I am currently working on an eye tracking project investigating some aspects of reading in Arabic. Eye tracking is a research method in which eye movements are studied while a person does some sore sort of task, and by analyzing the eye movement data we can draw conclusions about mental activities during that task. One of the areas where eye tracking technology has had a major impact is on reading. For adult, proficient readers, reading is a highly automatic, to the degree that we are not completely aware of what is going on. When reading in normal pace it sometimes feels like the words are beamed straight into your brain. Only occasionally do you stop to dicier a word or backtrack to reread some portion of the text. Eye tracking offers an interesting way to do very precise measurements what it is we are doing when we read, how the eyes move, whereto, and how quickly.

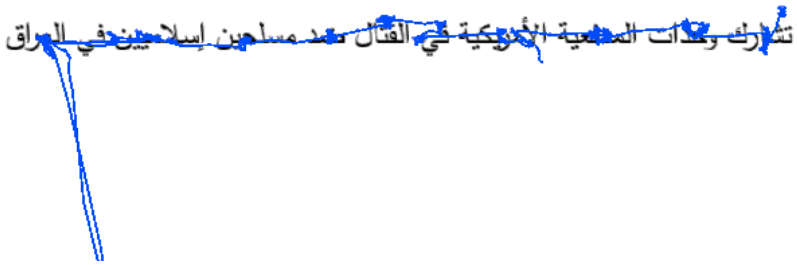
Most modern eye tracking equipment works by filming they eye whilst shining infrared light on it. It records the position of the pupil and the position of the reflection of the infrared light in the eye and from that information the computer calculates the angle of the eye-ball at any given time. With some further calculations we can know point on a computer screen (typically) that the person is looking at.

One of the things we are usually not aware of when reading is that the eye moves in jerky, stepwise motions. We typically have the sensation of the eye evenly moving across the line, but in fact it moves very quickly movement and then then stops for a little while to take in information. During the movements, called *saccades*, we are in blind, that is the eye moves so quickly that we cannot perceive anything. The movement only serves to let us move the eye to another part of the text, a bit further down the line. Here we make another brief pause, called *fixation*, during which the eye takes in information that is processed by the brain, before the eye jumps to another location in the text.

This is illustrated in the video below. It shows how I read a pdf with an article in my field that I hadn't read before. It shows my eye-movements in in real time. Each line is a movement and each circle a fixation. (The data has been cleaned from noise and some other effects. More on this below.) The particular equipment used to record this data is not the most accurate and the text on the screen is very small, so the recorded movements are a bit off. It is for example difficult to see exactly which line I am reading at any given time. But you can clearly see the jerky motions of reading. Notice also how I move down to read the footnote, and then also for some reason check out the page header before moving on.

The following video is me reading Arabic. As you can see I read this sentence fairly slowly. (To my defense its been several moths since I last read something substantial in Arabic.) This data is recorded with larger text and on much more accurate eye-tracking equipment. This eye-tracker takes records the position of the eye 1000 times per second and was recorded with my chin and forehead resting on a stand to ovoid unwanted head movement. The green ball shows how my eye moves.

Even if I am reading slowly this is quick and a bit difficult to follow. So instead we can draw all the recorded eye-positions (1000 per second, remember) on the line of text:



Figur 1: Raw eye-movement on a line of Arabic text

You can see the cluster blue dots on each word, with a squiggly line between each cluster. Each cluster is were I keep my eye more or less steady for a short period of time, a fixation, and the lines between them are saccades. I move my eye from word to word. When you read normally, this you typically skip some smaller words. Notice in the video above of me fairly quickly reading an article how my the are only so many fixations (circles in the video) on each line, fewer than the number of words on each line. Some words are skipped. The strange downward movement far below the line from the last word in the sentence is actually a blink. As the eyelid moves down it covers part of the pupil so that the eye-tracker only sees the lower part of it and calculates its center to be further down, and records a downward movement of the eye.

Now, we know that the eye moves in saccades (quick jerky motions) and fixations (periods of relative stillness between saccades). So we can say that all recorded positions where the eye does not move much, clusters of blue in the image above, are fixations, and that quick movements are cascades. We then get something that can be illustrated as in the image below.

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The light blue circles in this image mark fixations with numbers indicating the duration of these fixations in milliseconds. You can see, for example, that longer words, such as the second and the third word, there are (embarrassingly) ling periods of rest of more than half a second. On the two occasions of the show word *fī* 'in' (fifth and tenth from the left) the fixations are much shorter. This kind of short word would often be completely skipped in normal paced reading, getting no fixation. The orange lines mark saccades.

This way you can get a very precise idea of how the eyes moved when reading this line. Do this on a number of people and you can see exactly what words are difficult, where people have to backtrack to reread, or how reading as an actual physical activity differs between different kinds of reading or between poor and skilled readers.