





# EyeDentify3D: A Python package for gaze behavior classification

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## Software

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## Summary

With the technological advances of eye-tracking technologies, researchers can now place participants in real-world settings and measure their gaze orientation in 3D space. Although more ecological, this kind of data is complex to analyze. Indeed, most researchers are more interested in the extraction of gaze behaviors (e.g., fixations, saccades, smooth pursuits, visual scanning) than in the raw gaze data itself. However, most existing algorithms for gaze behavior classification were developed for 2D screen-based eye-tracking data and are not suitable for 3D data. To address this gap, we developed EyeDentify3D.

## Statement of need

EyeDentify3D is a Python package for extracting gaze behavior from 3D eye-tracking data. It was designed to: 1. Extract and interpret data from various eye-tracking systems (e.g., HTC Vive Pro, Pupil Invisible, Meta Quest Pro, Pico Neo 3 Pro Eye). 2. Provide a simple user interface, where only a few lines of code are needed to extract the desired gaze behaviors. 3. Offer the possibility to inspect visually the results of the classification.

EyeDentify3D was designed to be used by both neuroscientists, sport scientists. It has already been used to analyze the gaze behavior of basketball players ([Trempe et al., 2025](#)), baseball player, and boxers. We cannot wait for our toolbox to be used to analyze gaze behavior in other contexts!

## Background

Each frame of the trial are classified based on the following criteria: - **Invalid**: The eye-tracker has declared having low confidence in the gaze orientation measurement (this often happen when the eyes are closed, the eye orientation is outside the eye-tracker's measurement range, or if the eye-tracker was not positioned correctly on the participant). - **Blink**: The eye openness is below the threshold ([Chen & Hou, 2021](#)). - **Saccade**: Two criteria must be met to detect a saccade. 1) The eye movement must be faster than a dynamics threshold. The dynamics threshold is determined using a rolling median over a user defined window size. 2) The eye movement acceleration must be larger than a user defined threshold for at least two frames. This ensures that the eyes are moving rapidly between two targets with an acceleration when leaving the first target and a deceleration when arriving to the second target ([Van Opstal & Van Gisbergen, 1987](#)). - **Visual scanning**: The gaze (head + eyes) velocity is larger than a threshold ([McGuckian et al., 2020](#)). Visual scanning should usually be identified after saccades as visual scanning behavior would also present high eye velocity. - **Inter-saccadic interval**: Our inter-saccadic interval classification was adapted from the 2D version of Larsson et al. ([2015](#)). Intersaccadic intervals lasting more than a duration threshold are identified between the already

identified frames. These intervals are subdivided into windows of a user defined size. Each window is classified as either coherent or incoherent based on the gaze movement (moving in a consistent direction or not). Adjacent coherent and incoherent windows are merged together to form segments. Then, these segments are further classified as either - **fixation** or **smooth pursuit** behaviors based on the four criteria described in Larsson et al. (2015): - Dispersion:  $p_D < \eta_D$  - Consistent direction:  $p_{CD} > \eta_{CD}$  - Positional displacement:  $p_{PD} > \eta_{PD}$  - Spatial range:  $p_R > \eta_{maxFix}$

All behaviors are mutually exclusive (except for invalid and blink that can happen simultaneously). For example, a frame cannot be classified as both a saccade and a fixation. Thus, the order of the identification is important as the first behavior identified will take precedence over the others.

More details on the definition of events and how they are identified can be found in the documentation. (TODO: add link to documentation here !!!!!!!!!!!!!!!!!!!!!)

Finally, EyeDentify3D enables visualisation of the classified gaze data and extraction/export of metrics related to the behaviors (e.g., duration, time ratio spent in each behavior, number of occurrences, saccade amplitude, smooth pursuit trajectory length, etc.).

## Note on the implementation

We believe that the choices made in EyeDentify3D are the most suitable for the analysis of gaze behavior in 3D space (especially in sporting context). However, other choices could have been made and we are very open to implement other identification methods in the future, if needed.

## Acknowledgements

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## Conflict of interest

The authors declare no conflict of interest.

## Declaration of generative AI

During the preparation of this work the developer used ChatGPT, Claude, and Copilot to speed up development and enhance code clarity. Aider and Claude were also used to write tests. After using these tools/services, the developer reviewed and edited the content as needed and takes full responsibility for the content of the repository.

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