Inquiry-based method for in situ assessment of driver's situational awareness

Aleksa Ćirković[1], Kristina Stojmenova Pečečnik[1]

[1]University of Ljubljana, Faculty of electrical engineering
E-mail: ac3204@student.uni-lj.si, kristina.stojmenova@fe.uni-lj.si

Abstract. *This paper presents a method designed to assess drivers' situational awareness by employing a combination of general driving questions and situational-specific inquiries in real time during driving. It aims to evaluate the driver's situational awareness, which plays a vital role in ensuring safe and efficient driving practices. The method is based on a mobile application that consists of a user-friendly interface that presents a series of carefully selected questions, encompassing general driving knowledge and understanding of specific driving conditions or vehicular behavior. The general driving questions are aimed at evaluating the understanding of traffic rules, road signs, and driving practices. Situation-specific aim to evaluate the driver's perception of the environment, and their ability to anticipate, react, and make informed decisions in real time.*

This paper presents the method and a short user study that was used to evaluate it. The test users rated their user experience positively and praised the application for its comprehensiveness and ease of use. The results between the established method used as a reference system and the new proposed were also aligned, confirming that the new inquiry-based method for real-time assessment can be used for the assessment of driver's situational awareness.

1 Introduction

Situational awareness (SA) plays an important role in any dynamic process of human decision-making, as it provides the level of knowledge required to make effective decisions and take appropriate actions [1]. According to SA theory [1], to achieve SA it is necessary to perceive the elements of the environment, understand their meaning, and be able to project their status in the near future. Various methods have been developed to assess SA, which generally fall into three categories: self-assessment, inference, and query-based techniques [2].

Self-rating techniques are usually based on questionnaires and scales, where the operator is asked to provide a (numerical) subjective evaluation of their SA for a given period of time or during the execution of a given task. Their greatest advantage is their simple and cost-effective implementation. However, their greatest advantage over query techniques is also one of their greatest disadvantages: because they are completed at the end of a task, they can often reflect only the last part and not necessarily the total duration of the task.

SA has also been evaluated using inferential or external procedures that seek implicit evidence of the operator's SA using observable and measurable correlates. There is no single format for conducting inferential SA assessment; the individual's performance and behavior are observed using various techniques as indirect evidence of the presence or absence of appropriate SA. This can be done by expert observation of the operator and completion of behaviorally anchored rating scales developed for performance assessment. Because there isn't a defined metric for inferential assessment, comparison of results can be difficult and sometimes even impossible.

Query techniques ask operators to report information about the system that points to their SA. The best-known query technique is the Situational Awareness Global Assessment Technique (SAGAT) [3], which accesses SA by showing the operator a simulation of the system being operated. SAGAT uses a frame-freeze technique to pause in critical situations and asks the operator questions to assess their SA at that moment. SAGAT has also been recognized as an intrusive metric because it requires stopping the process and does not allow for continuous or real-time assessments. One query method that attempts to avoid this is the Situation Present Assessment Method (SPAM) [4]. SPAM is a real-time assessment query technique, which occurs during the continuous operation of the system. The operator is presented with a query request, which proceeds to the presentation of the query only after the operator accepts it. Based on its characteristics, SPAM is a very good method for assessment of a driver's SA, however, the method has not been adapted for the automotive domain.

This motivated us to develop a query-based method for real-time assessment of driver's situational awareness, which draws inspiration from SPAM while taking into consideration all of the specifics of driving and operating a vehicle.

2 Method development

The method is based on a mobile application, which can be displayed on any mobile device, that has at least Android 8 (Codename: Oreo, API Level: Level 26) and a minimum RAM of 1536MB. The collected data via application is stored online using Firebase Realtime Database, which is a cloud-hosted NoSQL database service provided by Firebase, a platform developed by Google. The mobile device is then placed on the vehicle's dashboard or any other place that is in the driver's visual field of view, and their arm's reach.

The application consists of five components: Starting Activity, Welcome Screen, Main Activity, Questions, and Ending Activity.

Upon launching the application, the Starting Activity records the application's start time of completing the task. The user is then presented with the Welcome Screen, which displays an animated app logo. After a random interval between 1 and 2 minutes, the Main Activity appears, offering the user the option to accept or decline a question. Choosing to decline redirects the user back to the Welcome Screen, initiating the process anew. Choosing to accept the question leads to the component called Questions, where the user is presented with a multiple-choice question retrieved from the Firebase Database, along with four answer options. Once the user selects an answer, the Welcome Screen reappears, and the process restarts.

Upon answering all predefined questions (in our case we decided on 10; the number of questions can be adapted to the length of the driving task), the application terminates, and the ending time is recorded as the ending time of completing the task.

At the end of the task, all collected data, including request time, request response time, response value, answer response time, answer value, answer correctness, and task completion time (answer all questions), is stored in the Firebase Database.

2.1 Starting Activity

The sole purpose of this component is to store the time the application starts using Shared Preferences and to immediately launch the next component called Welcome Screen.

2.2 Welcome Screen

This component is used to:

1. Check whether the total number of questions has been reached. If it is, open the Ending Activity which shuts down the application. If it is not, then proceed with running this component.
2. Save the time this component is opened into Shared Preferences so we can later subtract that value from the time the next component is opened and therefore calculate the “request time” or time needed for the application to send the request for a new question.
3. Get the value from the Shared Preferences provided in the component Main Activity which saves the user's response (accept or decline) to the new question request. If the user accepts the question, the application opens the next component called Main Activity at the random interval between 1 and 2 minutes. If the user declines the question, then the application opens the next component at a random interval between 20 and 30 seconds.

2.3 Main Activity

This component is used to:

1. Save the time this component is opened into Shared Preferences so we can later subtract that value from the time the user selected accept or decline to calculate the "request-response time".
2. Save the value of the user’s response to the question request (accept/decline) into Shared Preferences, so the application knows at which interval to send the new question request.
3. Play an audio signal of 4000Hz at 65dB to attract the user's attention [5]. This way user gets an auditory notification of a new question request.
4. Run a visual animation for a new request notification to attract the user’s visual attention (**Error! Reference source not found.**). On the screen are shown two buttons, one to accept the question, and one to decline it. The Accept button reroutes the user to the next component called Questions. The Decline button brings the user back to the component Welcome Screen.

2.4 Questions

This is the most complex of all components. Here the following data is saved into Shared Preferences: time to select an answer to the question from the multiple-choice list (answer time), which answer the user selects (answer value), and the answer the user picked the correct answer (answer correctness). The multiple-choice always present four possible answers that the application gets from the Firebase Database. One option is always “I don’t know”. The questions are presented in a predetermined order, so every user can get their questions in similar parts during the driving simulation. Here are some examples of these questions:

1. You may not park: “On a hill”, “In a parking lot”, “On a crosswalk or in a marked bicycle lane”, or "I don't know".
2. When your vehicle is being overtaken, you should: "Stop your vehicle and let the vehicle overtake", "Increase the speed of your vehicle", "Not obstruct the other vehicle from overtaking", or "I don't know".
3. Can you overtake on this road: "Yes", "No", "Only when it is dark outside", or "I don't know".
4. Your first response to reduced visibility should be: "Turning on your headlights", "Reducing your speed", "Turning on your windshield wipers", or "I don't know".

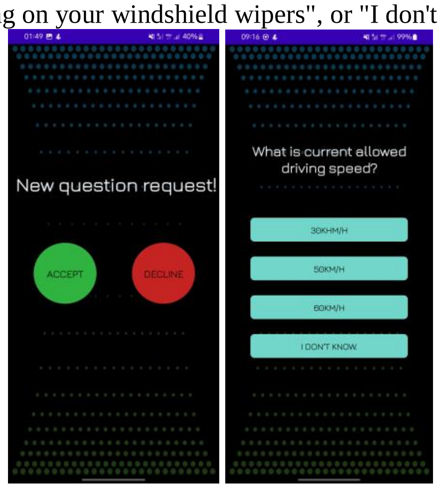

Figure 1. (left) New question request, (right) Example of questions

2.5 Ending Activity

The purpose of this component is to calculate the “task completion time”. To do so, it looks at the starting time of the application from Shared Preferences and using that, calculates the running time of the application. It also converts it into a format of minutes, seconds, and milliseconds. When that is calculated and stored into Shared Preferences then the application terminates.

3 Method evaluation

The new method was evaluated with a short user study. The study was conducted in a simulated driving environment consisting of a mobile driving simulator with real car parts (seat, steering wheel, and pedals) and a physical dashboard. The visualization of the driving environment was displayed on three 49-inch curved TVs providing a 145° field of view. SCANeR Studio was used to create the driving situation. Tobi Pro 2 eye tracker was used to collect the participant's gaze and insight into their visual attention on the road. Due to the paper length limitation, the collected pupillometry data is not presented in this submission.

3.1 Participants

13 people participated in the study, 7 male and 6 female, all between the ages of 20 and 35 (M = 22.538, SD = 3.522). All of them had between 1 and 16 years of driving experience (M = 4.308, SD = 3.603), and 6 of which have never driven a driving simulator before. Most of them drive their cars between a few times a week and a few times a month. Participation in this study was voluntary, and participants could stop participating in the study at any time.

3.2 Participant's tasks

The participant's primary task was the safe operation of the vehicle. They were asked to complete a 30 km route while driving on suburban, urban, and regional roads. The route featured multiple crossroads, other road participants, changes in speed limits, and a rich driving environment, to make up for a naturalistic driving experience.

The participant's secondary task was answering the questions from the application. At the same time the driving simulation started, we started the application.

3.3 Variables

In the study, we wanted to evaluate the sensitivity and user experience of the newly proposed method for the assessment of driver's situational awareness. To do so, we observed the following dependent variables:

- Situational awareness: collected with our application, and with the SART questionnaire [6] as a reference measure, and
- User experience: collected with User Experience Questionnaire [7].

4 Results

4.1 Situational awareness – data collected with the new method

The results of the request-response time, answer response time, and answer correctness from the newly proposed method are presented in Table 1.

The data collected with the application also showed that on average, declined the question request in 2.923% (SD = 7.898), and selected the "I do not know" answer for 3.077% (SD = 4.615). The average task completion time was 18:35.697 (SD = 1:22.124) [min:s.ms].

Table 1. Situational awareness performance data collected with newly proposed methods

ID	Request response time [ms]	Answer response time [ms]	Answer correctness [%]
1	M=3553.7, SD=4675.244	M=13140.702, SD=11472.598	M=80, SD=40
2	M=7616, SD=10230.043	M=21569.8, SD=11472.434	M=70, SD=45.8
3	M=3185.9, SD=614.145	M=11383.8, SD=5980.885	M=90, SD=30
4	M=5807.4, SD=11138.082	M=10523.6, SD=4838.669	M=80, SD=40
5	M=8007.3, SD=15917.088	M=14512.1, SD=6579.702	M=70, SD=45.8
6	M=3329.091, SD=725.583	M=10104, SD=4823.689	M=60, SD=49
7	M=8335.6, SD=10754.765	M=33395.1, SD=21166.514	M=80, SD=40
8	M=3275.1, SD=2429.146	M=12315.5, SD=5247.296	M=90, SD=30
9	M=2389.5, SD=594.928	M=8599.8, SD=3269.639	M=90, SD=30
10	M=2672, SD=1473.302	M=10955.6, SD=5985.571	M=70, SD=45.8
11	M=7805.4, SD=3816.003	M=13440, SD=5561.818	M=90, SD=30
12	M=2910.8, SD=2293.999	M=12878.9, SD=7674.738	M=100, SD=0
13	M=6212.857, SD=5903.183	M=8838.8, SD=3685.220	M=60, SD=49

4.2 Situational awareness – data collected with SART

SART is a questionnaire-based technique consisting of ten questions that ask the operator about different dimensions of situational awareness. The operator answers the questions on a seven-point rating scale, where 1 = Low and 7 = High. The ten questions correspond to ten dimensions of SA, which are then grouped into the three SA constructs: Attentional Demand (D), Attentional Supply (S), and Understanding (U) of the situation. The ratings are then combined to calculate a measure of the participant's situational dimension using the formula SA = U – (D – S). Scores on the SART can range from a maximum of 46 to a minimum of -14, with a higher score indicating better situational awareness [6].

The results collected with SART are presented in Table 2.

Table 2. SART results per participant

ID	SART - U	SART - D	SART - S	SART score
1	11	6	26	31
2	14	14	22	22
3	17	5	26	38
4	11	7	20	24
5	17	6	26	37
6	13	8	25	30
7	14	15	20	19
8	16	10	27	33
9	12	10	23	25
10	14	12	19	21
11	16	10	24	30
12	17	6	27	38
13	12	12	19	19

4.3 User Experience

The participants rated their user experience with the application with User Experience Questionnaire [7]. The UEQ scores scale ranges from -3 (terribly bad) to +3 (extremely good). Values between -0.8 and above +0.8 are considered neutral, values above +0.8 represent a positive rating, and values below -0.8 a negative rating. The results revealed positive evaluations in several key features (Figure 1). Attractiveness, Efficiency, Stimulation, and Novelty all received favorable feedback, highlighting the app's visually appealing design, seamless performance, engaging user experience, and innovative elements. The quality that received the highest rating was Perspicuity.

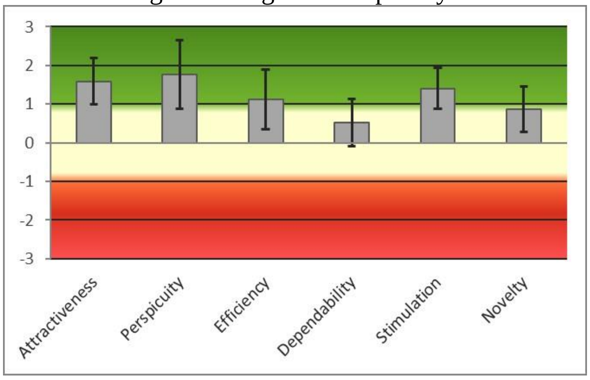

Figure 1. UEQ results

Participants praised the app's clarity and user-friendliness, emphasizing its ability to enhance situational awareness without causing distractions or confusion. Dependability, on the other hand, received a neutral evaluation, indicating room for improvement in terms of reliability and consistency. These results show the application evokes a good user experience and is overall rated positively.

5 Discussion

To ensure accuracy and fairness, the application utilizes a sophisticated scoring algorithm that analyzes the driver's responses. The algorithm considers factors such as the correctness of the answers, response times, and the appropriateness of situational decision-making. While most available methods only focus on the correctness of the answers, this method also provides information about the time the driver needs to respond to a question and the time needed to accept a new question. These two prices of information provide a further understanding of how long it takes for a driver to gain appropriate situational awareness because they only accept a question after they try to gather enough information to try to answer a question correctly.

When looking at the results collected with the user study, we can see that the results collected with the questionnaire, which was used as a reference system, have a comparable trend to the ones collected with the application. This indicates that the new method can be used for the assessment of driver's situational awareness. Furthermore, the application was rated positively on user experience, indicating that it was designed appropriately.

The application's results can be utilized in various ways. Individual drivers can identify areas for improvement and enhance situational awareness skills. Driving schools can integrate the application into training programs, tailoring instruction to student needs. Fleet management and insurance companies can evaluate driver risk profiles and implement targeted interventions. Using the widespread use of smartphones, this application provides an accessible and cost-effective solution for assessing driver's situational awareness.

References

[1] Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. In *Human Factors Journal*, *37(1)*, 32-64.

[2] Fracker, M. L. (1991). Measures of situation awareness: Review and future directions.

[3] Endsley, M. R. (1988, May). Situation awareness global assessment technique (SAGAT). In Proceedings of the IEEE 1988 National Aerospace and Electronics Conference (pp. 789-795). IEEE.

[4] Durso, F.T. and Dattel, A.R. (2004) 'SPAM: the real-time assessment of SA', in Banbury, S. and Tremblay, S. (Eds.): A Cognitive Approach to Situation Awareness: Theory and Application, pp.137–154, Ashgate Publishing Ltd., Hampshire.

[5] Stojmenova, K., Policardi, F., & Sodnik, J. (2018). On the selection of stimulus for the Auditory Variant of the Detection Response Task Method for driving experiments. *Traffic injury prevention*, *19*(1), 23-27.

[6] Taylor, R. M. (1990). Situational awareness rating technique (SART): The development of a tool for aircrew systems design. In Situational awareness in aerospace operations.

[7] Laugwitz, B., Held, T., & Schrepp, M. (2008, November). Construction and evaluation of a user experience questionnaire. In Symposium of the Austrian HCI and usability engineering group (pp. 63-76). Springer, Berlin, Heidelberg.