DAZE: A Real-Time Situation Awareness Measurement Tool for Driving

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Abstract
A driver's situation awareness (SA) while on the road is a critical factor in his or her ability to make decisions to avoid hazards, plan routes and maintain safe travel. Understanding SA can therefore be a great help when designing or evaluating new interfaces intended to support these decisions. However, existing tools for measuring SA in simulated environments require halting the simulation currently in-progress to question participants or administering post-drive questionnaires. Through our experience developing interfaces for autonomous vehicles in both simulated and on-road environments, we have found a need for real-time SA measurement designed specifically for both simulation and on-road driving scenarios. We are developing a tool, inspired by the Waze [tm] driving app, to measure SA through real time on-road event questions. The system has been tested in lab and will be further evaluated against current SA measurement tools.

Author Keywords
Driving Assessment; Situation Awareness; Autonomous Vehicles; Human-Machine Interaction

ACM Classification Keywords
H.1.2. User/Machine Systems.

Introduction

Current best practice for measuring SA during driving simulations requires experimenters to either (a) freeze the simulation and survey participants' immediate awareness, effectively suspending their immersion in the simulated environment, and requiring them to reinsert themselves back into the situation afterward, or (b) ask participants to complete a post-activity questionnaire, hoping that they can recall and distinguish specific events that may have occurred a while ago. While these methods are well tested, it is desirable to measure SA in real time without stopping the driving activity or relying on recollection of prior events. In addition, for on-road activities it is not feasible to stop the driving activity and measure SA. This paper outlines current approaches to measuring SA and presents a new, real-time measurement tool design specifically for driving. The tool is designed to resemble the commercially available navigation application Waze [tm], which itself was designed to keep drivers apprised of real-time on-the-road situations. We are designing the tool to be used in both lab and on road simulation environments without the need for the driving activity to be stopped.

Background

Because SA is an important factor in avoiding immediate driving hazards, navigating in unfamiliar places and ensuring safe, timely travel, as new interface technologies are developed, we want to understand how they influence drivers' SA. Endsley defines SA as having three levels: (1) Perception of elements in the environment, (2) Comprehension of elements meaning, and (3) Projection of elements future status [1].

Current Measures of SA and their Limitations

Current tools for measuring situation awareness in driving environments were originally adapted from aviation simulation tools. These methods include eye-tracking, question probes (post activity and during activity), subjective ratings, task performance measures and simulation freeze technique [2].

Eye tracking can be an effective measure of Level 1 SA and provides an objective measure of what drivers see on the road and thus what they should perceive [3]. However, eye tracking requires highly controlled lighting and a 2D image plane for accurate measurement. These limitations make eye tracking difficult to use in highly immersive simulator environments with wrap-around screens or on actual roads.

The freeze frame technique (SAGAT) involves freezing a simulation and blacking out the screen. The driver is then asked specific questions about the environment, such as the position, type, and future status of elements within the scene [2]. Although one of the most well tested SA measurement tools, the freeze frame technique can only be used within a simulator, and thus is not applicable for on-road testing scenarios. Significant overhead is also required during the planning and development of a simulation study as the simulation must be stopped and then resumed during the activity. This makes measuring situation awareness across many studies cumbersome and often too obtrusive for some driving studies.

Subjective ranking techniques include either ranking by drivers themselves or ranking by outside observers. Within military avionics, the SART techniques involve pilots ranking themselves across 10 dimensions related to SA post flight [4]. Although a well tested tool, it must be

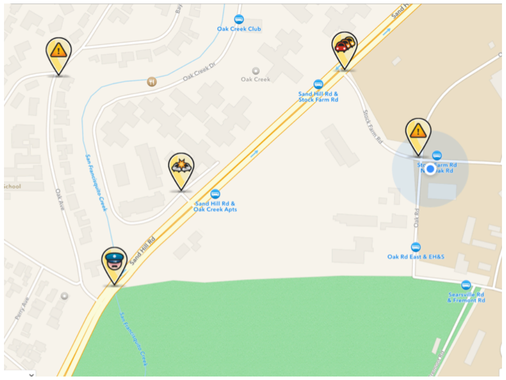

Figure 1 - On road, Apple Maps implementation of DAZE navigation screen.

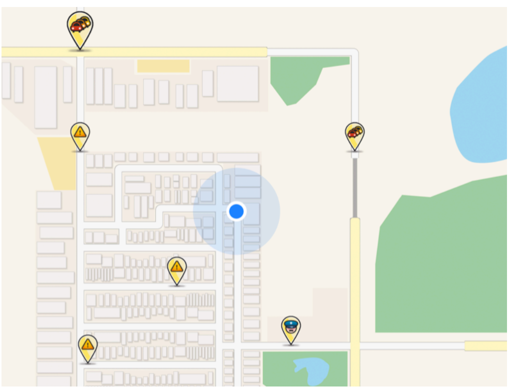

Figure 2 - Stylized simulator map for DAZE navigation screen.

modified for driving activity and only provides a subjective measure of driver SA. Subjective ratings from outside observers can provide unobtrusive measures of SA and has the advantage of being usable in action or on video. However, these require the use of many subject matter experts to review the participant's behavior and results can still be of questionable accuracy and reliability [5].

Question probes can provide objective measures of what elements are perceived in the environment and also can address Level 2 SA – comprehension, and Level 3 SA – prediction of future state. Post driving probes do not interrupt the driving activity, but rely on the memory of the driver for reliable measure. Real-time probes are less intrusive than the freeze frame technique and can also be used in real-world environments. However, real-time probes must be carefully designed to not alert the driver's attention to elements in the environment, nor should they be too cumbersome to address as to take away from their ability to perform the primary task [5]. Current best practices for real-time probes are seen in the Situation Present Awareness Method (SPAM) [0]. This method utilizes response accuracy and time as a measure of SA. However, these methods have not been adapted for driving tasks.

Design Requirements

Through our lab's previous experiments we have found that driver behavior is often different between simulated and on-road environments. During simulations, drivers are more willing to focus their attention on interfaces that we are developing or testing than the on-screen road environment. Alternatively, in on-road studies, participants focus their attention primarily on the road environment, frequently looking around or up from the interface, due to the motion of the vehicle or the risk of actual danger. Through testing automotive interfaces in both simulation and on-road scenarios, our lab has found a need for a simple and consistent measurement tool for SA that is usable in both environments. Additionally, we propose that the type of SA relevant to actively operate a vehicle differs from what is required to monitor an autonomous vehicle. To overcome the shortcomings of current SA measurement tools and develop a tool that would work across environments, we developed the following design requirements:

- Should function well in both simulation and on-road driving scenarios
- Should not require driving simulation or on-road driving to be stopped
- Should allow for the driver to answer queries with simple and unobtrusive interaction
- Should model current driving application interaction models
- Should capture timing and response data based on driver responses
- Should require minimal modification to a simulator or car's physical interface

With this perspective, we have been developing and intend to validate a driving specific SA measurement tool. Our aim is to create a tool that will complement current evaluation tools for new automotive interfaces.

Description of the DAZE Measurement Tool

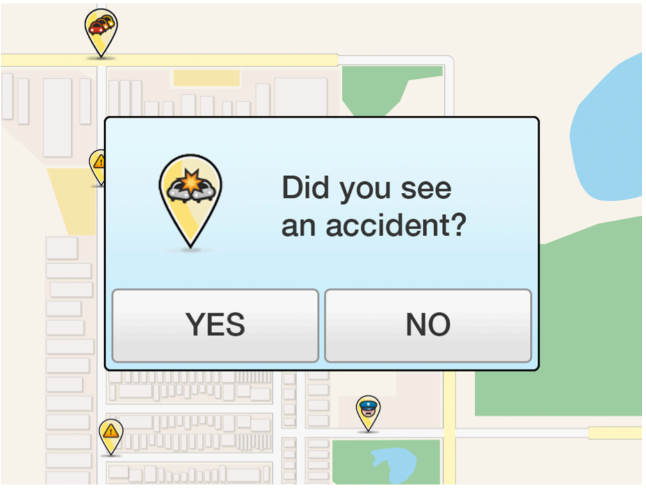

Figure 3 - Event popup displayed in app. The driver can select 'yes' or 'no' to record whether they saw an on road event. Response answer and time are recorded in-app.

The measurement tool we have developed is inspired by the Waze [tm] navigation app. While driving, Waze alerts drivers to various road conditions and hazards along the drive. In addition, the application asks users to confirm if they did or did not see a particular road event. For example, if there was an accident on the side of the road, the application will warn oncoming drivers that there was an accident 0.2 miles ahead. It also includes a popup window that allows drivers to confirm or deny the continuing existence of that accident. This interaction maps well to Level 1 perception SA. During actual usage, Waze can improve SA by making drivers aware of their surroundings while approaching on-road events. However, if drivers could be probed after already passing an event, this interaction model could be used to *measure* perceptual SA.

Functional Implementation

The main screen is a functioning navigation map, showing current road position as well as various Waze-like event markers. The on-road version is built upon the Apple Maps API, allowing for vehicle location tracking on accurate road maps. The simulation version has been is built upon the simulation map and visually stylized to mimic Apple Maps. The simulator servers then communicate real-time road position and update the car location on the live map.

To measure SA, our application utilizes pop-up messages and asks drivers if they have seen a specific event that the car has just passed, such as an accident or the presence of a police officer. The driver responds to the probe by selecting either "Yes" or "No" and the pop-up message closes back to the main screen.

Events

Various types of events can be simulated or appear during real driving conditions. Common events include locations of police officers, road construction, school zones, heavy traffic, accidents, and road hazards (such as an object in the road). To effectively measure SA it is important that probes be related to the goals of the driver. For example, during automated driving it is important that the driver avoid road hazards that the autonomous system may not be able to detect or that require intervention by the driver. The events chosen are based on the typical events signaled in the Waze app [0], as well as events adapted from a goal directed task analysis for avoiding road hazards conducted by Bolstad et. al. [8].

In our development version of DAZE, drivers are presented with each of the six events during an approximately 20 minute drive. These include: 1) police officer, 2) accident, 3) construction, 4) school zone, 5) hazard, 6) and heavy traffic. Three events exist on the drive and three do not exist, to prevent drivers from always selecting that they had seen an event. Pop-up messages, such as the one shown in [7] are presented a fixed distance after each event has been passed along the road so that drivers cannot view the event in side or rear view mirrors to confirm, but must recognize the event before it is passed. This prevents the probe from alerting the driver to the event and thus altering the driver's perception and awareness.

The app records driver response time and answers. Since the events are passed in real time and visibility of the scene is not obscured, response time can be used as a measure of awareness with lower response times correlating with higher SA [8]. In addition, the response time can also be a measure of cognitive load as the pop-up nature of the messages is similar to secondary task cognitive load testing techniques [9].

Events in the application are triggered via UDP messages sent from a server. This allows for the applications to work in any system with a local wireless network. In a simulation environment, messages for events can be triggered automatically from within simulator software. On the road, events can be triggered from a laptop computer. In addition, GPS geofencing can be used to automatically trigger event popups based solely on the location of the car. This allows for fully automated measurement during an on road experiment.

Testing and Validation Plan

The current measurement tool has been functionally tested in a simulator environment and on the road. Further comparison with validated measures is still required. Our plan is to compare DAZE to a driving specific SAGAT freeze test and a self-report measurement tools within a simulation environment. We also intend to test DAZE against self-report within an on-road environment. For on-road testing we also will evaluate the safety of the system during driving as the live prompts could distract the driver.

Figure 4 - In simulator and in car testing of DAZE.

Conclusion

Within automotive interface assessment there are currently no well-tested tools for situational awareness that can work in real-time within both simulation and on-road environments. We have designed the DAZE application to create a simple and consistent measurement tool for SA across driving assessment environments. Our goal is to develop a tool that will allow for the measurement of SA to be easily implemented during the evaluation of new driving interfaces.

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