Bachelor-assignment

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Influence of braking on the state of arousal of young drivers measured through EDA during a driving lesson in a simulator.

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8/7/2013
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1. Introduction

1.1. This Research

This research is about the influence of usage of the brake in an automobile. This is done by collecting data from novice drivers during their driving lessons in a simulator. The main purpose of this research is to give an answer to the question if the usage of the brake in an automobile is of influence to the arousal of novice drivers. Here for there will be made a distinction between braking to decelerate a car and the use of a brake when the car is already standing still (for example to wait for a red sign, or with parking). For this research there will be assumed that arousal can be measured through EDA (Electroldermal Activity) and by this the state of the driver.

1.1.1. Goal

The goal of this research is to show that certain actions during driving can influence the state of arousal a driver has. After the research is done I would like to give a better overview about which actions regarding the braking action result in a higher arousal. This outcome can then be used by developers of simulators and driving instructors, so that they can offer more precise and good instructions during driving lessons. This research can also be used for more experienced drivers to get to know how their body responds to situations in traffic, so that they can make better decisions.

This research gives insights on the difference in arousal during various braking situations. There are off course more than one variable that is of influence to arousal, but this research is limited to the usage of the brake in a car (reasons for this will be explained below).

1.2. Theoretical Framework

1.2.1. Mental workload

First of all there has to be clear what exactly should be measured. We would like to know about the arousal of the participants (see also next paragraph), but where does this arousal come from? De Waard (1996) states in his book about the measurement of driver's mental workload that the mental workload can be measured through arousal. The technology for measuring the task demands of human operators during their interactions with machines has been of abiding interest to engineering psychologists (Hancock, 2011). “The performance of the man machine system has a usually nonlinear, often precipitous, and sometimes catastrophic decrement with increased task load.” “Workload” covers a broad spectrum of human activity, but in “mental workload” we limit these activities to the primarily mental and physical coordination ones, such that muscular fatigue is not an important factor (Meshkati & Hancock, 2011). Furthermore Meshkati and Hancock (2011) describe that mental workload is a primitive construct which everybody knows, but hardly anybody can define in precise, operationally useful terms. Mental workload is intrinsically complex and multifaceted. Most operational definitions of mental workload observe task activity as a measure of workload, but there are serious difficulties in this approach. Workload is determined by the interaction of task demands, the conditions under which it is performed and skills, behaviors and perceptions of an individual (Malmo, 1959). In a study Helander (1974) shows that there is a correlation between brake pressure and electro-dermalresponse (EDR), which is a sensitive measure for detecting increases in task demand during driving.

1.2.2. Electrodermal Activity measuring Arousal

Now that is clear that arousal can be used for the measurement of mental workload it is important to know how to exactly measure arousal of a person during a driving lesson. Therefore, it is relevant to know what Electrodermal Activity (EDA) exactly is and how it can be used for research. For the use of EDA the assumption is that most of the facets of human behavior express themselves in physiological body reactions and that these reactions are involuntary and uncontrollable (Bouscein & Backs, 2008). With EDA we can measure the state of arousal of a person, because it measures the activity of the sweat glands, which are activated through the sympathetic subdivision of the autonomous nervous system. This part also initiates the fight-or-flight response (Picard, 2009). EDA is an indicator of arousal, cognitive workload, emotion and stress-strain (Brookhuis & de Waard, 2011).

In earlier research Healey and Picard (2005) already showed that physiological signals are a useful metric for providing feedback about a driver’s state because they can be collected continuously and without interfering with the driver’s task performance. Hereby the driver’s state is how aroused someone is during the tasks he completes. EDA is divided into tonic (SCL = skin conductance level) and phasic phenomena (SCR = skin conductance response or reaction). Skin conductance response (SCR) is a physiological measure of psychological and autonomic arousal (Armel & Ramachandran, 2003). Tonic skin conductance measures are obtained either as SCL's in response-free recording intervals or as the number of non-stimulus-specific SCR's in a given time window. The use of the term "response" for phasic electrodermal phenomena suggests that there is a distinct relationship to a stimulus producing an SCR. However, there are often phasic parts of EDA which cannot be traced to any specific stimulation. These are called "spontaneous" or "nonspecific" SCR's. The NS.SCR (NonSpecific Skin Conductance Response) can be used to find out when and how strong somebody is aroused during a certain task. SCR can be divided into components: frequency, which means the number of SCR's in a given time window; amplitude, which refers to the height of a single response; latency, which is the time from stimulus onset to response onset in case of a specific SCR; rise time, which is the time from the onset of a response to its maximum; and recovery time, indicating the time that is needed to recover either 50% or 63% of the amplitude (Bouscein, 2012).

There have been a number of studies that link highly aroused stress states with impaired decision-making capabilities, decreased situational awareness, and degraded performance which could impair driving ability (Lincke, Richter, & Schmidt, 1973, Leonard & Wierwille, 1975, Mcruer & Klein, 1975, Bertollini, Johnston, Kuiper, Kukula, Kulczycka, & Thomas, 1994).

1.2.3. Driving Simulators

Now that is known what EDA is and in which way it can be used in research the next point is to know something about driving simulators. This is because all of the participants of the research were driving in a driving simulator and data is also collected from this same simulator. This was done because it was a safe and easy way to collect a lot of data. The driving simulator takes record of the activities of the person who is controlling it, for example accelerating and steering, but also distance to certain objects in the virtual environment. Because the simulator constantly measures what is happening, this data can be used to study the behavior of the person controlling it. This is of great importance for this research, because the simulator data and the EDA data can be put together to get a better view on driving in a simulator.

Driving simulators in general have gotten much attention from different researchers in the field of human factors and ergonomics (e.g. De Groot, De Winter, Mulder & Wieringa, 2011; Brookhuis & de Waard, 2010; Lewis-Evams, de Waard, Jolij & Brookhuis, 2012). A driving simulator is a good tool to learn driving for new drivers, because it gives the driver an impression as if he is driving a real vehicle (Lee, Kim & Cho, 1998; De Winter, Wieringa, Kuipers, Mulder & Mulder, 2007). Advances in computer technology have facilitated the development of interactive simulators, in particular those with large visual displays and motion bases(Bertollini, Johnston, Kuiper, Kukula, Kulczycka, & Thomas, 1994, Freeman, 1994).

There are three main justifications for using driving simulation rather than in-vehicle testing: Safety, Equipment cost and Experimental Control. Safety, because some research is too hazardous to be conducted in vehicles on the road. Equipment cost, because simulators allow study of driver responses to changes in the vehicle without having to construct a vehicle with those features or performance characteristics. Experimental control, because a wider variety of test conditions can be prescribed and consistently applied in a driving simulator than on the road (Reed & Green, 1995). A number of studies have assessed the validity of driving simulators. Good correlations have been found between driving performance in simulators and on the road. The dynamic performance of operators has been shown to be similar in simulators. (Lincke et al. 1973, Leonard and Wierwille 1975, McRuer and Klein 1975, Bertollini et al. 1994). How applicable driving simulation really is to the real world is unclear however, because analyses of perceptual criteria carried out in driving simulation experiments are controversial. On the one hand recent data suggest that, in driving simulators with a large field of view, longitudinal speed can be estimated correctly from visual information. On the other hand, recent psychophysical studies have revealed an unexpectedly important contribution of vestibular cues in distance perception and steering, prompting a re-evaluation of the role of visuo-vestibular interaction in driving simulation studies (Kemeny & Panerai, 2003).

1.2.4. Young novice drivers in the real world

With the information about the driving simulator we would like to know more about how young drivers act when they learn to drive in these simulators. Unfortunately there is little research about young novice drivers in driving simulators, there is however research about young drivers who drive in the real world. Because in the last paragraph I showed that the performance of drivers in a simulator is similar to drivers in the real world it is good to look at the research that has been done on this.

It is well established that young drivers play a disproportionally large role in traffic crashes (Macdonald, 1994). Young drivers are more likely to be injured or killed then their more experienced counterparts (U.S. Department of Education, 1988). The young novice driver problem is often considered to stem from two main factors, age and inexperience. This distinction between age and inexperience corresponds to what several authors (Deery & Love, 1996 & Elander, West & French, 1993) have termed driving style (or behavior) and driving skill (or performance). The first is expected to improve with practice or training, while the second relates to decision-making aspects of driving.

Besides the research from Broeks(2012) and Schnittker (2012) there is no further research about the behavior of persons who have absolutely not driven a car before. This research is done in a simulator, real world studies about persons who take their driving lessons are unfortunately not available.

According to Healey and Picard (2005) there is an increase in driver stress due to anticipatory, monitoring, and planning effects. In addition, the expected physiological effect of a stressor occurs slightly after the stimulus and may take several seconds or several minutes to recover, depending on the type of stimulus event (Sternbach, 1966). The results of the article of Healey and Picard (2005) showed that three stress levels could be recognized with an overall accuracy of 97.4% using 5-min intervals of data and that heart rate and skin conductivity metrics provided the highest overall correlations with continuous driver stress levels. As stated earlier there are no articles about young drivers who drive in simulators; however there are a few articles about learning to drive.

Ray Fuller (2001) states in his article that a useful starting point to know how we learn to drive is through the SHEL model, which describes the various interfaces between the human operator, the car and its operating environment. SHEL is an acronym for Software, Hardware, Environment and Liveware, where Liveware stands for the human operator (Edwards, 1988). The SHELL model is one of the most well known models which describe the components necessary for successful human-machine integration and system design (Wiegmann & Shappell, 2000). The last thing of importance is the interaction between braking and arousal.

1.2.5. Braking and arousal

With all the information about drivers, arousal and simulators there still is a final key element for this research. Although there are quite a few studies about simulators and driving in the real world (e.g. De Groot, De Winter, Mulder & Wieringa, 2011; Brookhuis & de Waard, 2010; Healey & Picard, 2005). There is little research on the effects of braking on arousal, or the mental workload and braking. Helander (1974) does state that there is a large positive correlation between EDR and braking activity and that there is no correlation between pushing the brake in an unmoving car. Even though he also points out that there is no sign of cause-effect, there is a clear sign that these two variables are connected to each other. Helander (1974) also concluded that EDR is a sensitive measure for detecting increases in task demand during driving.

1.2.6. Research question

Because there is further little known about the influence of braking on arousal the main question of this research will be: What is the influence of braking on the state of arousal or young drivers in a driving simulator?

The hypotheses (with sub-hypotheses) of this study are:

H1 – Using the brake pedal provides a higher number of NS.SCR's.

S1 – There are more NS.SCR's during the use of the brake pedal to decelerate.

S2 – There are more NS.SCR's during the use of the brake pedal without the vehicle having speed.

H2 – Using the brake pedal provides higher total amplitude of the NS.SCR's.

S1 – There is higher total amplitude of the NS.SCR's during the use of the brake pedal to decelerate.

S2 – There is higher total amplitude of the NS.SCR's during the use of the brake pedal without the vehicle having speed.

2. Methods

Due to the fact that I am using the same data as Broeks (2012) and Schnittker (2012), I also make use of the information Broeks provided about his participants, materials and data gathering procedure. The analysis of the data however will be different from what Broeks and Schnittker did in their research.

2.1. Participants

The participants in this research are young adults who did not have any driving skills and started with their driving course. Participants are recruited among students that started at the driving school ”Auto en Motor Rijschool Lucassen”. The driving school offers regular driving lessons and simulator driving lessons. Students who have started with the simulator driving lessons were asked to participate in the research. A maximum of five participants could participate in the study. All participants have no previous driving experience at another driving school. Three male and two female students participate in the research, four of them are 17 years old and one of them is 18 years of age. They are required to read and sign an informed consent form. If the participant is under the age of 18, a signature from one of the parents is required.

2.2. Materials

The research is conducted using a driving simulator constructed by Green Dino. The driving simulator “Classic” (see Figure 2) consist of a metal framework with three beamers projecting a 180° virtual environment in front of the driver (GreenDino, 2012). The vehicle controls of the simulator resemble that of a real car with a manual gearbox. Force feedback was provided on the steering wheel and acceleration cue were supplied by vibrating elements in the steering wheel and seat. The dashboard, interior and mirrors were integrated in the projected image. The simulator driving program offers twenty session taking about twenty-five minutes each. The sessions are divided into individual sections that vary from three to twelve minutes. Each session then consists of 3 to 6 sections and is graded at the end of the section. An overall report is available at the end of each session. The simulator provides real time instructions to the participant during the sessions, depending on their driving skills. The simulator records all the actions done by the participant in the driving simulator, together with movements inside the virtual environment. These actions are logged with a sampling frequency of 8Hz. The simulator creates a new log file for each section that is completed by a participant. A webcam recorded the participants inside the simulator.

The electrodermal activity of the participants was measured using a Q-sensor. Researchers at MIT developed a wrist worn EDA-sensor that can be used outside laboratory settings (Poh, Swenson, & Picard, 2010). This product is brought to the consumer market by Affectiva in the form of a Q-sensor. The Q-sensor is the size of a watch and has no wires connected to it. Electrodermal activity is measured with two electrodes pressed to the skin. The skin conductance is expressed in micro-Siemens (μS). The Q-sensor also measures skin temperature and acceleration on the X, Y and Z axes. These measurements are done at 32Hz. Using the button on the Q-sensor it is possible to place makers in the EDA-data. To get accurate measurements the Q-sensor has to be worn ten minutes prior to the experiment. The skin between the two electrodes needs to build up an amount of sweat to make resistance measurements feasible.

2.3. Procedure

The research is conducted at the office of ”Auto en Motor Rijschool Lucassen”. During a simulator driving course students follow the lessons at this location. The driving school offers one hour lessons that consist of two sessions. The simulator driving course consists of ten lessons. Students that follow the simulator driving course can take only one lesson each day. The time between the first and the last lesson depends on the number of lessons a student takes in a week. Participant 5 completed the course in only four weeks, Participants 1, 2 and 4 took eight weeks to complete the course and participant 3 took the longest time with 10 weeks.

Students that participate in the research are expected ten minutes prior to their simulator driving lesson. Right upon arrival the Q-sensor was placed, allowing some sweat to build up between the electrodes and the skin. During the ten minutes waiting time the participant read the instruction that explains the upcoming sessions. After ten minutes the participant is seated in the simulator and the video recording starts. Before the start of the lesson the participant is asked to push the button on the Q-sensor to place a marker in the EDA-data. During the sessions the participant is driving the simulator alone. Further instructions will only be given when a participant needs help or when the driving instructor thinks it is needed. At the end of each session the driving instructor will review the scores with the participant. When the participant has completed two sessions the video recording is stopped. After reviewing the last scores with the driving instructor the participant is asked to fill in the NASA-TLX test. After the test the Q-sensor is removed and the participant is done for the day. The data from the simulator, video recording and Q-sensor is stored at a central location. These steps will be repeated for each participant until they have completed all twenty session. During the last session of each participant the driving instructor changed the type of simulator vehicle from a car into a lorry or bus, to give participants an impression of how this vehicle handles.

2.4. Data Analysis

Unfortunately some data was missing for some participant, because for unknown reasons the simulator did not always record during a session. A total of four sessions are missing in the dataset. The last session that is done in a lorry or bus is excluded from the dataset. The data that is collected in this session is not relevant for the research, because the aim of this research is about drivers in normal cars.

The remaining data creates a large dataset. This contains data from the simulator, EDA measurements and video images. These different resources need to be synchronized. The simulator collects data on position, movements of the car and the position of the driving instruments. It also scores the performance of participants on the driving tasks that were presented. All these variables are logged and can be accessed. The EDA measurement data contains information on the skin conductance, skin temperature, acceleration on the X, Y and Z axle and the time. The participants also were asked to create markers in each data file. The video images provide an image of the participant in the simulator and also show part of the simulator screen.

Data from the Q-sensor is converted to text files, this made the data usable in Matlab. Skin conductance is a physiological signal with relatively slow changing levels and sudden peaks associated with discrete arousal events (Reimer, Mehler, Coughlin, Godfrey, & Tan, 2009). The number of peaks is represented in the NS-SCR. A script in Matlab is used to convert the skin conductance units into usable NS-SCR's per minute. This is done by filtering the data with a Butterworth filter (cut-off frequency= 1/32 Hz). Next, the first derivative was taken from this signal. In order to label each NS-SCR the first derivative was searched for data points with a minimum speed difference of .0009 µS/ms.

The simulator collects a large amount of data but it is outside the range of this research to analyze all of them. The simulator log file data that has been used for this research contains information on the usage of the brake pedal and whether the vehicle is decelerating or accelerating. The variable of the brake pedal has a 1 when the brake is not used and a 0 when the brake is used. For the deceleration and acceleration variable there is also a binary distinction. Hereby the value 1 is used for deceleration/acceleration and 0 is when the car is not decelerating/accelerating.

The video images are used to synchronize the EDA data to the log files. The video images contain information on when a marker is created in the EDA data. It also shows when the simulator starts a new section of the driving course. It is possible through video analysis to determine when a new section of the simulator session starts relative to the EDA marker. This process has been done by two researchers (Broeks and Schnittker). The null hypothesis in which the two researchers significantly differ has been tested with a *Kruskal Wallis* test. The interobserver reliability showed no significant differences between the two researchers, $\kappa = .787$, $p < .01$. The synchronized data can be used for analyze in Matlab.

Several Matlab scripts have been used to analyze and modify the data so it would be useful for statistical comparison in SPSS 21. This is first done by selecting which situations would be useful for the hypotheses. The three situations used are the following. The first situation is the control situation. In the control situation there was no use of the brake pedal and also no acceleration or deceleration. The second situation is waiting situation. Hereby the brake pedal is used but without the vehicle to slow down, because it is already standing still. The third situation is reducing speed. This means that the brake pedal is used and there for a deceleration of the vehicle takes place. The last situation is a deceleration of the vehicle without use of the brake pedal. This can come from letting the gas go, or driving up a hill.
These situations were found from the simulator data and the time stamps from where these situations occurred were placed in a file. This meant that there was one matrix with data from all five participants about the situations they were in and how long they were in this situation consecutively. After this the script searched for NS-SCR's at the moments that the participant was in one of the three above mentioned situations. This was done by looking at the EDA data and comparing whether a certain NS-SCR was in the same time limits as the

situation was. After the script found all these NS-SCR's this data was added to the already existing matrix about the situations. Each row in the matrix now contained the following information in order: Participant, Session, Situation, Timestamp, NS-SCR nr and the Amplitude of the NS-SCR. This part resulted in a matrix of 268.130 rows of information.

Table 1: an example of the matrix with information from the simulator and the EDA after running the first script.

Participant	**Session**	**Situation**	**Timestamp(ms)**	**NS-SCR ID**	**Amplitude(μS)**
1	1	1	1632	0	0
1	1	1	1751	0	0
1	1	1	12257	3	0.0107
1	1	1	19259	4	0.5627
1	1	1	19877	4	0.5627

Because it was hard to analyze the data this way it had to be modified into a different matrix. To do this there was added something to the original script which concluded the data from the previous matrix. This was done by selecting a certain time jump and a minimal number of entries to be relevant for the final dataset. The maximal time jump used was 150 milliseconds, because the data showed that when taking a smaller time jump certain blocks of information that belonged to each other were cut into two different blocks of data and on the other site taking a bigger time jump showed that sometimes data which wasn't belonging to a block was taken into account. The reason that there wasn't defined a minimal time jump is because the simulator sampled with 8HZ (8 samples per second) so there would always be a minimal time jump of 125 milliseconds. After some experimentation and running of the script with different numbers of minimal entries the conclusion was that the best results were obtained with four minimal entries. This means that there had to be four consecutive measures with a maximum time jump of 150 milliseconds between them before they were counted as a useful block of information. After all this was defined the script that was run completed a new matrix with data where now were blocks of the information. The rows in this matrix contain the following information: Participant, Session, Situation, Duration, NS-SCR nr and Amplitude. This resulted in a matrix of 11.743 rows of information.

Table 2: an example of the matrix with information from the simulator and the EDA after running the second script.

Participant	**Session**	**Situation**	**Duration(ms)**	**NS-SCR ID**	**Amplitude(µS)**
1	1	1	1373	0	0
1	1	1	2626	4	0.5627
1	1	1	4255	7	0.5206
1	1	1	9123	0	0
1	1	1	1118	23	0.0332

The last thing that was done to modify the data was to summarize the data for every participant and every lesson he or she did. This means that there was a row for every participant and every lesson he did. In this row was also the total number of NS.SCR's, the total amplitude and the total time in every situation. This way it was easier to test between the different situations and participants.

Before there can be tested whether there is a difference between the control situation, the waiting situation and the reducing speed situation there have to be remarked that as can be seen in the results in the next section there is a big difference in the amount of NS-SCR's but also in the time spend in a certain situation between participants. Besides this there is also a difference between for example 10 NS-SCR's with a total amplitude of 1 and 5 NS-SCR's with a total amplitude of 100. In the last situation, even if there were less NS-SCR's, the NS-SCR's that were there had an higher amplitude. Therefore the NS-SCR's have been computed to NS-SCR's per second in a certain situation per session.

After this has been done it was possible to do a paired sample t-test for each of the combinations of two situations.

For the amplitude it also first had to be corrected for the difference in time in a certain situation between participants. This is because the total amplitude as the number of NS-SCR's is influenced by how long a certain situation takes on. This will be done for the three comparisons between the three situations, and because this new variable is not normally distributed there will be done a non-parametric test.

3. Results

Before any further analysis is done, all the data was tested for normality with the Kolmogrov-Smirnov test. Hereby the null hypothesis (assuming normality) was rejected with $p < 0.0005$ (df=50, α=0.05) for the number of NS-SCR's as well for the amplitude of the NS-SCR's and the time in a certain situation. Consequentially the used statistical tests here for were non-parametric. The null hypothesis for normality with the Kolmogrov-Smirnov test for the number of NS-SCR's per second in each situation turned to have a normal distribution. These tests will be done with the parametric tests.

3.1. Electrodermal Activity

The electrodermal activity of every person differs from each other. The first thing checked therefore is if there is any difference between the number of NS-SCR's from the five participants in the three situations together and the second will be if there is any difference between the amplitude of the NS-SCR's from the five participants in the three situations. To test this a Kruskal Wallis test is performed on the data. For both the number as the amplitude of the NS-SCR's the null hypothesis is rejected, which means that there is a significant differences between the five participants χ^2 = 19,098, p = 0,001 and χ^2 = 16,876, p = 0,002.

Figure 1. Overview of the total quantity of NS-NSR's per lesson and per participant in the three situations.

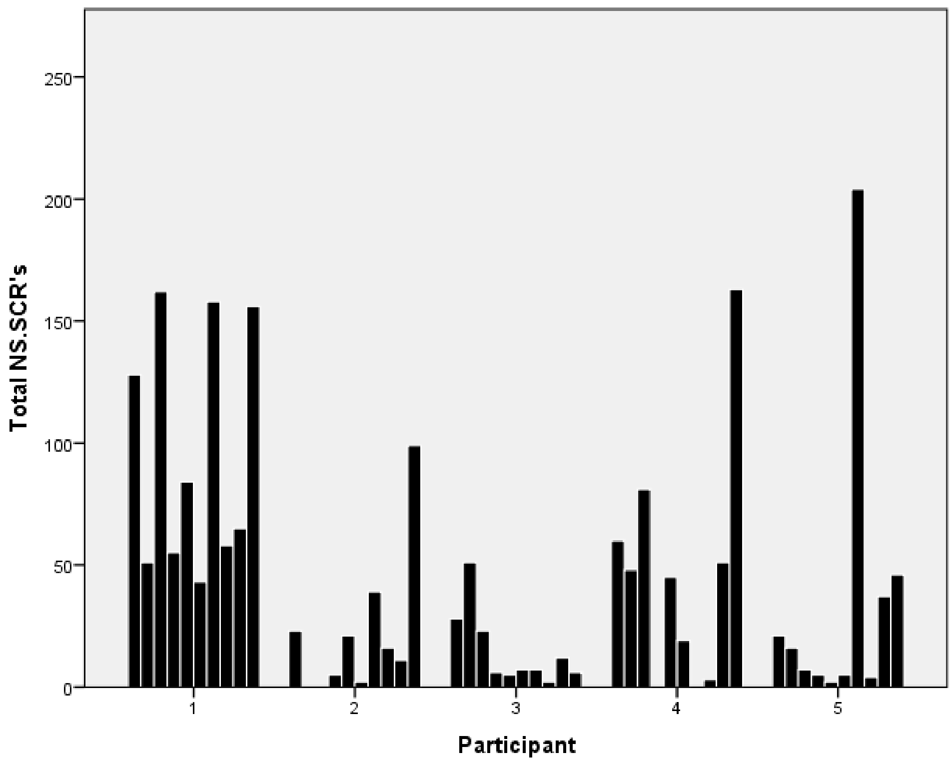
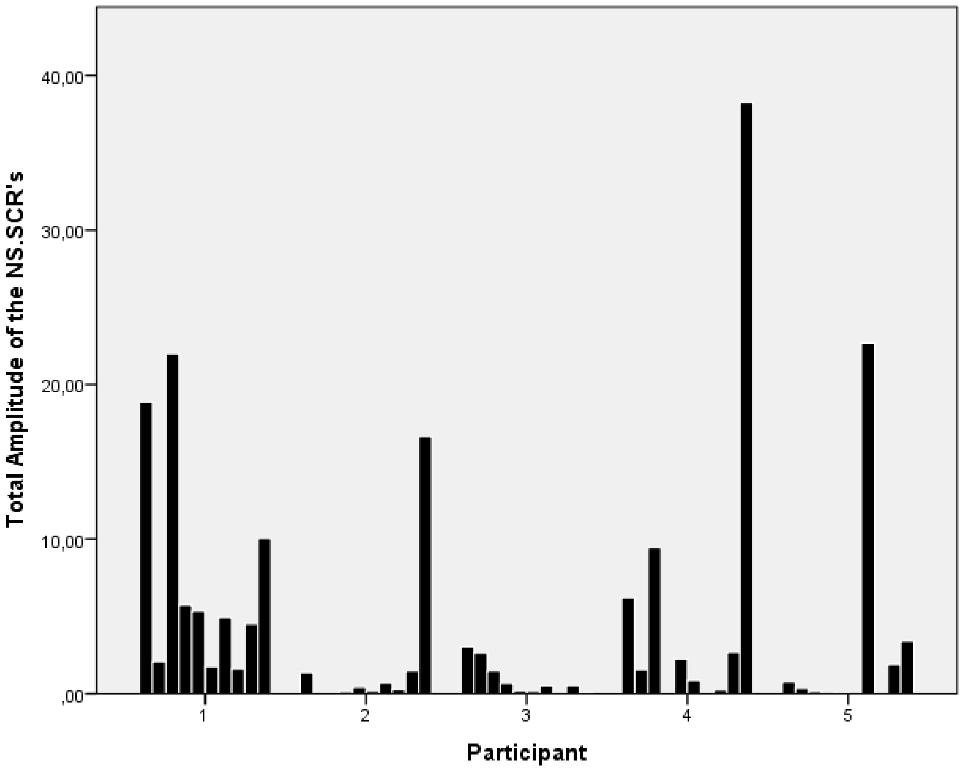


Figure 2. Overview of the total amplitude of NS-SCR's per lesson and per participant in the three situations.



There is also a difference between how long the participants are in a certain situation during their lessons, this is also tested with a Kruskal Wallis test for each of the three situations. What is remarkable here is that there is a significant difference between the participant for the control situation and the braking situation, respectively χ^2 = 9,718, p = 0,045 and χ^2 = 12,085, p = 0,017, but that the null hypothesis can't be rejected for the waiting situation, χ^2 = 6,334, p = 0,176 and therefore that there is no significant difference between the participants in how long they are in the waiting situation. This is remarkable because in every way the participants differed from each other, except for the time they were in the waiting situation.

Further descriptive statistics were applied to the EDA data from the participants during for each of the three situations separately.

3.1.1. Descriptive statistics for the control situation

The highest number of NS-SCR's during a lesson in the control situation was 201 NS-SCR's by participant 5, followed by participant 1 with 155 NS-SCR's, participant 4 with 75 NS-SCR's, participant 2 with 59 NS-SCR's and participant 3 with 20 NS-SCR's.

For the amplitude the results are just a little bit different. Participant 5 has the highest total amplitude with 22,39 µS, followed by participant 1 with 14,29 µS, then participant 2 with 12,33 µS and the two lowest total amplitudes are from participant 4, with 9.05 µS and participant 3 with 1,85 µS.

For the time we see the following ranking. Participant 5 was the longest in the control situation per session with an overall time of 1667 seconds. Participant 2 was second with an overall time of 1361 seconds, followed by participant 3 with 990 seconds and participant 1 with 969 seconds. Participant 4 was the shortest amount of time per session in the control situation with a total of 509 seconds.

3.1.2. Descriptive statistics for the waiting situation

The highest number of NS-SCR's during a lesson in the second situation was 48 NS-SCR's by participant 4, followed by participant 1 with 26 NS-SCR's, participant 2 with 17 NS-SCR's, participant 5 with 9 NS-SCR's and participant 3 with only 2 NS-SCR's.

For the amplitude the results are just a little bit different. Participant 4 has the highest total amplitude with 14,60 µS, followed by participant 2 with 1,53 µS, then participant 1 with 1,46 µS and the two lowest total amplitudes are from participant 5, with 0,43 µS and participant 3 with 0,18 µS.

For the time we see the same ranking as for the number of NS-SCR's. Participant 4 was the longest in the second situation per session with an overall time of 131 seconds. Participant 1 was second with an overall time of 60 seconds, followed by participant 2 with 56 seconds and participant 5 with 29 seconds. Participant 3 was the shortest amount of time per session in the second situation with a total of only 10 seconds.

3.1.3. Descriptive statistics for the speed reducing situation

The highest number of NS-SCR's during a lesson in the braking situation was 49 NS-SCR's by participant 1, followed by participant 4 with 40 NS-SCR's, participant 3 with 31 NS-SCR's, participant 2 with 23 NS-SCR's and participant 5 with 11 NS-SCR's.

For the amplitude the results are just a little bit different. Participant 4 has the highest total amplitude with 14,62 µS, followed by participant 1 with 6,92 µS, then participant 2 with 2,79 µS and the two lowest total amplitudes are from participant 3, with 1,32 µS and participant 5 with 0,63 µS.

For the time we see the following ranking. Participant 3 was the longest in the braking situation per session with an overall time of 270 seconds. Participant 4 was second with an overall time of 194 seconds, followed by participant 1 with 192 seconds and participant 2 with 140 seconds. Participant 5 was the shortest amount of time per session in the braking situation with a total of 126 seconds.

Table 3: Overview of the descriptive statistics of the three situations

Variable	Situation	N	Mean	Median	Stddev.OfMean	Min	Max
Total number of NS-SCR's	Control	46	33.54	20	41.03	2	201
Total amplitude of NS-SCR's (µS)	Control	46	2.74	0.97	4.59	0.05	22.39
Total time (seconds)	Control	46	502	425	276	170	1667
Total number of NS-SCR's	Waiting	46	3.35	0	8.34	0	48
Total amplitude of NS-SCR's (µS)	Waiting	46	0.52	0	2.16	0	14.60
Total time (seconds)	Waiting	46	9	0,75	23	0	130
Total number of NS-SCR's	Reducing Speed	46	9.63	3.5	12.12	0	49
Total amplitude of NS-SCR's (µS)	Reducing Speed	46	1.06	0.19	2.46	0	14.62
Total time (seconds)	Reducing Speed	46	105	103	69	1.37	270

3.2. Braking

3.2.1. Mean number of NS-SCR's

The first paired sample t-test was between the NS-SCR's per second of the control situation and the waiting situation. The results of the test were that the null hypothesis, the mean number of NS-SCR's per second is higher in the control situation than in the waiting situation can be rejected $t = 4.762$, $p < 0.0005$. This means that there are significantly more NS-SCR's per second in the waiting situation than there are in the control situation.

The second paired sample t-test was between the NS-SCR's per second of the control situation and the speed reducing situation. As in the first paired sample t-test, after this test we could also reject the null hypothesis, the mean number of NS-SCR's per second is higher in the control situation than in the speed reducing situation $t = 2.125$, $p = 0.195$, which means that there are significantly more NS-SCR's per second in the speed reducing situation than there are in the control situation.

The final paired sample t-test was testing whether the waiting situation has more NS-SCR's per second than the speed reducing situation. This final test showed that we also could reject this null hypothesis $t = 4.446$ $p < 0.0005$. This means that besides significantly more NS-SCR's per second than the control situation, the waiting situation also has significantly more NS-SCR's per second than the speed reducing situation.

The correlation between the number of NS.SCR's per second in the control situation and the speed reducing situation is high ($r = 0.890$). The correlation between the number of NS.SCR's per second in the control situation and the waiting situation is low ($r = 0.335$) and so is the correlation between the number of NS.SCR in the waiting situation and the reducing speed situation ($r = 0.288$).

3.2.2. Amplitude

The first Wilcoxon signed rank test between the amplitudes of the control situation and the waiting situation resulted in a rejection of the null hypothesis that the amplitude of the control situation NS-SCR's are higher than the amplitude of the waiting situation NS-SCR's $W = 865$, $p < 0.0005$. This means that the NS-SCR's from the waiting situation are significant stronger than the NS-SCR's from the control situation.

The second Wilcoxon signed rank test is the test between the amplitudes of the control situation and the speed reducing situation. The results of this test were to reject the null hypothesis $W = 891$ $p < 0.0005$. This means that as the amplitudes of the waiting situation, the amplitudes of the speed reducing situation are also significantly higher than the amplitudes of the speed reducing situation.

The last Wilcoxon signed rank test of the amplitudes of the waiting situation and the speed reducing situation. Here the null hypothesis that there is a difference between the amplitudes of the waiting situation and 3 is not rejected $W = 253$, $p = 0.310$. Not rejecting the null hypothesis means that there is no significant difference between the amplitudes of the waiting situation and the speed reducing situation.

The correlation between the total amplitude of the NS.SCR's per second in the control situation and the speed reducing situation is moderate ($r = 0.658$). The correlation between the total amplitude of the NS.SCR's per second in the control situation and the waiting situation is low ($r = 0.317$) , but opposing to the correlation of the number of NS.SCR's, the correlation between the total amplitude of the NS.SCR's in the waiting situation and the reducing speed situation is high($r = 0.859$).

4. Discussion

The goal of this research was to show how braking can influence the state of arousal of young drivers in a simulator during a driving course at a driving school. During this course the young drivers learned the basic skills of driving. During the entire course the EDA levels from the participants were measured through the use of a wristband. The large amount of data generated by the simulator and EDA measure were studied and showed some interesting results.

All hypotheses concerned the braking aspect of driving. The first hypothesis was about the number of NS.SCR's that occur during the driving lessons. Like other actions that are done during driving, braking does also demand an increase in task demand during driving (Helander, 1974). Helander (1974) also states that there is no correlation between pressing the brake in an unmoving car and the EDR's. In the first subhypothesis of the first hypothesis a similar result was found as in the research of Helander (1974), there are more NS.SCR's per second in the situation that someone uses the brake to reduce speed than there are NS.SCR's when someone is not using the brake and does not decelerate or accelerate. However in contradiction to the research of Helander (1974) in this research was found that there also are more NS.SCR's in using the brake in an unmoving vehicle than there are when not using the brake and there also is no deceleration and/or acceleration. When looking at the correlations found in this research we do see a similar result with the number of NS.SCR's of the three situations.

The second hypothesis was about the total amplitude of the NS.SCR's in the three different situations. Again, when looking at the results of Helander (1974) this results comes to a slightly different result. The total amplitudes of the two situations where someone is using the brake is different from the situation where someone doesn't use the brake and also not decelerates or accelerates. On top of that there is also no difference found between the two situations where the brake is used. The result of the correlation measures shows that with the total amplitude of the NS.SCR's in every situation there is a correlation between the control situation and the reducing speed situation and that there is a high correlation between the two situations where someone uses the brake. Here also is no correlation between the control situation and the situation where someone uses the brake but the vehicle is not moving. This again corresponds to the research from Helander (1974).

Looking at the general EDA data we see that there is a big difference between the five participants. As stated in the introduction EDA is an indicator of arousal, cognitive workload, emotion and stress-strain (Brookhuis & de Waard, 2011). The different tasks the participants had to do in the driving simulator can for the one be more stressful than for the other. The participants also can have experienced difference in the difficulty of the tasks and there for also may have had differences between the corresponding EDA levels. The EDA levels of people also differ from person to person (Picard, 2009). This research found the same conclusion where the total EDA of the participants differed from each other. All the tests showed that there were differences between all five participants.

4.1. General limitations

This study has some general limitations that need to be considered. The generalization of this study is limited, even though five participants produced a lot of data to consider it is not representative enough for the whole population of young drivers without any experience. It did however make it possible to take into account all the data that was produced by each one of them in three different situations.

The data is split up into the three different situations and there for can't be evaluated as a whole. The data was also split into blocks of different lengths with either a NS.SCR or not. SCR can be related to a stimulus that occurred 5 seconds before the SCR. However with the choice to split up in blocks per NS.SCR it is not possible to make statements on specific events that happened during the simulation.

There was no baseline established for the participants EDA levels, because the measuring started at the moment the participant started the simulation and also ended when the simulation ended. Therefore it is not possible to compare the state of arousal from a participant before and/or after with the state of arousal during the simulator driving lessons.

4.2. Recommendations for further research

This study creates possibilities for new follow-up studies. The goal was to see if using the braking during a driving simulator lesson was of influence on the state of arousal of a person. This gave a result that was hard to compare with earlier research, because there is done little research on drivers without experience and there is also little research on the use of a brake during driving. Some results were in line with earlier research. This leads to new research options.

The dataset used of this research was much bigger than the variables used in this research and the EDA data from the participants presented much more differences between the participants. Further analyzing of this data can even explain more on the behavior of people in a driving simulator. This can for example be done by comparing it to the EDA levels before and/or after a lesson in a driving simulator. Another option is to compare the EDA data from the participants in the driving simulator to the same data from participants who drove in a real world car. With this results there can be made a comparison between real world and driving simulator. This would be good, because at this moment there is little known about young novice drivers who drive in the real world. It will also contribute to the knowledge about how good driving simulators are at this moment, because the simulators are constantly changing through development.

4.3. Conclusion

The goal of this study was to show that certain actions during driving can influence the state of arousal a driver has. The action this research looked upon was the use of the brake pedal during driving and in an unmoving vehicle. The behavior of the participants was measured with objective measures. The participants differed from each other in their EDA levels. Some participants had more NS.SCR’s during the different situations than others had. The reducing speed situation and the waiting situation turned out to be different in the number of NS.SCR’s per second but not in the amplitude of these NS.SCR’s. Both of the situations did differ with the control situation, where the participant did not use the brake, but the vehicle also did not slow down or speed up. The results were fairly consistent with what was expected, but there is still room for further research on this subject.

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