urgency in terms of TOT and their influence on human errors such as the LD and foot placement when taking over the driving task. A higher urgency is found to incorporate less accuracy when taking over the driving task by the driver compared to a lower urgency.

The speech-rate were varied in three steps, namely -10, 0, and +10, with respect to the standard given speech-rate per urgency type (NTR: 0; STR: +25; UTR: +50). The variation in speech-rates did not provide significant differences in terms of the TOT. However, the speech-rate is still relevant for indicating a certain urgency as shown for the standard given difference in speech-rate.

The syntax, or signal words, were varied for each take-over type in three levels. The words were chosen on basis of the research of Hellier et al. (2002) and were assigned as is shown in table 1. Significant words were found for the STR and UTR, but not for the NTR. Still, the findings are useful for the design of the variables and their levels for a larger experiment. For the final design of the variables and their levels, it is chosen that the TOT between the three urgency levels are widespread, which means that the urgency level is more recognisable for the driver (which is one of the goals for this study). For the syntax, this means that for the low urgency (NTR), the signal word with the highest mean TOT is chosen, which is "Hazard". For the middle urgency (STR), the signal word with the middle mean TOT which is "Caution", whereas the highest urgency level (UTR) is chosen to have the signal word with the quickest TOT, which is "Deadly".

The lane width influences the LD when the driver takes over the vehicle. A narrower lane width has less LD than a wider lane. This means that the driver is consciously or unconsciously aware of the capacity it has to deviate the vehicle on the lane. Overall, a narrow lane means less LD, which is the preferred option to choose in all cases.

A final design for the variables, varying in levels for each urgency, are presented by table 2 and can be used for testing the influence of the personality trait against these variables in a larger experiment.

Table 2

Final design of the variables for each type of urgency

Urgency	Type	Speech-rate	Syntax	Lane width
Low	*NTR*	*+0*	*"Hazard, take-over at your earliest convenience"*	*2.5*
Middle	*STR*	*+25*	*"Caution, take-over as soon as possible"*	*2.5*
High	*UTR*	*+50*	*"Deadly, take-over immediately"*	*2.5*

Relating the research findings to literature, additional conclusions can be made, and findings can be validated. From literature (e.g., Bazilinskyy & de Winter, 2017; Politis et al., 2014) urgency levels can be made clearly distinguishable by a certain speech-rate, which was executed in this research by giving each take-over type a standard speech-rate that differs relative to each other. Furthermore, the signal words, found by Hellier et al. (2002) who indicate these signal words in terms of urgency and gender of speaker, are used in this research for varying the different types of urgency. As found by this experiment, some of these words do indeed indicate the urgency level, especially the words used for the STR and UTR variables. The lane width in relation to the lateral deviation was found to be significant for higher urgencies, this is supported by Politis et al. (2013). The finding of a learning curve for keeping in the lane are not found exactly in literature, but some tend to remark them in their research (e.g., De Groot et al., 2011; Van Leeuwen et al., 2011).

Recommendations

This N=1-study proves that validating variables and their levels are interesting and useful for in a larger experiment. Even more, the setup in terms of hard- and software can be tested beforehand, errors could be solved, and indications about results could already be made. However, the personality trait could not be tested in this N=1-study. Therefore, more participants are needed to say something about the influence of the personality trait on a speech-based auditory take-over request.

Some differences between variables and their levels were not significant, which could be researched further in a larger experiment. The variables and their levels are tested on one participant, namely the lead researcher, which has the agreeableness personality. It could be that other personalities have different outcomes on these variables and levels. Further research in terms of more participants could give insights in these differences. This N=1-study gave an insight in the usefulness of such an experiment and allows researchers to get insight of what to expect and how to design their experiment efficiently.

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Appendix B

B.1 Data Management Plan (DMP)

MSc-CiTG - Driving simulator study with the involvement of the Big Five personality traits

A. General TU Delft data management questions

1. Is TU Delft the lead institution for this project?

- Yes, leading the collaboration.

2. If you leave TU Delft (or are unavailable), who is going to be responsible for the data resulting from this project?

Themis Marfoglia and Thijs Ebbers (Master students CiTG-TIL), Dr. D.D. Heikoop (Supervisor project), Prof.dr. M.P. Hagenzieker, Dr. J.A. Annema, Dr. Ir. J.C.F de Winter.

3. Where will the data (and code, if applicable) be stored and backed-up during the project lifetime?

- Project Storage at TU Delft (Dr. D.D. Heikoop will apply for the project storage).

4. How much data storage will you require during the project lifetime?

- 250 GB - 5 TB (Storage for small data like heart rate and filled in questionnaires, but also video footage of the driving experiment. This data will be stored for 10 years (Prof.dr. M.P. Hagenzieker will be responsible for this data)).

5. What data will be shared in a research data repository?

- Not all data can be publicly shared - please explain below which data and why cannot be publicly shared Our thesis reports will be publicly available through the repository of the TU Delft. All other data cannot we publicly available, this data entails the personality data of the participants and all driving metrics, heart rate, and skin conductance data that are collected during the driving simulator experiment.

6. How much of your data will be shared in a research data repository?

- < 100 GB (Only the Master thesis's will be shared (only pictures and plain text))

7. How will you share your research data (and code)?

- My data can't be shared in a repository, so the metadata will be registered in Pure instead and all research publications resulting from the project have a statement explaining what additional datasets/materials exists; why access is restricted; who can use the data and under what circumstances.

8. Does your research involve human subjects?

- Yes, more than 100 participants.

9. Will you process any personal data? Tick all that apply (leave all unchecked if you do not process any personal data)

- Other types of personal data - please explain below
- Telephone numbers
- Names and addresses
- Photographs, video materials, performance appraisals or student results
- Special categories of personal data (specify which): race, ethnicity, criminal offence data, political beliefs, union membership, religion, sex life, health data, biometric or genetic data
- Gender, date of birth and/or age
- Email addresses and/or other addresses for digital communication
- Other types of personal data include heart rate, skin conductance, personality

B. TU Delft questions about management of personal research data

1. Please detail what type of personal data you will collect, for what purpose, how you will store and protect that data, and who has access to the data.

Please provide your answer in the table below. Add an extra row for every new type of data processed:

Type of data	How will the data be collected?	Purpose of processing	Storage location	Who will have access to the data
Possession of a driving license	Online questionnaire	Possession of a driving licence is required for participating in the experiment.	If different from what was mentioned in Q3	Thijs Ebbers, Themis Marfoglia, and the comission of the thesis: D.D. Heikoop, M.P. Hagenzieker, J.S.F. de Winter, J.A. Annema (and everyone they allow to use the data)
Availability to participate in experiment	Online questionnaire	If the participant is not available during experiment data, the participant will be excluded from the experiment.		Thijs Ebbers, Themis Marfoglia, and the comission of the thesis: D.D. Heikoop, M.P. Hagenzieker, J.S.F. de Winter, J.A. Annema (and everyone they allow to use the data)
Consent form	Online questionnaire	To understand if the participant understood the information provided; if they agreed that the data is used for the purpose of this study; that their participation is voluntarily, and that they are not automatically selected after filling in the questionnaire (participants will be selected based on their personality)		Thijs Ebbers, Themis Marfoglia, and the comission of the thesis: D.D. Heikoop, M.P. Hagenzieker, J.S.F. de Winter, J.A. Annema (and everyone they allow to use the data)
Contact information	Online questionnaire	The following data will be collected: name and surname, e-mail address, telephone number. This will be used to contact the participants.		Thijs Ebbers, Themis Marfoglia, and the comission of the thesis: D.D. Heikoop, M.P. Hagenzieker, J.S.F. de Winter, J.A. Annema (and everyone they allow to use the data)
Demographic information	Online questionnaire	Gender, age, which country they are from, in what city they live, their profession, education. This data will only be used for the analysis of the data, once the participants have been selected and have participated in the experiment.		Thijs Ebbers, Themis Marfoglia, and the comission of the thesis: D.D. Heikoop, M.P. Hagenzieker, J.S.F. de Winter, J.A. Annema (and everyone they allow to use the data)

Driving experience questionnaire	Online questionnaire	How many years do they have a driving license? How many days they drove (average) in the last 12 months? Their mileage in the last 12 months? Experience with ADAS (Advanced driving assistance systems)? Which ADAS they used. This data will only be used for the analysis of the data, once the participants have been selected and have participated in the experiment.		Thijs Ebbers, Themis Marfoglia, and the comission of the thesis: D.D. Heikoop, M.P. Hagenzieker, J.S.F. de Winter, J.A. Annema (and everyone they allow to use the data)
Health questionnaire	Online questionnaire	If the participants use lenses or glasses, if they use drugs, and how often they use drugs. Also, this data will only be used for the analysis of the data, once the participants have been selected and have participated in the experiment.		Thijs Ebbers, Themis Marfoglia, and the comission of the thesis: D.D. Heikoop, M.P. Hagenzieker, J.S.F. de Winter, J.A. Annema (and everyone they allow to use the data)
Big Five questionnaire	Online questionnaire	44 questions from the Big Five questionnaire to identify which personality traits they have. This data will be used to select the participants for the experiment. Participants will not be classified as having a good or bad personality.		Thijs Ebbers, Themis Marfoglia, and the comission of the thesis: D.D. Heikoop, M.P. Hagenzieker, J.S.F. de Winter, J.A. Annema (and everyone they allow to use the data)

2. Will you be sharing personal data with individuals/organisations outside of the EEA (European Economic Area)?

- No

3. What is the legal ground for personal data processing?

- Informed consent - please describe the informed consent procedures. you will follow the informed consent that has been sent by mail to Kees den Heijer and Marlou Veloo.

4. Will the personal data be shared with others after the end of the research project, and if so, how and for what purpose?

- No data will be shared with others after the project.

5. Does the processing of the personal data results in a high risk to the data subjects?

If the processing of the personal data results in a high risk to the data subjects, it is required to perform a Data Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data during your research (check all that apply). If two or more of the options listed below apply, you will have to complete the DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to receive support with DPIA. If only one of the options listed below applies, your project might need a DPIA.
Please get in touch with the privacy team: privacy-tud@tudelft.nl to get advice as to whether DPIA is necessary.

If you have any additional comments, please add them in the box below.

- Evaluation or scoring
- Sensitive personal data

Evaluation or scoring; this does not exactly apply to our research, due to the fact we will evaluate or score the participants on their personality traits, but this is not done repeatedly (as consulted with Marlou Veloo (privacy officer TU Delft)).

B.2 Ethical approvement

Date 11-02-2020
Contact person Ir. J.B.J. Groot Kormelink, secretary HREC
Telephone +31 152783260
E-mail j.b.j.grootkormelink@tudelft.nl

Human Research Ethics Committee
TU Delft
(http://hrec.tudelft.nl/)
Visiting address
Jaffalaan 5 (building 31)
2628 BX Delft
Postal address
P.O. Box 5015 2600 GA Delft
The Netherlands

Ethics Approval Application: Big Five personality traits and driving with automated driving systems - a simulator study
Applicant: Heikoop, Daniël

Dear Daniël Heikoop,

It is a pleasure to inform you that your application mentioned above has been approved.

Dear Daniël,

The information about the project is very thoroughly presented to the participants. HREC would like to suggest to you change the order of consent form and experiment information: i.e. put the consent-form at the start of the document.

Kind Regards,

Jan Salden

Acting Secretary HREC

Good luck with your research!

Sincerely,

Dr. Ir. U. Pesch
Chair HREC
Faculty of Technology, Policy and Management

B.3 Consent form

Information sheet regarding the experiment and study + Informed consent form
February 2020

1. Research group

1.1 Researchers in charge of the project

T. Ebbers	MSc. Student	Delft University of Technology
T. Marfoglia	MSc. Student	Delft University of Technology
M.P. Hagenzieker	Professor	Delft University of Technology
J.C.F. de Winter	Associate professor	Delft University of Technology
J.A. Annema	Assistant professor	Delft University of Technology
D.D. Heikoop	Post-doctoral researcher	Delft University of Technology

1.2 Organizations

Faculty of Civil Engineering and Geosciences, Department of Transport, Delft University of Technology.

This study is part of the research project 'Meaningful Human Control over Automated Driving Systems' (MHC-ADS) of the Department of Transport and Planning, Delft University of Technology.

2. This document

This informed consent document consists of two parts:
1. Information sheet
2. Informed consent form

You are asked to read this document carefully before signing the informed consent form. Information is provided regarding the purpose of this study, your participation, the procedure of the experiment, the expected benefits, risks associated with this experiment, information regarding data protection, privacy and confidentiality, the sharing of the results, and who are responsible for this study. If something is unclear or needs additional explanation, please contact any of the researchers. After reading the information sheet and if all questions or concerns are answered, you can choose to participate in this study. To participate, please fill in the informed consent form on the last page of this document. Your signature is required for participation.

3. Purpose of this research

An increasing number of vehicles are already equipped with longitudinal and lateral automated support up to SAE level 2 (SAE, 2018). Nowadays, SAE level 3 automated vehicles are the next step in which the human driver is still a fallback-ready user in case the vehicle is requesting it. This part, also called the transition of control, whereby the vehicle needs to interact with the human driver to take over control is interesting to research, especially when human drivers differ in personality traits. A driving simulator study with around 100 participants will be performed regarding the time it takes a driver to get full control of the vehicle. Moreover, this will be done by speech-based auditory feedback in several stages of urgency. Various measurements will be carried out for the aim of this research and will be analyzed and published in order to contribute to the research in the interaction between the vehicle and the human driver.

4. Participation

4.1 Location of the experiment

The experiment will be held at the faculty of Civil Engineering and Geosciences at Delft University of Technology: Stevinweg 1, 2628CN, Delft. The driving simulators are located on the 4th floor, room 4.32.6.

4.2 Eligibility criteria

You are invited to participate in this experiment if:

- You are 18 years or older
- You have a car driving license
- You are not under the influence of drugs, alcohol or other substances that compromise your driving ability.
- You have not experienced (severe) simulation or motion sickness.

The researchers reserve the right at any time to refuse or excuse (from an in-progress session) any participant who meets/no longer meets the study requirements or who is behaving in an unnecessarily unsafe manner.

4.3 Voluntary participation and the right to refuse or withdraw

Participating in this study is completely voluntary. If you have any questions or concerns regarding this study, please contact one of the researchers. If you do agree to participate in this study, you can withdraw at any moment without comment or penalty. Withdrawal from the experiment is possible until 10 working days after completing the experiment. In case of withdrawal, all personal data will be removed from this study. Participants will be given the opportunity to get insight into their own data obtained in this experiment - ask any of the researchers to provide you with this data.
Rectification of the data is not possible.

5. Procedure

This study consists of one driving simulator experiment. The experiment focuses on the personality of drivers and their behavior in automated vehicles. In the experiment, transitions of control between the automated driving system and the driver will be simulated. Data regarding how drivers experience these control transitions, and their according to driving behavior, will be collected. The data will be collected by the driving simulator, a camera and by sensors mounted on the fingers of the participants to measure heart rate and electrical conductivity of the skin.

5.1 Experiment

You will be asked to perform one driving sessions of approx. 30 minutes in a highway setting. Data from this experiment will be used to analyze the effect of personality on the experience of transitions of control in automated vehicles. The simulated vehicle is a generic sedan car. The simulated vehicle is controlled in the same way as a normal car with automatic gearbox: it has pedals and turn signals. Furthermore, the dashboard of the vehicle will be simulated showing the turn signals, speedometer and tachometer. Also, side view mirrors and a rearview mirror are simulated.
The following data will be collected: steering and pedal input, eye movement, heart rate, skin conductance level.

5.2 Prior to the simulator sessions

Prior to the simulator sessions, this information sheet with the informed consent form will be sent to you. Furthermore, you are asked to fill in a demographic questionnaire,

a driving experience questionnaire, a healthiness questionnaire, and the Big Five personality test.
Once at the experiment location, a safety instruction will be given on operating the driving simulator.

5.3 Practice simulator session

The experiment includes a practice round, in which you can get familiar with the driving simulator like the virtual environment and the steering wheel and pedals. This practice round will take around 5 minutes in which you have some freedom to drive around and to follow some instructions.

5.4 Simulator session instructions

5.4.1 Driving

In the experiment, you will be asked to drive as normally as you are allowed to do in normal driving conditions with respect to traffic regulations. Moreover, you will be driving in the utmost right lane on a three-lane highway and are allowed to take-over slower vehicles if circumstances permit this.

5.4.2 Controls

In the first part of the scenario, the vehicle is driving autonomously on the highway at 100 km/h. During this part of the scenario, no input of the human driver is necessary (like steering or gas pedal input). The vehicle could ask at a certain moment to take-over control of the vehicle, in which you have to put your hands on the steering wheel and feet on the pedals.

5.4.3 Scenario

In the scenario, other vehicles will be driving around on the highway and you need to treat them just like you would do in a normal driving situation. Moreover, the scenario allows overtaking other vehicles and driving faster than the maximum speed. You are asked to drive like the normal driving rules you know, so use your direction indicator and do not drive faster than allowed.
The full scenario is a long stretch of a highway, in which several turns are included. You are driving first in automated mode, while at a certain time the vehicle is requesting to take-over control and drive further in manual mode till the vehicle again informs that it will take over the driving task from you.

5.5 Duration and time commitment

The experiment will take around 60 minutes, which includes the welcome, signing the consent form, getting familiar with the driving simulator in the test round and filling in the questionnaire.

6. Expected benefits

The outcome of this experiment will be used for the research into automated vehicles. It will not directly benefit you as a driver immediately, but it will improve the understanding of automation and the interaction between a vehicle and a human driver. Your contribution to this project will help make automated vehicles in the future even more likely and better.

7. Risks associated with participation

In the simulator, participants may experience simulator motion sickness. The experiment can be stopped immediately if necessary, by the participant or by the researcher. Furthermore, the participant needs to wear the seatbelt during the experiment. Taking off the seatbelt during the experiment will cause the test to stop.

If the participant loses control over the vehicle, this can result in an accident in the virtual scenario. This does not harm the participant physically, but it can be emotionally demanding. To overcome these types of problems, no other persons are visible in the scenario and other vehicles are non-solid objects (the participant can drive through them).
The simulator is located in a small room at the faculty CiTG of the TU Delft, in which no mechanical ventilation is available. To get more airflow in the room, a fan will be used. Participants can fall over the cables of this fan or from the simulator itself. But due to the fact, these cables are stuck on the floor by tape, the chance is small. During the experiment, temporary cables can be necessary to fulfill the simulator study, so before the participant can leave the simulator, the researcher needs to take these cables away.

8. Privacy and confidentiality

All data collected in this study will be stored securely as of the Data Management policy of Delft University of Technology. Only the researchers involved in this study can access the data. Data will be stored, encrypted and pseudonymised, on the TU Delft server. This data will be stored for 10 years. The non-identifiable data from this study will be stored in an open-access database for future use in comparative studies and for secondary analysis.

9. Sharing of results

The results of the study are presented in the research reports of the researcher. Moreover, the study might be presented in a scientific journal. The data of the driving simulator could be used in follow-up research into this field like in related studies, simulator training and the design of vehicles.

10. Responsibility

The researchers and the institution involved in this research are not responsible for any damages during the travel to or from the location of the experiment.

11. Questions/further information about the project

If you have any questions or comments regarding the study and the experiment, or if you require further information, please contact one of the researchers:

Researchers	*E-mail addresses*	*Telephone numbers*
T. Ebbers	t.ebbers@student.tudelft.nl	+31 (0)630989569
T. Marfoglia	t.marfoglia@student.tudelft.nl	+31 (0)681220906
M.P. Hagenzieker	m.p.hagenzieker@tudelft.nl	
J.C.F. de Winter	j.c.f.dewinter@tudelft.nl	
J.A. Annema	j.a.annema@tudelft.nl	
D.D. Heikoop	d.d.heikoop@tudelft.nl	

12. Ethical approval and complaints regarding the conduct of the project

This study will be approved by the Human Research Ethics Committee (HREC) of the TU Delft. A verification of this approval can be obtained by sending an email to HREC@tudelft.nl. If you have any complaints or suggestions about the ethical conduct of this project, please contact HREC by sending an email to the above-mentioned email address.

Consent form

Please tick the appropriate boxes	Yes	No
Taking part in the study		
I have read and understood the study information dated Februari 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.	□	□
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.	□	□
I understand that taking part in the study involves collecting data like video-recording, which will be transcribed as text, and completing questionnaires.	□	□
Risks associated with participating in the study		
I understand that taking part in the study involves the following risks: motion sickness due to the experiment in a driving simulator. Emotional discomfort when experiencing a virtual accident.	□	□
Use of the information in the study		
I understand that the information I provide will be used for master's theses, conference presentations and articles in scientific journals.	□	□
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.	□	□

Future use and reuse of the information by others

I give permission for the data obtained with the sensors, camera and driving simulator, as well as all data from the questionnaires that I provide to be archived in the TU Delft repository so it can be used for future research and learning. ☐ ☐

Signatures

______________________	______________________	____________
Name of participant	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 what they are freely consenting.

______________________	______________________	____________
Researcher name	Signature	Date
______________________	______________________	____________
Researcher name	Signature	Date

B.4 MATLAB script

Script: Indicating participants by personality trait from output Excel file of Qualtrics.

```
clear all;
clc;


%% Computations

%You have to input the cells where the names of the participants are:
[~,names]  = xlsread('Answers.xlsx','Hoja1','B2:C70');

%You have to input the cells where the answers of the participants are:
m = xlsread('Answers.xlsx','Hoja1','AG2:BX70')';

s = length(names);

%Compute the score of each category:

E=[m(1,:)+6-m(6,:)+m(11,:)+m(16,:)+6-m(21,:)+m(26,:)+6-
m(31,:)+m(36,:)];
A=[6-m(2,:)+m(7,:)+6-m(12,:)+m(17,:)+m(22,:)+6-m(27,:)+m(32,:)+6-
m(37,:)+m(42,:)];
C=[m(3,:)+6-m(8,:)+m(13,:)+6-m(18,:)+6-
m(23,:)+m(28,:)+m(33,:)+m(38,:)+6-m(43,:)];
N=[m(4,:)+6-m(9,:)+m(14,:)+m(19,:)+6-m(24,:)+m(29,:)+6-
m(34,:)+m(39,:)];
O=[m(5,:)+m(10,:)+m(15,:)+m(20,:)+m(25,:)+m(30,:)+6-m(35,:)+m(40,:)+6-
m(41,:)+m(44,:)];

n=[E;A;C;N;O];

%We extract the mean and then divide by the standard deviation of each
category in
%order to have a matrix with all the normalized scores.

norm=(n-mean(n))./std(n);

m_norm=norm.*(norm==max(norm))-100*(norm~=max(norm));

[snor,index]=sort(m_norm','descend');

%Snor is the matrix with all the scores sorted from bigger to smaller.
%Index is the order where each person is in the sorted matrix.

l_len=sum(snor~=-100);

disp('Category E list')
names(index(1:l_len(1),1))'
disp('Category A list')
names(index(1:l_len(2),2))'
disp('Category C list')
names(index(1:l_len(3),3))'
disp('Category N list')
names(index(1:l_len(4),4))'
disp('Category O list')
names(index(1:l_len(5),5))'
```

B.5 C++ Script

Script: Automated to manual and manual to automated driving.

```
using UnityEngine;
using System.Collections;

public class AgentSwitcher : MonoBehaviour {
    private Agent agent;

    public bool isHuman = true;

    public void Awake() {
        agent = GetComponent<Agent>();
    }


    public void SwitchAgent() {
        isHuman = !isHuman;

        if (agent != null) {
            agent.switchToHumanOrAgent(isHuman);
        }
    }

    private void DoActivateTrigger()
    {
        StartCoroutine("Switch");
    }

    IEnumerator Switch() {
        if (agent == isHuman) {
            yield return new WaitForSeconds(0);
            SwitchAgent();
        }
        else {
            StartCoroutine("WaitingTime");
        }
     }

    IEnumerator WaitingTime() {
        yield return new WaitForSeconds(10);
        SwitchAgent();
        // AND turn indicators off
    }

    void Update() {
        if (Input.GetKeyDown(KeyCode.M)) {
            StopCoroutine("WaitingTime");
            SwitchAgent();
            // AND turn indicators off
        }
    }
}
```

B.6 Poster

Driving simulator experiment

Two master theses regarding behaviour of drivers in automated vehicles based on their personality

When: March till April 2020

Duration experiment: approx. 30 minutes

Where: Driving simulator is located at TU Delft, faculty of CiTG

TU Delft

Apply by filling in the questionnaire:

tiny.cc/simulatortest

Appendix C

C.1 Original work plan pilot study

How personality affects take-over time during conditional driving automation with a speech-based auditory take-over request: A simulator study

The new direction of my thesis, which consists of performing the simulator test only with one person (N=1), will be executed at the end of April. This simulator test will, due to regulations of the TU Delft, have a duration of five days. The simulator test is for testing the settings in the simulator, like steering wheel, pedals, screens, cameras, and audio, but also to see which kind of data is logged and how all this can be optimized in such a way, that performing this simulator study with a large group of participants (e.g. N=100), will lead to an unbiased and efficient experiment.
For this one-person simulator testing, a schedule and plan of action are formalized to do as much as possible in an efficient way in these five days.

Testing
In the driving simulator, the software package of Unity with several builds of the driving simulator environment will be tested. These builds are already designed in such a way that the variables to optimize, with a certain level, are already implemented and ready for use. On basis of randomization and counterbalancing, the timetable in table 15 will indicate which build number needs to be picked off the outcome of the table. Furthermore, several hardware needs to be set up and tested such as the camera, the storage mediums and the headphones. These are not yet equipped or not set up earlier in the right way for this test so these must be set up first. The data-logging of the hardware (e.g. steering wheel/pedals) needs to be investigated and tested to find out how the data is being saved and logged. After the hardware and software are set up correctly, a test-driving scenario will be tested before the experiment will start.
One experiment takes 10 minutes to complete, where in 9 minutes the take-over request will be initiated, and the driver can drive manually for approximately a minute before the experiment will end. All the scenario files are made beforehand (marked with a random number from 1 to 81) and are available to start immediately from the computer. The camera will be set before the experiment begins and afterwards the data will be stored on the computer and storage medium. Taking 15 minutes for every experiment to finish will be sufficient.

The main focus of this research is on the dependent variable namely the take-over request, varying in three levels of urgency. The three types of take-over requests will be referred to as 'Urgent Take-over Request' (UTR); 'Semi-urgent Take-over Request' (STR) and 'Non-urgent Take-over Request' (NTR).

Table 13. Overview of all variables that influence the take-over performance

Take-over performance variables
Take-over type
Take-over time
Take-over speech-rate
Take-over semantics
Take-over syntax
Take-over information
Environment
Weather
Traffic intensity
Traffic speed
Traffic users

Lane width
Total number of lanes
Obstacles on lane
Passengers

Variables

In the simulator test, the independent variables will be varied to optimize them. The independent variables chosen to be optimized in the test are the take-over type, take-over syntax, take-over speech-rate and the width of the lane.

Take-over type

The take-over request is varied in three types or urgency, namely an urgent take-over request (UTR), semi-urgent take-over request (STR) and non-urgent take-over request (NTR). These take-over types will be randomized during the real driving experiment, which can be varied in 3! different orders. Due to the design of this test experiment, where only one take-over request will be tested in each scenario, the take-over type will be counterbalanced together with the other variables to counteract order effects.

Take-over speech-rate

The speech rate is important in a take-over request when urgency is involved. For this research, the online tool Acapela- box (https://acapela-box.com) is used to reproduce natural speech-based phrases. Furthermore, this tool is used in some researches into speech-based messages in automated vehicles such as Bazilinskyy & de Winter, (2017). The tool has a built-in feature to adjust the speech-rate, which in this case is useful to vary and to optimize. For the UTR, the speech rate is set to fast (+50), meaning a 78% duration of its nominal value. Moreover, for the STR the speech rate is set to a value of 87% (+25) of the nominal speech duration and the non-urgent speech is set to a value of 100% (+0, normal duration).

Take-over syntax

The phrase pronounced by the take-over request is important in terms of wording such as the length of the sentence or the use of signal words. Several signal words are available for indication a certain urgency which in this case will be varied to choose the most suitable belonging to the situation. The mean ratings of the urgency of signal words are researched by Hellier et al. (2002) in a research of speech warnings. The outcome of this research is used to design these signal words and are used in this research for finding the optimal sentence for each take-over request.

NTR:	TXT 1. *Note*, take-over at your earliest convenience
	TXT 2. *Risky*, take-over at your earliest convenience
	TXT 3. *Hazard*, take-over at your earliest convenience
STR:	TXT 1. *Warning*, take-over as soon as possible
	TXT 2. *Attention*, take-over as soon as possible
	TXT 3. *Caution*, take-over as soon as possible
UTR:	TXT 1. *Danger*, take-over immediately
	TXT 2. *Deadly*, take-over immediately
	TXT 3. *Beware*, take-over immediately

Lane width

The width of the lane is an interesting variable due to the aim of this study, namely the research of the take-over performance. In this take-over performance, lane deviation depends directly from the lane width which can be adjusted in the scenario. In Europe, the lane width varies between the 2.5 and 3.5 meters. Moreover, in countries such as the Netherlands, the left lane is sometimes just 2.5 meters wide whereas the right lane is 3.5 meters because of the freight traffic (Ministerie IenW, 2007).

This lane will be varied between 2.5 and 3.5 meters to optimize the lane width concerning the lane deviation of the driver.

More variables can be varied but in the amount of time available, a selection is made with the above-mentioned variables and their levels. A summary of the chosen variables and their levels are shown in table 14.

Table 14. Variables and their variety of levels

Variable	Levels
[A] Take-over type	[0] UTR [1] NTR [2] STR
[B] Take-over speech-rate	[0] -10 [1] 0 [2] +10
[C] Take-over syntax	[0] TXT 1 [1] TXT 2 [2] TXT 3
[D] Lane width	[0] 2.5 meters [1] 3.0 meters [2] 3.5 meters

Counterbalanced design

To perform a valid experiment, the design of the experiment needs to be counterbalanced to evaluate the performance through the test conditions. Otherwise this confounding influence will affect the accuracy of the results of the experiment. Counterbalancing is a method to arrange the test conditions in a different order for each group, this group could be a certain group of participants but will in this case only one participant. A counterbalanced design could be made with help of statistics and by hand calculation, but the software Ngene (Version 1.2.1) can do this automatically and guarantee in this way that the design is optimized with no correlations and is counterbalanced (See Appendix C2).

Due to the fact four types of variables are used where each of them varies in three levels, the order in which the kind of level of the certain variable is given in the take-over request is important. This is also known as the permutation of the levels, in how many positions can the levels be placed. The experiment has 4 variables, so 3*3*3*3 = 81 variations of order so 81 tests in the experiment.

Apparatus

For the five days of testing, several devices are needed and on beforehand taken to the CiTG building.

- *Driving simulator.* Already installed in the CiTG department Transport & Planning on the 4th floor. The software, screens, chair, steering wheel and pedals are ready for use.
- *Driving environment files.* USB stick with the programmed Unity file with several driving environment scenarios will be copied to the unity software.
- *Backup system.* Laptop with external backup hard-disk and camera for relieving the simulator computer in terms of CPU usage and for safety of the research files.
- *Headphone.* A headphone is needed to reduce the ambient noise outside the simulator environment (the vehicle engine noise and road noise of the simulator is hearable and will be hearable during the take-over request to meet reality).
- *Camera.* A camera with a resolution of 1920x1080 need to be installed in front of the driver to track the eye and hand movement. The images of this camera will be used for indicating the take-over time (hands on wheel, eyes on road) due to the fact the simulator steering wheel is not always as accurate as needed. The images are analyzed by the researcher itself.

Safety

Due to the COVID-19 regulations, the CiTG building (location experiment will take place) will be unoccupied during the days of the experiment. Only at the main entrance people of the security will be present during the day and due to safety, a copy of the timetable (Table 15) will be given to them to indicate when the experiment will start and end, and when the researcher will have a break and eventually wants to go out for a walk. Moreover, contact details will be given to have contact in case of emergency situations.

For own safety and that of other researchers, alcohol wipes and hand soap will be used to clean the simulator room afterwards in order to prevent the spread of bacteria and viruses.

Table 15. Timetable of the driving simulator study

Date	**28-04-2020**	**30-04-2020**	**04-05-2020**	**07-05-2020**	**11-05-2020**
Day	*Tuesday*	*Thursday*	*Monday*	*Thursday*	*Monday*
9.00 – 9.15	Setting up hardware	Setting up hardware	Setting up hardware	Setting up hardware	Setting up hardware
9.15 – 9.30	Setting up hardware	Setting up software	Setting up software	Setting up software	Setting up software
9.30 – 9.45	Setting up software	Test 18	Test 38	Test 62	Test
9.45 – 10.00	Setting up software	Test 19	Test 39	Test 63	Test
10.00 – 10.15	Several tests	Test 20	Test 40	Test 64	Test
10.15 – 10.30	Several tests	Test 21	Test 41	Test 65	Test
10.30 – 11.00	Coffee break	Coffee break	Coffee break	Coffee break	Coffee break
11.00 – 11.15	Test 1	Test 22	Test 42	Test 66	Test
11.15 – 11.30	Test 2	Test 23	Test 43	Test 67	Test
11.30 – 11.45	Test 3	Test 24	Test 44	Test 68	Test
11.45 – 12.00	Test 4	Test 25	Test 45	Test 69	Test
12.15 – 12.30	Test 5	Test 26	Test 50	Test 70	Test
12.30 – 13.30	Lunch break	Lunch break	Lunch break	Lunch break	Lunch break
13.30 – 13.45	Test 6	Test 27	Test 51	Test 71	Test
13.45 – 14.00	Test 7	Test 28	Test 52	Test 72	Test
14.00 – 14.15	Test 8	Test 29	Test 53	Test 73	Test
14.15 – 14.30	Test 9	Test 30	Test 54	Test 74	Test
14.30 – 15.00	Coffee break	Coffee break	Coffee break	Coffee break	Coffee break
15.00 – 15.15	Test 10	Test 31	Test 55	Test 75	Test
15.15 – 15.30	Test 11	Test 32	Test 56	Test 76	Test
15.30 – 15.45	Test 12	Test 33	Test 57	Test 77	Test
15.45 – 16.00	Test 13	Test 34	Test 58	Test 78	Test
16.00 – 16.15	Test 14	Test 35	Test 59	Test 79	Test
16.15 – 16.30	Test 15	Test 36	Test 60	Test 80	Test
16.30 – 16.45	Test 16	Test 37	Test 61	Test 81	Test
16.45 – 17.00	Cleaning and shutting down	Cleaning and shutting down	Cleaning and shutting down	Cleaning and shutting down	Cleaning and shutting down

C.2 Counterbalancing using Ngene

Ngene syntax

design
;alts = TOR, null
;rows = all
;fact
;model:
U(TOR) = A * takeover_request[0,1,2] + B * speech_rate[0,1,2] + C * takeover_syntax[0,1,2] + D * lane_width[0,1,2]/
U(null) = 0
$

Ngene correlations

Attribute	[A] Takeover request	[B] Takeover speech-rate	[C] Takeover syntax	[D] Lane width
[A]	1	0	0	0
[B]	0	1	0	0
[C]	0	0	1	0
[D]	0	0	0	1

Ngene outcome

Test	[A] Takeover request	[B] Takeover speech-rate	[C] Takeover syntax	[D] Lane width
1	0	1	2	1
2	1	2	2	1
3	1	0	1	0
4	2	1	2	0
5	1	0	0	0
6	0	2	1	1
7	2	0	2	1
8	0	1	0	0
9	2	2	0	0
10	1	2	1	2
11	2	1	0	2
12	2	2	2	2
13	2	1	1	2
14	2	2	1	0
15	1	0	2	2
16	0	2	0	0
17	2	1	1	0
18	2	1	0	1
19	1	1	0	2
20	2	2	0	1
21	0	2	2	0
22	2	2	2	0
23	1	0	1	2
24	0	0	0	0
25	1	1	2	2
26	0	0	2	0
27	2	0	1	2
28	1	0	2	0
29	2	0	0	2
30	0	1	1	1
31	1	1	0	0
32	0	0	1	1
33	1	2	0	0
34	2	0	0	0
35	1	0	0	1
36	1	2	2	2
37	1	1	1	1
38	0	1	0	2
39	2	2	2	1
40	0	2	1	0
41	0	1	2	2
42	1	2	0	1

43	2	2	0	2
44	0	2	0	2
45	0	0	1	0
46	2	1	0	0
47	0	2	0	1
48	0	0	2	2
49	2	1	2	2
50	1	1	1	2
51	2	2	1	1
52	0	1	1	2
53	2	0	2	0
54	0	1	0	1
55	0	2	1	2
56	1	2	1	1
57	2	2	1	2
58	1	1	1	0
59	2	1	1	1
60	0	2	2	2
61	0	0	0	2
62	1	1	2	1
63	1	1	2	0
64	2	1	2	1
65	0	0	0	1
66	2	0	0	1
67	1	0	0	2
68	1	0	2	1
69	1	2	1	0
70	1	2	0	2
71	0	1	1	0
72	0	2	2	1
73	0	1	2	0
74	1	2	2	0
75	2	0	2	2
76	1	0	1	1
77	1	1	0	1
78	2	0	1	1
79	2	0	1	0
80	0	0	1	2
81	0	0	2	1

Appendix D

Data analysis simulatortest CiTG - Thijs Ebbers, May 2020

Legend				
UTR	Urgent Takeover Request	FOP	Foot on Pedal	
STR	Semi-urgent Takeover Request	FPE	Foot Placement Error	(Pressing accidentally brake pedal while pressing accelerator)
NTR	Non-urgent Takeover Request	HOW	Hands on Wheel	
TAM	Takeover Automation to Manual	EOR	Eyes on Road	
THI	Takeover time Human after Initation	EM/LM	Early/Late Morning	
LD	Lane Deviation	EA/LA	Early/Late Afternoon	

D.1 Results (Excel)

	Day		Takeover request				Takeover Automation to Manual (TAM)											Takeover time Human after Initiation (THI)																Game
Test	Part of day	Time of day	Type	Speech rate	Syntax	Lane width	Time		Frame	Position			Velocity			Acceleration	RPM	Foot On Pedal (FOP)				Eyes On Road (EOR)			Hands On Wheel (HOW)			Takeover time	Lateral Deviation (LD)					Tetris
Number	*Part*	*hour*	*Level of Urgenc*	*Duration*	*Sentence*	*Meters*	*Seconds*	*Minutes*		*x*	*y*	*z*	*x*	*y*	*z*	*m/s^2*	*r/min*	*TAM*	*FOP*	*THI*	*FPE*	*TAM*	*EOR*	*THI*	*TAM*	*HOW*	*THI*	*TOT*	*TAM*	*x1*	*x2*	*Biggest*	*%*	*Score*
1	EM	10.00	UTR	0	3	3	467,450	7,791	22590	4874,468	1,238	212,286	-0,0118	-0,0026	-27,4493	0,9000	2516	536,91	540,52	3,61	0	507,98	510,64	2,66	532,80	535,42	2,62	**3,61**	501	498	593	593	18,36	4.328
2	EM	10.15	NTR	+10	3	3	460,856	7,681	22538	4874,464	1,238	212,676	-0,0146	-0,0005	-27,5891	-1,2000	2617	512,31	517,25	4,94	0	508,14	511,02	2,88	508,14	510,27	2,13	**4,94**	500	462	571	571	14,20	2.898
3	EM	10.30	NTR	-10	2	2,5	468,351	7,806	22443	4874,475	1,341	212,994	-0,0179	-0,0010	-27,3472	-0,7999	2582	540,46	543,48	3,02	1	545,87	548,54	2,67	545,87	548,74	2,87	**3,02**	473	411	512	512	8,25	6.835
4	LM	11.30	STR	0	3	2,5	459,787	7,663	22700	4874,477	1,341	212,917	-0,0171	-0,0005	-27,5684	-1,2000	2617	512,13	515,31	3,18	1	500,60	503,83	3,23	500,60	503,67	3,07	**3,23**	472	441	474	474	0,42	4.924
5	LM	11.45	NTR	-10	1	2,5	479,731	7,996	23689	4874,471	1,341	212,938	-0,0113	-0,0033	-27,1405	0,2000	2518	514,97	517,14	2,17	1	537,58	539,89	2,31	537,58	540,32	2,74	**2,74**	478	385	517	517	8,16	1.295
6	LM	12.00	UTR	+10	2	3	458,463	7,641	22638	4874,469	1,238	212,486	-0,0162	-0,0012	-28,1512	0,0000	2615	567,04	569,12	2,08	1	558,99	561,02	2,03	558,99	560,97	1,98	**2,08**	501	368	479	368	26,55	5.851
7	LM	12.15	STR	-10	3	3	450,872	7,515	22256	4874,472	1,238	212,211	-0,0053	-0,0002	-27,4898	-1,0500	2608	549,03	551,43	2,40	1	544,17	546,49	2,32	544,17	546,93	2,76	**2,76**	500	418	438	438	12,40	9.529
8	EA	13.45	UTR	0	1	2,5	460,741	7,679	22745	4874,476	1,341	213,029	-0,0074	-0,0029	-28,1415	-0,2000	2622	520,64	523,16	2,52	0	527,94	530,63	2,69	527,94	530,41	2,47	**2,69**	476	466	498	498	4,62	4.938
9	EA	14.00	STR	+10	1	2,5	456,314	7,605	22536	4874,473	1,341	212,841	-0,0056	0,0026	-28,1046	0,4000	2593	530,60	532,97	2,37	0	521,85	524,04	2,19	521,85	524,17	2,32	**2,37**	477	468	495	495	3,77	3.218
10	EA	14.15	NTR	+10	2	3,5	455,985	7,600	22524	4874,474	1,135	211,796	-0,0094	-0,0004	-27,7881	-0,9501	2623	520,67	522,92	2,25	1	514,51	516,47	1,96	514,51	516,86	2,35	**2,35**	538	609	528	609	13,20	2.999
11	EA	14.30	STR	0	1	3,5	457,543	7,626	22594	4874,468	1,135	211,835	-0,0105	-0,0007	-28,1505	0,0000	2689	500,55	503,01	2,46	1	495,45	497,13	1,68	495,45	497,75	2,30	**2,46**	537	466	602	466	13,22	1.420
12	EA	14.45	STR	+10	3	3,5	455,214	7,587	22470	4874,464	1,135	212,097	-0,0142	-0,0025	-28,0372	-0,5000	2627	543,51	546,20	2,69	0	535,80	538,16	2,36	535,80	538,31	2,51	**2,69**	538	528	556	556	3,35	2.032
13	EA	15.00	STR	0	2	3,5	454,957	7,583	22451	4874,467	1,135	211,806	-0,0159	0,0049	-28,1052	0,4500	2685	544,04	546,95	2,91	0	537,69	540,68	2,99	537,69	540,88	3,19	**3,19**	537	476	523	476	11,36	2.885
14	EA	15.15	STR	+10	2	2,5	450,528	7,509	22245	4874,466	1,341	213,127	-0,0111	0,0037	-27,7881	1,0500	2534	503,25	505,90	2,65	0	496,91	499,82	2,91	496,91	499,59	2,68	**2,91**	475	467	484	484	1,89	3.233
15	LA	15.45	NTR	-10	3	3,5	453,263	7,554	22366	4874,460	1,135	211,957	-0,0010	0,0001	-27,4026	-0,9000	2627	511,00	513,55	2,55	0	505,07	506,80	1,73	505,07	507,53	2,46	**2,55**	540	536	605	605	12,04	8.209
16	LA	16.00	UTR	+10	1	2,5	454,358	7,573	22422	4874,474	1,341	213,167	-0,0218	-0,0057	-27,6842	1,1001	2650	534,88	537,46	2,58	1	525,06	527,70	2,64	525,06	527,75	2,69	**2,69**	478	449	507	449	6,07	7.593
17	LA	16.15	STR	0	2	2,5	453,887	7,565	22407	4874,472	1,341	212,827	-0,0067	-0,0036	-28,1429	0,2000	2689	507,50	510,77	3,27	0	500,71	503,94	3,23	500,71	503,79	3,08	**3,27**	477	478	489	489	2,52	4.548
18	LA	16.30	STR	0	1	3	452,987	7,550	22365	4874,477	1,238	212,339	-0,0102	0,0001	-27,4695	-1,1000	2638	500,81	503,33	2,52	0	494,87	497,47	2,60	494,87	497,89	3,02	**3,02**	505	499	534	534	5,74	6.810
19	LA	16.45	NTR	0	1	3,5	453,973	7,566	22401	4874,470	1,135	211,814	-0,0242	0,0026	-28,1495	0,0999	2689	543,91	547,93	4,02	0	538,31	542,41	4,10	538,31	542,55	4,24	**4,24**	538	522	596	596	10,78	1.480
20	LA	17.00	STR	+10	1	3	451,985	7,533	22306	4874,465	1,238	212,631	-0,0113	-0,0013	-28,1014	-0,3000	2625	496,38	499,51	3,13	0	489,97	493,26	3,29	489,97	493,14	3,17	**3,29**	501	495	516	516	2,99	2.378
21	LA	17.15	UTR	+10	3	2,5	456,751	7,613	22416	4874,467	1,341	213,051	-0,0200	-0,0034	-27,2019	0,4001	2610	498,38	500,81	2,43	1	490,60	493,04	2,44	490,60	493,08	2,48	**2,48**	473	468	514	514	8,67	4.936
22	LA	17.30	STR	+10	3	2,5	453,480	7,558	22384	4874,468	1,341	212,853	-0,0070	-0,0006	-27,4900	-1,1000	2638	505,39	508,08	2,69	0	498,43	501,03	2,60	498,43	501,17	2,74	**2,74**	475	468	517	517	8,84	3.958
23	LA	17.45	NTR	-10	2	3,5	451,516	7,525	22282	4874,467	1,135	212,190	0,0013	0,0045	-27,7033	-1,0000	2651	525,33	529,96	4,63	0	517,41	522,27	4,86	517,41	522,32	4,91	**4,91**	538	522	536	522	2,97	1.170
24	EM	09.45	UTR	-10	1	2,5	456,101	7,602	22508	4874,472	1,341	212,793	-0,0048	-0,0038	-28,1348	0,3000	2688	519,92	522,52	2,60	1	512,44	514,97	2,53	512,44	515,12	2,68	**2,68**	476	474	489	489	2,73	2.585
25	EM	10.00	NTR	0	3	3,5	451,889	7,531	22299	4874,464	1,135	211,781	-0,0021	-0,0006	-27,1837	0,3500	2608	493,33	497,11	3,78	0	487,96	491,75	3,79	487,96	491,91	3,95	**3,95**	538	537	573	573	6,51	2.553
26	EM	10.15	UTR	-10	3	2,5	453,541	7,559	22384	4874,468	1,341	212,761	-0,0156	0,0030	-27,2009	0,4000	2514	505,36	507,37	2,01	1	495,81	497,92	2,11	495,81	498,21	2,40	**2,40**	475	475	488	488	2,74	2.123
27	EM	10.30	STR	-10	2	3,5	450,549	7,509	22231	4874,477	1,135	211,862	-0,0099	0,0000	-27,2770	-0,7999	2573	492,37	495,15	2,78	0	486,90	489,72	2,82	486,90	490,39	3,49	**3,49**	541	507	557	507	6,28	2.779
28	EM	10.45	NTR	-10	3	2,5	450,988	7,516	22259	4874,469	1,341	212,815	-0,0032	-0,0019	-27,1239	-0,3000	2540	493,73	496,59	2,86	0	488,38	492,05	3,67	488,38	492,51	4,13	**4,13**	476	433	479	433	9,03	7.958
29	LM	11.15	STR	-10	1	3,5	449,236	7,487	22180	4874,476	1,135	211,969	-0,0091	0,0000	-27,3052	-0,7500	2575	496,56	498,84	2,28	0	489,31	491,57	2,26	489,31	492,18	2,87	**2,87**	551	533	616	616	11,80	4.867
30	LM	11.30	UTR	0	2	3	449,921	7,499	22205	4874,479	1,238	212,227	-0,0075	0,0016	-27,2424	-0,6000	2562	497,05	499,10	2,05	1	488,80	490,87	2,07	488,80	490,97	2,17	**2,17**	502	504	493	493	1,79	2.371
31	LM	11.45	NTR	0	1	2,5	450,812	7,514	22247	4874,473	1,341	212,957	-0,0196	-0,0020	-27,2618	-0,7999	2616	494,33	497,19	2,86	0	487,54	490,47	2,93	487,54	490,68	3,14	**3,14**	476	456	476	456	4,20	3.891
32	LM	12.00	UTR	-10	2	3	450,222	7,504	22222	4874,474	1,238	212,715	-0,0073	-0,0009	-27,1909	-0,5000	2608	491,75	493,78	2,03	0	485,79	487,90	2,11	485,79	488,03	2,24	**2,24**	501	500	549	549	9,58	2.777
33	LM	12.15	NTR	+10	1	2,5	452,041	7,534	22310	4874,475	1,341	213,538	-0,0158	0,0014	-27,2670	-0,7000	2616	502,84	506,75	3,91	0	496,36	500,53	4,17	496,36	500,75	4,39	**4,39**	473	466	478	466	1,48	2.589
34	LM	12.30	STR	-10	1	2,5	449,402	7,490	22198	4874,474	1,341	212,876	-0,0063	-0,0034	-27,1924	0,3500	2608	494,18	496,56	2,38	0	484,33	486,81	2,48	484,33	487,11	2,78	**2,78**	477	474	495	495	3,77	9.138
35	EA	13.30	NTR	-10	1	3	458,365	7,639	22572	4874,468	1,238	212,476	-0,0148	-0,0021	-27,2437	0,4500	2613	506,92	509,52	2,60	1	498,95	501,58	2,63	498,95	501,51	2,56	**2,63**	498	459	528	459	7,83	3.481
36	EA	13.45	NTR	+10	3	3,5	449,576	7,493	22202	4874,473	1,135	211,990	-0,0216	-0,0011	-27,3031	0,6000	2618	502,75	505,41	2,66	1	495,48	498,46	2,98	495,48	498,84	3,36	**3,36**	537	526	541	526	2,05	7.476
37	EA	14.00	NTR	0	2	3	449,336	7,489	22181	4874,475	1,238	212,739	-0,0117	-0,0006	-27,3495	-0,8500	2623	504,20	508,72	4,52	0	491,46	495,87	4,41	491,46	496,22	4,76	**4,76**	501	490	501	490	2,20	3.761
38	EA	14.15	UTR	0	1	3,5	448,255	7,471	22138	4874,475	1,135	212,101	-0,0074	0,0004	-27,4881	-1,1000	2641	497,25	499,26	2,01	1	488,31	490,51	2,20	488,31	490,57	2,26	**2,26**	541	537	584	584	7,95	3.416
39	EA	14.30	STR	+10	3	3	456,913	7,615	22341	4874,461	1,238	212,607	-0,0039	-0,0009	-27,1822	-0,5000	2608	498,64	501,29	2,65	0	491,32	494,54	3,22	491,32	494,77	3,45	**3,45**	502	498	516	516	2,79	3.475
40	EA	14.45	UTR	+10	2	2,5	450,336	7,506	22240	4874,467	1,341	213,143	-0,0058	-0,0051	-27,5919	1,0500	2646	491,75	493,37	1,62	0	484,04	485,84	1,80	484,04	486,11	2,07	**2,07**	475	498	448	448	5,68	9.817
41	EA	15.00	UTR	0	3	3,5	449,575	7,493	22205	4874,475	1,135	211,805	-0,0132	0,0006	-27,2773	-0,7500	2617	489,45	490,81	1,36	0	481,62	483,87	2,25	481,62	484,02	2,40	**2,40**	542	533	557	557	2,77	1.920
42	EA	15.15	NTR	+10	1	3	448,966	7,483	22171	4874,471	1,238	212,458	-0,0136	-0,0004	-27,3338	-0,8000	2622	493,15	496,06	2,91	0	487,29	490,68	3,39	487,29	491,26	3,97	**3,97**	501	492	501	492	1,80	2.601
43	EA	15.30	STR	+10	1	3,5	449,237	7,487	22186	4874,474	1,135	211,802	-0,0117	-0,0007	-27,7495	-1,0000	2654	492,43	494,57	2,14	0	482,02	484,52	2,50	482,02	484,72	2,70	**2,70**	539	530	569	569	5,57	1.145
44	LA	15.45	UTR	+10	1	3,5	449,688	7,495	22209	4874,474	1,135	212,009	-0,0213	-0,0013	-27,3460	-0,8500	2623	497,28	498,72	1,44	0	491,66	493,29	1,63	491,66	493,84	2,18	**2,18**	543	529	544	529	2,58	1.965
45	LA	16.15	UTR	-10	2	2,5	448,561	7,476	22152	4874,471	1,341	213,012	-0,0151	-0,0009	-27,3053	-0,7501	2620	491,75	493,36	1,61	1	483,43	485,04	1,61	483,43	485,39	1,96	**1,96**	477	470	493	493	3,35	4.373
46	LA	16.30	STR	0	1	2,5	451,355	7,523	22292	4874,471	1,341	212,911	-0,0197	-0,0041	-27,2555	0,5500	2513	492,79	494,55	1,76	1	483,39	485,15	1,76	483,39	485,74	2,35	**2,35**	475	472	486	486	2,32	3.409
47	LA	16.45	UTR	+10	1	3	450,047	7,501	22229	4874,479	1,238	212,351	-0,0107	-0,0005	-27,4124	-0,9500	2630	497,89	499,52	1,63	1	491,35	493,14	1,79	491,35	493,19	1,84	**1,84**	503	483	557	557	10,74	2.058
48	LA	17.00	UTR	-10	3	3,5	448,101	7,468	22126	4874,471	1,135	211,800	-0,0209	-0,0015	-27,2625	-0,7500	2616	497,42	499,22	1,80	1	489,56	491,41	1,85	489,56	491,45	1,89	**1,89**	541	532	582	582	7,58	2.687
49	LA	17.15	STR	0	3	3,5	449,421	7,490	22196	4874,477	1,135	211,953	-0,0205	-0,0019	-27,2237	-0,6499	2612	494,84	497,33	2,49	0	488,75	491,76	3,01	488,75	491,89	3,14	**3,14**	537	449	548	449	16,39	3.771
50	LA	17.30	NTR	0	2	3,5	449,398	7,490	22193	4874,466	1,135	212,394	-0,0087	-0,0052	-27,1692	0,2501	2606	494,73	497,87	3,14	0	482,92	486,70	3,78	482,92	486,75	3,83	**3,83**	543	535	567	567	4,42	3.625
51	LA	17.45	STR	+10	2	3	450,639	7,511	22240	4874,472	1,238	212,537	-0,0058	-0,0031	-27,8821	0,9501	2663	495,07	496,92	1,85	0	487,92	491,06	3,14	487,92	491,07	3,15	**3,15**	502	502	521	521	3,78	5.804
52	EM	08.15	UTR	0	2	3,5	449,396	7,490	22174	4874,470	1,135	212,216	-0,0209	0,0010	-27,5083	-1,1500	2642	496,11	497,95	1,84	0	488,95	490,89	1,94	488,95	490,85	1,90	**1,94**	540	496	546	496	8,15	10.051
53	EM	08.30	STR	-10	3	2,5	448,642	7,477	22158	4874,479	1,341	213,032	-0,0105	-0,0006	-27,4350	-1,0000	2633	496,69	499,68	2,99	0	488,98	492,59	3,61	488,98	492,77	3,79	**3,79**	477	461	477	461	3,35	4.328
54	EM	08.45	UTR	0	1	3	448,768	7,479	22164	4874,473	1,238	212,534	-0,0063	0,0002	-27,5007	-1,1499	2642	490,01	492,22	2,21	0	483,19	485,56	2,37	483,19	485,53	2,34	**2,37**	506	493	583	583	15,22	2.454
55	EM	09.00	UTR	+10	2	3,5	469,398	7,823	23184	4874,469	1,135	212,058	-0,0090	0,0042	-27,4363	0,8500	2631	895,88	897,37	1,49	1	882,03	883,92	1,89	882,03	884,00	1,97	**1,97**	540	437	593	437	19,07	10.614
56	EM	09.15	NTR	+10	2	3	452,144	7,536	22317	4874,475	1,238	212,246	-0,0172	0,0034	-27,2040	0,3500	2609	503,94	506,40	2,46	0	499,21	501,39	2,18	499,21	501,80	2,59	**2,59**	500	494	535	535	7,00	8.423
57	EM	09.30	STR	+10	2	3,5	461,997	7,700	22812	4874,470	1,135	212,184	-0,0048	0,0034	-27,1842	0,3500	2607	494,38	497,61	3,23	1	487,30	490,53	3,23	487,30	490,48	3,18	**3,23**	543	536	574	574	5,71	2.352
58	EM	09.45	NTR	0	2	2,5	449,554	7,493	22201	4874,472	1,341	213,070	-0,0028	-0,0043	-27,4006	0,7999	2628	489,55	492,89	3,34	0	484,24	488,62	4,38	484,24	488,53	4,29	**4,38**	476	476	493	493	3,57	4.603
59	EM	10.00	STR	0	2	3	449,422	7,490	22197	4874,474	1,238	212,729	-0,0115	-0,0042	-27,8467	1,0000	2658	483,91	487,13	3,22	0	478,80	482,57	3,77	478,80	482,61	3,81	**3,81**	502	498	518	518	3,19	1.764
60	EM	10.15	UTR	+10	3	3,5	448,870	7,481	22150	4874,469	1,135	211,738	-0,0153	-0,0012	-27,4871	0,9500	2636	489,78	491,74	1,96	1	482,78	484,79	2,01	482,78	484,86	2,08	**2,08**	538	514	572	572	6,32	3.457
61	EM	10.45	UTR	-10	1	3,5	470,575	7,843	23238	4874,467	1,135	211,880	-0,0098	-0,0008	-27,4184	0,7999	2629	520,40	522,26	1,86	0	514,02	516,35	2,33	514,02	516,42	2,40	**2,40**	542	538	597	597	10,15	1.539
62	LM	11.00	NTR	0	3	3	461,343	7,689	22777	4874,477	1,238	213,111	-0,0174	0,0032	-27,1711	0,2500	2606	530,76	533,92	3,16	0	523,61	527,09	3,48	523,61	527,17	3,56	**3,56**	501	493	511	511	2,00	2.628
63	LM	11.15	NTR	0	3	2,5	460,040	7,667	22712	4874,479	1,341	212,777	-0,0074	-0,0025	-27,1937	0,3500	2608	508,54	511,55	3,01	0	500,84	504,47	3,63	500,84	504,93	4,09	**4,09**	477	474	486	486	1,89	2.937
64	LM	11.30	STR	0	3	3	461,842	7,697	22816	4874,471	1,238	212,565	-0,0085	-0,0035	-27,7467	1,1000	2653	516,60	519,58	2,98	0	501,57	504,84	3,27	501,57	504,14	2,57	**3,27**	502	501	523	523	4,18	6.342
65	LM	11.45	UTR	-10	1	3	460,819	7,680	22750	4874,466	1,238	212,366	-0,0094	-0,0026	-27,4373	0,8499	2631	526,38	528,57	2,19	0	516,07	518,27	2,20	516,07	518,30	2,23	**2,23**	502	490	536	536	6,77	9.338
66	LM	12.00	STR	-10	1	3	458,716	7,645	22627	4874,476	1,238	212,410	-0,0063	-0,0019	-27,1675	0,2999	2606	514,99	517,75	2,76	0	507,16	510,13	2,97	507,16	510,64	3,48	**3,48**	502	498	522	522	3,98	10.211
67	LM	12.15	NTR	-10	1	3,5	460,668	7,678	22738	4874,475	1,135	211,732	-0,0092	-0,0019	-27,2917	-0,8000	2618	510,38	513,03	2,65	0	504,30	508,96	4,66	504,30	509,53	5,23	**5,23**	538	527	554	554	2,97	9.620
68	LM	12.30	NTR	-10	3	3	459,035	7,651	22663	4874,471	1,238	212,629	-0,0068	-0,0019	-27,1678	0,2000	2606	508,08	511,54	3,46	0	497,39	501,68	4,29	497,39	502,52	5,13	**5,13**	503	500	516	516	2,58	2.581
69	LM	12.45	NTR	+10	2	2,5	459,173	7,653	22664	4874,464	1,341	213,171	-0,0132	-0,0045	-27,6463	1,1000	2646	503,71	506,93	3,22	0	497,20	501,10	3,90	497,20	501,79	4,59	**4,59**	476	474	486	486	2,10	2.581
70	LM	13.00	NTR	+10	1	3,5	457,416	7,624	22582	4874,467	1,135	212,128	-0,0105	-0,0004	-27,6489	-1,1000	2642	519,02	521,55	2,53	1	512,96	516,12	3,16	512,96	516,34	3,38	**3,38**	542	537	573	573	5,72	8.528
71	EA	13.45	UTR	0	2	2,5	476,061	7,934	23505	4874,474	1,341	212,971	-0,0122	-0,0057	-27,5782	1,0500	2644	718,96	720,68	1,72	1	708,84	710,64	1,80	708,84	710,49	1,65	**1,80**	476	476	496	496	4,20	9.561
72	EA	14.00	UTR	+10	3	3	472,587	7,876	23192	4874,473	1,238	212,387	-0,0086	-0,0033	-27,8453	0,9999	2658	519,48	521,20	1,72	0	509,19	511,16	1,97	509,19	511,28	2,09	**2,09**	502	489	563	563	12,15	2.363
73	EA	14.15	UTR	0	3	2,5	464,064	7,734	22829	4874,464	1,341	212,789	-0,0111	0,0005	-27,9420	-0,7000	2670	529,95	531,89	1,94	1	519,55	521,74	2,19	519,55	521,49	1,94	**2,19**	475	473	500	500	5,26	1.856
74	EA	14.30	NTR	+10	3	2,5	457,950	7,633	22575	4874,474	1,341	213,127	-0,0002	-0,0032	-27,1621	0,2501	2605	502,56	504,97	2,41	0	492,72	495,95	3,23	492,72	496,67	3,95	**3,95**	477	477	492	492	3,14	8.865
75	EA	14.45	STR	-10	3	3,5	458,916	7,649	22590	4874,476	1,135	211,969	-0,0107	0,0007	-27,5201	-1,2000	2642	513,15	515,58	2,43	0	507,22	510,53	3,31	507,22	510,60	3,38	**3,38**	538	532	577	577	7,25	8.449
76	EA	15.00	NTR	-10	2	3	461,750	7,696	22678	4874,469	1,238	212,340	0,0016	-0,0029	-27,6139	1,0500	2646	501,52	504,63	3,11	0	495,66	499,28	3,62	495,66	499,90	4,24	**4,24**	502	502	524	524	4,38	8.661
77	LA	15.45	NTR	0	1	3	465,406	7,757	22957	4874,467	1,238	212,444	-0,0064	-0,0024	-27,3070	0,6499	2619	508,77	512,46	3,69	0	500,76	504,24	3,48	500,76	505,32	4,56	**4,56**	501	500	512	512	2,20	9.078
78	LA	16.00	STR	-10	2	3	461,048	7,684	22702	4874,469	1,238	212,734	-0,0004	-0,0035	-27,8453	0,9999	2658	521,09	523,62	2,53	0	514,82	517,69	2,87	514,82	518,03	3,21	**3,21**	502	499	526	526	4,78	2.462
79	LA	16.15	STR	-10	2	2,5	461,706	7,695	22748	4874,475	1,341	212,733	-0,0146	-0,0055	-27,7552	1,1001	2654	504,97	508,08	3,11	1	499,13	502,66	3,53	499,13	502,91	3,78	**3,78**	479	475	487	487	1,67	3.248
80	LA	16.30	UTR	-10	2	3,5	462,387	7,706	22791	4874,477	1,135	211,824	-0,0098	-0,0019	-27,2121	-0,6500	2611	506,36	507,89	1,53	1	497,34	499,32	1,98	497,34	499,26	1,92	**1,98**	541	538	573	573	5,91	1.108
81	LA	16.45	UTR	-10	3	3	455,079	7,585	22428	4874,464	1,238	212,449	-0,0064	-0,0019	-27,1806	0,3000	2607	520,97	522,84	1,87	0	516,27	518,89	2,62	516,27	518,61	2,34	**2,62**	500	498	521	521	4,20	8.519

D.2 Take-over type (TOT)

NTR	STR	UTR
4,94	3,23	3,61
3,02	2,76	2,08
2,74	2,37	2,69
2,35	2,46	2,69
2,55	2,69	2,48
4,24	3,19	2,68
4,91	2,91	2,40
3,95	3,27	2,17
4,13	3,02	2,24
3,14	3,29	2,26
4,39	2,74	2,07
2,63	3,49	2,40
3,36	2,87	2,18
4,76	2,78	1,96
3,97	3,45	1,84
3,83	2,70	1,89
2,59	2,35	1,94
4,38	3,14	2,37
3,56	3,15	1,97
4,09	3,79	2,08
5,23	3,23	2,40
5,13	3,81	2,23
4,59	3,27	1,80
3,38	3,48	2,09
3,95	3,38	2,19
4,24	3,21	1,98
4,56	3,78	2,62

Anova test needed due to having three groups of data
Unifactoriële variantie-analyse

SAMENVATTING

Groepen	*Aantal*	*Som*	*Gemiddelde*	*Variantie*
NTR	27	104,61	3,874444444	0,72122564
STR	27	83,81	3,104074074	0,16798661
UTR	27	61,31	2,270740741	0,14018405

Variantie-analyse

Bron van variatie	*Kwadratensom*	*Vrijheidsgraden*	*Gemiddelde kwadraten*	*F*	*P-waarde*	*Kritische gebied van F-toets*
Tussen groepen	34,73802469	2	17,36901235	50,6190252	8,08931E-15	3,11379226
Binnen groepen	26,7643037	78	0,343132099			
Totaal	61,5023284	80				

D.3 NTR: Take-over speech-rate (TOT)

-10	0	10
3,02	**4,94**	**4,24**
2,74	**2,35**	**3,95**
2,55	**4,39**	**3,14**
4,91	**3,36**	**4,76**
4,13	**3,97**	**3,83**
2,63	**2,59**	**4,38**
5,23	**4,59**	**3,56**
5,13	**3,38**	**4,09**
4,24	**3,95**	**4,56**

Unifactoriële variantie-analyse

SAMENVATTING

Groepen	*Aantal*	*Som*	*Gemiddelde*	*Variantie*
-10	9	34,58	3,842222222	1,24946944
0	9	33,52	3,724444444	0,77605278
10	9	36,51	4,056666667	0,254625

Variantie-analyse

Bron van variatie	*Kwadratensom*	*Vrijheidsgraden*	*Gemiddelde kwadraten*	*F*	*P-waarde*	*Kritische gebied van F-toets*
Tussen groepen	0,510688889	2	0,255344444	0,33595784	0,71796031	3,402826105
Binnen groepen	18,24117778	24	0,760049074			
Totaal	18,75186667	26				

D.4 STR: Take-over speech-rate (TOT)

15	25	35
2,76	**2,37**	**3,23**
3,49	**2,69**	**2,46**
2,87	**2,91**	**3,19**
2,78	**3,29**	**3,27**
3,79	**2,74**	**3,02**
3,48	**3,45**	**2,35**
3,38	**2,70**	**3,14**
3,21	**3,15**	**3,81**
3,78	**3,23**	**3,27**

Unifactoriële variantie-analyse

SAMENVATTING

Groepen	*Aantal*	*Som*	*Gemiddelde*	*Variantie*
15	9	29,54	3,282222222	0,1621944
25	9	26,53	2,947777778	0,1245194
35	9	27,74	3,082222222	0,1955194

Variantie-analyse

Bron van variatie	*Kwadratensom*	*Vrijheidsgraden*	*Gemiddelde kwadraten*	*F*	*P-waarde*	*Kritische gebied van F-toets*
Tussen groepen	0,509785185	2	0,254892593	1,5857008	0,2255228	3,402826105
Binnen groepen	3,857866667	24	0,160744444			
Totaal	4,367651852	26				

D.5 UTR: Take-over speech-rate (TOT)

35	45	55
2,68	2,08	3,61
2,40	2,69	2,69
2,24	2,48	2,17
1,96	2,07	2,26
1,89	2,18	2,40
2,40	1,84	1,94
2,23	1,97	2,37
1,98	2,08	1,80
2,62	2,09	2,19

Unifactoriële variantie-analyse

SAMENVATTING

Groepen	Aantal	Som	Gemiddelde	Variantie
35	9	20,4	2,266666667	0,081425
45	9	19,48	2,164444444	0,0684778
55	9	21,43	2,381111111	0,2792611

Variantie-analyse

Bron van variatie	Kwadratensom	Vrijheidsgraden	Gemiddelde kwadraten	F	P-waarde	Kritische gebied van F-toets
Tussen groepen	0,211474074	2	0,105737037	0,7391375	0,4880841	3,402826105
Binnen groepen	3,433311111	24	0,14305463			
Totaal	3,644785185	26				

D.6 Take-over syntax (TOT)

NTR	STR	UTR
2,74	2,37	2,69
4,24	2,46	2,69
3,14	3,02	2,68
4,39	3,29	2,26
2,63	2,87	2,18
3,97	2,78	1,84
5,23	2,70	2,37
3,38	2,35	2,40
4,56	3,48	2,23
3,02	3,19	2,08
2,35	2,91	2,17
4,91	3,27	2,24
4,76	3,49	2,07
3,83	3,15	1,96
2,59	3,23	1,94
4,38	3,81	1,97
4,59	3,21	1,80
4,24	3,78	1,98
4,94	3,23	3,61
2,55	2,76	2,48
3,95	2,69	2,40
4,13	2,74	2,40
3,36	3,45	1,89
3,56	3,14	2,08
4,09	3,79	2,09
5,13	3,27	2,19
3,95	3,38	2,62

Unifactoriële variantie-analyse

SAMENVATTING

Groepen	Aantal	Som	Gemiddelde	Variantie
NTR	27	104,61	3,874444444	0,721225641
STR	27	83,81	3,104074074	0,16798661
UTR	27	61,31	2,270740741	0,140184046

Variantie-analyse

Bron van variatie	Kwadratensom	Vrijheidsgraden	Gemiddelde kwadraten	F	P-waarde	Kritische gebied van F-toets
Tussen groepen	34,73802469	2	17,36901235	50,61902517	8,08931E-15	3,11379226
Binnen groepen	26,7643037	78	0,343132099			
Totaal	61,5023284	80				

D.7 NTR: Take-over syntax (TOT)

1	2	3
2,74	3,02	4,94
4,24	2,35	2,55
3,14	4,91	3,95
4,39	4,76	4,13
2,63	3,83	3,36
3,97	2,59	3,56
5,23	4,38	4,09
3,38	4,59	5,13
4,56	4,24	3,95

Unifactoriële variantie-analyse

SAMENVATTING

Groepen	Aantal	Som	Gemiddelde	Variantie
1	9	34,28	3,808888889	0,787111111
2	9	34,67	3,852222222	0,932394444
3	9	35,66	3,962222222	0,610419444

Variantie-analyse

Bron van variatie	Kwadratensom	Vrijheidsgraden	Gemiddelde kwadraten	F	P-waarde	Kritische gebied van F-toets
Tussen groepen	0,112466667	2	0,056233333	0,072405764	0,930355789	3,402826105
Binnen groepen	18,6394	24	0,776641667			
Totaal	18,75186667	26				

D.8 STR: Take-over syntax (TOT)

1	2	3
2,37	**3,19**	**3,23**
2,46	**2,91**	**2,76**
3,02	**3,27**	**2,69**
3,29	**3,49**	**2,74**
2,87	**3,15**	**3,45**
2,78	**3,23**	**3,14**
2,70	**3,81**	**3,79**
2,35	**3,21**	**3,27**
3,48	**3,78**	**3,38**

Unifactoriële variantie-analyse

SAMENVATTING

Groepen	*Aantal*	*Som*	*Gemiddelde*	*Variantie*
1	9	25,32	2,813333333	0,15845
2	9	30,04	3,337777778	0,089294444
3	9	28,45	3,161111111	0,138011111

Variantie-analyse

Bron van variatie	*Kwadratensom*	*Vrijheidsgraden*	*Gemiddelde kwadraten*	*F*	*P-waarde*	*Kritische gebied van F-toets*
Tussen groepen	1,281607407	2	0,640803704	4,983495593	0,015482816	3,402826105
Binnen groepen	3,086044444	24	0,128585185			
Totaal	4,367651852	26				

D.9 UTR: Take-over syntax (TOT)

1	2	3
2,69	**2,08**	**3,61**
2,69	**2,17**	**2,48**
2,68	**2,24**	**2,40**
2,26	**2,07**	**2,40**
2,18	**1,96**	**1,89**
1,84	**1,94**	**2,08**
2,37	**1,97**	**2,09**
2,40	**1,80**	**2,19**
2,23	**1,98**	**2,62**

Unifactoriële variantie-analyse

SAMENVATTING

Groepen	*Aantal*	*Som*	*Gemiddelde*	*Variantie*
1	9	21,34	2,371111111	0,081311111
2	9	18,21	2,023333333	0,017425
3	9	21,76	2,417777778	0,252344444

Variantie-analyse

Bron van variatie	*Kwadratensom*	*Vrijheidsgraden*	*Gemiddelde kwadraten*	*F*	*P-waarde*	*Kritische gebied van F-toets*
Tussen groepen	0,836140741	2	0,41807037	3,572431145	0,043842764	3,402826105
Binnen groepen	2,808644444	24	0,117026852			
Totaal	3,644785185	26				

D.10 Lane width (LD)

NTR	STR	UTR
8,25	0,42	4,62
8,16	3,77	6,07
9,03	1,89	8,67
4,20	2,52	2,73
1,48	8,84	2,74
3,57	3,77	5,68
1,89	2,32	3,35
2,10	3,35	4,20
3,14	1,67	5,26
14,20	12,40	18,36
7,83	5,74	26,55
2,20	2,99	1,79
1,80	2,79	9,58
7,00	3,78	10,74
2,00	3,19	15,22
2,58	4,18	6,77
4,38	3,98	12,15
2,20	4,78	4,20
13,20	13,22	7,95
12,04	3,35	2,77
10,78	11,36	2,58
2,97	6,28	7,58
6,51	11,80	8,15
2,05	5,57	19,07
4,42	16,39	6,32
2,97	5,71	10,15
5,72	7,25	5,91

Unifactoriële variantie-analyse

SAMENVATTING

Groepen	*Aantal*	*Som*	*Gemiddelde*	*Variantie*
NTR	27	146,67	5,432222222	14,479264
STR	27	153,31	5,678148148	16,4672
UTR	27	219,16	8,117037037	34,469768

Variantie-analyse

Bron van variatie	*Kwadratensom*	*Vrijheidsgraden*	*Gemiddelde kwadraten*	*F*	*P-waarde*	*Kritische gebied van F-toets*
Tussen groepen	118,9520025	2	59,47600123	2,72758	0,071616807	3,11379226
Binnen groepen	1700,822037	78	21,80541073			
Totaal	1819,77404	80				

D.11 NTR: Lane width (LD)

2,5	3	3,5
8,25	14,20	13,20
8,16	7,83	12,04
9,03	2,20	10,78
4,20	1,80	2,97
1,48	7,00	6,51
3,57	2,00	2,05
1,89	2,58	4,42
2,10	4,38	2,97
3,14	2,20	5,72

Unifactoriële variantie-analyse

SAMENVATTING

Groepen	*Aantal*	*Som*	*Gemiddelde*	*Variantie*
2,5	9	41,82	4,646666667	9,0353
3	9	44,19	4,91	17,2171
3,5	9	60,66	6,74	17,8801

Variantie-analyse

Bron van variatie	*Kwadratensom*	*Vrijheidsgraden*	*Gemiddelde kwadraten*	*F*	*P-waarde*	*Kritische gebied van F-toets*
Tussen groepen	23,40086667	2	11,70043333	0,7953617	0,4629607	3,402826105
Binnen groepen	353,06	24	14,71083333			
Totaal	376,4608667	26				

D.12 STR: Lane width (LD)

2,5	3	3,5
0,42	12,40	13,22
3,77	5,74	3,35
1,89	2,99	11,36
2,52	2,79	6,28
8,84	3,78	11,80
3,77	3,19	5,57
2,32	4,18	16,39
3,35	3,98	5,71
1,67	4,78	7,25

Unifactoriële variantie-analyse

SAMENVATTING

Groepen	*Aantal*	*Som*	*Gemiddelde*	*Variantie*
2,5	9	28,55	3,172222222	5,687144444
3	9	43,83	4,87	8,825675
3,5	9	80,93	8,992222222	18,85024444

Variantie-analyse

Bron van variatie	*Kwadratensom*	*Vrijheidsgraden*	*Gemiddelde kwadraten*	*F*	*P-waarde*	*Kritische gebied van F-toets*
Tussen groepen	161,2426963	2	80,62134815	7,249455423	0,0034447	3,402826105
Binnen groepen	266,9045111	24	11,1210213			
Totaal	428,1472074	26				

D.13 UTR: Lane width (LD)

2,5	3	3,5
4,62	18,36	7,95
6,07	26,55	2,77
8,67	1,79	2,58
2,73	9,58	7,58
2,74	10,74	8,15
5,68	15,22	19,07
3,35	6,77	6,32
4,20	12,15	10,15
5,26	4,20	5,91

Unifactoriële variantie-analyse

SAMENVATTING

Groepen	*Aantal*	*Som*	*Gemiddelde*	*Variantie*
2,5	9	43,32	4,813333333	3,5747
3	9	105,36	11,70666667	57,7062
3,5	9	70,48	7,831111111	23,87898611

Variantie-analyse

Bron van variatie	*Kwadratensom*	*Vrijheidsgraden*	*Gemiddelde kwadraten*	*F*	*P-waarde*	*Kritische gebied van F-toets*
Tussen groepen	214,9348741	2	107,467437	3,785847138	0,037235761	3,402826105
Binnen groepen	681,2790889	24	28,3866287			
Totaal	896,213963	26				

D.14 Foot placement error

Urgency	Placement error	SD
NTR	0,22	0,4236593
STR	0,22	0,4236593
UTR	0,56	0,5063697