According to Poole and Ball’s (2006) common three eye tracking metrics and additional pupil and blink metrics, we classified all eye tracking metrics into four main types:

**Fixation-derived metrics:** Fixations with or without AOI information can be processed. A common metric is defined by the number of fixations per AOI, which indicates the relevance of the AOI for the users. To compare the distribution of attention between AOIs, the sum of fixation durations may be used. Table 1 shows all fixation-derived metrics related to spatial reasoning and problem-solving strategies.

**Saccade-derived metrics:** The characteristics of the saccades may indicate the quality of visual cues in the stimulus or the extent of visual searching. For example, large saccade amplitude can indicate meaningful cues that draw the attention from a distance, or a high frequency of saccades could come from much visual searching. Therefore, saccade-derived metrics can serve to indicate difficulties with the visual encoding. Table 2 shows all saccade-derived metrics related to spatial reasoning and problem-solving strategies.

**Scanpath-derived metrics:** The scanpath consists of the full sequence of fixations and saccades. Therefore, scanpath-derived metrics can acquire information about visual reading strategies or pinpoint specific problems with the visualization design during the task. The transition matrix is the common approach to analyzing transition patterns between AOIs, albeit it does not represent the full sequence but only the collection of pairs of fixations from the sequence. Table 3 shows all scanpath-derived metrics related to spatial reasoning and problem-solving strategies.

**Pupil and Blink metrics:** These two metrics are associated with cognitive workload. Lower blink rates indicate higher workload or attention while higher rates are associated with fatigue. Larger pupil sizes indicate more effort. In addition, Beatty reported that the maximum amplitude of pupil sizes indicates memory and processing load that fluctuates with task difficulty. Table 4 shows all pupil and blink metrics related to spatial reasoning and problem-solving strategies.

Table 1. Fixation-derived Metrics of Eye Tracking

|  |  |  |
| --- | --- | --- |
| **Metric Name** | **Role in Spatial Reasoning** | **Interpretation in Problem-Solving Strategy Analysis** |
| Fixation Duration | Electronic mental rotation test (EMRT) response accuracy would be associated with fewer fixations and shorter average response times, (Roach, 2017) | Longer durations indicate deeper cognitive processing or difficulty. |
| ~~Mean Fixation Duration~~ | ~~Depth of processing~~ |  |
| Fixation Count (FC) | Cognitive load | More fixations suggest exhaustive search or uncertainty. |
| Fixation Spatial Density (SD) | Visual exploration spread |  |
| First Fixation Probability |  | Highlights areas where users start or finish their analysis. |
| Last Fixation Probability |  | Highlights areas where users start or finish their analysis. |
| Time to First Fixation on Target | Salience or priority recognition | Fast fixations on critical AOIs may suggest efficient strategy. |
| Dwell Time | Sustained attention on AOIs | Total time spent on a specific AOI can indicate its perceived relevance. |
| Attention Switching Frequency |  | High values may indicate multi-element tracking or comparison across options. |

Table 2. Saccade-derived Metrics of Eye Tracking

|  |  |  |
| --- | --- | --- |
| **Metric Name** | **Role in Spatial Reasoning** | **Interpretation in Problem-Solving Strategy Analysis** |
| Saccade Length | Breadth of visual scanning | Longer saccades suggest exploratory or non-linear strategies. |
| Saccade Amplitude | Breadth of visual scanning |  |
| Saccade Frequency | Intensity of search | Indicates search intensity or switching behavior. |
| Saccade Rate | Intensity of search |  |

Table 3. Scanpath -derived Metrics of Eye Tracking

|  |  |  |
| --- | --- | --- |
| **Metric Name** | **Role in Spatial Reasoning** | **Interpretation in Problem-Solving Strategy Analysis** |
| Scanpath Length | Exploration extent | Longer paths indicate broader or less efficient exploration. |
| Scanpath Regularity | Systematic strategy vs. erratic searching | More regular patterns might reflect systematic strategies. |
| Transitional Matrix | Interaction between AOIs | Show how often users move between AOIs, useful for modeling cognitive strategies. |
| Edit Distance |  | Compare scanpaths between participants or to an expert strategy. |
| Entropy of Gaze Transitions | Randomness vs. directed strategy | Higher entropy implies exploratory, less structured problem-solving. |
| Gaze Distribution |  | Helps detect whether attention is narrowly or broadly focused. |

Table 4. Pupil and Blink Metrics of Eye Tracking

|  |  |  |
| --- | --- | --- |
| **Metric Name** | **Role in Spatial Reasoning** | **Interpretation in Problem-Solving Strategy Analysis** |
| Fixation Duration | Depth of processing | Longer durations indicate deeper cognitive processing or difficulty. |
| Mean Fixation Duration | Depth of processing |  |
| Fixation Count (FC) | Cognitive load | More fixations suggest exhaustive search or uncertainty. |
| Fixation Spatial Density (SD) | Visual exploration spread |  |
| First Fixation Probability |  | Highlights areas where users start or finish their analysis. |
| Last Fixation Probability |  | Highlights areas where users start or finish their analysis. |
| Time to First Fixation on Target | Salience or priority recognition | Fast fixations on critical AOIs may suggest efficient strategy. |
| Dwell Time | Sustained attention on AOIs | Total time spent on a specific AOI can indicate its perceived relevance. |
| Attention Switching Frequency |  | High values may indicate multi-element tracking or comparison across options. |

Table 5. Definition of Eye Tracking Metrics

|  |  |  |
| --- | --- | --- |
| **Metric Name** | **Definition** | **Reference** |
| **Fixation-derived metrics** |  |  |
| Fixation Duration | The length of time the eye remains still. | Skaramagkas et al., 2023 |
| Mean Fixation Duration | Average time of all fixations during a task. | Joseph & Murugesh, 2020 |
| Max Fixation Duration | Maximum duration among all fixations. | Skaramagkas et al., 2023 |
| Fixation Count (FC) | Total number of fixations during a task. | Sharafi et al., 2015 |
| Fixation Rate (FR) | Fixations per unit time or ratio of fixations in AOI to all fixations. | Sharafi et al., 2015 |
| Fixation Spatial Density (SD) | Proportion of grid cells visited by fixations. | Sharafi et al., 2015 |
| Convex Hull | Area enclosing all fixation points. | Sharafi et al., 2015 |
| First Fixation Probability | Likelihood AOI receives the first fixation. | Skaramagkas et al., 2023 |
| Last Fixation Probability | Likelihood AOI receives the final fixation. | Skaramagkas et al., 2023 |
| On-target Fixation | Fixation falling within target AOIs. | Sharafi et al., 2015 |
| ROAFT | Ratio of ON-target to ALL-target fixation time. | Sharafi et al., 2015 |
| NRRF | Normalized rate of relevant fixations. | Sharafi et al., 2015 |
| Time to First Fixation on Target | Time elapsed before first fixation on target AOI. | Skaramagkas et al., 2023 |
| Dwell Time | Total time spent fixating on AOI. | Skaramagkas et al., 2023 |
| Gaze Samples | Individual data points capturing gaze position. | Joseph & Murugesh, 2020 |
| Attention Switching Frequency | Rate of switching between AOIs. | Joseph & Murugesh, 2020 |
| TFO (Time to First Fixation on Options) | Time to fixate on decision options. | Sharafi et al., 2015 |
| First-Pass Duration | Sum of fixations in first visit to AOI. | Sharafi et al., 2015 |
| Gaze Time | Total time looking at AOI. | Sharafi et al., 2015 |
|  |  |  |
| **Saccade-derived metrics** |  |  |
| Saccade Length | Distance between two consecutive fixations. | Skaramagkas et al., 2023 |
| Number of Saccades | Count of saccadic movements. | Skaramagkas et al., 2023 |
| Saccade Amplitude | Angular distance of saccade. | Skaramagkas et al., 2023 |
| Saccade Velocity | Speed of eye movement between fixations. | Skaramagkas et al., 2023 |
| Saccade Frequency | Number of saccades per time unit. | Skaramagkas et al., 2023 |
| Saccade Rate | Saccades per time or per AOI. | Skaramagkas et al., 2023 |
| Saccade Duration | Time spent on each saccade. | Skaramagkas et al., 2023 |
| Max Saccade Duration | Longest duration of a saccade. | Skaramagkas et al., 2023 |
| Saccadic Acceleration | Change in velocity over time during saccade. | Skaramagkas et al., 2023 |
| Microsaccade Amplitude | Amplitude of small fixational saccades. | Skaramagkas et al., 2023 |
| Microsaccade Rate | Frequency of microsaccades. | Skaramagkas et al., 2023 |
| Smooth Pursuit Gain | Ratio of eye movement speed to target speed. | Skaramagkas et al., 2023 |
| Saccadic Regression | Backward saccades during reading or viewing. | Skaramagkas et al., 2023 |
|  |  |  |
| **Scanpath-derived** |  |  |
| Scanpath Duration | Total time from first to last fixation in scanpath. | Skaramagkas et al., 2023 |
| Scanpath Length | Cumulative length of all saccades. | Skaramagkas et al., 2023 |
| Scanpath Regularity | Similarity in scanpath over repetitions. | Skaramagkas et al., 2023 |
| Saccade/Fixation Ratio | Ratio of saccades to fixations. | Skaramagkas et al., 2023 |
| Scanpath Direction | General direction of eye movement trajectory. | Skaramagkas et al., 2023 |
| Transitional Matrix | Matrix of transitions between AOIs. | Skaramagkas et al., 2023 |
| Edit Distance | String-based similarity between scanpaths. | Skaramagkas et al., 2023 |
| SPAM | Sequential Pattern Mining of scanpaths. | Skaramagkas et al., 2023 |
| ScanMatch | Algorithm for comparing scanpaths. | Skaramagkas et al., 2023 |
| Revisits to AOIs | Count of return fixations. | Sharafi et al., 2015 |
| Entropy of Gaze Transitions | Measure of randomness in gaze shifts. | Sharafi et al., 2015 |
| Gaze Transition Rate | Rate of moving between AOIs. | Sharafi et al., 2015 |
| Gaze Distribution | Spread of gaze across AOIs. | Sharafi et al., 2015 |
|  |  |  |
| **Pupil and Blink metrics** |  |  |
| Pupil Dilation | Change in pupil size. | Skaramagkas et al., 2023 |
| Pupil Size | Absolute or average diameter of pupil. | Skaramagkas et al., 2023 |
| Percent of Change in Pupil Size | Relative change from baseline. | Skaramagkas et al., 2023 |
| Pupil Size Std | Standard deviation of pupil size. | Skaramagkas et al., 2023 |
| Blink Rate | Blinks per minute. | Skaramagkas et al., 2023 |
| Blink Duration | Time eyes remain closed during a blink. | Skaramagkas et al., 2023 |
| Velocity of Blinking | Speed of eyelid closure and opening. | Skaramagkas et al., 2023 |
| Blink Latency | Time before first blink. | Skaramagkas et al., 2023 |

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