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EYE-TRACKING AND SUBTITLE READING: A SYSTEMATIC REVIEW

FORTALEZA
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Trabalho de Conclusão de Curso apresentado ao Curso de Letras-Inglês do Departamento de Estudos da Língua Inglesa, suas Literaturas e Tradução da Universidade Federal do Ceará, como requisito parcial à obtenção do título de Licenciado em Letras - Inglês.

Orientadora: Profa. Dra. Diana Costa Fortier Silva.

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ABSTRACT

Watching subtitled material has been repeatedly suggested to be a good source of Second Language Acquisition (SLA). With the use of eye-tracking based methodologies, many studies have observed this phenomenon and have documented the effectives and drawbacks of using subtitled materials in SLA. Hence, it is important to systematize these findings in order to be able to visualize what past research has found, where we stand, and possible future research endeavors. In this context, this systematic review is aimed at reviewing and analyzing recent studies on the reading of subtitles based on eye-tracking methodologies. It illustrates the beginnings of this technology and how it operates, the measures used in the studies, and what they reveal in terms of one's cognitive processing while engaged in video watching activity from a Cognitive Load Theory (CLT) perspective. The results show that, despite indicating the inherent possibility to use standards for eye-tracking measures, the studies vary considerably and sometimes lack clarity as to their full replicability. Concerning CLT, it might still be early to come up with robust answers considering the results reported in the reviewed studies, especially considering the variability of the nature of the studies herein included. The outcomes from this research bring about the need for the standardization in eye-tracking studies while encouraging the field to conduct more research so that we can count on a more comprehensive and clear method of measuring all facets involved in subtitled video watching tasks and eye-tracking based methodologies in the future.

Keywords: Eye-tracking, Cognitive Load, Measures.

RESUMO

Assistir a material legendado tem sido repetidamente sugerido como uma boa fonte de aquisição de segunda língua (ASL). Com o uso de metodologias baseadas em rastreamento ocular, muitos estudos observaram esse fenômeno e documentaram a eficácia e as desvantagens do uso de materiais legendados em ASL. Por isso, é importante sistematizar esses achados para poder visualizar o que pesquisas anteriores descobriram, onde estamos e possíveis futuros esforços de pesquisa. Neste contexto, esta revisão sistemática tem como objetivo revisar e analisar estudos recentes sobre a leitura de legendas com base em metodologias de rastreamento ocular. É demostrado o início dessa tecnologia e como ela opera, as medidas usadas nos estudos e o que elas revelam em termos de processamento cognitivo enquanto engajadas na atividade de assistir vídeos a partir de uma perspectiva da Teoria da Carga Cognitiva (TCC). Os resultados mostram que, apesar de indicar a possibilidade inerente de usar padrões para medidas de rastreamento ocular, os estudos variam consideravelmente e às vezes falta clareza quanto à sua replicação total. Com relação à TCC, ainda pode ser cedo para obter respostas robustas considerando os resultados relatados nos estudos revisados, especialmente considerando a variabilidade da natureza dos estudos incluídos. Os resultados desta pesquisa trazem a necessidade da padronização em estudos de rastreamento ocular, ao mesmo tempo em que incentivam o campo a conduzir mais pesquisas, para que possamos contar com um método mais abrangente e claro de medir todas as facetas envolvidas em tarefas de visualização de vídeos legendados e metodologias baseadas em rastreamento ocular no futuro.

Palavras-chave: Rastreamento Ocular, Esforço Cognitivo, Medidas.

SUMMARY

1 INTRODUCTION

Our eyes are truly wondrous 'piece of machinery'. They are super-fast, very accurate, and work non-stop whenever we are awake (even when sleeping if we take Rapid Eyes Movement – REM – into account), but we are so used to it that most of the time we take it for granted. Studying the eyes is nonetheless studying the most important channel of communication between our brain and the outer world. We rapidly remember the importance of our eyes when the famous pool question is asked: 'Which of the five senses would you give up?'. A Linkedin article from 2015[1] shows that sight is the last sense people would choose to give up followed by hearing, this demonstrate how important it is for us to 'see' things. During a long time, it was impossible to determine exactly the place where we were looking at, but given the relevance of this fact early scientists entered the realm of eye-tracking studies and gave the first steps into this world of 'seeing how we see'.

The first studies on eye-tracking were carried out within the field of Psychology, and only then was the linguistic point of view taken into consideration. As the natural flow is to be expected, the first studies analyzed reading of words only, then studies evolved to observing the reading alongside pictures and later on what we have today: the study on reading subtitles while watching a video input. The advent of cinema has led us to a new behavior in reading, since now we are being reeducated to read while watching. Also, globalization has contributed to this scenario considerably. Subtitling, among many factors, has the advantage of being cost effective, so it is no surprise that it is largely adopted around the world in comparison to dubbing. This moving image that is added to the studies drastically alters the way one observes (reads) the words being displayed, rendering old studies ineffective to grasp the essence of this new kind of reading. For this, many studies in the area have been conducted in the last decade, trying to clarify many unanswered questions upon the subject. But as in the study by Hessels, R. *et al*. (2018) shows, there seems to be a huge misuse in the definitions used in eye-tracking studies as basic as 'fixation' and 'saccades'.

In Rayner (1998), we are presented with a complete study on eye-tracking technology regarding the cognitive processing that revolves reading, even though this article was published more than two decades ago, it is a seminal and still very influential one given the thoroughly detailed level of information it passes on to a reader. It is based on Rayner's perspectives that most of the discussion in this article will be held.

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[1] https://www.linkedin.com/pulse/you-had-give-up-one-5-senses-which-would-choose-annette

The goal of this article is to analyze articles from the eye-tracking and reading subtitles area published in the last decade and try to see if there is any converging and or diverging point among them, always bearing in mind the different purposes and uniqueness that can ask for special measures. To accomplish this goal, this study raises the following Research Questions (RQs):

(RQ1): What eye-tracking measures are used in the subtitling studies herein selected and discussed?

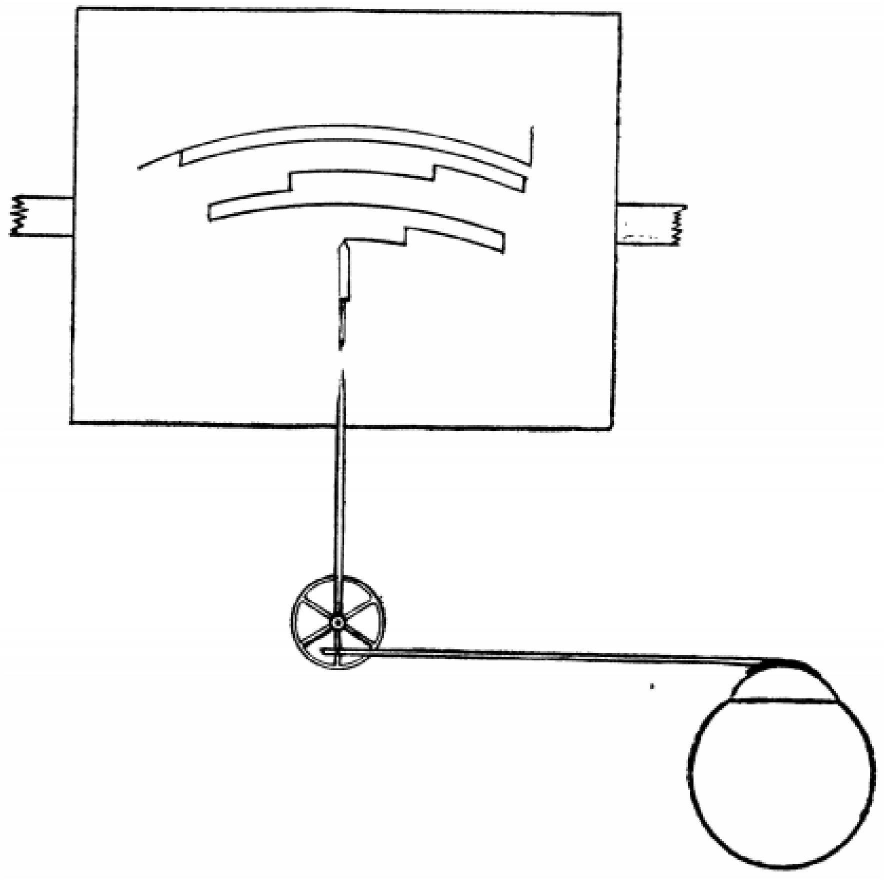
(RQ2) What do the measures reveal in terms of processing as well as cognitive load while reading subtitles?

This systematic review aims to analyze recent studies on the reading of subtitles based on eye-tracking methodologies. It illustrates the beginnings of this technology and how it operates, the measures used in the studies, and what they reveal in terms of one's processing. To this end, the article has been divided into four sections. This first introductory section presents the background information of this paper. The second section introduces the major historical steps that comprise the evolution of eye-tracking. The third section addresses with how eye-tracking technology operates concerning our eyes' anatomy and physiology. The fourth section centers on the critical presentation of the recent articles and their findings alongside the discussion of the measures gathered in the studies herein discussed. The fifth section provides a general perspective on what we can expect for the future eye-tracking studies.

2 HISTORICAL OVERVIEW OF EYE-TRACKING EVOLUTION

To start this journey, we have to go back to 1879 when Louis Émile Javal first observed that the human eye read in a particular pattern that was not fluid or continuous as it was imagined, but rather doing fast jumps (*saccades*) and brief stops (*fixations*) along the course of reading. Then we advance to 1898 when Edmund B. Huey, in an attempt to record the eye movements while reading, created a very basic apparatus that we can call an early eye-tracker.

Figure 1 - Representation of Huey's eye-tracking device

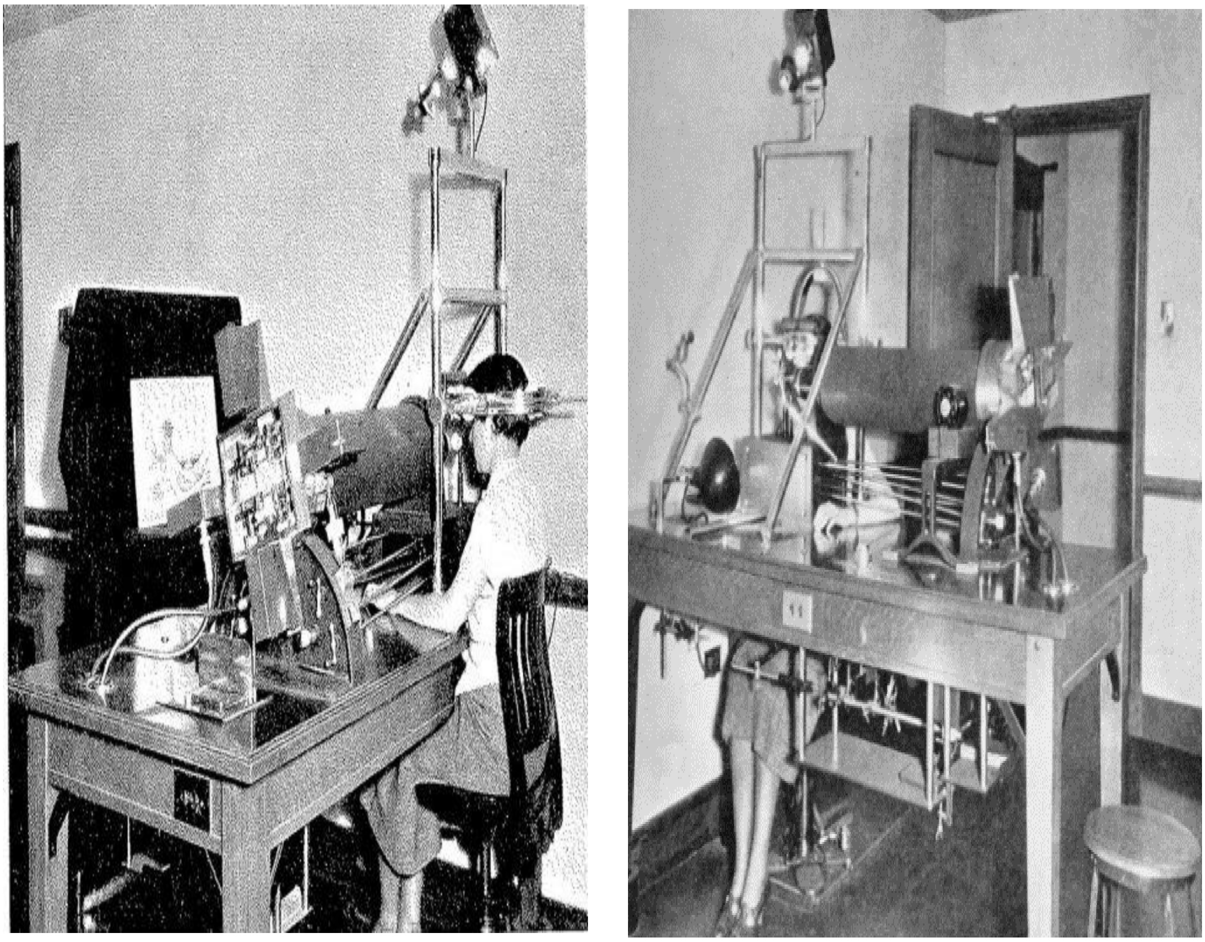


Source: The American Journal of Psychology, Vol. 9, No. 4 (Jul., 1898), pp. 575-586

The device was really intrusive, as the picture shows, since it consisted of a round piece of plaster attached to the eye with some levers bound to it recording the eye movements on a kymograph. The subject could not blink during the recording so the eyelids were kept open during the session with the help of springs. Additionally, some cocaine had to be dropped in order to anesthetize and not cause any pain or injury in the subjects. The method was so intrusive that only two subjects, Prof. Hodge and Huey himself, were the only ones to make use of it.

Fast forward to 1935, we have an eye-tracking device invented by Guy Thomas Buswell. The device worked wonders for the time it was created due to the fact that it was not intrusive to the subjects. It consisted of a head mounting and some sets of mirrors and prisms and two big cameras. As some modern eye-trackers, this device registered gaze position by capturing corneal reflection generated by a beam of light that was emitted from the apparatus. An astonishing number of two hundred subjects made part of this study, and they ranged from children to adults, which epitomizes a huge evolutionary leap that the technology had had.

Figure 2 – Rear and frontal view of Buswell's eye-tracking machine.



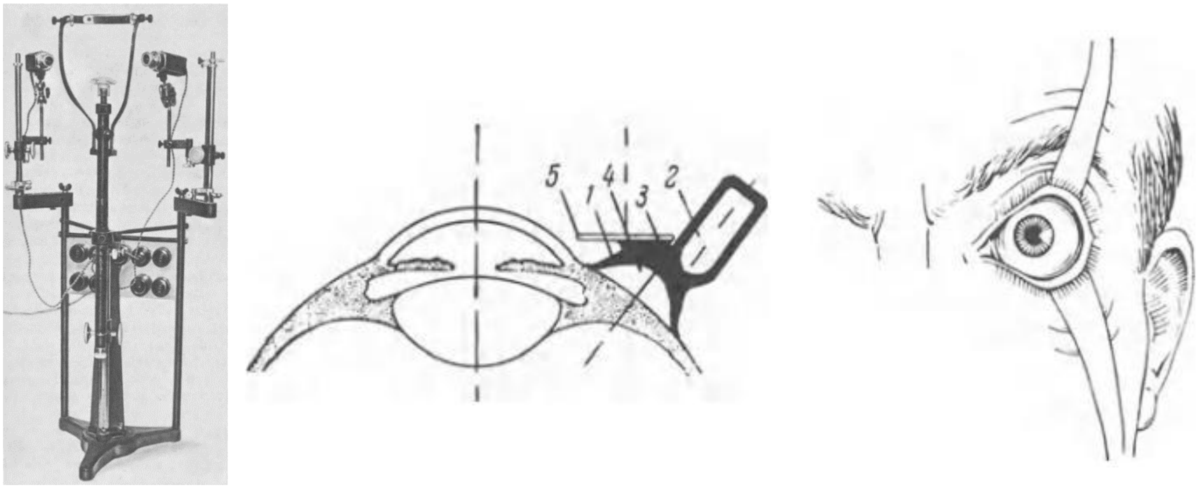
Source: Busswell, 1935.

The device was firstly intended to 'see' how the eyes move when looking at a piece of art and not for the reading itself, but since the reading parts of the experiment were so rich in novelties to this field of study, it conducted phenomenal educational enhancement. This eventually guaranteed Buswell a place on the 'Reading Hall of Fame', a title that was inducted to E.B. Huey in 1978.

In 1939, Richard Jung theoretically created a device that could track the eye movements in real time. The technology became known as electrooculography (EOG). By applying electrodes near to the eye it was possible to record the horizontal and vertical muscle moves, but since Jung focus of research was neurophysiology the 'eye tracking' aspect did not develop any further

As technology advanced, Russian psychologist A. L. Yarbus created a new apparatus to record the eye movement: a 'suction cap'. This cap was attached to the human eye and it was made of rubber instead of plaster; like the ones from Huey. Yarbus, experiments consisted of exposures no longer than minutes due to the operational obstacles of the device.

Figure 3 – (A) Yarbus eye-tracking machine. (B) The special 'cap' invented to attach to the human eye. (C) Adhesive plaster positioning the lids to receive the cap.



Source: Eye Movements and Vision, Alfred L. Yarbus (1967)

His legacy is of great importance since he documented each and every step of the study in a way that it is easily possible to replicate it. Also, one of the remarkable discoveries that his work brought about to the eye-tracking scene was that our eyes do not always look equally to a picture but rather we focus on what is more important to us or we may change the way we look at something based on an instruction.

> The human eyes voluntarily and involuntarily fixate on those elements of an object which carry or may carry essential and useful information. The more information is contained in an element. The longer the eyes stay on it. The distribution of points of fixation on the object changes depending on the purpose of the observer. i.e., depending on the information which he must obtain. for different information can usually be obtained from different parts of an object. The order and duration of the fixations on elements of an object are determined by the thought process accompanying the analysis of the information obtained. Hence people who think differently also, to some extent, see differently. (YARBUS, 1967, p. 211)

His work is very influential until today, and many researchers revisit his study either to enlighten any doubt arisen by the method, to reproduce it with modern equipment or to use its implications in marketing matters.

The number of techniques for eye-tracking increased in the 60s when David A. Robinson developed the Scleral Search Coil (SSC) method. It consists of a magnetic search coil attached to the sclera (the white part of the eye) that picks the signal generated by eyes' movements. Since it was still an invasive method and could only be used for a few minutes, the technique was later replaced by newer and more advanced types of trackers. Today, SSC method is capable to be used for more than just a few minutes (up to 2 hours as stated in SPRENGER, 2008) and the possibilities for new studies have reemerged.

After the 70s, the eye-tracking technology escalated quickly and allowed researchers to do more since the devices became lighter, precision and accuracy increased, it granted more head movement for the subjects and became less and less intrusive. Such advances have allowed the emergence of seminal work by Rayner (1978), Just and Carpenter (1980), Posner (1980), and Wright and Ward (2008).

A great progress or expansion in the area was done by the introduction of portable eye-trackers. Today, we have eye-tracking glasses (head mounted), and with this addition the experiments and possibilities have broken the barrier from the enclosed laboratories studies and gained the capacity to observe innumerous day by day activities. Many studies are now conducted with the use of those eye-tracking glasses, and the goal of these studies can vary from what a professional soccer player looks at when he is on the field to what we look at the most or first when we shop in a supermarket.

Figure 4 – (A) Woman wearing a mobile eye-tracker. (B) Heat map generated from looking at items in a supermarket (red areas represent more fixations)

Source: In Vivo BVA.

In the present time, technology has advanced to a point that non-intrusive video based eye-trackers are not only available for anyone to buy but are affordable as well. As a matter of fact, you can imagine a comparison between what a mobile phone is today and what it was like ten years ago, a low-end smartphone of today's can easily beat a flagship smartphone that is one decade old. This is possible because the processors have become more powerful and storage space has gotten even beefier as time has gone by and the same happened to eye-trackers: they have gotten lighter, faster, and more portable. Tobii 4C is a good example of a portable "home-user" eye-tracker made by a professional company, but it is also possible to buy the Sentry eye-tracker made from Steelseries, a company that is focused on gaming products. Some famous Youtubers and streamers use these low-end eye-trackers to create videos of various contents and some more experienced users even dare to combine the device to play games as well.

Figure 5 – SteelSeries Sentry eye-tracker.

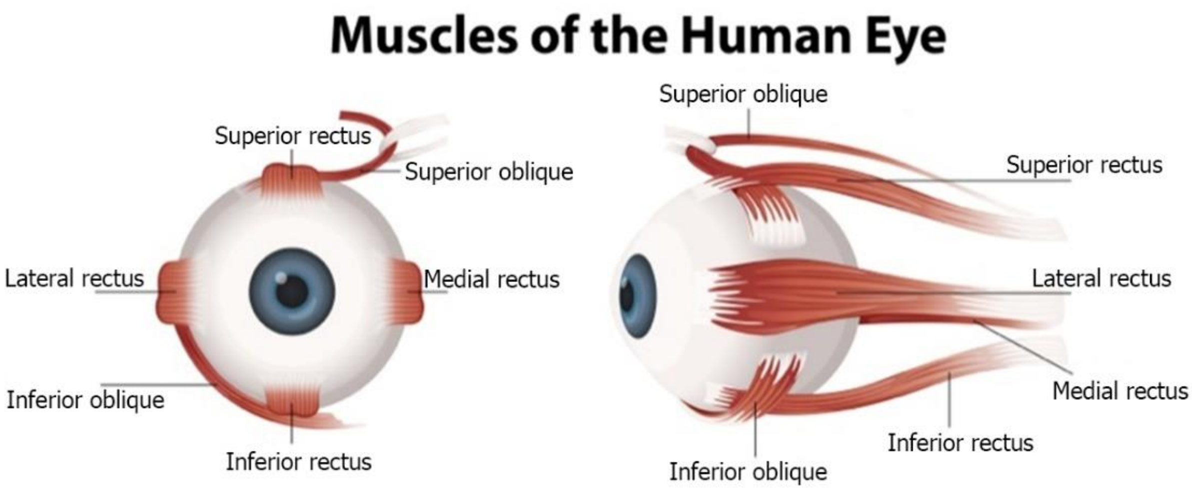
Source: https://ksassets.timeincuk.net/wp/uploads/sites/54/2015/02/SteelSeries-Sentry-press-1-1-3.jpg

3 EYES' PHYSIOLOGICAL AND ANATOMICAL FEATURES AND THE EYE-TRACKING

We are so used to looking at all the things in the world and 'taking it for granted' that we cannot imagine the amount of meticulous processes and structures that underlie this incredibly fast and optimal gazing machine we call "eye". In this section, some of the physiology and anatomy of our eyes that are relevant to eye-tracking will be briefly addressed in order to provide background knowledge to the topic of this paper.

When we think about moving, the first thing that comes to our mind are muscles because, with the help of their contractions and relaxation, we can basically 'move' our body the way we want. There are three types of muscles in our body: the skeletal (voluntary), smooth, and cardiac. Just like our limbs, we use muscles when we move our eyes, and since it is a voluntary movement, these muscles make part of the skeletal group and we have a total of six of them exclusively to do this job.

Figure 6 – Frontal and side view of the six muscles that move our eyes.



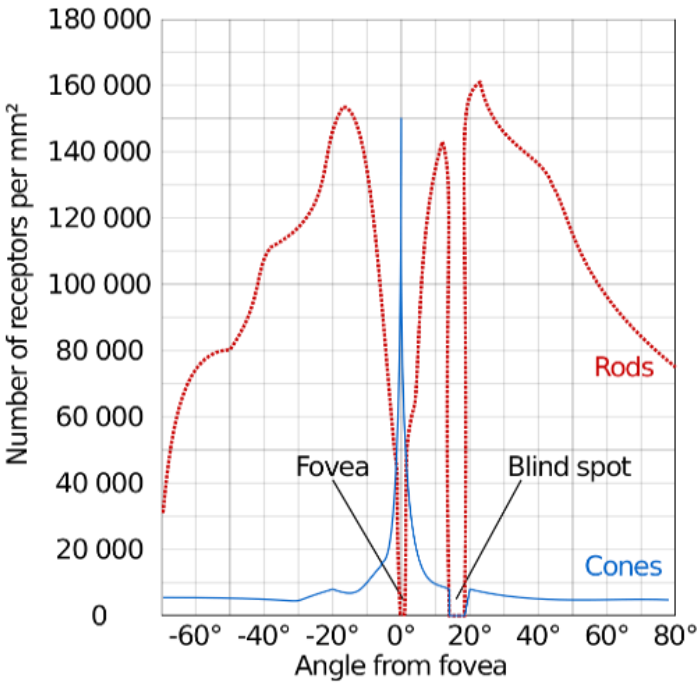
Source: https://alsnewstoday.com/wp-content/uploads/2017/01/shutterstock_155583182.jpg [adapted]

Each of the six muscles are specified to a type of movement; superior and inferior rectus are in charge of upward and downward movements, respectively. Similarly, lateral rectus and medial rectus realize outward and inward movements while superior oblique deals with downward and outward movements and inferior oblique controls upward and outward movements. Combining all the possibilities together we have plenty of different positions that our eyes can move, not accounting for head movement this is already a difficult challenge for an eye-tracker to adjust to.

The EOG technique from the late 30s operates with the principle of muscle movements. Hence, the electrodes were placed near the eye to detect any movement and therefore generating an electrical field that could have its signal caught and translated into the real-time tracking. Due to some limitations on this technique like signal drifting (KEEGAN, 2009) that would require re-calibration, the impossibility to monitor torsional eye movements and being less accurate than visual inspection (KUNG, 2007), it is not used for eye gaze studies in general but it is still used for clinical tests related to eye movement in patients.

In a perfect world scenario, we as human beings would love to have the capacity to gaze at something, let's say a bedroom, and be able to cover the whole area from side to side with highly detailed precision of all the objects in there, this is, we would love to have a big field of view paired with unmatchable level of resolution. But just that it does not happen, our eyes have a very limited point of focus in comparison to the wide field of view, however we can perceive a lot of what is "outside the focus". In an endeavor to compensate this, evolution made a superb tradeoff with our eyes, we can boast a big field of view (about 180º horizontal and 150º vertical, as seen in HEILIG, 1992) that perceives the whole picture and is genuinely good at capturing movements, and a gigantic acuity when our eyes focus on something.

Figure 7 – Cones (require more light to produce signal) and rods (can produce signal with a single photon) distribution.



Source: https://upload.wikimedia.org/wikipedia/commons/thumb/3/3c/Human_photoreceptor_distribution.svg/250px-Human_photoreceptor_distribution.svg.png

All this tradeoff between field of view and acuity obliges our eyes to "move" if we want to have the capacity to distinguish things, and to see "things" our eyes need light to enter through its cornea and create the image that is going to be passed from the optic nerve only to be processed by our brain. All this leads us to the most commonly used type of eye-tracker we have available today, modern eye-trackers take advantage of this light dependency of the eyes (see MITSUGAMI, 2005), and by means of calculating the light reflexes on the cornea (glint) in relation to the pupil's center they can effectively pinpoint our gaze locations.

A development to this technique was the use of infrared lights to illuminate the eyes, since we cannot see IR light under normal conditions we do not get distracted by it, but the camera recording our eyes is able to see this IR light and so the corneal reflection is ameliorated with this help from a direct source of light raising its contrast. A drawback that the use of IR light possess is that the ambient light has to be controlled, one cannot make use of it if in a bright room or let's say full of windows allowing sunlight to enter it. Albeit the difficulties imposed by the light restriction limitation, the combination of video recording and IR (sometimes near infrared light [NIR]) to track is the pinnacle of what we have to today standards.

3.1 Basic eye-tracking measures

When analyzing data from any eye-tracking device, researcher need to select basic measures that they wish the device to capture for future analyses. As far as the most common eye-tracking measure is concerned, *fixation* is the leading measure when it comes to the analyses, which can be defined as the moment when 'our eyes remain relatively still' (RAYNER, 1998, p. 373). There is a need to emphasize this 'relatively still' aspect since our eyes do not stay completely still during the fixation period, and thus a spatial margin is to be considered when calculating fixations instead of relying only on a temporal (milliseconds) way of measure. The counterpart to fixation is the *saccade*, which can be defined as the 'movements of the eyes that bring other parts of the text onto the most sensitive part of the retina for information uptake.' (HESSELS *et al*., 2018). Deriving from fixation we can add a number or other terms that can be used as measures, namely: *gaze points* (the physical representation of the fixations), *heat maps* (a more enhanced and complete physical representation of the fixations), *revisits* (when a subject re-enters a specific area of interest), *regressions* (unlike revisit, regression only occurs in reading, it is the backward movement – from the right to the left – of our eyes), and *average fixation duration* (the mean of all fixations, be it of a specific person or the whole group).

The area of interest (AOI) is an area chosen by the researcher to limit the range of operation on which the eye-tracker can get the data they desire. The AOI is the digital realization of what we can be said to be the scope of the study since it delimits the data to a specific position, the AOI is best measured in pixels as we are talking about seeing on screen. Some researches use vague terms to delimit the AOIs as 'they were limited to the subtitle only', but we cannot know if they (AOI) are tightly restricted to the subtitle area only without any leakage of area entering into the visual scenario itself. The AOI can vary a lot, most studies delimit it to the 'subtitle area', but if one aims to observe the shifts between image and words so there should be different AOIs. Recent studies (see FOX, 2018) also account for dynamic AOI, especially when they want to observe integrated titles (when the words move along with the video) and this brings a new level of difficulty since the area (pixels) to be measured can be in constant movement and even fade in or blend with the movie.

4 RECENT RESEARCH ON SUBTITLING AND EYE-TRACKING MEASURES

The interest in studying subtitles and captions is not a new one, since it has been the scope of many previous papers (see Curti, G. H. [2009], d'Ydewalle, G. & Pavakanun, U. [1997], Garza, T. [1991], Koolstra, C. M., Jonannes, W. & Beentjes, J. W. J. [1999], and Vanderplank, R. [1990].). The aim of examining subtitles varies drastically, but we can say that frequent purposes for using subtitles in a study is to check vocabulary learning, content comprehension, vocabulary knowledge, and ultimately to check whether it is beneficial or not in comparison to a non-subtitled input.

With the addition of modern eye-trackers in the 90s it became possible to analyze even further those studies encompassing subtitles. Since eye-tracking methodology provides an objective data to the research, that is, our gaze (overt attention) is continuously being tracked and coupling with the eye-mind assumption[2] (covert attention) we can detect the processing of words by the subjects. In this systematic review I have gathered relevant studies from the last decade on the topic, (eye-tracking and subtitling), focusing on their eye-tracking measures, findings, and some of the research gaps. The papers have been organized chronologically and their review comprises articles from this decade (2010) on.

Perego *et al*. (2010) discusses theoretical, methodological, and applied implications on both subtitle and multiple-source communication based on a previous experimental study they had carried. The study analyzed the cognitive processing of a subtitled excerpt taking into account many variables, such as: eye-movement data, word recognition, and visual scene recognition.

The authors hypothesized that reading is cognitively effective and does not require a tradeoff between image vs. text processing. They also tested the influence of line segmentation quality in two-line subtitles on cognitive processing. The study used an Tobii 1750 eye-tracking system and the measures adopted were fixation (set to a minimum duration of 100 ms and 30-pixel radius), path length and visual shifts.

For the first aim, the experiment results showed agreement to fact that there is no tradeoff between subtitle recognition and scene recognition. Perego *et al.* (2010) explain that the findings "clearly show that participants did not tradeoff subtitle and scene processing" (p. 236). For the second aim, the ill-segmented (bad quality) subtitles, the main finding was that

[2] The eye mind assumption is the idea that a link exists between what we look (fixation) and what we process, albeit knowing that it is possible to fixate on something and think about anything else or even more, that peripheral vision (not fixated) can transfer meaning, it is still relevant to use this line of thinking.

both subtitles, well and ill-segmented, showed the same results in many different types of tests. The final goal, which was to provide empirical evidence on the cognitive processing of subtitled films by considering both performance measures and eye-movement showed consistent results with previous works. In accordance to previous findings, the time spent on the subtitles area matched with those found in previous studies; the new finding is the absence of tradeoff between scene and subtitles, and the result that was in discordance to earlier studies regards the saccade mean duration on two-line subtitles, a finding that might be explained by the genre of the movie used, which could account for the different means, according to the authors.

Hefer (2011) examines the contrastive nature of First Language and Second Language[3] subtitle reading. She believes that given the existing multilingual context in South Africa (Afrikaans L1 speakers are near bilingual regarding their level of proficiency in English), there should be a difference in the reading of subtitles according to the language being displayed to the readers.

The data was collected using the SMI iViewX Hi-Speed eye-tracking system, recorded on BeGaze 2.5 and analyzed in Statistica. It measured fixation time total and dwell time total as duration parameters and fixation count as count parameter, all of them were measured according to AOIs.

In this study, the null hypothesis (i.e. no difference in subtitle reading within and between the different groups[4]) was refuted and the research one was supported (i.e. there are differences in subtitle reading for these groups and the differences are attributed to L1 and L2 subtitle reading). Hefer analyzes some other factor that would refute the research hypothesis and support the alternative hypothesis (i.e. there are differences in subtitle reading for these groups, but the differences are attributed to other factors and/or influences, and not to L1 and L2 reading), but none revealed evidence to maintain the alternative hypothesis. She concludes the article by mentioning that the subtitles might not have been very effective to the readers since they spent much time reading them than one would have likely supposed to do.

[3] The terms Foreign Language and Second Language are of indispensable importance to the literature, their differences and what they mean may guide one's view and so they should be given close attention. Considering the distinctions of these terms as posed by Krashen (1982/2009) I team with Ellis (2008) as the differences in learning process between those two situations are still unknown. Therefore, L2 will be adopted as an umbrella term in this study. The same justification will be adopted for the terms Learning and Acquisition. All of these assertions in this study are meant for suitability and convenience

[4] There were four groups in total, three test groups and one control. Test groups were divided into TAE (Test Afrikaans English), TEA (Test English Afrikaans) and CAA (Control Afrikaans Afrikaans) and the control group consisted of the CEE (Control English English) group. The input material was split in two parts, hence the Afrikaans/English distinction in the groups.

Another interesting finding was that all groups spent in overall more time reading two-line than one-line subtitles, this is in accordance with d'Ydewalle & De Bruycker (2007) and a secondary finding is that the extent to which participants claimed to be exposed to subtitles did not facilitated the reading and processing of it.

Szarkowska *et al.* (2011) investigate the topic of how different the reading of captions in three different forms by three different types of readers may be. The authors firstly hypothesized to see differences among hearing, hard of hearing, and deaf participants in caption reading time; the second hypothesis was that fixation rates for edited caption would be lower compared to standard and verbatim captions.

The equipment used was the Eye-Link CL eye-tracking system (500 Hz sampling rate). The authors examined four dependent variables: the proportion of dwell time spent on caption reading relative to scene viewing, fixation count, deflections from image to captions, and overall comprehension.

The authors found that, for the first hypothesis, significant results were found for the deaf group and the hearing one when comparing the reading of verbatim caption, as they had predicted, since the deaf group showed longer dwell time for this type of caption. For the hard of hearing, there was an analogous comparison showing only the dwell time for edited captions, which was found to be shorter than the other two captions. For the hearing condition, no differences were found in any type of captions since they relied on their hearing more than the reading.

Their second hypothesis was also confirmed since the analysis showed that fixation rate was the lowest when watching with edited captions. When analyzing the deflection, the authors discovered that the hard of hearing group was the one that deflected the most when watching with the standard and the verbatim captions, and that the other groups did not show many differences within the types of captions. The comprehension test did not show any significant differences between the participants and type of captions.

This study is very resourceful as it unveils many findings, plus it took into account not only the hearing population but the hard of hearing and deaf as well. The authors comment that the sample size of the study was little than expected (42 people in total) and was not evenly distributed among the three categories, but even so at least now there is scientific evidence on the topic.

Krejtz, Szarkowska, and Krejtz (2013) address the question whether a change in the shot of a scene can cause a re-reading of the subtitles or not. The authors recognize that the literature on the topic is in line with the fact that subtitles should not be displayed while shot changes, but they believe that a scientific support is needed in terms of eye movements.

The device used was a SMI RED eye-tracking system (sampling rate of 120 Hz) and the study analyzed subject hit count, number of fixations, first fixation duration, fixation time percent and transition matrix before, during and after shot changes in subtitles displayed over a shot change. The study also established a reading speed of 12 characters per second (cps) using EZTitles subtitling software and all videos were set to a frame rate of 25 fps.

After analyzing multiple variables to verify whether subtitles were indeed re-read by the subjects, the author did not find any evidence that this is true even though they acknowledged that the shot shifts caused the subjects to get a little disturbance in their gaze and increased the shifts between the image and the subtitled area. These results were similarly obtained by Linde and Kay (1999) where subjects deflected more in crossing film cuts and the reading pattern among the 3 groups (deaf, hard of hearing and hearing) also produced result in accordance to previous studies (Conrad, 1977; Di Francesca, 1971; Rodda & Grove, 1987; Torres Monreal & Santana Hernández, 2005; Szarkowska *et al.*, 2011; Trybus & Karchmer, 1977).

To conclude, the authors refuted the idea that shot changes can cause re-reading of subtitles in all three groups and propose that further studies involving foreign language proficiency should be held to supply more data to this topic.

Kruger and Steyn (2013) investigate the extent to which subtitle reading can improve academic performance. They believe that this study has the potential to help future research by creating a robust index of reading for dynamic text as well as to contribute to the debates upon whether subtitles do promote an increase in academic performance. They also mention that the study on dynamic text is needed since most of the studies were based on static images and they greatly differ in nature from the dynamic ones.

Eye movement data was collected using iView X remote eye-tracking system (RED) (50hz sampling rate). For the measures we have a novelty, the Reading Index for Dynamic Texts (RIDT), the authors describe the index as: "a product of the number of unique fixations per standard word in any given subtitle by each individual viewer and the average forward saccade length of the viewer on this subtitle per length of the standard word in the text as a whole"

After examining the data from two groups, no significant result in performance between them was found, but an analysis of the test group revealed that the participants who fully read the subtitles had a higher score than the ones who did not do it. The authors conclude by stating that future research can now rely on a valid test (RIDT) to verify if participants are reading the texts and thus enhance the behavioral/comprehension studies.

It is important to mention here that this measure (RIDT) does not take into account the regressions and refixations, that is, it only englobes movements from left to right and thus may not fully demonstrate the real facets subtitle reading

> Not all saccades move forward (to the right) with the direction of the text. Regressions, which comprise 10-15% of the eye movements during reading, actually move backward to previously read or skipped text. The percent of regressions depends on the difficulty of the text; more difficult texts lead to more regressive saccades. Similarly, more difficult texts lead to longer fixation durations and shorter saccades. Fixation duration, saccade length, and percent regressions — all of which are considered global measures of reading difficulty — are all clearly influenced by text difficulty. Additionally, the type of reading material and the reader's goal during reading influence these measures. (RAYNER, & POLLATSEK, 1989)

As seen in Sharmin S., Wiklund M., & Tiittula L. (2016), they adopted a method that count regressions as a metric in eye movements, since many other studies like Sanders & Stern (1980), Rayner *et al.* (2006) and Specker (2008) either used regressions as a measure to verify an effect or found that regressions revealed reading characteristics among subjects.

Kruger, Hefer, and Matthew (2013) investigate the extent to which subtitles may influence the cognitive load (CL) of the readers (see Mayer and Moreno [1998] for additional information on this matter). Given the lack of empirical findings on the topic, the authors justify the importance of the study based on the possible links of earlier literature with real data on cognitive load/overload and subtitle reading.

In order to measure the cognitive load, the authors used various techniques: eye-tracking methodology (here they used the SMI iViewX™ RED [50hz sampling rate]), Electroencephalography (EEG), and self-reported measures (mental effort, frustration level, and comprehension effort). The authors explain that measuring CL is difficult, hence not many studies were carried out on the subject, but with the several techniques employed it is then possible to generate indirect, subjective, direct, and objective data.

The authors sought to answer three questions, in the first one they tested participants to examine the effects of the subtitles on CL, the second question was to see how reliable the measures are and the final question investigated if the subtitles indeed create cognitive overload (CO). For the first question, the results showed that the participants who watched the non-subtitled material had a higher CL than the ones who watched with subtitles. The reliability of the measures for the test group (with subtitles) showed a positive correlation between the percentage change in pupil diameter (PCPD) and EEG measures, whereas for the control group (without subtitles) this was not observed. The final question regarding CO was refuted, and the results did not show any presence of it under the subtitled circumstance.

The authors acknowledge that since this is the first time a study like this is carried out, it is still too early to render bigger conclusions, but they have made the first steps to shine some light in the pathway for future research.

Winke, Gass and Sydorenko (2013) use eye-tracking to analyze the reading behavior of captions by L2 students and how the native language affects that behavior. They believe that earlier research was limited since the methods adopted were based on direct questionnaire for the participants instead of the precise data generated from the eye-tracking methodology. To venture this, four groups of native English speaker learning different languages were divided, the languages they were learning was Arabic, Chinese, Russian or Spanish.

The equipment used was the EyeLink 1000 (2009) Eye-tracking system (1000hz sampling rate). Only fixations were analyzed in this study and they were calculated in two ways: (a) the sum of all fixation durations on captions divided by the total time the captions were shown on the screen, and (b) the average duration of fixations on captions.

Eye-tracking method allowed the authors to answer the three questions. The first question intended to see how often foreign language learners read captions while on screen, and the results showed that the learners fixated an average 68% of the time when captions were available on screen, but the group learning Chinese deviated consistently more than the other groups. The authors conclude that the language being learned may influence how often learners read the captions. In relation to the second question, they conducted a mixed design (4x2) ANOVA to compare the time learners spent reading captions across the four language groups. The results supported the hypothesis that a specific language can affect the time a person spends reading. To answer the final question, the authors used the same data from question two. The only group that showed a positive influence on content familiarity and reading was the Chinese learners group, while all the others did not show great impact by their level of familiarity to the videos.

The authors mention the various limitations of the research, such as the method used to analyze the results as well as the lack of measures for the reading ability of the participants; a less severe limitation was the irregularity of the length within the captions from the four languages. The authors conclude by stating that further research is needed to investigate the split-attention effect (when visual working memory has to be shared between captions and images) and caption reading.

Bisson *et al*. (2014) investigate the processing of subtitles in native and foreign language. They consider that earlier studies may not have shed light to the full extent of the issue due to limitations on research methodologies.

The Eyelink 1 eye-tracker (250hz sampling rate) was adopted for this study. It measured total fixation duration, number of fixations and average fixation duration for each subtitle in a first moment and then those measures were averaged for each participant, they also calculated the number of skipped subtitles for each participant. They analyzed the subtitles in three modalities: standard, reversed and intralingual. It is important to notice that in this study the AOIs for the subtitles comprised the entire width of the lower part of the screen (subtitled area).

After analyzing the data from the eye-tracker, the authors looked at the subtitle reading behavior between the standard group (supposed to be the one with the highest reading time spent on) and the intralingual group, and no significant differences were found for any of the measures. The authors acknowledge that the lack of familiarization of subtitles by their participants might have caused no differences to emerge in the average of fixation duration. The authors comment on the well-established automatic reading behavior and found it surprising to verify that participants read even when they did not know the language being displayed. Furthermore, the authors believe that according to the experience, the reading behavior can be influenced by a number of factors, including the dynamic nature of the subtitles appearing and disappearing on the screen, the similarity of the two languages, their saliency, the redundancy of information (especially in 1-line subtitles), and even the expectation that the participants had regarding the experiment. The authors took the opportunity and investigated if there was incidental acquisition of L2 vocabulary, but the study could not provide reliable results since there was a “no movie” condition that was able to show results which matched the ones who indeed watched the movie, thus, somehow invalidating it.

One of the biggest takeaways from this study is acknowledged by the authors that a longitudinal study in the future should be carried out to provide more precise data on the acquisition of L2 vocabulary with the help of subtitles.

Kruger, Hefer and Matthew (2014) use eye-tracking combined with EEG and self-questionnaire to bring light to the topic of attention distribution in the context of subtitled lecture. They base the relevance of this study on the assertion that a cognitive overload may occur when information is presented simultaneously in different sources, and in an educational context this means much for it can be hazardous to the learning process.

The eye-tracking system used was the SMI iViewX™ RED (50hz refresh rate) and it analyzed only two measures: the percentage dwell time (%DT) and the Reading Index for Dynamic Texts (RIDT; see Kruger & Steyn, 2014). To delve further in the research, they also used electroencephalography (EEG) method to assess (objective-direct) measure, since its data can capture the difficulties observed in task manipulations.

The authors explain that the comprehension test was used to check for the understanding of the lecture and as an objective indirect measure of CL. The test consisted of multiple choice questions strictly related to the lecture and two tests were administered: Test 1 was administered right after the stimulus to measure the short-memory and Test 2 was administered two weeks later to measure long-term memory.

There were two objectives in the study: the first was to examine the impact of attention distribution and subtitles in language comprehension, and the second was to observe to what extent the subtitles would affect the cognitive load. The first one was tested and even though some differences were found between the groups, they were not statistically significant, and when the relationship between the subtitles and the cognitive load was tested, the authors did not find any relevant data that could lead to a cognitive overload. There were few differences in the data among the groups for the self-reported questionnaire as well as the EEG finding, but none were statistically significant.

To conclude, the authors acknowledge that even though the sample was rather a restrict one, they could provide insights into the use of subtitles in educational contexts since it improved the results either in short-memory test or in long-memory test. The study is also in accordance with the findings of D'Ydewalle and De Bruycker (2007) and Perego *et al*. (2010) concerning the cognitive effectiveness of subtitles. Based on this study, the authors claim that the next logical step would be a more comprehensive study that covers the influence of language history on cognitive load in the presence of subtitles.

Perez, Peters and Desmet (2015) investigate the influence of two attention enhancing techniques that may affect L2 learning. They believe that this study is necessary since most studies for L2 vocabulary learning have been conducted in terms of reading (only one input), while this one unveils the effects that captioning (standard and keyword) has on vocabulary learning (bimodal input).

The device used to record participants' gaze was the Tobii X120 standalone eye-tracker (120hz). The study observed gaze duration (the sum of all fixations), second pass reading time (the sum of refixations) and total fixation duration (the sum of all fixations including refixations).

Apart from the two captioning methods this study also considered Test Announcement as variables. After analyzing the data, they posit that from a theoretical point of view the learning of new words is facilitated by the effort that the learners put in their attention to the task, and that this attention can be 'enhanced' with the use of salient captions and announcement of the task. From a pedagogical point of view, the study supports a new type of captioning to be included in the classroom (keyword captions) as well as the test announcement (intentional) since the group that got better overall results was the one that had explicit instructions and watched the material with keyword captions.

Muñoz (2017) investigates two aspects of the learners, namely age and proficiency, in contrast to their reading behaviors in L1 and L2. She believes that these characteristics, never studied before, deserve an importance in this field of research.

The author does a literature review that comprises many aspects of what has been studied in subtitles and learning. She also brings up some well-accepted theories, such as the advantages of using L2 subtitles and the cognitive load it may impose to low-level learners, which is one of the reasons why many pieces of research are carried out with intermediate level learners. Muñoz notes that little has been studied in terms of the characteristics 'unique' to learner themselves, which are of crucial pedagogical importance.

The device used for gaze recording was the Tobii T120 (120hz sampling rate) integrated eye-tracker. Through analyzes of fixation the following measures were calculated: percentage of subtitles skipped, total fixation count on text, average fixation duration on text and total fixation duration on text.

After analyzing the data collected with children, adolescents and adults (with variable proficiency levels) the study showed many differences in the measures when comparing the children to the other two groups, but adolescents and adults showed very similar results. The results found here oppose the ones of d'Ydewalle and De Bruycker (2007) mainly because of the children's lack of proficiency, but it also revealed affirmative answers to the questions posed by Winke *et al*. (2010) as it showed that beginners differed in many measures from intermediate and advanced level participants.

The author states several limiting factors that occurred in the research, such as the uneven distribution between age and proficiency in the groups, and suggests that further research could conduct a study with full bilingual children to compensate for this. Another limitation is the material, since given the age range of the participants, it may not be very appealing to all. Finally, the article is seen as a contribution to the digital world and the existing new pedagogical views, and so professionals can take benefit from them to make crucial choices in the learning sphere.

Kruger *et al*. (2018) explore the area of subtitling and cognitive load under three different conditions: standard subtitles, integrated titles, and no subtitles. They consider that very little is known about the impact subtitles have on cognitive load and the engagement with a film or the immersion into its fictional world.

Eye recordings were done using the SMI iViewX RED250 eye-tracking system (250hz) combined with the Emotiv EEG EPOC+ headset. The authors used participants' fixation count and duration while looking at onscreen text to determine CL, and used the electroencephalography (EEG) to measure changes in the CL, since it has been used before and has shown the capability to be sensitive to task difficulty manipulations. They also used the RIDT from Kruger and Steyn (2014) to check the extent to which the subtitle was read or processed. A table summarizes the measures as RIDT and fixations per character being connected to the subtitle reading, mean fixation duration measuring extraneous load and revisits measuring average load.

After discussing about the way the data was recorded/collected, the authors address the results. Transportation data showed no significant differences among the three groups. For the reading of subtitles, no differences were found between the groups. Fixation count per character was higher in the standard subtitles group, but mean fixation duration and split attention showed no difference between the groups. EEG measures were averaged for 13 scenes and the mean score did not show any significant values, but for isolated results when watching fast paced scenes it showed that the integrated titles conditions was less cognitively demanding than the others.

The authors finish the article by stating that this is a good beginning on how to triangulate the various points of intersection to measure the CL, such as self-response questionnaire, eye-tracking method, and EEG measures. They reinforce that the results obtained revealed no significant differences for subjective and objective measures, but they argue that further studies need to be done since the type of movie being watched might play a key role. A future and more fine-tuned study is then proposed with a more consistent type of clip to be analyzed as well as different kinds of movies.

This systematic review showed the latest trends in subtitling studies with the help of eye-tracking. Now, in light of what has been presented, I turn to the answers of the RQs posed in the beginning of this paper. As regards RQ1 (What eye-tracking measures are used in the subtitling studies herein selected and discussed?):

It is clear that the major measure studies use is the fixation (the angle our fovea encompasses) and all the subcategories that derives from it. Recent studies also combined electroencephalography (EEG) with eye-tracking to measure cognitive load and immersion as well as other factors to enrich the pieces of research herein reported.

It is important to notice that some studies used skipped subtitles as a measure, but none of them have observed the parafoveal or peripheral relation that it may have in this fact. Also, some of the studies reviewed presented several limitations that compromise replication. Furthermore, another great amount of them mentioned the fact that L1 plays a major role on the results found, so we could (and shall) replicate those studies in different language conditions to verify whether or not similar or different results are obtained. Nonetheless, the studies using EEG also report that the singularity of each subject may interfere with the results. which could be the case of somehow normalizing the data to consider those differences.

In relation to answer RQ2 (What do the measures reveal in terms of processing as well as cognitive load while reading subtitles?), a great deal of caution is needed since the sole assumption of measuring CL is not an easy task, as stated by Kruger, Hefer, and Matthew (2013). The cognitive processes, such as the effort caused by tradeoffs that the shifting between subtitles and video can cause, and the plain difficulty in the act of reading subtitles and listening to an audio source may inflict on a subject is impossible to be traced within the articles here reviewed. The majority of the studies converge to a point of positive relation in the use of subtitles and easiness of processing/acquiring an L2. Additionally, it is a different duty to diagnose the same result for CL, the studies on this topic are new and they are still triangulating an accurate way to measure it.

5. FINAL REMARKS

This systematic review showcases the different facets that eye-tracking studies encompass when they aspire to understand the influences of using subtitles to aid L2 learning purposes. The primary concern that can be highlighted is the lack of standardization given the fact that when a piece of research uses eye-tracking methodologies, it must follow at least two precise measures: spatial and temporal. Spatial measure in eye-tracking is calculated in pixels (the smallest element a monitor can exhibit) whereas temporal measure is calculated in milliseconds. Yet, some studies do not clearly reveal the criteria adopted (settings) to measure these two very elementary conditions.

Moreover, hardware-wise consideration can be a concern too. Studies use a wide variety of eye-tracking devices, their sampling rate range from 50hz to 1000hz, and the incredible amount of data generated could impact the analyses. Even though modern eye-trackers are considered non-intrusive, they still cannot precisely calculate head movements, and most of the time subjects need to stay still while watching the material. This, in itself, is another factor to be considered for future research.

All in all, eye-tracking has evolved through the decades, but as any other piece of technology it needs to be in constant evolution. As a result, many pieces of research consider tackling the same topic they have studied before to assure solid results, and the same can be said for future years, as eye-tracking technology evolves we will have access to faster equipment with greater accuracy and eventually more room for head movement and hopefully the ability to tolerate blinks and drifts. Thus, so previous research can always be revisited, which may allow us to attain new results based on well-built data.

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