Eye Tracking Analysis Guide

IMOTIONS®

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Introduction

This eye tracking analysis guide will help take you from big data to valuable insights, by walking you through different analysis options and considerations for eye tracking analysis and visualizing eye tracking data, highlighting how this can be done in iMotions.

Regardless of whether you are using screen based eye trackers, eye tracking glasses, eye tracking in a virtual environment or web camera-based eye tracking, you can accumulate thousands of data points. ***What are you going to do with all of that data?***

With any behavior research experiment, whether it takes place in a lab, in the field or in the comfort of your respondents' home, the best time to consider your analysis strategy is before you collect data. If you're not sure what you're looking for, how will you know when you've found it?

Behavior Research Best Practice

Start with formulating research questions. From there, create hypotheses with clear independent variables and dependent variables that align with your questions. To get valuable insights from your data, you will need to find connections between your independent and dependent variables. This is what effective experimental design is all about!

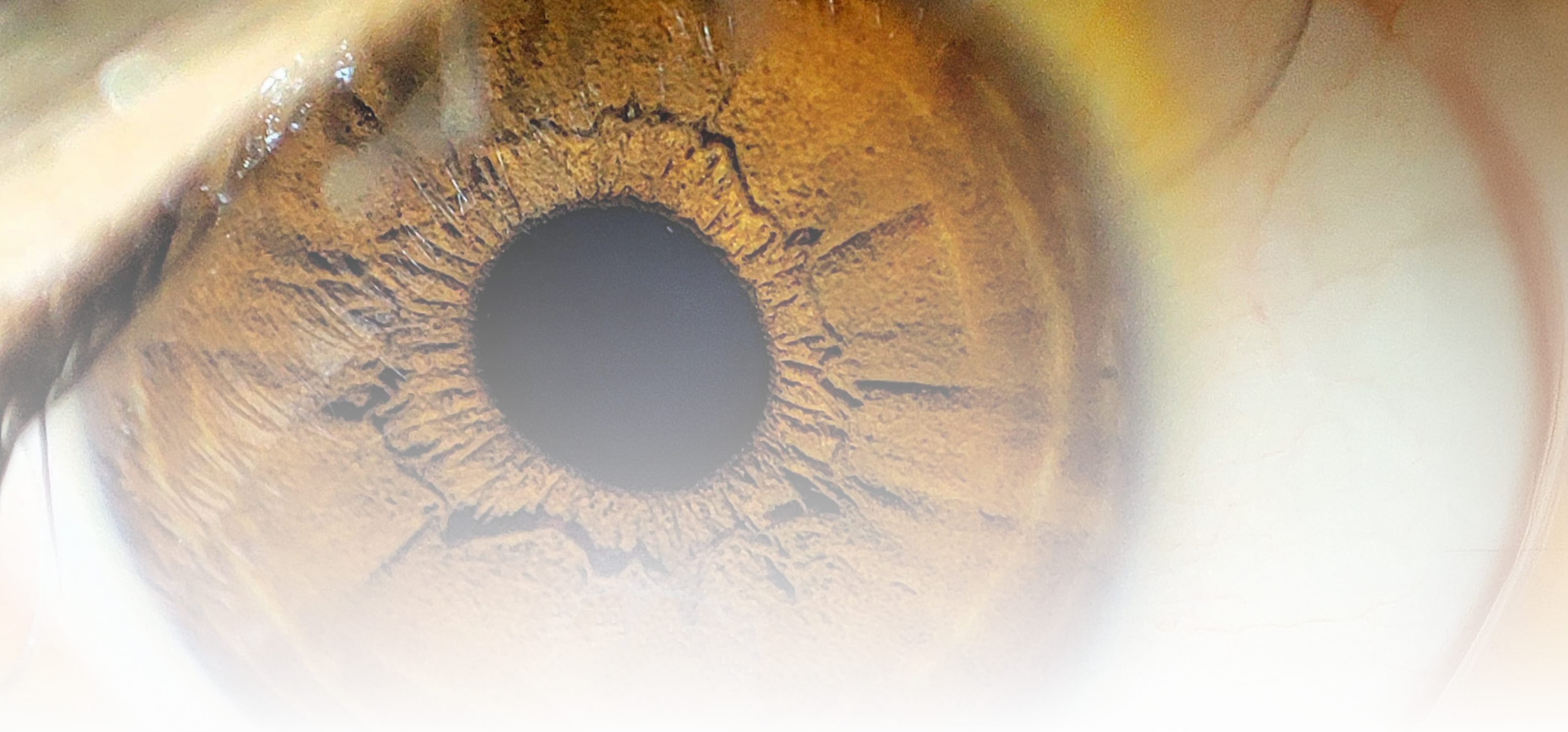
Use this Eye Tracking Analysis Pocket Guide to envision what the answer to your research question would look like.

- Do you need quantitative analysis? Is your answer a bar graph comparing different groups of respondents or different stimuli. Is it a correlation between metrics?
- How can you best visualize your answer? What types of images or videos best communicate your findings? Heatmaps? Scan paths?
- Is Eye Tracking enough? Can your research question be answered with eye tracking alone or would it help to have multiple modalities?
- Have you considered your statistics? How confident do you need to be in the answer to your research question? Is it a life or death situation? Are millions of dollars riding on the answer? How many respondents do you need to reach that confidence level? How accurate and precise do you need your hardware to be?

For more information about Experimental Design, check out our following resources:

- The Importance of Research Design: A Comprehensive Guide
- Experimental Design: The Complete Pocket Guide
- Independent and Dependent Variables in Research: Key Roles & Examples

If you have already collected data and you're not sure what to do with it, this guide is a useful overview of the different analyses and data visualization options for eye tracking data.



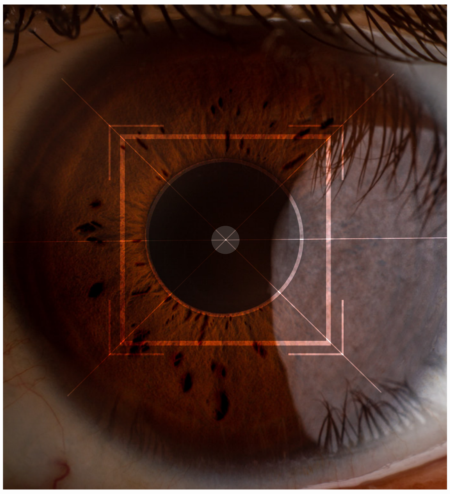
Eye Tracking Data

The movement of the eyes gives us a lot of information about conscious and nonconscious experiences. Eye tracking is used to investigate visual attention, cognitive load and emotional responses. Visual attention is the most widely used application for eye trackers, so if that is your interest, you can navigate directly to that section.

When people think of eye movements, they often think of whether a person is looking side to side, or up and down. They consider what respondents are looking at and not looking at. Eyes have two other movements that are useful in behavior research and give nonconscious insights: the movement of the pupils and the movement of eyelids.

Movement of Pupils: Pupillometry

Pupils change in response to changes in light, emotionally charged stimuli, and changes in cognitive load regardless of whether the information was visual. Pupilometry has also been used to study long-term memory encoding. While pupilometers are typically used in clinical practice and research, many eye trackers are also able to measure changes in pupil dilation.



Because controlling the lighting in experiments is not always easy, having data from additional modalities (such as GSR if you are interested in emotional valence, or EEG if you are interested in cognitive load) increases researcher’s confidence in the interpretation of pupillometry data.

For more information about pupillometry visit our article here.

Insight Box: Lighting and Pupil Dilation

Because pupils are sensitive to light, it is important to be mindful of the lighting in the space that the study is conducted. Lighting varies with the time of day, amount of cloud cover, and simply by moving from one room to another.

- Screen-based stimuli: Be mindful of the light emitted from the screen. Change from a light stimulus to a dark stimulus will cause pupil dilation. You do not want to misinterpret this as being related to cognitive load or emotional valence, when in fact it is more easily explained by changes in lighting.

- Eye tracking glasses and VR Eyetracking: these studies require similar considerations as lighting can change as the participant moves around.

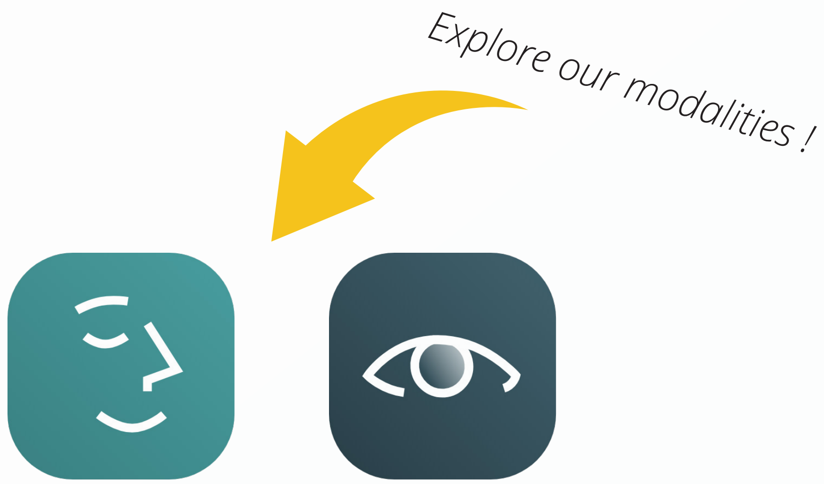
Movement of Eyelids: Blink Detection

The simple act of blinking is a small movement with big potential. Blinking behavior can give insights into our cognitive processes (such as attention and workload) as well as our emotional state.

In clinical contexts, blink measurements are used for treating dry eye syndrome and to investigate neurological disorders such as Parkinson's, Tourette Syndrome, and Multiple Sclerosis.

Blink rate can also be used to help assess mental workload, fatigue, and attention. Blinking plays a role in nonverbal communication during social interactions. Moreover, environmental factors such as screen usage and air quality can influence blink frequency, making it a valuable measure across psychology, ophthalmology, ergonomics, and neuroscience.

With iMotions, blinks, blink rate and interlink intervals can be measured with eye tracking or with facial expression analysis.



Facial Expression Analysis module

Eye Tracking

Movement of Eyes: Fixations and Saccades

Many researchers using eye trackers are interested in movement of the eye because their research question is related to attention. Gazes, fixations and saccades are the main eye movements that make up eye tracking data.

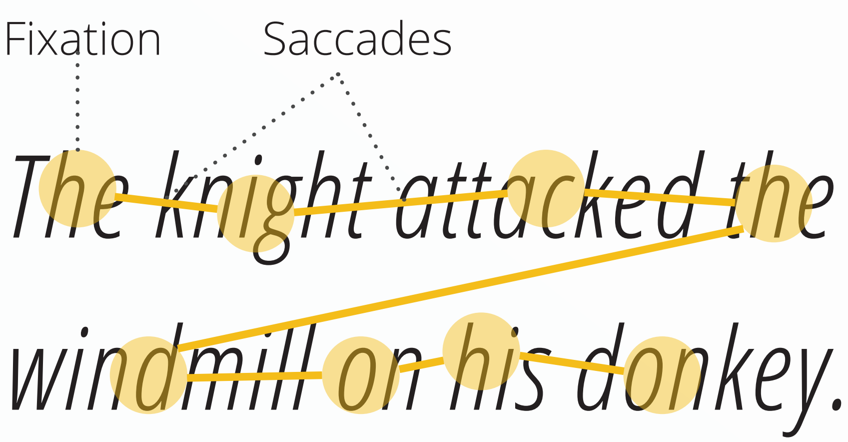
- Gaze: the basic unit of measure for eye tracking data. For more information about how gaze is estimated from raw eye tracking data, visit our article.

- Dwell Time: The time a gaze is directed toward an area of interest (AOI). AOIs are essential for quantitative analyses related to attention.

- Fixations: a period in which our eyes are locked toward a specific object, this is one of the most important metrics in attention-related research. Typically, the fixation duration is 100- 300 milliseconds. Depending on the classifier used, a fixation can be a longer dwell or multiple gazes close to each other in time and space (see Insight Box: Classifiers)

- Saccades eye movements between fixations. Need a high sampling eye tracking device to capture data on saccades. These are particularly interesting in studies about reading and other behaviors that require fast eye movements.

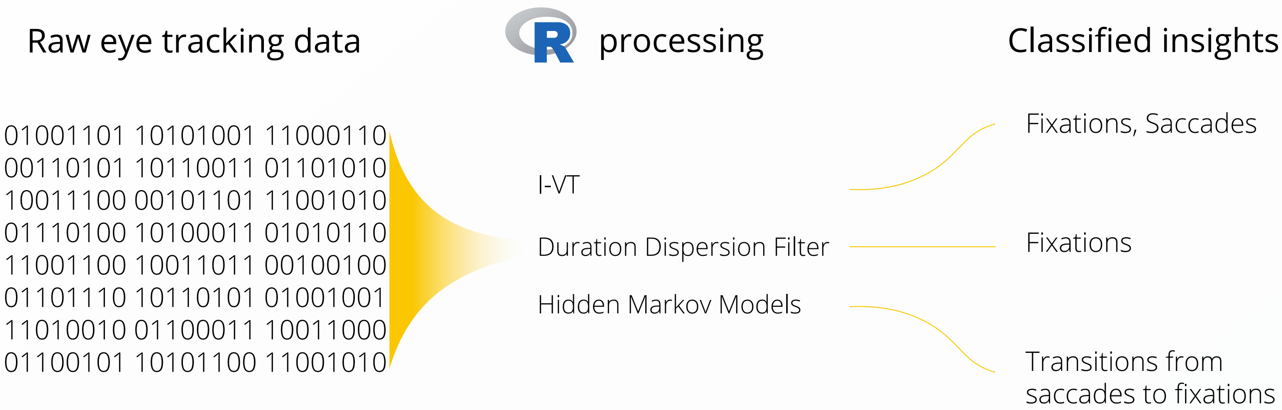
  For more information about other eye movements such as microsaccades, smooth pursuit and vergence, please visit our article. For more information about eye tracking data collection and an overview of eye tracking metrics (such as time to first fixation, revisits, and durations), check out our Eye Tracking Pocket Guide.



Insight Box: Classifiers

In order to measure eye movements such as gazes, fixations, and saccades, algorithms are applied to the raw eye tracking data. iMotions R Notebooks use three different filters to classify eye movements.

- I-VT (velocity-threshold identification filter) sets a velocity threshold in which movements faster than the threshold are considered saccades and slower movements are considered fixations.
- Duration Dispersion Filter: This filter uses gaze points that occur close to each other in space (small visual angle) and in time to classify fixations.
- Hidden Markov Models: These time series data algorithms use the data and uses the data to learn about the transitions from fixations to saccades. This is the default analysis used in our web camera eye tracking because it is a robust approach to account for individual variation in testing environments.



Schematic representaiton of data classifying logic using iMotions R-processing

Visual Attention

Eye tracking offers researchers a fascinating window into the intricacies of human attention. Behavioral researchers leverage eye movement data to understand what captures respondents' attention and what goes unnoticed. Researchers can quantify attentional capacity (to enhance learning and working environments) and uncover valuable insights into cognitive states (such as detecting fatigue).

Start with the Study Design

In eye tracking studies that focus on eye movements, respondents are going to look at something, this is considered the stimulus. The type of stimulus used to collect data influences which data visualizations are best suited to represent the data and how to do quantitative analyses.

In eye tracking studies generally have two types of stimuli, static and dynamic.

- **Static stimuli** are things that do not change or move, like a still image presented on a screen or a still object.
- **Dynamic stimuli** are things that move or change, such as a video or scrolling through a webpage

For the sake of this analysis guide and how the interface of iMotions works, if study design involves freedom of movement for the respondent, (e.i, the respondents are wearing eye tracking glasses or you are doing eye tracking in VR), this will be considered a dynamic stimulus because the stimulus data can be imported as a video.

Knowing which type of stimuli you are working with is important to determining which analyses you should do. For both types of stimuli, heatmaps and scan paths can be used for visualizations and AOIs are used for quantitative analyses.

Static Stimuli

Visualizations

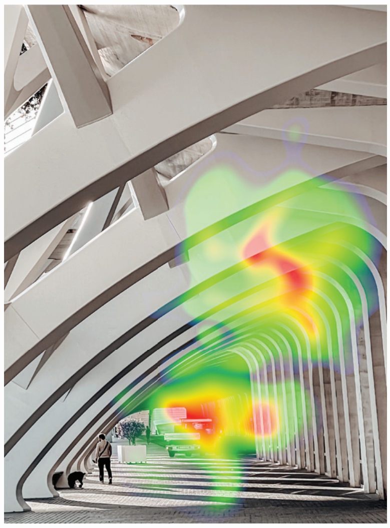
Heatmaps Tell Us Where, Gaze Paths Tell Us When

Data visualization is an important part of storytelling. Some eye tracking behaviors are easier to represent with a picture or video, and tedious to describe with words.

If you have already collected eye tracking data and are trying to figure out which quantitative analyses to conduct, visualizing your data can help you form hypotheses for further quantitative analysis. Both heatmaps and gaze paths can be used to determine where to place AOIs, which are the most important quantitative analysis tool for eye tracking.

Heatmaps

Heatmaps give us an idea of which parts of a stimulus attracted visual attention using color. Typically, the heatmap colors are displayed over the stimulus image indicating "hot spots" where more gaze points occurred (often in red). Heatmaps can show gaze or fixation data and typically represent aggregate data, meaning data from more than one respondent. This can be done by making heatmaps of different respondent groups.

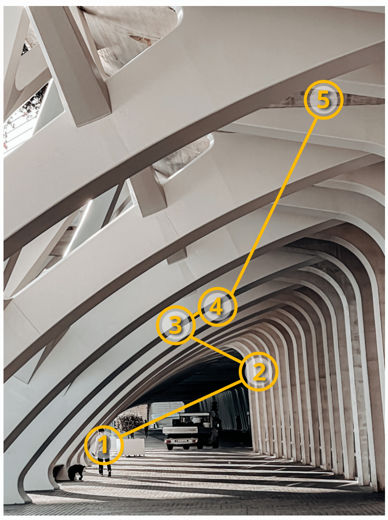


Heatmaps can also be applied to dynamic stimuli in cases where multiple respondents experienced the same dynamic stimulus (for example, a video). For more information, see below.

For more information on heatmaps, visit our article.

Gaze Paths

Gaze paths show sequences of gazes, so that we can see in what order different parts of the stimulus were visually explored. This is useful for determining which part of the stimulus the respondents are drawn to first, second, last, or repeatedly. For example, when a respondent looks at a painting, they might first look at what is front and center, or boldly colored and then their attention will move to other parts of the picture.



Unlike heatmaps that visualize aggregate data, gaze paths are useful for representing individual respondent eye tracking data. However, researchers might present a gaze path to represent a typical pattern of visual exploration of a certain group and another gaze map from a single individual to represent a different group.

You can decide if you want the gaze path to be dynamic or static. A static gaze path shows all of the gazes at once, numbered in the order they occur. A static gaze path would appear as a video over the still image, which can visually function as the replay of the eye tracking data.

Emotional Heatmaps

If you are using facial expression analysis and eye tracking, you can combine these data to create emotional heatmaps. These heatmaps use gaze data and color the heatmap according to emotional valence. This is useful if you want to see which part of a website elicits frustrated brow furrows or what respondents are looking at when they smile at a video. For more information, check out this article.

Quantitative Analysis: Introduction to AOIs

Areas of Interest (AOIs) are the powerhouse of eye tracking analysis. AOIs are shapes drawn on stimuli in a study so that the data can be separated by location on the screen. Eye-tracking metrics such as dwell time, time to first fixation, and revisits come from AOIs. While heatmaps and gaze paths are excellent tools that help us understand the set-up of the study and visualize some of the results, AOIs allow us to analyze attention in a quantitative way.

AOIs are user-defined regions of the displayed stimulus. You can filter eye tracking data (such as fixations and dwell times) based on AOIs which is useful when evaluating the performance of two or more specific areas on the same picture, object, website or program interface. AOIs can be used to compare groups of participants, conditions, or different features within the same scene.

For static stimuli, this is relatively simple. You can indicate which area of the stimulus you are interested in having specific metrics on (usually by drawing an outline of the area in their analysis software). All eye tracking data corresponding to the pixels within the region is grouped. If you have an image with two different versions of a product, you could draw one AOI around version 1 and another around version 2. Then you could compare the data collected in each of these AOIs. This means you can see which version had the earliest time to first fixation or accumulated the most dwell time. You could see which had the most revisits. AOIs make these analyses possible. AOIs allow you to make graphs and perform statistics.

AOIs are also important analysis tools for dynamic stimuli for the same reason, but the practical aspect of this is more complicated because drawing AOIs on a dynamic stimulus can be tedious and inconsistent. With dynamic stimuli, gazemapping and AutoAOIs can help you place AOIs and perform quantitative analysis even in study designs with respondents that have freedom of movement.

An example of four AOIs, each corresponding to a different burger, used to test various metrics across different parts of the stimulus

Three ways to create AOIs

Place AOIs manually. This allows you to decide exactly where the AOI should be and what shape. Draw a shape around the object you are interested in collecting eye tracking metrics for.

Gaze Mapping This technique “maps” gaze points from the eye tracking data onto a reference image, making manual AOI placement simpler because they are placed on a single image.

Automated AOIs These tools use algorithms to create masks over selected moving objects that precisely reflect their shape and location. In each frame, an AOI is automatically created to fit the mask so that the AOI moves and morphs as the object does.

Dynamic Stimuli

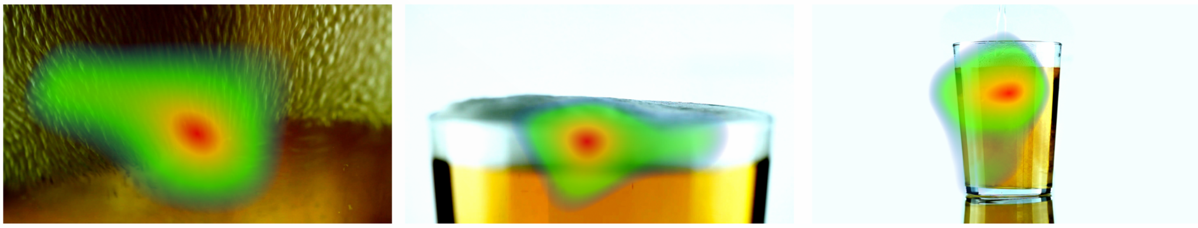
Many of the eye tracking data analysis tools that are useful for studies with static stimuli are also relevant for dynamic stimuli.

Visualizations

Heatmaps

Heatmaps can also be applied to dynamic stimuli in cases where multiple respondents experienced the same dynamic stimulus (for example, a video). In these cases, a heat map is made of each frame of the video, so the heat map changes from frame to frame.

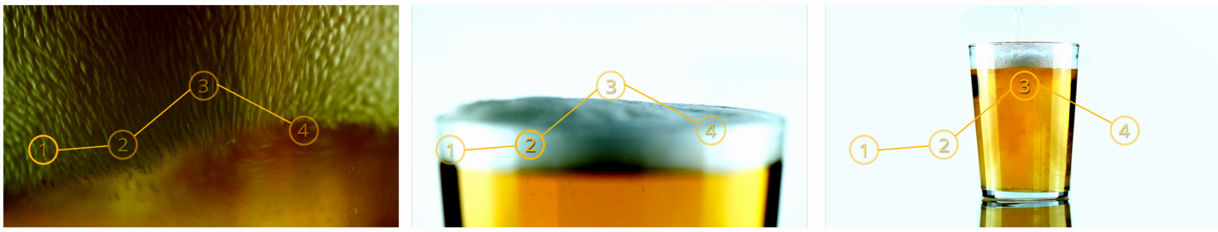
1 second | 5 seconds | 10 seconds



Gaze Paths

Similar to gaze paths with static stimuli, you can overlay a dynamic gaze path to a video so that you can see where an individual respondent was looking in each frame, indicated by a moving circle.

1 second | 5 seconds | 10 seconds



Quantitative Analyses: Gaze Mapping and Automated AOIs

Drawing AOIs on dynamic stimuli can be tedious because, (when considering the pixels the AOI is composed of) the object changes location, size and shape as it moves. This often requires “stepping-through” hundreds or thousands of frames to place and adjust AOIs.

- In order to get quantitative insights from a study with a video stimulus, you had to manually create AOIs on moving objects. This meant that AOIs had to be adjusted frame-by-frame throughout the video in order to follow the object.

- To get quantitative insights from a study in which respondents had freedom of movement (scrolling through a website, walking around with eye tracking glasses or exploring a virtual environment), this was even more cumbersome. Because of the freedom of movement, each respondent generates a unique video to be analyzed, so AOIs had to be placed and adjusted manually for each video, from each respondent!

Gaze mappig Heatmaps

In studies where respondents have freedom of movement (such as eye tracking glasses or VR environments, or scrolling through a website or software) gaze mapping can help visualize where respondents are casting their gaze. In this case, eye tracking data is mapped onto a reference image of the object you would like respondents to explore. A heat map can be made on the reference image in the same way a heat map is created for a static image. This is covered in more detail in the following section on gaze mapping.

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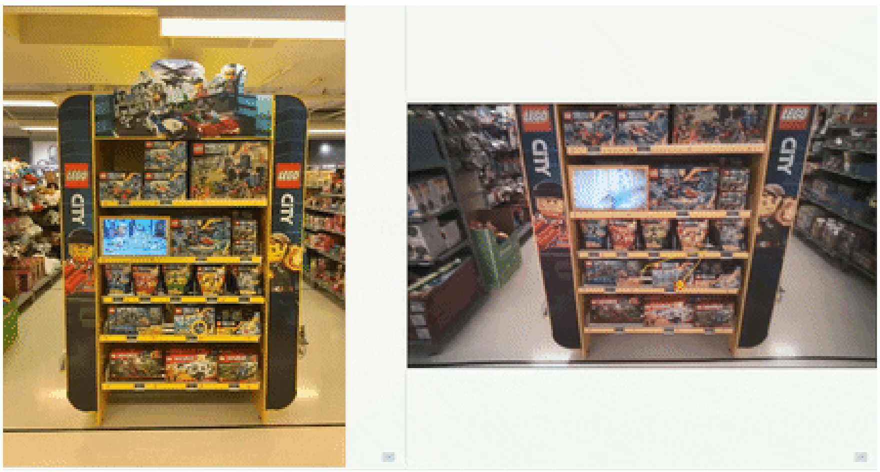
This was (and still is) a cumbersome undertaking for studies with long dynamic stimuli or many participants. It often requires multiple researchers to create AOIs for a single study. This can create a new problem because each researcher is not likely to place AOIs in the same way as another, even with training and strict protocols.

Luckily, there are new solutions. Gazemapping and AutoAOIs are eye tracking analysis tools for dealing with movement during eye tracking, reducing the workload of frame-by-frame analysis, making the process of creating AOIs easier and more consistent.

Gaze mapping

This eye tracking analysis technique takes the video from eye tracking glasses or a virtual environment and superimposes the gaze information on a still image of the object of interest. For example, if the study was examining how respondents visually navigate a physical map, you could take the gaze information from the eye tracking data and superimpose it on a still image of the map. Then, you can make AOIs on this still image, similar to the static stimuli AOIs described previously. For more detailed information and examples, visit our article.



An example of superimposed footage (right) over a still image of a LEGO shelf (left)

Automated AOIs

This eye tracking technique is similar to the manual effort of stepping through frames to create and adjust AOIs, but an algorithm finds the object for you on each frame and places the AOI. How the algorithm defines an object depends on the type of classifier used to create the algorithm. For more detailed information about Auto AOIs, classifiers, examples and best practice, visit our article.

An example of automatic created AOI tracking a moving car

Comparison of Gaze mapping and AutoAOIs

Unsure whether to use Gaze Mapping or AutoAOIs? This article helps you decide.

Explore our automated AOI module!

Automated AOIs

Key Features:

- Automatic Object Recognition and Retargeting

  Instead of manually targeting each object in every frame, our algorithm detects and tracks objects automatically across frames, eliminating the need for constant manual retargeting.

- Smart Object Identification

  The software helps users define AOIs by recognizing the outlines of objects in dynamic content, ensuring that every area of interest is captured without missing important data.

Conclusion

Eye tracking analysis provides a powerful lens into human attention, cognitive load, and emotional responses. By leveraging the data generated from eye movements, researchers can extract meaningful insights that drive decision-making across fields such as psychology, neuroscience, marketing, and user experience research.

Throughout this guide, we have explored the fundamental concepts of eye tracking, including pupilometry, blink detection, fixations, and saccades. We have also examined best practices for study design, data visualization techniques such as heatmaps and gaze paths, and quantitative analyses using Areas of Interest (AOIs). Additionally, we discussed approaches for handling both static and dynamic stimuli, introducing advanced techniques like gaze mapping and automated AOIs to streamline the analysis process.

Key Takeaways:

- Start with a Clear Research Question: A well-defined research question ensures that your eye tracking study is structured effectively, leading to valuable insights.
- Choose the Right Visualizations: Heatmaps reveal areas of interest, while gaze paths provide insights into viewing sequences. AOIs allow for precise quantitative comparisons.
- Account for External Influences: Factors such as lighting, participant movement, and hardware precision can impact the validity of eye tracking data.
- Consider Multimodal Approaches: Eye tracking data can be enriched when combined with physiological measures such as GSR, EEG, or facial expression analysis to provide deeper insights into human behavior.
- Leverage Automation for Efficiency: Tools like gaze mapping and AutoAOIs reduce manual workload and enhance consistency in dynamic stimulus analysis.

Eye tracking technology continues to evolve, offering new capabilities and more accurate data collection methods. As research methodologies advance, the ability to integrate eye tracking with other biometric and behavioral measures will further refine the interpretation of human attention and cognitive processing.

By applying the principles and techniques outlined in this guide, researchers can move from raw eye tracking data to actionable insights, making informed decisions that improve user experiences, optimize designs, and deepen our understanding of human behavior.

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