Evaluating and Increasing Drivers' Situational Awareness (SA) in Advanced Driver-Assistance Systems (ADAS)

Junyan Chen

University of Waterloo

Abstract

This research aims to evaluate and increase the drivers' Situational Awareness (SA) in Advanced Driver-Assistance Systems (ADAS). This article started with a summary of the prior work, including their theory, methods, conclusions, and limitations. SA is the same Human Factor method that all research shares, though the Situation Awareness Global Assessment Technique (SAGAT) is the most common one among other research, it is intrusive. Therefore, based on the previous research, we proposed our empirical experiment which uses a non-intrusive technique to capture the drivers' Object Of Interest (OOI) under different traffic situations and road conditions. We plan to use a mobile eye-tracking device for the drivers on real roads and perform a two-way ANOVA over our data in 3 groups from 2 levels to determine if any difference exists. This research summarized related research and pointed out a feasible path for future works in the field of study of SA in ADAS.

Keywords

Situational Awareness (SA), Advanced Driver-Assistance Systems (ADAS), Situation Awareness Global Assessment Technique (SAGAT), Object Of Interest (OOI), Human-Centered Design, Human-Computer Interaction (HCI), SA Measurement, Eye-Tracking, Human Factors, Fatigue, Drowsiness, Detection, Driving.

Introduction

Inattention kills drivers. According to the Preliminary 2022 Ontario Road Safety Annual Report, 11.0% of fatalities in car accidents were caused by drunk driving, and 17.7% of fatalities were caused by speeding. As two famous factors in car accidents, they were already identified clearly by the public. However, lying exactly between those two, 16.4% of fatalities were caused by inattention driving(Government of Ontario). It is shocking how high the danger level is, especially when it happens unconsciously at most times. The previous 2 reasons mostly are behaviors the driver chose to act like that intentionally, but people can't realize that they were in low attention.

In the study of human factors, we have a similar term to include attention which is called “situational awareness” (SA). There are three stages of situational awareness. From stage 1 to stage 3, they are “perception”, “comprehension”, and “projection”. “Perception” is the stage in which the information from the outside is received by the person. “Comprehension” is the stage in which the information received previously is processed and understood by the person. “Projection” is the stage in which the person immediately realizes what will happen in the near future. Therefore, to decrease the fatalities caused by inattentive driving, and to increase the safety level of driving, we aim to research methods to evaluate and increase the drivers' situational awareness.

To be more specific, we limited our research target to drivers who drive cars with Advanced Driver-Assistance Systems (ADAS). Refer to Figure 1.1, According to the definition of Automation by the Society of Automation Engineers (SAE), there are 5 levels of automation plus a level 0 which means no automation at all(“SAE levels of Driving AutomationTM”). At the time the article was composed, there were already cars of level 5 driven on the road in some countries. However, when the research was established, it was common for manufacturers to announcing their product only supports automation level L2. Therefore this research strictly began with automobiles under automation level 3, which means the car is still driven by the human driver. Any automobile attributed to automation level 3 or above was not the research target.

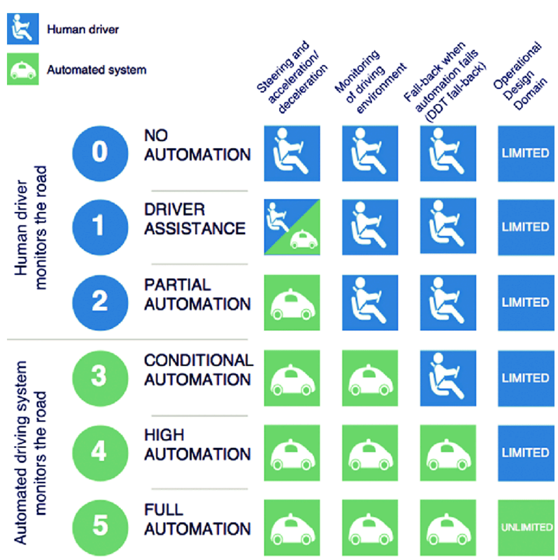

Figure 1.1

Starting with literature reviews, we reviewed articles from Google Scholar, ELSEVIER, ACM Digital Library, and IEEE Explore. We focused on their methods and results, so we could generate our methods of research.

Human Factor Methods

All the articles I found were research in the field of driving integrating with the study of SA. That means that all 10 articles used the SA method. SA is a great point to start with when increasing drivers' performance in ADAS. For driving automation levels under level 3, which is considered ADAS, the vehicle is still identified as driven by the driver. At this point, purely increasing the intelligence of the car cannot satisfy people's pursuit of driving safety, which leads people to another approach that is increasing the drivers' performance. One significant way to accomplish this is by increasing the drivers' SA.

Talking about the measuring methods, Situation Awareness Rating Technique (SART) and Subject Matter Expert (SME) were mentioned, but not as the most widely used. Situation Awareness Global Assessment Technique (SAGAT) is the most popular one, 4 articles used this technique, while one article points out that the Situation Presence Assessment Method (SPAM) is theoretically more effective(Pečečnik, 2023). SAGAT is a technique that is applicable in most fields of research of SA. It is effective globally. SAGAT and SPAM are both SA measuring techniques that require the sample to answer questions while performing. However, compared with its advanced version, SPAM, SAGAT is limited somewhere. First, SAGAT interrupts the sample, which causes a freeze during the experiment and leads to an unnatural moment. Second, SPAM records the time the sample answers questions, which provides more details and data to the researcher.

Other methods like Human-Computer Interaction (HCI), Human Machine Interaction (HMI)(Wulf, Rimini-Döring, Arnon, & Gauterin, 2015), and quantification were used in specific articles but were not common.

Data Collection Methods

6 articles used direct observation(Jia, Jianping, Changrun, & Lixi, 2023), though one of them is observation integrated with query(Saito, Itoh, & Inagaki, 2016). 3 articles somewhat used advanced technology, 2 of them performed their experiment using eye-tracking(Shirpour, Beauchemin, and Bauer, 2020)(Morales-Alvarez, Marouf, Tadjine, & Olaverri-Monreal, 2021), while another one performed using advanced electrocardiogram (ECG)(Zhang, Wu, Chen, Wang, Huang, & Zhang, 2022). The last one discussed different ways of measuring SA, therefore it did not perform any experiment, which means there will not be any statistical analysis for it in the next section.

Compared with the others, direct observation has advantages naturally. First, it is easy to perform. It does not require extra equipment to observe the sample. All required is observing and recording. Second, it happens naturally. Without being under a simulation or in a lab, the sample acts as how it acts. It prevents samples from acting irregularly or being nervous which decreases the accuracy of data extraction. But is it unbeatable? Of course not. Without the help of powerful advanced technology like eye-tracking or ECG, the efficiency decreases a lot. Direct observation requires the researcher to sit there and observe the sample. Only one sample could be observed one time. Such a technique will not have too much pain if the desired information is just in one picture, but when the researcher wants a set of information during a procedure being performed within a continuous time interval, this is a problem. This situation applies to most research on SA because people's SA cannot be told within one picture. Another pain here is simply performing direct observation itself gains only a little information, which is not enough for more analysis. However, there are always exceptions. One of the articles analyzed their data from multiple dimensions but they experimented with each sample multiple times under different variables(). This brings another issue of the learning effect. Therefore, an ideal way to experiment is to integrate multiple types of experimental methods. One of the articles integrated direct observation and queries, which is a great example.

Statistical Analysis Methods

There is one article that mainly talks about the differences in measurements of SA, which has no experiments or analysis. Other than that, 3 articles do not perform any analysis, instead, they have only proposed their experimental procedure(Chandiwala, & Agarwal, 2021). One article used the GPR model and another article used Endsley's SA Model. Their analyzing techniques are specifically appropriate for their experiments but may not be generally useful.

The remaining 4 applied classic statistical analyzing techniques, they are one correlation and regression analysis, one t-test, and 2 one-way ANOVA. Correlation and regression analysis were more used for fitting a line or curve to a set of data points to establish a predictive relationship, it helps identify trends and forecast future outcomes. This technique is helpful for experiments that hope to directly gain a functional result. However, for the experiments mainly focusing on finding if a significant difference exists, a t-test or one-way ANOVA is more applicable. For the article used the t-test, it is more appropriate to use one-way ANOVA since there are multiple groups to be compared, but a t-test can only compare two groups.

Hence, one-way ANOVA is the most popular analysis technique. Whereas, it depends on how the experiment was designed. It could be a t-test if there are only two groups to be compared. It could be correlation and regression analysis if the researchers want to predict some future. It could even perform no statistical analysis if the research focus is not to compare.

Literature Conclusion

Conclusions from different articles vary from each to each. It’s hard to include all the conclusions here, but similarity still exists. 5 articles suggest new ways of SA detection. They all share the similarity of being non-intrusive and mainly focusing on the drivers’ head position or eye-glance region. 3 articles proposed things decreasing the drivers’ SA and they all mentioned the secondary task. One article proposed a solution to drivers’ fatigue from the approach of controlling the vehicle by the computer. The article compares measurements of SA without any experiment and concludes that SAGAT is the most widely used, while SPAM is better than SAGAT because it’s nonintrusive, however, the participants could be prepared for the questions.

Literature Limitation

They also share the same limitation, which is the sample limitation. Though some researchers tried to avoid it in their experiments by involving samples from different groups, sample limitation is always hard to avoid for most researchers. Other than that, some experiments have limitations since they were designed. It usually happens when the experiment is performed in the lab under simulation. People can drive anywhere and anytime so it’s hard to cover all environmental situations. The third limitation that happens to most experiments is that their technique is intrusive to the sample, which makes the samples perform abnormally, causing errors in the stage of data gathering.

Methods

By learning from the previous research done in this field, we have generated a blueprint for our empirical experiment. Most experiments done in the past were limited to only several road conditions. They have controlled the condition that the driver drives solely on a straight road to find out what decreases their SA. Here we want to seek the answer to our research question "Does Drivers' SA vary under different traffic situations and road conditions". As SAGAT and SPAM are both intrusive, I am going to use neither of them, instead, referring to Kim and their teams' research, they found that eye glance is associated with awareness of road hazards(Kim, Martin, Tawari, Misu, & Gabbard, 2020). Hence we are going to design our experiment similarly but taking a step further. The basic idea is to have the drivers driving with an eye-tracking device, so we can gather the drivers' stare points at specific traffic situations and road conditions. Other than different traffic in the country and city, we will also be focusing on different road conditions including straight roads, turning, and crossing. In that way, we will be able to capture the drivers' Object Of Interest (OOI) on real roads(Hofbauer, Kuhn, Püttner, Petrovic, & Steinbach, 2020).

Recruitment

We plan to recruit 8 drivers with valid Ontario driver's licenses since the drivers drive in the same province and share the same driving culture and rules. We will try to recruit participants from different genders, and ages. They will be divided into 2 groups randomly. Group 1 will drive in downtown Kitchener for 30 minutes at 6 pm, which is about the most crowded hour. Group 2 will drive from Conestoga Mall to Elora, which is approximately a 30-minute country drive. Compared with the preliminary empirical experiment design, we cut down the number of participants a lot, so it can be more feasible for us to get the expected number of participants. Meanwhile, we abandoned the part of AI analysis, since we will not have enough data resources to train a model.

We will run the experiment with each participant one by one, so we do not need to wait until all 8 participants are found to start the experiment. Before each participants start their experiment, we will announce the experiment agreement and have them sign it. The agreement contains a brief declaration of the purpose of the study, the behavior expectation for the participants, which is to drive how they drive regularly, a notification for the participants that their eye-moving data will be recorded, and a promise that any data gathered in this experiment will only be used for this study and possible related further study but not any other commercial purpose.

Variables

The independent variable is the traffic situation, which includes Crowded (City Drive) and Not Crowded (Country Drive), and the road conditions, which include Straight, Turning, and Crossing. The dependent variable is the stare points.

Equipment

The experiment will take place on the road with a 2024 Mazda 3 Hatchback, provided by our research team.

To gather the data, we will be using a Tobii Pro Glasses 3. Refer to Figure 2.1 this mobile eye-tracking device is an excellent solution for real-world human factor research. It has 4 micro cameras on the lens to track the eyes and one camera in the front to record what the wearer sees now. Therefore it captures the wearer's gaze and the real-time scene the wearer sees.

Figure 2.1

To run the statistical analysis, we will be using R Studio, Version 2023.12.0+369 (2023.12.0+369). It allows the user to perform most statistical analyses with a simple programming language.

Statistical Analysis

We will run basic statistics over our user sample together and in each group separately. We will be focusing on the mean and standard deviation of age and driving age.

We will also calculate the basic statistics for mileage in the city and the time taken in the country in the experiments.

By observing the video captured by the mobile eye-tracking device, we can compare the stare points at different road conditions under different traffic situations, which means there will be 6 scenarios in total. Since there are 3 groups of data in 2 levels to be compared, we will perform the two-way ANOVA to determine if there is a statistically significant difference between their OOI in country and city.

Results

Since we have the background information of the users, the background information statistics will be able to give us a clear figure of our sample. The statistics of the mileage and time elapse can reflect the driving skills from participant to participant. If the quality of the trip is too low, it indicates the driver's driving skill is not ideal and their SA is relatively low, which might not give us clear information about a regular driver's SA and we will consider running the experiment with another participant to replace the data.

By performing the two-way ANOVA, we will be able to get a clear signal that if there is statistically significant evidence that difference exists. The comparison will happen from 2 levels and there will also be another comparison of those two levels' interaction with each other.

The first comparison is between driving in crowded and not crowded traffic". If we find evidence that difference exists, the experiments that took place in not crowded situations need to be performed under a crowded situation since the drivers' SA changes under different traffic situations.

The second comparison is between driving on straight roads, turns, and crossing. If we find evidence that difference exists, the experiments that took place solely on straight roads have to extend their experiment conditions into more road conditions since the drivers' SA changes under different road conditions.

The third comparison is to determine if the road conditions and traffic situations affect each other. Since they objectively exist and will not be affected by our experiment, the result of this statement is probably no affection.

Discussion

Principle Results

The results from this experiment are going to be answers to 3 true or false questions. “Is the drivers’ situational awareness different when driving in crowded and not crowded traffic”, “Is the drivers’ situational awareness different when driving on straight roads, turns, and crossing”, and “Does the drivers’ situational awareness in different traffic situations get affected by different road conditions.” If any difference exists there, it would be a piece of evidence that the previous research done by other research teams should be performed again to assess their research target under different situations and conditions.

Limitations

Though our research was established on the previous work and we tried to improve from their limitations, a lot of limitations are hard to avoid. Thus, our research has several limitations.

First, our sample size is relatively small and it might not be representative of a larger group of people. We have only considered recruiting participants from south Ontario, even possibly only from the Kitchener and Waterloo Region. However, if we repeatedly perform this experiment, we might be able to get enough data to train an AI module that can identify common stare points of the driver under different situations and conditions, then it could be possible for us to run this experiment massively for a larger population since the analyzing part would be easier. Even more, we could take one step further to detect the SA level of the driver and warn in real time.

Second, though this experiment aims to compare driver’s SA under different situations and conditions, a lot of other situations and conditions were not covered. Due to safety considerations, we did not cover the situation on the highway and hazardous weather like snow or storm, but those situations are possible for the drivers to encounter and they are exactly the moments the drivers’ SA decreases a lot. If the current experiment could be performed safely on a larger group of people, we can consider taking it into those risky situations. Nevertheless, the researcher must be more than cautious to prevent the participants from danger, so extra considerations and reactions must be planned.

Comparison with Prior Work

Compared with prior works done by other researchers, our research ensures the generality of their results and gives supporting evidence for the direction of future works. Most previous studies took place in simulators or closed areas. Our experiments take place on the road and give a real touch to the result. Our experiment can testify if their results have generality. If not, what situations and conditions make their results lose their generality, and how they can perform it again?

Due to the generality of drivers, it is so hard for any experiment to conclude with a result that applies to the whole world. We all attempt to eliminate sample limitations by recruiting a diverse sample group, but it is still such a small attempt compared with such a large actual user group. With ADAS in cars, it is becoming more feasible to gain experimental results from automobile manufacturers as long as they are willing to attempt to ask if the user would like to improve their product together, just like the user experience improvement program service provided on smartphones.

Conclusions

Our literature research has provided us some remarkable theories in the field of study of SA in ADAS.

First, comparing with the rest of the SA measurements, SAGAT is the most common one, while SPAM allows the participant to perform continuously. However, both of them are intrusive, there is difference from the experiment to the reality when applying those two measurements.

Second, there is a trend that more and more researchers chose to combine multiple methods in their experimental design, so they can gain data from different aspects at the same time and conclude multiple results after statistical analysis.

Third, Eye-glance is associated with awareness of road hazards. Several different articles and researches have conclude this same statement. This is also an important supporting statement allows our experiment to be established.

Our experiment has two possibilities. One, we found some difference, the other one, no difference at all.

We are expecting some differences between different situations and conditions. Ideally, our research can help the researchers identify what situations or conditions they should consider differently when performing experiments related to SA. For example, if there is statistically significant evidence that the drivers' SA is different in city and in country, it would be necessary for the previous researchers to perform their experiment again under crowd and not crowd situations.

If there is shockingly no difference, we are also happy to say the previous results from the past research have generalities and this field of study can proceed with their results safely, thus, this study on SA in ADAS can progress and evolve more quickly.

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Conflicts of Interest

We have no conflicts of interest to disclose.

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Abbreviations

SA: Situational Awareness

ADAS: Advanced Driver-Assistance Systems

OOI: Object Of Interest

SAGAT: Situation Awareness Global Assessment Technique

SAE: Society of Automation Engineers

SART: Situation Awareness Rating Technique

SME: Subject Matter Expert

SPAM: Situation Presence Assessment Method

HCI: Human-Computer Interaction

HMI: Human Machine Interaction

ECG: Electrocardiogram