RATIONALE

This technical report is being stabilized because it covers a technique for video-based annotation of driver visual behavior which is mature and not likely to change in the foreseeable future. This technique is used and referenced in other standards and publicly available documents.

STABILIZED NOTICE

This document has been declared "STABILIZED" by SAE Driver Metrics, Performance, Behaviors and States Committee and will no longer be subjected to periodic reviews for currency. Users are responsible for verifying references and continued suitability of technical requirements. Newer technology may exist.

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1. SCOPE

This SAE Recommended Practice defines key terms used in the description and analysis of video based driver eye glance behavior, as well as guidance in the analysis of that data. The information provided in this practiced is intended to provide consistency for terms, definitions, and analysis techniques. This practice is to be used in laboratory, driving simulator, and on-road evaluations of how people drive, with particular emphasis on evaluating Driver Vehicle Interfaces (DVIs; e.g., in-vehicle multimedia systems, controls and displays). In terms of how such data are reduced, this version only concerns manual video-based techniques. However, even in its current form, the practice should be useful for describing the performance of automated sensors (eye trackers) and automated reduction (computer vision).

1.1   Introduction

Vision provides the primary source of information available to the driver. Information is gathered by looking at objects and events, which in turn enables decision-making, control, and navigation of the vehicle in the road traffic environment. Assessment of driver visual behavior (eye glance behavior) provides a method to quantify the driver's visual allocation to the roadway, traffic control devices, in-vehicle information sources, controls and mirrors and as such can be a useful tool in many ergonomic studies of the driver. These would include evaluation of the visual demands of in-vehicle information devices, assessment of visual distraction, driver fatigue, workload, individual differences (e.g., novice versus expert) and basic studies of visual allocation in driving.

DVIs and other advanced display and control systems associated with intelligent transportation systems (ITS) can present a range of driver-related information. If these visual displays have associated controls (e.g., to select a zoom level or menu option), then the associated hand-controlled activities may also be visually guided and become part of the visual demand associated with a display application. For this reason, it may be important to consider not only the visual behavior in relation to information display, but also the duration and frequency of glances associated with driver control actions.

Practical assessments of drivers in real or simulated environments are conducted to quantify the allocation of visual behavior to an area of interest (AOI). It may be quantified by the location, duration, and frequency of glances to an AOI in the visual scene. This approach often employs commonly available video-recording equipment. However, it does not preclude the use of more sophisticated technologies such as eye trackers. See references for a general discussion on capture techniques for video based eye glance data (e.g., Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006; Smith, Chang, Glassco, Foley, & Cohen, 2005).

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 ISO Publications

Copies of these documents are available online at http://webstore.ansi.org/

ISO 15007-1:2014   Road vehicles - Measurement of driver visual behavior of transport information and control systems - Part 1: Definitions and metrics

ISO 15007-2:2014   Road vehicles - Transport information and control systems: Equipment and procedures related the measurement of driver visual behavior - Part 2: Test Report

2.1.2 Cited Publications

Howett, G. (1983), "Size of Letters Required for Visibility as a Function of Viewing Distance and Observer Visual Acuity," National Bureau of Standards Technical Note 1180," Washington, DC

Yarbus, A. (1967), "Eye Movements and Vision," New York: Plenum Press

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

American Psychological Association (APA) (2010), "Publication Manual of the APA," 6th edition. Washington DC (see Statistical Measures)

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Smith, D.L., Chang, J., Glassco, R., Foley, J., and Cohen, D. (2005). "Methodology for Capturing Driver Eye Glance Behavior During In-Vehicle Secondary Tasks." *Transportation Research Record,* 1937, pp 61-65

Snyder, H., and Monty, R. (1986), "A Methodology for Road Evaluation of Automobile Displays," Vision in Vehicles, 227-237, A. G. Gale et al., Eds. Elsevier Science Publishers B. V. (North-Holland)

Taoka, G. (1991), "Distribution of Driver Spare Glance Durations," *Transportation Research Record*, 1318, pp 142-146.

The Alliance of Automobile Manufacturers (2006). "Statement of Principles on Human Machine Interface (HMI) for In-Vehicle Information and Communication Systems."

Tijerina, L., Kiger, S., Rockwell, T. H., and Wierwille, W. W. (1996, October), "NHTSA Heavy Vehicle Driver Workload Assessment Final Report Supplement—Task 5: Heavy Vehicle Driver Workload Assessment Protocol," (DOT HS 808 467). Washington, DC: National Highway Traffic Safety Administration

Tijerina, L., Kiger, S., Rockwell, T. H., and Tornow, C. (1996, October), "NHTSA Heavy Vehicle Driver Workload Assessment Final Report Supplement—Task 7A: In-cab Text Message System and Cellular Phone Use by Heavy Vehicle Drivers on the Road," (DOT HS 808 467), Washington, DC: National Highway Traffic Safety Administration

Victor, T., Bargman, J., Boda, C.-N., Dozza, M., Engstrom, J., Flannagan, C., Lee, J.D., and Markkula, G. (2014). "Safer Glances, Driver Inattention, and Crash Risk: An Investigation Using the SHRP 2 Naturalistic Driving Study." Phase II Final Report. Transportation Research Board of the National Academies.

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3. DEFINITIONS

3.1 AREA OF INTEREST (AOI)

A pre-determined area within the visual scene, e.g., a rear-view mirror (see Figure 1).

3.2 DIRECTION OF GAZE

The AOI (see Figure 1) to which the eyes are directed.

3.3   DWELL TIME

The sum all consecutive fixations and saccades within the AOI between transitions to other AOIs (see Figure 2). This is typically measured in milliseconds or seconds.

3.4   FIXATION

Alignment of the eyes so that the image of the fixated AOI falls on the fovea for a given time period.

3.5   FRAME

The basic unit of observation for data reduction based on the video data capture rate. It is one of the successive pictures recorded to video capturing all pixels of the image. The data reducer (or data reduction software) examines a video display of the driver's eyes frame by frame to determine the driver eye fixation location.

3.6   GLANCE/GLANCE DURATION

The maintaining of visual gaze within an AOI, bounded by the perimeter of the AOI; comprised of at least one fixation and a transition to or from the AOI. See Figure 2, e.g., Glance 1 = T1 + F2. This is typically measured in milliseconds or seconds.

3.7   GLANCE FREQUENCY

The number of glances to an AOI within a sample interval where each glance is separated by at least one glance to a different AOI. This is typically measured in glances per second.

3.8   GLANCE LOCATION PROBABILITY

The probability that the eyes are fixated at an AOI (or set of related AOIs) during a sample interval. This would be defined as the number of glances to an AOI divided by the number of glances to all AOIs in the sample.

3.9   LINK VALUE PROBABILITY

The probability of a glance transition between two different locations. Operationally, the link value probability between AOIs A and B is defined as the number of glance transitions from A to B plus the number of glance transitions from B to A; this sum divided by the total number of glance transitions between all pairs of locations in the sample interval time.

3.10   SACCADE

The brief movement of the eyes between fixations. See Figure 2, e.g., S1.

3.11   SAMPLE INTERVAL

A reference time period that constitutes a sample of interest (e.g., an in-vehicle task or maneuver) in the video data.

3.12   TOTAL EYES OFF ROAD TIME (TEORT)

The summation of all glance durations to all AOIs other than the road scene ahead during a sample interval in seconds.

3.13   TOTAL GLANCE TIME

The summation of all glance durations to an AOI (or set of related AOIs) during a sample interval. This is typically measured in seconds.

3.14   TRANSITION

The change in eye fixation location from one AOI to a different AOI.

3.15   TRANSITION TIME

The duration of a transition (see Figure 2). This is typically measured in milliseconds.

3.16   VISUAL DISPLAY (DVI or ITS device)

A visual display is a device that presents information to vehicle occupants.

NOTE: That can include those parts of a control that identify it or show its state.

3.17   VISUAL ANGLE

The angle subtended at the eye by the largest dimension of a viewed object or the angle of separation between viewed objects. This is typically measured in degrees, minutes, or arc.

3.18   VISUAL DEMAND

The degree or quantity of visual activity (determined by e.g., number of glances, total glance time) required to extract information from an object to perform a specific task.

4.   MEASURING EYE GLANCE BEHAVIOR IN DRIVING

To put the previous terms in context, it is important to understand the process of visual perception through saccadic eye movements. The main function of a saccade is to change the point of fixation to direct the most sensitive region of the retina (the fovea) to a particular object of perception (Yarbus 1967). These saccades are typically less than 20° in amplitude and have an angular velocity of up to 400° per second. After one or more saccades, fixations of 0.2 to 0.4 seconds are made to process information. A glance is considered as a series of fixations at an AOI until the eye is directed at a new area. Operationally, the glance duration includes the prior transition time (to be consistent with ISO 15007). These transition times typically range from 0.10 to 0.5 seconds depending upon the distance between the two AOIs.   Dwell time is defined as the glance duration minus the prior transition time or the sum of all fixations and saccades in the AOIs between transitions or shifts of gaze to other AOIs (see Figure 2).

It should be noted that gazes to the road usually involve several glances. A graphical depiction of the visual allocation process describes the definitions to follow (see Figure 1).

The chronological relationship of driver visual allocation between and among AOIs is illustrated in Figure 2. Each horizontal segment represents a fixation (alignment of the eyes so that an image of the fixated AOI falls on the fovea of the eye for a given time period). Slanted lines represent saccades or transitions.
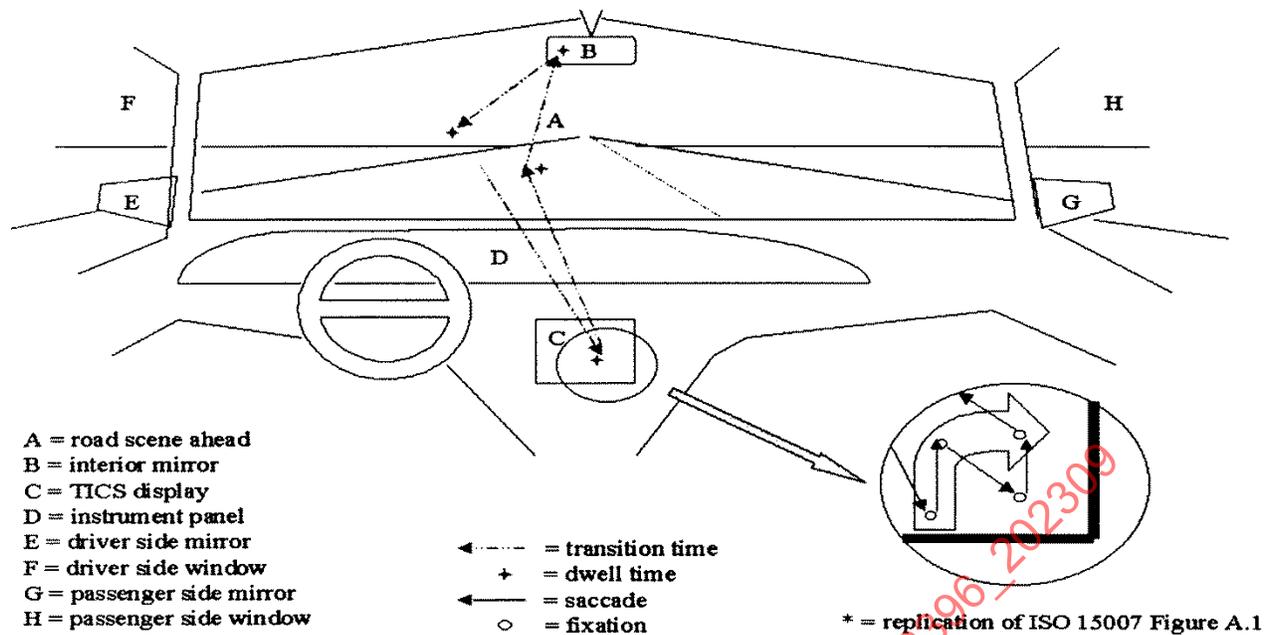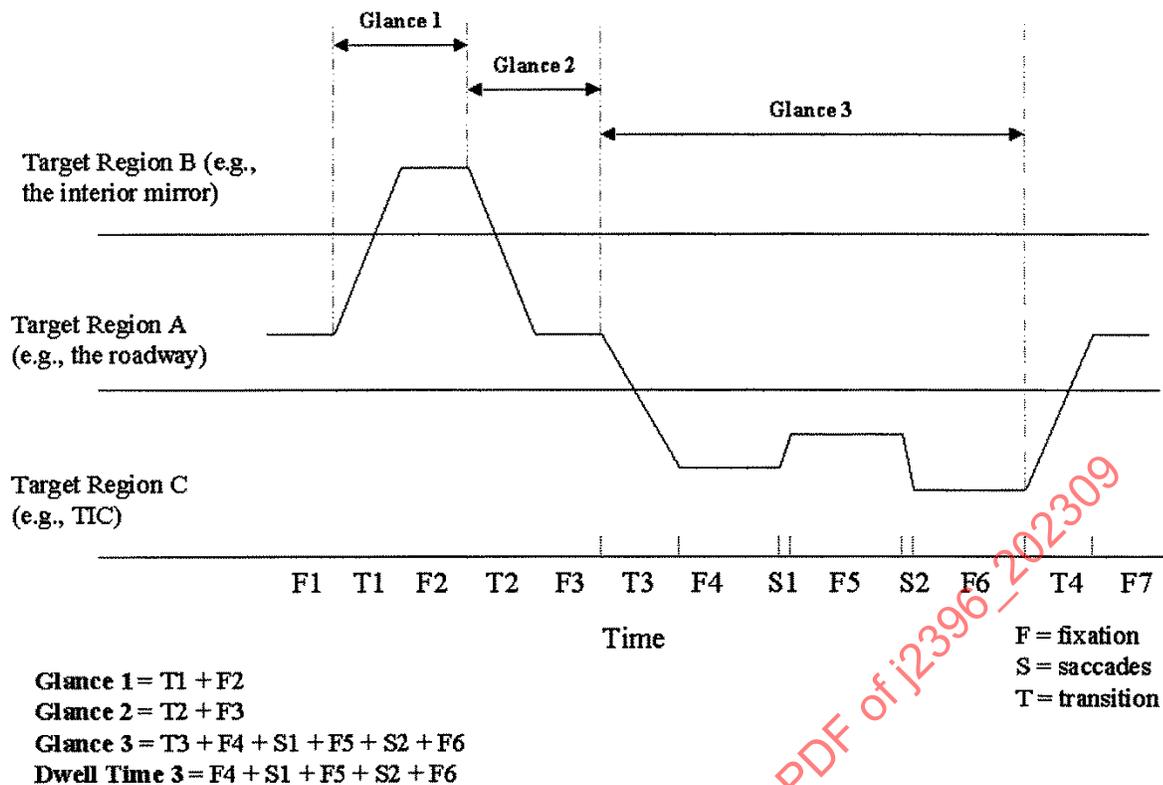
A = road scene ahead
B = interior mirror
C = TICS display
D = instrument panel
E = driver side mirror
F = driver side window
G = passenger side mirror
H = passenger side window

◄ ·––· = transition time
+ = dwell time
◄——— = saccade
○ = fixation

* = replication of ISO 15007 Figure A.1

**Figure 1 - Pre-defined AOIs and an illustration of driver fixation
and saccadic movements between and within an AOI (C)***

It is also important to review the basic data reduction protocol for video-based visual allocation studies. Data reduction is, of course, dependent upon the data collection system employed. In the simplest form, video frames are coded and the frame count number recorded manually when the eye begins and leaves an AOI.   Many software solutions are available to synchronize video-based eye glance reduction with other measures during a particular study (e.g., speed, lateral movement); in addition, many people write their own software for synchronization.

Clearly there are four strategies possible for defining a glance: (see Figure 2)

a.   Ignore transition times

b.   Assign transition times forward to the next AOI

c.   Assign transition times back to the previous AOI

d.   Add both transitions to and from a AOI to that AOI

Glance 1 = T1 + F2
Glance 2 = T2 + F3
Glance 3 = T3 + F4 + S1 + F5 + S2 + F6
Dwell Time 3 = F4 + S1 + F5 + S2 + F6

F = fixation
S = saccades
T = transition

* = adapted from ISO 15007 Figure A.2

***Figure 2 - Chronological relationship of driver visual allocation
between and within AOIs****

To be consistent with ISO 15007, it is recommended that the second strategy (b) as stated previously be used. For example, the glance duration to AOI B (the interior mirror) would include both the transition from A to B plus the fixation time at B (T1 + F2 in Figure 2). (Any glance duration less than 0.2 seconds should be ignored and added into the following AOI.)

Because of the tedious nature of data reduction, it is recommended that some or all of the strategies as follows be incorporated to relieve fatigue and promote accuracy.

a. Limit the duration of data reduction by individual data reducers; introduce frequent rest periods.

b. Build in flags for data which fall outside expected duration ranges for follow up checks.

c. Perform test-retest checks on reducers with the same data.

d. Test inter rater reliability on test sections of the data using two or more reducers.

e. Limit analysis to specific events of interest (e.g., glances to the instrument panel).

5.   DEVELOPING A GLANCE ALLOCATION MEASURE DATA BASE

5.1   Required Statistical Measures

5.1.1   Measure Specification

Over a sample interval (experimental condition), for each participant, participant grouping, and AOI, specify for glance frequency and glance duration:

a.   N (the number of observations)

b.   The total sample interval in minutes/seconds

c.   Arithmetic mean (before aggregation into class intervals)

d.   Variance (before aggregation into class intervals)

e.   Frequency distribution of the data (for distributions of glance durations, use 0.1 second class intervals)

f.   Cumulative glance distribution

g.   Percent of total glances over or below a threshold

In some applications data conditioning, (e.g., lognormal transformations) may be necessary to handle outliers. Other derived measures of interest might include number of glance durations above a threshold total glance time by AOIs, percentage of time directed to specific AOIs, and total eyes off road time (TEORT) scene.

5.1.2   AOIs

The previous measures are computed for each of the AOIs of interest as follows:

a.   Road scene ahead

b.   Left side mirrors/monitors

c.   Right side mirrors/monitors

d.   Interior mirrors/monitors

e.   Passenger side window

f.   Driver side window

g.   In-vehicle device(s) including backup camera screens

h.   Instrument panel (IP) (radio or gauges of interest)

i.   Total eyes off road time (this would be derived by measuring the time allocated to non-road scene AOIs between glances to the road scene)

j.   Out of view - the eye located on a AOI not specified or out of camera view

k.   Over the shoulder head turns

The previous AOIs apply when the vehicle is in motion.

5.2   Optional Summary Techniques

Depending upon computer statistical packages available, the following statistical summary methods can provide greater insights from the previous data.

a.   95% confidence limits

b.   Quantiles

c.   Medians

d.   Cumulative distributions

e.   3rd and 4th moments of the distribution (skewness and kurtosis)

f.   Box plots with outliers

g.   Coefficient of variation

h.   Correlation with other experimental measures, (e.g., speed, lane exceedances, etc.)

5.3   Experimental Evaluation of DVIs Against Comparison Conditions

The measures derived previously for a given set of experimental conditions should be compared with baseline conditions, (e.g., without the use of an experimental device).

6.   SPECIFICATION OF INDEPENDENT VARIABLES

To allow comparison of similar studies by different experimenters, the conditions of the study shall be described, namely the drivers (characteristics, instructions, debriefing, exclusion), the road, traffic, lighting, and road delineation, and the test vehicle. Providing this information is good human factors practice for understanding how the factors affected the eye glance data.

6.1   Specification of AOI Factors

6.1.1   AOI Classification

Typically, AOIs include road scene, mirrors (left, center, and right side), in-vehicle displays, controls and typical instrument panel (IP) devices, (e.g., speedometer). Depending upon the care exercised in calibration (see as follows) adjacent instrument panel AOIs can be differentiated depending upon the visual angle between them.

All non-road scene AOIs should be specified by:

a.   Name

b.   The location of the center of each AOI nominally measured horizontally and vertically from the eye when the latter is directed to the road ahead

6.1.2   DVI or Information Display Specification

Specify:

a. Overall size of display – height and width in centimeters.

b. Size of alphanumeric characters and symbols in millimeters (include font). A photograph of the display(s) with a reference-sized object included will document the measurement.

c. The color of alphanumeric characters and symbols and their contrast with the background. Demonstrate with photos, color if feasible. Where possible, measure both AOI and background brightness.

d. Any special display characteristics of importance to the evaluation of the data - flashing messages, refresh rates, menu choices, error recovery procedures, system latencies, data entry syntax, etc.

6.1.3   AOI Calibration Procedures

Prior to data collection and at intervals within the test runs (usually every 30 min) calibration exercises must be performed to account for participant postural changes during data collection and to aid in data reduction. The participant is asked to visually fixate on each of the AOIs while being recorded. This calibration recording segment is used to assist data reducers in making decisions on where the driver is fixating with any particular glance.

6.2   Specification of Driver Factors

6.2.1   Participant characteristics

For all participant drivers, provide the following information:

a. Driver age (or age brackets)

b. Gender

c. Licenses held and corrective lenses required – specify if bifocals

d. Corrected far visual acuity (e.g., use of a Snellen chart)

e. Corrected 750 mm visual acuity (IP distance) – use modified Snellen or Landholt C chart (see Howett, 1983)

f. Driving experience (years) and current driving experience (miles)

g. Experience with the test vehicle (minutes)

h. Any special training in the use of the DVI with the operational vehicle. Attach any training protocol.

i. Special skills required - manual dexterity, voice activation requirements, etc.

j. Any controlled participant state (e.g., alcohol, number of hours without sleep, etc.)

These measures are not for screening but for reporting differences between participants that might explain performance differences.