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ESL Reading Research Based on Eye Tracking Techniques

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ABSTRACT

Reading is a complex cognitive process. Through eye tracking techniques the cognitive features can be observed in depth and therefore a better grasp of the instant cognitive processing of language can be achieved. Compared to traditional methods, the greatest advantage of eye tracking is that the reader proceeds with reading coherently and fluently without interrupt and interference, which secures the results in higher ecological validity. This study is mainly about studies on eye movement features in ESL reading and particularly illustrates eye movement patterns, the relationship between eye movement and perceptual processing and eye movement control, aiming at providing some basic evidences for explaining the relationship between eye movement behavior and cognitive processing thus helping to solve some theoretical problems in reading.

Key words: Reading, eye movement, information tracking, cognitive process, perception span

INTRODUCTION

Reading is a complex cognitive process and through eye tracking techniques, the cognitive features of reading process can be observed more in-depth and therefore a better grasp of real-time cognitive processing the language comprehension can be achieved. Eye movement as an index to investigate reading process is an important area of psycholinguistics and reading psychology. In reading activities, the research of the relationship between cognitive processing and eye movement behavior can be dated back to the 19th century, when the research focused on the basic parameters and features of eye movement. Since the 1970s, with the development of eye movement recording technology and particularly the use of computer technology, the study on the reading process has entered a new phase. A common eye tracker is shown in Fig. 1. An eye tracking system is shown as in Fig. 2.

Eye tracking technology is still in the exploratory stage and the evolution of eye tracking technology application is shown in Fig. 3.

Psychologists began to attach importance to the relationship among eye movement, perception and cognition and describe the cognitive processing by using eye movement parameters. With the development of eye movement research in reading, some new advanced techniques (e.g., eye movement contingent display) were applied. On the basis of the eye movement newer technologies, the scope of reading research was further expanded and no longer confined to the basic eye

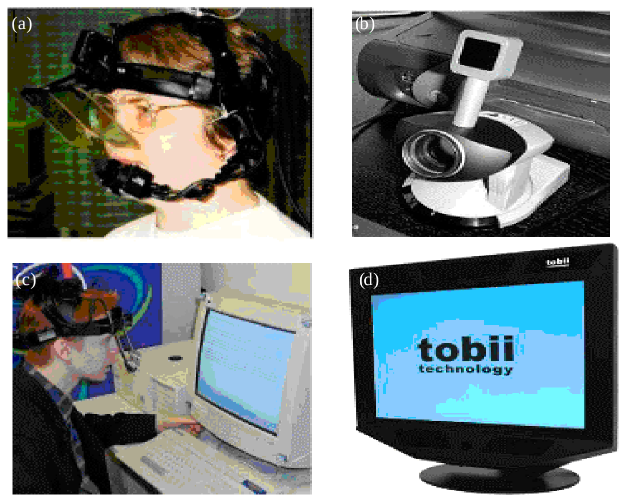

Fig. 1(a-d): Common eye tracker, (a) ASL, (b) SMI, (c) Eyelink and (d) Tobii

Fig. 2: Motion capture and eye tracking system

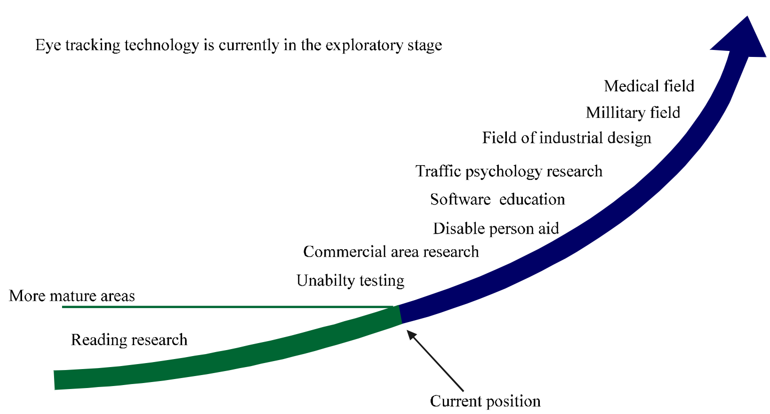

Fig. 3: Eye tracking technology applications

movement parameters; the information about side-vision areas was concerned about, expecting to know about what information the reader would get from side-vision area and its effects on the length of gazing at the fovea regional words. Compared to traditional methods, the greatest advantage of eye tracking is that the reader proceeds with reading coherently and fluently without interrupt and interference, which secures the results in higher ecological validity. From indicators of eye movement, what the brain is processing can be inferred and the reading process is understood in depth, which will help solve a lot of theory problems in reading.

Needless to say, there are great prospects in ESL reading research based on eye tracking techniques.

EYE MOVEMENT PATTERNS IN THE READING PROCESS

An eye-tracking system usually monitors the reaction and the typical mobile of the target human eye on a digital image. People's eyes are usually kept moving until it stays at a certain point. Eye movement patterns may reflect the choice of visual information and psychological mechanisms of the cognitive processing is to revealed, which are important. During the process of reading research, psychologists have found different eye movement parameters to reflect the real-time cognitive processing. The main patterns of eye movement in reading course are: Fixation, saccade, regressive eye movement and return sweep. When the eyes are focused on a point, we call it fixation and when the eyes move between several solid points of view, we call it a glance.

Fixation: Fixation means that the time of the fovea alignment of an object exceeds 100 msec and in the meantime, the watched object will be fully processed, with a clear image formed at the fovea. When reading, readers get the main information by gazement. For skilled readers, the average gazing time is from 200-250 msec (Rayner, 1978). However, individual differences are large. In addition, when the same reader is at different times or reads different texts, the watching duration are quite different. With respect to a reader, the gazing duration when reading some articles is between 100 and 500 msec (Rayner, 1978). Readers often watch on functional words shorter than adjectives. Factors of watching time include word frequency, word length, word predictability and so on (Rayner, 1998; Townsend and Bever, 2001).

Saccade: Saccade refers to people's continuous eye movement when reading (Fig. 4). It is a rapid eye movement; its speed is generally 500 degrees per second. Once the saccade starts, you can not change the direction of movement until it ends. Saccade accounts for 10% of the reading time. Average saccade distance is 8-9 characters (equivalent to twice perspective). In the saccadic course, eye sensitivity will be reduced, which is known as saccadic suppression.

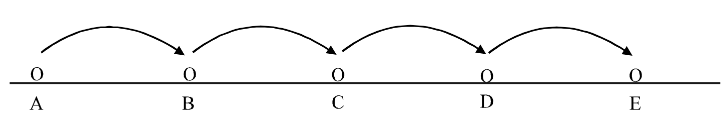

Fig. 4: Saccade schematic diagram

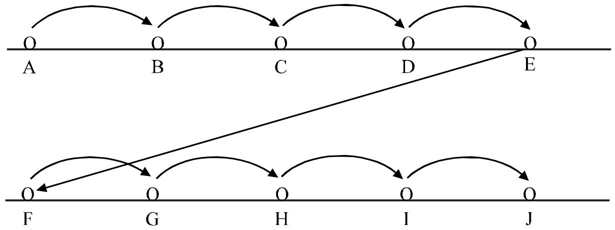

Fig. 5: Regressive eye movement schematic diagram

The reader can not obtain information on this process, because the presented information is only fleeting. Saccade time is effected by saccade distance (Rayner, 1998). The farther saccade distance, the longer the time spent.

Regressive eye movement: Regressive eye movement refers to the process of eye movements that the readers watch the new words from right to left and then return to the content which has been watched over, as is shown in Fig. 5.

Research shows that when a word is needed to be watched back, the watch time of the word is often longer than those which is not needed to (Rayner *et al.*, 2003). Skilled readers are back at about 10-20% of reading time. Frazier and Rayner (1982) proposed three regressive eye movement modes: (1) Advancing regressive eye movement, that watching point is back to the beginning of a sentence and then re-read the sentence, (2) Retreating regressive eye movement, that is just to read content which is read verbatim from right-to-left and (3) Selecting style regressive eye movement, through the eyes jumping back on the misunderstood sentence. From the perspective of information processing, the highest efficiency of these three strategies is the selecting regressive eye movement, for it just needs to re-read the ingredients of misunderstood sentences. Regressive eye movement helps readers to post deep processing. The reason of regressive eye movement may be that there is something wrong with the word the reader is watching or the reader does not understand the article (Rayner, 1998). In addition, when there is anaphoric reference in the sentence, that is, using a pronoun to refer to a previous word or a group of words, regressive eye movement is also prone.

Return sweep: There are similarities between regressive eye movement and return sweep, because they are both a right-to-left eye movement. However, the return sweep is reading from the end line to the beginning of the next line, though also a right-to-left eye but different from the regressive eye movement. So, in order to distinguish from the regressive eye movement, we call it return sweep, which is a natural eye movement from one line to another, as in Fig. 6 from E to F.

Eye fixation usually takes 100-600 msec, when the brain begins processing visual information received from the eye at every point of fixation. Saccade usually refers to jumping quickly from one fixation point to another fixation point. Typically the saccade average time is 20-40 msec. During this period, the eye does not transmit information to the brain.

Vision of the human eye is probably in 200°, the vast majority of light-sensitive cells are located in the fovea on the retina, which is enough for us to see a variety of things with color.

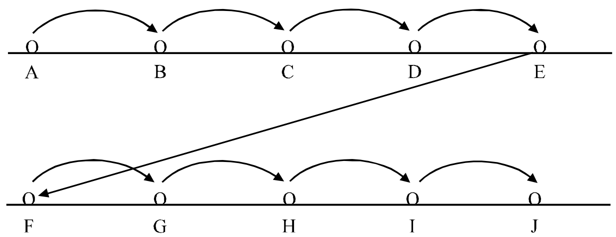

Fig. 6: Return sweep schematic diagram

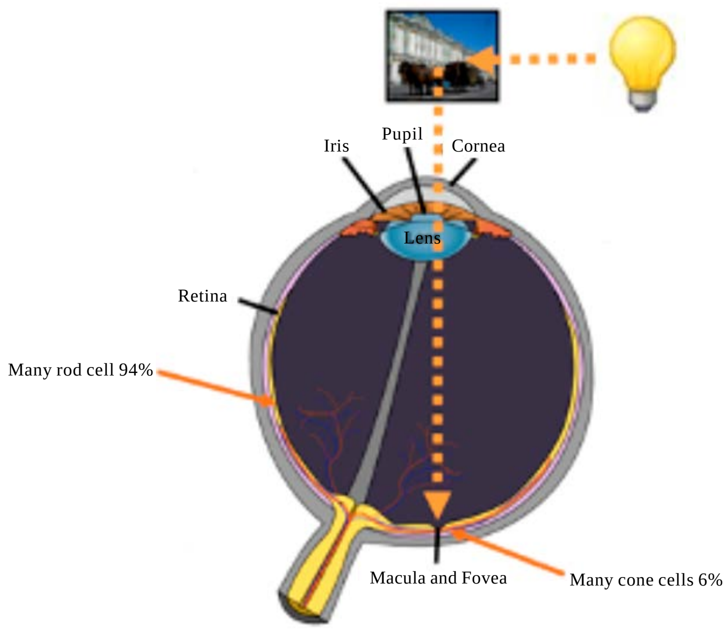

Fig. 7: Process of light-sensitive cells receiving visual information

The central concave area is quite small, usually covering only 1-2 degrees of our vision. It is worth mentioning that these light-sensitive cells in our brains also can accept the key factors of visual information, as is shown in Fig. 7.

When our eyes are in a resting state, the brain's attention may shift to other places. We can divert attention but the eyes do not move. Then, foveal vision monitoring is usually effective means of changing the attention judgment, because the brain typically does not process complex stimulation information outside the fovea. The brain is more efficient than the peripheral visual information when dealing with foveal visual information. Compared clear visual information, the brain needs to spend more effort to understand the fuzzy visual information. This is why you can track eye movements, especially watching to explain people's behavior. It's like we know, in order to understand the things, we can only watch it or very close to it. If someone is not looking, he could not see and read the text. Eye tracking records these mobile and when the eyes gaze, it can mark the location of the fovea. By analyzing the eye moves, we understand the people's behavior. The length of fixation time usually indicates brain processes of visual information processing and the occurrence of cognitive behavior.

The several ways of eye movement are often intertwined and the aim is to select the information, which will be noted in the fovea irritants imaging area to form a clear image. Data is collected from the eye, it becomes the cognitive processing index which researchers analyze and read in real-time. Based measure of the word, the eye movement data is as real-time indicators to analyze, eye movement analysis indicators are commonly: Single fixation time on the target word, first fixation duration of the word, gaze duration, total fixation duration. Gaze time is one of the best measures. Various eye movement pattern times are also extracted and there are mainly the number of fixation, the number of saccades, the number of regressive eye movement in different scene positions or between location. The time and location information can be used to analyze a variety of fine eye movement patterns, thus which reveals a variety of information processing and processing modes.

EYE MOVEMENTS AND PERCEPTUAL PROCESSING IN READING

Perceptual span and eye movement technology in reading process: Perceptual span may be able to obtain useful information on the area around the fixation point, in general, it is divided into left fixation span and right fixation span. With eye movement data, there is more accurate speculation in reading process, it is very important that the understanding of the perceptual span range size and information which is extracted from the perceptual span. In the past 20 years, psychologists often used three kinds of eye movement servo technology of moving window, foveal mask and boundary paradigms.

In the moving window paradigm, the size of the window is presented by changing, you can accurately measure the size of the perceived breadth. The basic principle is that when they found window is smaller than the perceptual span, reading speed is slow down. The contents of the window was presented normally in the experiment and the content outside the window were masked, random letters can be presented outside the window. Fovea shelter and moving window technique is very similar, the difference between them is that when readers gaze, fixation content around or contents inside the window are blocked and the information which is presented outside the window is normal (Rayner, 1998). At the edge paradigm, we must first determine the location of a word in the article, where is critical word location and then a boundary location is set. When the reader saccade is over the artificial developed one and it is invisible boundary location, target words will be presented to replace the previous stimulus, it is able to determine what information is obtained from the side vision (Rayner and Sereno, 1994).

The researchers found that the perceptual span of readers single (fixation is limited by the use of these technologies). When readers read in English, the information range is gotten from the current fixation point; it is locations from 3-4 letters at the left of fixation point to 14-15 letters at the right of the fixation point. Information to identify the word is confined in a range of 5-7 letters at the right of fixation point, this range is called the recognition range. This shows the scope of the perceptual breadth at both sides of watching point are asymmetrical. Different writing systems will affect the asymmetry and size of the perceptual span. Compared with the phonetic readers, the perceptual span range of readers to read Chinese and Japanese are small (Rayner and Sereno, 1994). Japanese research found that perceptual span is length of 13 characters (Binder *et al*., 1999). It is the length from the 7 words at left side of the fixation point to 6 word of the right side. For Chinese readers, their perceptual span is the length from one word at the left side of the fixation point to the right three words (Binder *et al*., 1999). In the writing text from left to right (such as English), there is a large range of perceptual span at the right of fixation point and in the right-to-left text (such as Hebrew), the range over the breadth of perception is large at the left of fixation point, the perceptual breadth is asymmetry, it is also affected by the dominant reading direction (Rayner and Sereno, 1994). In the reading process, the scope of the perceived breadth is limited in a single line, that can not extract the text message of the next line at the fixation point (Rayner and Sereno, 1994).

In addition to reading dominant direction and writing system itself influence on perceptual span, the size of the perceived breadth is also affected by many other factors (such as text difficulty, skill). Articles become difficult, the scope of the perceived breadth becomes small and especially the content difficulty of the fixation point would affect the reader to extract information on the next vision. In addition, unskilled readers can perceive 12 letters in length at the right side of the fixation point. It can be seen that the perceived span itself is not a definite value, it is one of these problems which is also mentioned later and processing models can not solve (Henderson and Ferreira, 1990).

Information obtained from the perceptual span: Readers get a variety of information which the reading process needs from perceptual span range. Rayner (1978) would divide the line of text into three regions on the retina: Foveal region, parafoveal region and peripheral region. Foveal vision region forms into 1-2 degree perspective angle with reader's fixation point, in this area, the reader visual acuity is high and you can clearly get a lot of information (Thomas, 1968). Visual acuity outside the fovea decreases significantly, its ability to identify is not better than the fovea. Vice foveal vision region forms into 10 degree angle around with reader's fixation point (Ditchburn, 1973). Edge visual area includes the entire area outside the vice foveal vision area. Readers can get different information on different areas of the retina, in the recognition range; you can get all the information to identify a word.

In addition to the identifying scope of the area, the reader can also get a variety of useful information. Readers can get the word visual features from sidelines vision. Rayner (1983) found glyph similar words appear in the next vision, it will facilitate the subsequent gaze target word naming response. Rayner *et al.* (1980) made preliminary letter identification hypothesis to explain what information was gained in the next vision and readers can get the first few letters information of a word in the side vision and this information can provide the necessary context information for identification of the letters (such as visual information or orthographic), it may cause to focus attention on the letters to be not identified, thus the word recognition is promoted (Rayner *et al.*, 1980). Whether start words are on the left or the right of watching point, the starting word is the same several letters with before the target word, it will promote the naming of the target word. In addition, the alphabetic writing is studied in the reading process and readers can acquire the shaped information and voice information from the sidelines vision (Jared *et al.*, 1999). Part of studies have shown that the side vision can obtain semantic information, the results of some studies indicate semantic information can not be obtained, font information or voice is only accessed (Rayner and Morris, 1992), outside the range of the area identification, information is not able to promote word recognition (Rayner *et al.*, 1980). By Chinese study for eye movement, similar results are also obtained with alphabetic writing, the reader can obtain font information and voice information from sidelines vision but there is no sufficient evidence that the reader can obtain semantic information from sidelines vision (Liu *et al.*, 2002).

EYE MOVEMENT CONTROL IN READING

In a gaze, what factors control the viewing time to be increased so that the subsequent saccade distance becomes shorter and there may be regressive eye movement? To answer this question, the eye movement control must be researched in reading. On reading eye movement control, there are two views: One is direct control, the identification of the current attention word is completed, it means that the eye receives a signal to the next step movement, the eye begins to move. Visual information is obtained from the current watching word and the next eye movement direction is decided. Another view is that cognitive control, eye movement control is that information is obtained based on just reading texts, while information is obtained by the watching word and it is not necessary. The results also provide evidence to support these two perspectives of eye movement control, which are the direct control and cognitive control.

O'Regan (1975) and Rayner (1979) found that saccade distance increases with increasing word length at the right side of the fixation point (O'Regan, 1975), in the reading process, the next fixation location information depends not only on the letters at the right of the current fixation but it is effected also by the right word boundary, the saccade length is decided by a length of a watched word and the next word length. For example, when next looking word length information is unknown, the reader saccade distance will be shorter than the length of the information and it is already known (Rayner, 1998). Further, the gap between words is also important for the reader. It not only helps the reader to distinguish between the start position and end position of the word but also it helps eye movement (Rayner, 1998). Bever (2002) study on the other hand provides the evidence for these conclusions.

Researchers investigated the fixations rest position from different aspects. In the process of reading eye movements and on the next gaze point, there are the existence of optimal fixation point and a preference for the fixation point. O'Regan and Schoen (1987) concluded that the best fixation refers to the position which the reader spent least time in a word perception, it is in a little at the right "preference gaze point". There are two effects in best fixation point: Re-fixation effect and processing-cost effect. Farther the sight of gaze word is away from the best fixation point, the greater the likelihood of the heavy gaze of the word, during the execution of saccadic eye and noise is caused by eye movements (Rayner, 1998). The reason for this phenomenon is that readers can obtain useful information from the side of the fovea. People watch a particular word and it may be considered as emission point of the next word and the distance between the fixation point and the target word will affect the specific gaze positions of the next word. If the gaze word appears in the article, it will show a heavy gaze effect but the effect of processing consumption is small (Inhoff and Liu, 1998). The watching effects and processing consumption effects are associated with reader cognitive processing depth and cognitive capacity.

By studying the eye movement control in reading, you can learn to read in the direction of eye movement and eye movement time and then the scientific method of reading is put forward to improve reading efficiency and to provide a theoretical foundation, especially, the basis research evidence is provided to explain the relationship between eye movements in the reading process and cognitive processes.

CONCLUSION

Reading process requires complex cognitive activity participation; eye movement recording method for real-time measurement of the reading process allows us a more profound understanding on the nature of the reading process. From the above brief review of eye movement control research progress in reading process, it can be seen that whether the position of the fixation point or regressive eye movement, saccade read and watch time studies have made some achievements. With the use of eye movement display technology and eye movement studies in reading process and a different language systems for cognitive processing will show different performance, which it has opened up new research fields for eye movement research in reading. In addition, eye movement processing model (Morrison, 1984), strategic and tactical model (Rayner and Morris, 1992), especially the EZ reader model (Reichle *et al.*, 1998), to some extent, is a more reasonable explanation for the eye movement control phenomena.

Although, eye movement data provide a wealth of information for reading cognitive processes, eye movement indicators can not be trusted to the degree of superstition. Eye movement technique is after all just a means of psychologist reading research and eye movement recording is not the most perfect reflection of only reading psychology. It also has many deficiencies and limitations. First, the eye is able to truly reflect the cognitive processing, which also involves the problem of "eye-brain" distance. Premise of eye movement research is that eye movement reflects real-time cognitive processing but whether it is able to accurately reflect the cognitive processing and it is also just a hypothesis. If we can absorb the derive tight causal logic in terms of experimental design of traditional methods, eye movement methods will better reveal the internal mechanisms of cognitive processing. The eye tracking technology is combined with traditional reading methods and Event-Related Potential (ERP) and Functional Magnetic Resonance Imaging (FMRI) technology to study cognitive processes of reading, the only way makes reading of eye movement more in-depth study, the result is more accurate. In addition, western researchers construct a theoretical model of eye movement control, even though it can explain the experimental results within a certain range but it can not explain the mechanisms of information processing at a higher level of abstraction but also further improvement is done on the basis of the experimental data accumulation, especially it is need to be combine the results of modern cognitive neuroscience, an integrated model of cognitive processes has been established to read with widely interpreted validity. We look forward to have more accurate and scientific indicators of eye movement control and mental processing model in future studies, the eye movement process is to described and explained in reading, by the eye movement analysis, the reading process can be inspected more in-depth, thus cognitive processing mechanisms and nature are revealed in reading processes.

REFERENCES

Bever, J.D., 2002. Negative feedback within a mutualism: Host-specific growth of mycorrhizal fungi reduces plant benefit. Proc. Biol. Sci., 269: 2595-2601.

Binder, K.S., A. Pollatsek and K. Rayner, 1999. Extraction of information to the left of the fixated word in reading. J. Exp. Psychol.: Hum. Percept. Perform., 25: 1162-1172.

Ditchburn, R.W., 1973. Eye-Movements and Visual Perception. Clarendon Press, Oxford, London, ISBN: 9780198573715, Pages: 421.

Frazier, L. and K. Rayner, 1982. Making and correcting errors during sentence comprehension: Eye movements in the analysis of structurally ambiguous sentences. Cognit. Psychol., 14: 178-210.

Henderson, J.M. and F. Ferreira, 1990. Effects of foveal processing difficulty on the perceptual span in reading: Implications for attention and eye movement control. J. Exp. Psychol.: Learn. Memory Cognit., 16: 417-429.

Inhoff, A.W. and W. Liu, 1998. The perceptual span and oculomotor activity during the reading of Chinese sentences. J. Exp. Psychol.: Hum. Percept. Perform., 24: 20-42.

Jared, D., B.A. Levy and K. Rayner, 1999. The role of phonology in the activation of word meanings during reading: Evidence from proofreading and eye movements. J. Exp. Psychol.: Gen., 128: 219-264.

Liu, W., A.W. Inhoff, Y. Ye and C. Wu, 2002. Use of parafoveally visible characters during the reading of Chinese sentences. J. Exp. Psychol.: Hum. Percept. Perform., 28: 1213-1227.

Morrison, R.E., 1984. Manipulation of stimulus onset delay in reading: Evidence for parallel programming of saccades. J. Exp. Psychol.: Hum. Percept. Perform., 10: 667-682.

O'Regan, J.K. and A.L. Schoen, 1987. Eye Movement Strategy and Tactics in Word Recognition and Reading. In: Attention and Performance XII: The Psychology of Reading, Coltheart, M. (Ed.). Erlbaum, Hillsdale, NJ., USA., ISBN-13: 9780863770845, pp: 363-383.

O'Regan, J.K., 1975. Structural and contextual const rains on eye movements in reading. Ph.D. Thesis, University of Cambridge.

Rayner, K., 1978. Eye movements in reading and information processing. Psychol. Bull., 85: 618-660.

Rayner, K., 1979. Eye guidance in reading: Fixation locations within words. Perception, 8: 21-30.

Rayner, K., G.W. McConkie and D. Zola, 1980. Integrating information across eye movements. Cognit. Psychol., 12: 206-226.

Rayner, K., 1983. Eye movements, perceptual span and reading disability. Ann. Dyslexia, 33: 163-173.

Rayner, K. and R.K. Morris, 1992. Eye movement control in reading: Evidence against semantic preprocessing. J. Exp. Psychol.: Hum. Percept. Perform., 18: 163-172.

Rayner, K. and S.C. Sereno, 1994. Eye Movements in Reading: Psycholinguistic Studies. In: Handbook of Psycholinguistics, Gernsbacher, M.A. (Ed.). Chapter 3, Academic Press, San Diego, CA., USA., ISBN-13: 978-0122808906, pp: 57-80.

Rayner, K., 1998. Eye movements in reading and information processing: 20 years of research. Psychol. Bull., 124: 372-422.

Rayner, K., B. Juhasz, J. Ashby and C. Clifton Jr, 2003. Inhibition of saccade return in reading. Vision Res., 43: 1027-1034.

Reichle, E.D., A. Pollatsek, D.L. Fisher and K. Rayner, 1998. Toward a model of eye movement control in reading. Psychol. Rev., 105: 125-157.

Thomas, E.L., 1968. Movements of the eye. Sci. Am., 219: 88-95.

Townsend, D.J. and T.G. Bever, 2001. Sentence Comprehension: The Integration of Habits and Rules. MIT Press, Cambridge, MA., ISBN: 9780262700801, Pages: 445.