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EYE MOVEMENTS DURING READING

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YOUNG REVIEWERS:

ARIEL, AYDEN, NATE, AND SERENA
AGES: 8–12

NABHANYA
AGE: 8

VANDYA
AGE: 11

Written words are everywhere. Learning to read is one of the main tasks of our early school years, and the ability to read opens up a world of possibilities—we can absorb ourselves in stories, remind ourselves of important information, and learn new things. But few of us think about what we are actually doing as we read. Moving the eyes is essential for reading. For instance, to read this sentence, you probably began by looking at the first word before moving your eyes to each word in turn. All the while, you are working hard to recognize and understand each word. In this article, you will learn about why eye movements are a necessary part of reading, how they are measured, what they tell scientists about what is happening in the mind during reading, and how they change as children grow into adults.

Reading is an incredible feat. When you look at writing, you are able to turn marks on a page into language—words that you can say and understand. As you read, you must move your eyes from word

to word. Eye movements are very interesting to scientists because they tell us a lot about what makes words easy or hard to read and understand. By the time you have finished reading this article, you should know much more about why and how you move your own eyes during reading.

FOVEA

The small area in the middle of a reader's vision that lets them see clearly.

PARAFOVEA

The area to the left and right of the fovea. Letters in the parafovea are a bit blurry but still helpful during reading.

PERIPHERY

The area beyond the parafovea. Your peripheral vision is very blurry and is not very helpful during reading.

WHY DO WE NEED TO MOVE OUR EYES AS WE READ?

When you look at a word, it falls on a small area in the center of your vision. This middle part of your vision is called the **fovea** (Figure 1). You depend on this part of your vision when you read because this is the only area where you see things really clearly. The area to the left and right of the point you are looking at is called the **parafovea**. Things in the parafovea are a bit blurry but can still be useful as you read. Further away from the point you are looking at is called the **periphery**. Information in this area is very blurry and not really useful during reading [1]. Because the clear (foveal) part of your vision is so small, you must move your eyes to read long words and sentences.

Figure 1

A child reads while using an eye tracker. The child is looking at the word "cat," which falls in the middle part of her vision (the fovea), where she can see that word clearly. The further away words are from where the child is looking, the less clear the words become. The parafovea takes in the words to the left ("tabby") and right ("slept") of the fovea. The periphery takes in the rest of the words in the sentence.

CAN YOU FEEL YOUR EYES MOVE?

SACCADES

Short, jerky eye movements that allow the eyes to move from point to point.

Eye movements are called **saccades** and they happen so quickly that people usually do not notice them. Saccades let you move your eyes from one point to the next. Each saccade is followed by a period of time in which the eyes are fairly still. As you read this sentence, pay attention to how it feels to move your eyes. Now go back and look for the word "attention." How did your eyes feel as you searched? Did your eyes feel like they were moving smoothly, or did you feel your eyes making stop-start movements as you tried to find the word you

were looking for? If you felt your eyes making stop-start movements, then you were feeling the saccades your eyes make as you read. When you look at something, we say you are **fixating** it. You can only read words when you are fixating them.

FIXATION

The period of time between saccades when the eyes have largely stopped moving.

HOW ARE EYE MOVEMENTS MEASURED?

Eye movements are measured with eye trackers, which are special video cameras. The eye-tracking camera is placed on the table in front of the reader, just below a computer screen (Figure 1). Chin and forehead rests are often used to keep the reader's head as still as possible. The eye tracking video camera takes 1,000–2,000 pictures of the eye each second. The computer quickly finds reflections of light in the reader's eye to work out where the person is looking and for how long. Eye trackers are very accurate. They know where the reader is looking to within a letter or two. They can also measure how long a reader looks at a word, to within a few thousandths of a second.

WHY STUDY EYE MOVEMENTS DURING READING?

Looking at a word allows a reader to take in new information, so how long a person looks at words during reading is important—it can show how easy or difficult it is for the person to read that word. When a word is difficult to read, the reader will look at it longer than they will look at a word that is easy to read. Difficult words (and long words) are looked at more often than easy words. You might look at a difficult word two or three times before you move on to looking at the next word, or you might come back to have another look at the difficult word after you finish reading the sentence.

Because eye movements are so good at telling scientists when reading gets difficult, we can change parts of a written text to explore the reasons why reading words and sentences can be easy or difficult. Figure 2 gives some examples of things that make eye movements shorter or longer.

WHAT TYPES OF EYE MOVEMENTS HAPPEN DURING READING?

Fixations

A fixation is the time a reader spends looking at a word. About 75–85% of the words in a sentence are fixated at least once during reading (Figure 3). Looking times are measured in milliseconds because fixations during reading are quite short. One millisecond is equal to 1/1,000 of a second. For adults, fixations can be as short as 60 ms or as long as 800 ms. Most fixations are around 225–250 ms [2]. That is about a quarter of a second!

Figure 2

Three examples of things that influence eye movements during reading.

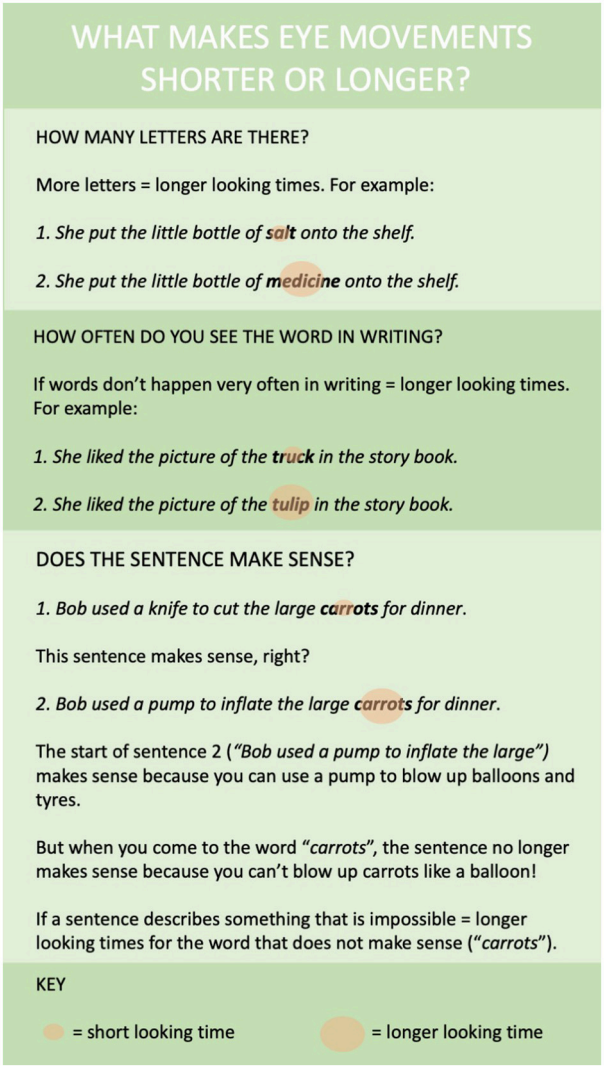

Figure 2

Figure 3

Eye movements during reading. The circles are periods of time in which the eyes fixate a word. The arrows are saccades, showing the direction that the eyes move, beginning on the left with the word "The." One word ("long") is not fixated at all. Most words are fixated once. One word ("tabby") is fixated three times—the first two fixations are on the letter "t" and then between the letters "b" and "y." The third fixation is a regression, in which the reader moves their eyes backwards, returning to the word from a later part of the sentence.

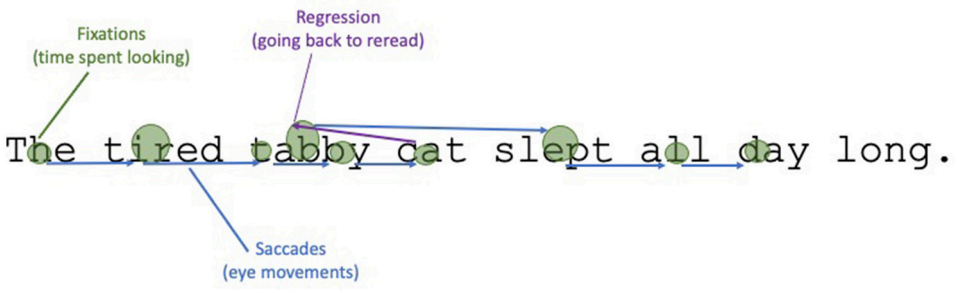

Figure 3

SKIPPING

A word is skipped during reading when it is not fixated.

Word Skipping

Not all words are fixated. About 15–25% are never looked at during reading. When this happens, it is called word **skipping**. Skipping happens most often when words are short or very common. It also

happens when a reader expects to see the word. Words like "the" and "a" are often skipped [3].

Direction of Reading

A reader's eye usually moves forward through a sentence. In English, that means the eyes move from left to right. In Arabic, which is written with the words going from right to left, the eyes move from right to left. Sometimes the eyes move backwards through a sentence. Moving backwards through a sentence allows the reader to have another look at words they have already gone past. These backwards eye movements are called **regressions**. To "regress" means to go back. Backwards eye movements happen about 10–15% of the time. Scientists think they happen when the reader does not understand a word or sentence the first time, so they look back to reread the difficult bit. Rereading tells scientists where the tricky words are.

REGRESSIONS

Backwards (right to left, in English) eye movements that allow the reader to reread difficult parts of a sentence.

DO CHILDREN AND ADULTS MAKE SIMILAR EYE MOVEMENTS?

Children and adults move their eyes differently during reading [4]. Children read more slowly than adults. For instance, 7–8-year-old children read about 95 words per minute. Eleven- to twelve-year-old children read about 210 words per minute. Adults read about 290 words per minute. Children look at words more often and for longer than adults do. They are also more likely to reread words than adults are. These differences become smaller as children grow older, suggesting that children get better at reading as they grow, which seems obvious—but what exactly are they getting better at?

One possibility is that children get better at recognizing written words and understanding what they read. In other words, children's language skills get better. Another possibility is that children get better at moving their eyes quickly and accurately. In other words, children get better at controlling their eye movements.

Some computer programs can help scientists decide which explanation is correct. These computer programs are like a robot that reads. The robot knows all the things that make reading easier or harder to do. If scientists tell the computer program that something (like language) is more important than something else (like eye-movement control), they can see what that does to the robot's eye movements. Then they can compare the robot's eye movements with the eye movements of real people. This type of study suggests that children's eye movements are different from adults' mostly because children have had less opportunity to develop their language skills [5]. So, what does this mean for you? The more words you learn, the better (and faster) your reading will be. One of the best ways to read faster and better is to read more!

SUMMARY

Eye movements give scientists a fascinating window into reading as it happens. Eye movements are useful because they are so good at telling scientists when reading is easy or hard to do. Now that you know how and why your eyes move, you can think about it the next time you are reading at school or at home. And remember, with some more practice, in a few short years you will be reading as well, and as quickly, as your teachers.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

ARIEL, AYDEN, NATE, AND SERENA, AGES: 8–12

We are kids who love science, outdoor adventures, and Pokemon Go. We also play computer games, and keep pets ranging from caterpillars to fluffy dogs.

NABHANYA, AGE: 8

Nabhanya is a 8 year old girl who is currently in 3rd grade. She is highly fascinated by experiments in science and mathematics. She has won two medals in Maths (International Maths Olympiad, Bricmaths) and one in cyber olympiad. She loves art, music, and dance. During her free time she enjoys pretend playing with her Barbie dolls, dressing them up, and making stories with them. She also likes playing with Lego toys. She currently lives with her parents in France.

VANDYA, AGE: 11

Vandya is a 11 year old girl who is currently in 3rd grade. She is a very highly creative individual with an inquisitive mind. She loves watching cartoons and reading books. She is also a Bharathanatyam dancer. During her free time she enjoys playing with her friends. She loves to take her dog for walking and playing. She currently lives with her parents and sister in USA.

AUTHORS

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I am a postdoctoral researcher at the Macquarie University Center for Reading in Sydney, Australia. I study how children and adults learn new written words as they read. Most of my work uses eye movements as a way of understanding how this learning happens. In my spare time, I like reading and playing with my kids. *signy.wegener@mq.edu.au

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I am a lecturer in the School of Psychological Sciences at Macquarie University. My research uses eye-tracking to understand how people read and write in languages and writing systems that are as rich and varied as English vs. Chinese. When I am not working, I enjoy running and use it to explore the city of Sydney (where I live) and nature.

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I am a professor of cognitive psychology and the head of the School of Psychological Sciences at Macquarie University. My research uses computational models and eye-tracking experiments to understand the mental processes that allow people to read. I enjoy traveling and reading, and most of my favorite "people" are cats.

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I am a reading researcher at the School of Psychological Sciences at Macquarie University. I am interested in how children learn to read and when during reading development word processing becomes more intuitive and automatized. I love eating ice-cream and being outdoors, especially near the beach, in the sun and in the water.

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I am a professor at the Macquarie School of Education and deputy director of Macquarie University Center for Reading in Sydney, Australia. I study how children and adults sometimes struggle with learning to read. I am an avid motorcyclist who wears high-visibility protective gear and waits for the affordable electric motorbikes to arrive in Australia.

ANNE CASTLES

I am a professor at the Macquarie University Center for Reading in Sydney, Australia. I do research on how children learn to read, and why some children have great difficulty. I also study various types of reading difficulty and try to find ways to help children who have these difficulties. In my spare time, I like reading (surprise) and spending time with my family, both animal and human.