

Multimodal Interaction

Lesson 8 Eye Tracking

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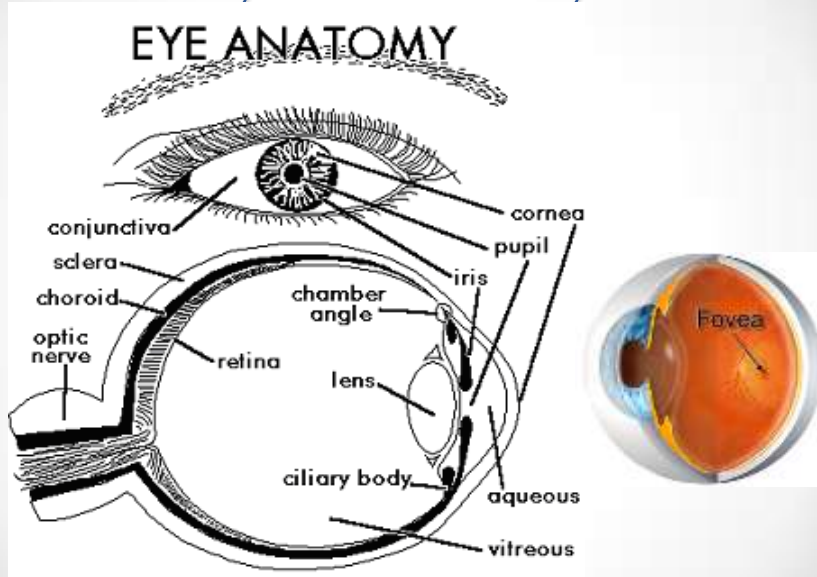
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What eye tracking is?

- **Eye tracking** measures either the point of gaze ("where we are looking") or the motion of an eye relative to the head.
- An **eye tracker** measures eye positions and eye movement.
- Eye trackers are used in research on the visual system, in psychology, in cognitive linguistics and in product design (e.g. HCI).

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Eye anatomy



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Eye movements

- **Fixation** or **visual fixation** is the maintaining of the gaze on a single location.
- Humans typically alternate **saccades** and **visual fixations**, the notable exception being in **smooth pursuit**, controlled by a different neural substrate that appear to have developed for hunting prey.
- **Smooth pursuit** are the movements that the eyes make while tracking an objects movement, so that it's moving image can remain maintained on fovea.

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Eye movements

- **Saccades**, are the short and rapid movement of eyes that is used while scanning a visual scene.
 - During each saccade the eyes move as fast as they can and the speed cannot be consciously controlled in between the stops.
- There are three categories of **fixational eye movements**:
 - **microsaccades**: small, jerk-like, involuntary eye movements, similar to miniature versions of voluntary saccades. They typically occur during prolonged visual fixation (of at least several seconds)
 - ocular **drifts**
 - ocular **microtremor**: a constant, physiological, high frequency (peak 80Hz), low amplitude (estimated circa 150-2500nm (1)) eye tremor; it occurs in all normal people even when the eye is apparently still and is due to the constant activity of brainstem oculomotor units.

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Short history

- The first study based on gaze measuring took place in 1878.
- Gaze study had more alternatives to develop when **photographing** techniques developed in the early 20th century and later, when the techniques of the moving image evolved.
- During the 1930's eye tracking was used in **reading study**. Gaze paths were researched while reading different kinds of fonts.
- Eye tracking were connected in **usability** study for the first time in 1950's. Then **Fitts** et al. used movie cameras to study air force pilots' eye movements while landing the plane.
- 1970's was more or less the golden decade of the gaze study. Techniques developed fast and psychological theories linked gaze study to cognitive processes.
- In 1980's eye tracking faced a new challenge as a method when computers started to increase.
- Nowadays eye tracking is a very useful method for different kinds of purposes. Examples:
 - it is a valid method when researching for example reading process or traffic behavior while driving.
 - it is a very important method when developing user interfaces for disabled peoples.
 - eye tracking is a very applicable method when analyzing users' behavior in WWW pages and in usability and accessibility research.

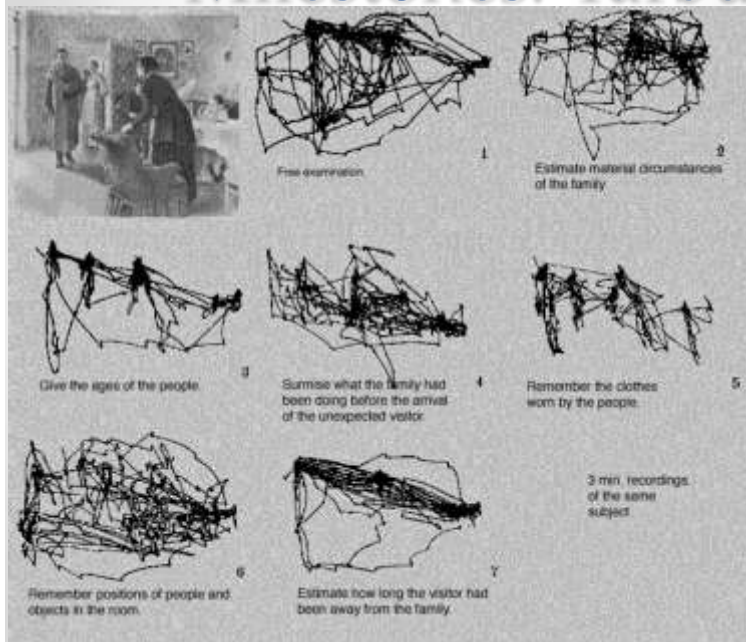
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Milestones: Yarbus

- In the 1950s, Alfred L. Yarbus did important eye tracking research and his 1967 book is very highly quoted. (Yarbus, A. L. Eye Movements and Vision. Plenum. New York. 1967 (Originally published in Russian 1962))
- "All the records ... show conclusively that the character of the eye movement is either completely independent of or only very slightly dependent on the material of the picture and how it was made, provided that it is flat or nearly flat."
- The cyclical pattern in the examination of pictures "is dependent not only on what is shown on the picture, but also on the problem facing the observer and the information that he hopes to gain from the picture."
- "Records of eye movements show that the observer's attention is usually held only by certain elements of the picture.... Eye movement reflects the human thought processes; so the observer's thought may be followed to some extent from records of eye movement (the thought accompanying the examination of the particular object). It is easy to determine from these records which elements attract the observer's eye (and, consequently, his thought), in what order, and how often."
- "The observer's attention is frequently drawn to elements which do not give important information but which, in his opinion, may do so. Often an observer will focus his attention on elements that are unusual in the particular circumstances, unfamiliar, incomprehensible, and so on."
- "... when changing its points of fixation, the observer's eye repeatedly returns to the same elements of the picture. Additional time spent on perception is not used to examine the secondary elements, but to reexamine the most important elements."

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Milestones: Yarbus



This study by Yarbus (1967) is often referred to as evidence on how the task given to a person influences his or her eye movement.

Milestones: Hunziker



- Hunziker (1970) studied on eye tracking in problem solving using simple 8 mm film to track eye movement by filming the subject through a glass plate on which the visual problem was displayed.

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Milestones: Just & Carpenter

- In 1980, Just and Carpenter formulated the influential *Strong eye-mind Hypothesis*, the hypothesis that "there is no appreciable lag between what is fixated and what is processed".
- If this hypothesis is correct, then when a subject looks at a word or object, he or she also thinks about (process cognitively), and for exactly as long as the recorded fixation. The hypothesis is often taken for granted by beginning eye tracker researchers. However, gaze-contingent techniques offer an interesting option in order to disentangle overt and covert attentions, to differentiate what is fixated and what is processed.
- The **gaze-contingency paradigm** refers to techniques allowing to change the display on a computer screen in function of where the viewer is looking.

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Methods to measure eye movements

- The most popular methods extract the eye position from **video images**
- **Recent prototypes capture images using a webcam.**
- Eye tracking techniques can be divided in groups depending on the **amount of physical touch** the user needs to load:
 - techniques based on infra red light projected from the eye
 - techniques based on electric potential measured from the skin around the eye
 - techniques based on the special contact lenses (**search coils**)
 - techniques based on the electrooculogram.
- The first of kind of techniques is the most comfortable way for the person in the test, because he doesn't have to wear any heavy helmet or special lenses, and information is sufficient for example when searching reading patterns for WWW pages.

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In more detail

(from <http://www.liv.ac.uk/~pcknox/teaching/Eymovs/emeth.htm>)

Electrooculography

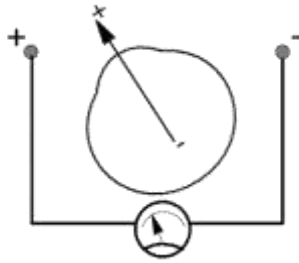
- Because there is a permanent potential difference between the cornea and the fundus of approximately 1mV, small voltages can be recorded from the region around the eyes which vary as the eye position varies.
- By carefully placing electrodes it is possible to separately record horizontal and vertical movements.
- However, the signal can change when there is no eye movement. It is dependent
 - on the state of dark adaption
 - on metabolic changes in the eye
 - on the state of the contact between the electrodes and the skin
 - there have been reports that the velocity of the eye as it moves may itself contribute an extra component to the EOG.
- It is not a reliable method for quantitative measurement, particularly of medium and large saccades. However, it is a cheap, easy and non-invasive method of recording large eye movements, and is still frequently used by clinicians.

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Electrooculography



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Infra-red oculography

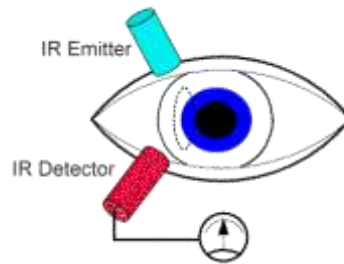
- If a fixed light source is directed at the eye, the amount of light reflected back to a fixed detector will vary with the eye's position.
- This principle has been exploited in a number of commercially available eye trackers.
- Infra-red light is used as this is "invisible" to the eye, and doesn't serve as a distraction to the subject.
- Infra-red detectors are not influenced by other light sources, the ambient lighting level does not affect measurements.
- Spatial resolution (the size of the smallest movement that can reliably be detected) is good for this technique, it is of the order of 0.1° , and temporal resolutions of 1ms can be achieved.
- It is better for measuring horizontal than vertical eye movements.

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Image based methods

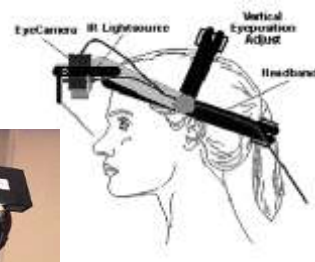
- With the development of video and image analysis technology, various methods of automatically extracting the eye position from images of the eye have been developed.
- A video image is combined with computer software to calculate the position of the pupil and its centre. This allows vertical and horizontal eye movements to be measured.
- However, image based methods tend to have temporal resolutions lower than that achieved with IR techniques. Spatial resolution can also be limited.
- As technology improves, the resolutions these systems can deliver will also improve.

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In more detail

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Image based methods



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In more detail

Image based methods

- Two general types of eye tracking techniques are used: **Bright Pupil** and **Dark Pupil**.
- Their difference is based on the **location** of the illumination source with respect to the optics.
 - If the illumination is **coaxial** with the optical path, then the eye acts as a retroreflector as the light reflects off the retina creating a bright pupil effect similar to red eye.
 - If the illumination source is offset from the optical path, then the pupil appears dark because the retroreflection from the retina is directed away from the camera.
- Bright Pupil tracking creates greater iris/pupil contrast allowing for more robust eye tracking with all iris pigmentation and greatly reduces interference caused by eyelashes and other obscuring features. It also allows for tracking in lighting conditions ranging from total darkness to very bright. But bright pupil techniques are not effective for tracking outdoors as extraneous IR sources interfere with monitoring

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In more detail

(from <http://www.liv.ac.uk/~pcknox/teaching/Eymovs/emeth.htm>)

Scleral search coils

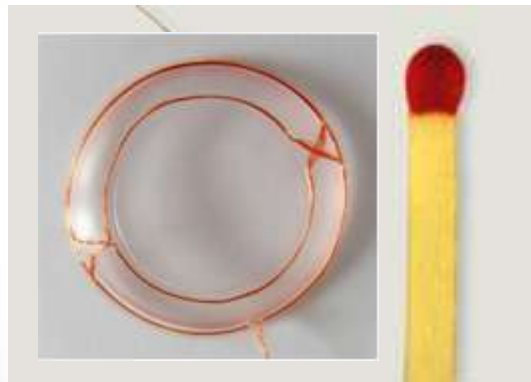
- When a coil of wire moves in a magnetic field, the field induces a voltage in the coil.
- If the coil is attached to the eye, then a signal of eye position will be produced. In order to measure human eye movements, small coils of wire are embedded in a modified contact lens or anulus. This is inserted into the eye after local anaesthetic has been introduced.
- The field is generated by two field coils placed either side of the head. This allows horizontal eye movement to be recorded.
- If it is necessary to also monitor vertical eye movements, then a second set of field coils, usually set orthogonally to the first set, is used. The two signals (one for horizontal, one for vertical eye movement) generated in the eye coil can then be disentangled using appropriate electronics.
- In experiments on eye movements in animals, the eye coils are frequently implanted surgically.
- The advantage of this method is that it has a very high temporal and spatial resolution allowing even the smallest types of eye movements (e.g. microsaccades) to be studied.
- It's disadvantage is that it is an invasive method, requiring something to be placed into the eye. This method is rarely used clinically, but is an invaluable research tool.

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In more detail

(from <http://www.liv.ac.uk/~pcknox/teaching/Eymovs/emeth.htm>)

Scleral search coils



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Usage


- Most common data forms collected via eye tracking are **heat maps** and **hot spots**, **gaze paths** and **areas of interest**.

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Before starting ... Calibration

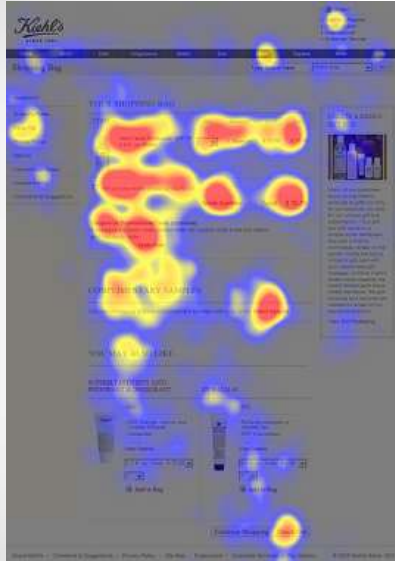
- Each individual's eyes move differently
- Calibration will adjust for those differences
- Accurate calibration leads to accurate eye control use

Initial Calibration

 <http://www.youtube.com/watch?v=pHtHsbps6II>

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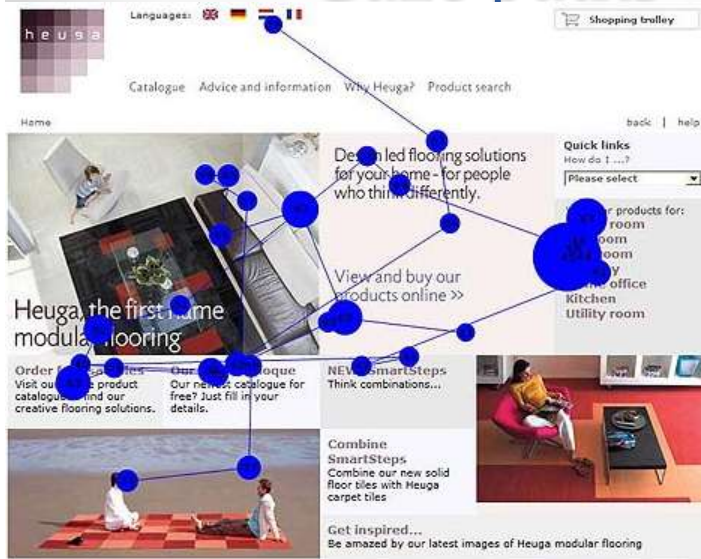
Heat map



The areas where users looked the most are red; the yellow areas indicate fewer views, followed by the least-viewed blue areas.

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Gaze paths



Saccades and fixations

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Areas of interest



The searched area can be split in to smaller areas.
After splitting it is possible to measure attention duration paid for ascertain area.
The data is called areas of interests.

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Example



Esempio di Eye Tracking su Sito-Perfetto.it
http://www.youtube.com/watch?v=tUsOy_om8T0

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F-shaped pattern

(from http://www.useit.com/alertbox/reading_pattern.html)

- Eye-tracking visualizations show that users often read Web pages in an F-shaped pattern: two horizontal stripes followed by a vertical stripe. Users first read in a horizontal movement. Next, users move down the page a bit and then read across in a second horizontal movement. Finally, users scan the content's left side in a vertical movement.
- Obviously, users' scan patterns are not always comprised of exactly three parts. Sometimes pattern may look more like an E or an inverted L than an F. Generally reading patterns roughly resemble an F.

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F-shaped pattern

(from http://www.useit.com/alertbox/reading_pattern.html)



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Implications

- **Users won't read your text thoroughly** in a word-by-word manner. Exhaustive reading is rare, especially when prospective customers are conducting their initial research to compile a shortlist of vendors.
- **The first two paragraphs must state the most important information.** There's some hope that users will actually read this material, though they'll probably read more of the first paragraph than the second.
- **Start subheads, paragraphs, and bullet points with information-carrying words** that users will notice when scanning down the left side of your content in the final stem of their F-behavior. They'll read the third word on a line much less often than the first two words.

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Image search

(from <http://psychology.wichita.edu/surl/usabilitynews/91/eyegaze.html>)

- The test included twenty undergraduate students (17 female, 3 male). Equipments were a regular PC and a Tobii eye-tracking system. In the picture section of the study all participants did three tasks each: browsing, search, search for a non—existent item.

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Browsing



When a user is just browsing the page the scan pattern is horizontal (from left to right and right to left).

Also most of the fixations are centered on the first couple of lines of pictures.

This is something that should be considered when designing a web page with thumbnail images (or something similar).

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Searching



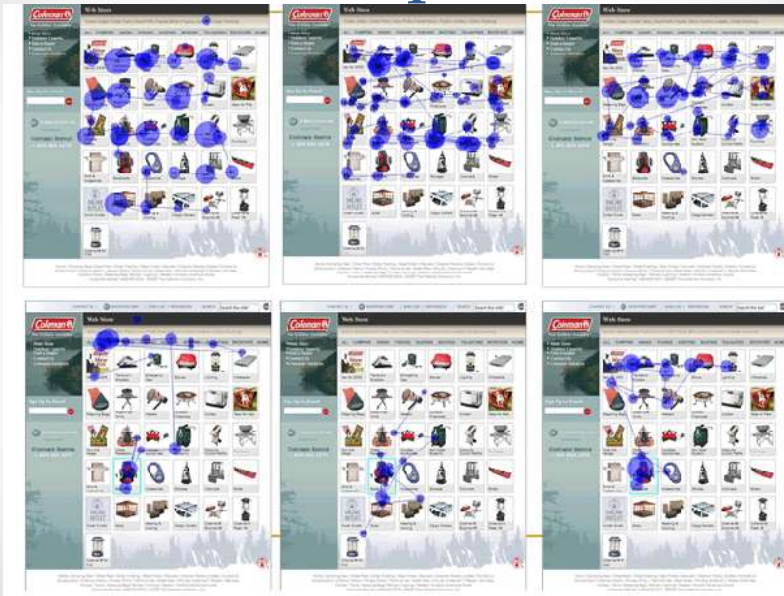
The second task was to find some specific item on the page. The results show that the scan path is fairly random until the target is found.

This is also valid to the last task where the user had to find an object that didn't exist.

Although the scan pattern is random the upper left corner usually did get most fixations and concentration from the users.

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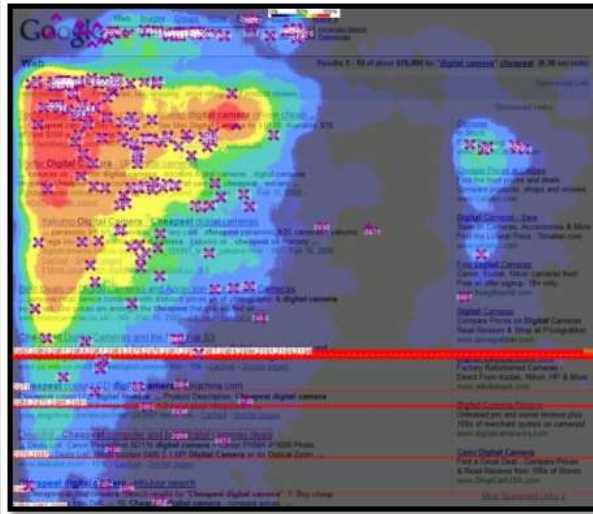
Gaze paths



Eye Tracking Study: How People Consume Information on the Internet

- From: Mark Thompson. **Eye Tracking Study: How People Consume Information on the Internet.**
<http://www.stayonsearch.com/how-people-consume-information-on-the-internet>

Search Engine Results Page (SERP)

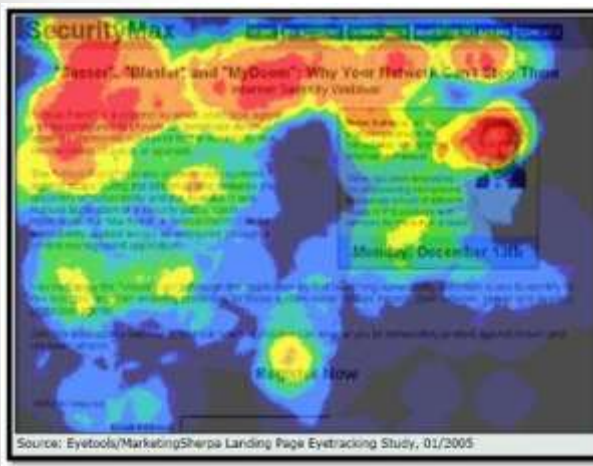


The majority of the users will start from the top left and work their way down the page. They will also drift over to the top right and look at a few of the top sponsored search results.

Being "Above the fold" is crucial in gaining visibility in search engines, as most people do not scroll down to see the rest of the results.

pdf.uniroma1.it

Landing page



On this landing page that people's eyes are drawn to the headlines, the top few sentences of the copy and the headshot. It's proven that people tend to look at images and photos first before diving into content.

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Video Landing page



On this Cnn.com video people will look at the man's face, the headline inside the video, and then down at the control panel for the video. They will also drift to the right to see the headline and the bullet points.

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Blog Post



This is a screenshot of a blog post. People's eyes are directed towards the blue hyperlinks, as well as the login area. The spacing between numbers help the user read each headline and find what they are looking for.

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Tips

- Break up the content by using other elements (photos, images, headlines, icons). Do not overwhelm them with lots and lots of text.
- Use bullet points and numbered lists to highlight areas of your content
- Use short, descriptive sentences
- Create gripping headlines
- Be creative with your images, try and deliver a compelling message
- Make headlines and important keywords bold
- Use italics
- Create descriptive hyperlinks
- Try using pull quotes for content that you want highlighted
- Create good spacing between your content

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Eye tracking for Natural Interfaces ...

Look at This_ Eye Tracking Coming to PCs

<http://www.youtube.com/watch?v=juAtghX4oVs&feature=fvst>



Look at This_ Eye Tracking Coming to PCs

<http://www.youtube.com/watch?v=A92WNMd46VI&feature=fvst>



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... and beyond



Eye Tracking Cristiano Ronaldo
<http://www.youtube.com/watch?v=2NcUkvIX6no>

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Readings

- Petri Laitinen and Else Lagerstam. **Using eye tracking to study and improve search interfaces.** <http://www.cs.uta.fi/hci/spi/ddsi/>
- Mark Thompson. **Eye Tracking Study: How People Consume Information on the Internet.** <http://www.stayonsearch.com/how-people-consume-information-on-the-internet>
- Jakob Nielsen (2006), **F-Shaped Pattern For Reading Web Content** http://www.useit.com/alertbox/reading_pattern.html
- Sav Shrestha & Kelsi Lenz. **Eye Gaze Patterns while Searching vs. Browsing a Website.** <http://psychology.wichita.edu/surl/usabilitynews/91/eyegaze.asp>

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