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# Eye Tracking Methods in Psycholinguistics and Parallel EEG Recording

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The development of technology has led to significant advances in applied research methods in the cognitive sciences. Eye tracking (oculography) is among the methods available for studying human behavior and its underlying cerebral mechanisms and cognitive processes and is a method for recording and analyzing oculomotor activity in real time. This review addresses the use of eye tracking in cognitive research both separately and in combination with electroencephalography, i.e., analysis of event-related potentials (ERP). Eye tracking will also be discussed in terms of its use in language research, from the study of comprehension and sentence construction to second language studies and bilingualism. Finally, the review will consider the parallel recording of eye movements and ERP. The review will draw attention not only to the strengths of the eye tracking technique, but also to studies which we believe can be addressed by using parallel recording of oculomotor activity and the EEG.

**Keywords:** eye tracking, oculography, EEG, ERP, cognitive sciences, multimodal methods, psycholinguistics, parallel recording.

**Eye Tracking Basics: Overview.** There are a number of key aspects that need to be taken into account before using eye tracking in research. First, the type of eye movement recording equipment to be used must be selected: electrooculography (EOG), scleral contact lens/search coil/aspiration cap (for example, see [Yarbus, 1965]), photooculography (POG), video oculography (VOG), or combined-type video oculography, in which gaze position is estimated from the relationship between the center of the pupil and the reflection of infrared light from the cornea [Duchowski, 2017].

This review will focus mainly on research using optical non-invasive binocular and/or monocular eye trackers, as these are currently the most widely used. Modern non-invasive eye tracking devices are divided, depending on form factor, into: head-mounted (for example, EyeLink II glasses (SR-Research, Ottawa, Canada)) or more modern options: Tobii Pro Glasses (Tobii, Danderyd, Sweden), Pupil Labs Core (Pupil Labs, Berlin, Germany) and static (installed on a desktop, on a computer monitor) or tower type: for example, SMI High speed (SMI, Germany), Eyelink 1000+ and Portable Duo (SR-Research, Ottawa, Canada), Tobii Eye tracker 4C (Tobii, Danderyd, Sweden)). Most advanced systems also allow remote operation for use in MRI scanners or MEG systems (e.g. EyeLink 1000+ with Long Distance Arm Mount (SR-Research, Ottawa, Canada)), while other systems can be used for eye tracking in virtual reality glasses (HTC Vive VR with Pupil Labs Pro eye tracker (Pupil labs, Berlin, Germany)). A typical eye tracker includes a computer, which is used to present experimental stimuli and control a camera that records eye movements. In some configurations (e.g. EyeLink 1000+ (SR-Research, Ottawa, Canada)), two computers are required for experiments (a main computer managing, processing, and filtering eye movement data and a computer for stimulus presentation, data storage and processing).

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In essence, modern eye trackers acquire data using the principle of video recording and analysis of the reflection of infrared light from the cornea and the position of the pupil (for a detailed description, see [Duchowski, 2017; Holmqvist et al., 2011]): the camera is paired with an infrared (IR) light emitter and monitors the reflection of IR light from the cornea (corneal reflection (Purkinje reflection P1)) and pupil position to estimate gaze coordinates [Duchowski, 2017]. The resulting dataset consists of measurements and events, where the measurement is a single recording of the position of the eyes in the *x* and *y* coordinates and the events are a set of measurements grouped by the type of eye movement: saccades, fixations, and tracking eye movements (TEM). Saccades are "movements" of the eye, which usually last from 30 to 80 msec, while fixations are periods of relative stability of the eye, lasting from several tens of milliseconds to several seconds [Holmqvist et al., 2011]. Tracking eye movements are smooth gaze shifts without saccades or fixations. Typically, TEM are recorded when tracking an object moving at a particular speed, for example, an airplane.

Eye movement data are usually divided into areas of interest (AOI) or regions of interest (ROI). For example, in a sentence, we can highlight individual words or phrases, or individual morphemes or letters, in the area of interest. In addition to eye movements, pupil size is also recorded, and this can be used as an additional metric [Laeng et al., 2012]. This technique is called pupillometry (see [Mathot, 2018] for a recent review). Some systems allow only binocular recording, i.e., parallel recording of both eye movements (binocular mode in SMI Red-M), while others (EyeLink 1000+ (SR-Research, Ottawa, Canada)) provide both binocular and monocular modes. Before data acquisition, it is important to decide whether binocular or monocular recording is optimal/necessary. Monocular mode is more commonly used [Raney et al., 2014] and the dominant eye is usually recorded (eye dominance can be determined using the Miles test [Miles, 1930]).

In addition, eye trackers have different sampling rates (from 30 to 2000 Hz). Higher frequencies provide better temporal resolution and data clarity. Higher frequencies are recommended where possible, especially if the target stimuli have small areas of interest or consist of a number of small areas of interest (see [Conklin et al., 2018] for a more detailed explanation). Further important eye tracker properties include accuracy, precision, reproducibility, and delay. Accuracy is the average difference between the actual coordinates of the gaze direction and the coordinates recorded by the system, in degrees of visual angle. As the video oculographs currently in use are not directly connected to the eyeball, this difference should be taken into account and reported when describing the data collection process. During calibration and validation procedures, the software provides the examiner with the average and maximum errors in degrees of visual angle. Depending on the conditions and the system itself, these can vary from 0.05 to 1°. If the mean error during validation exceeds 1°, the system should be recalibrated. Precision, as defined in Holmqvist's textbook [Holmqvist et al, 2011], is a measure of how consistently the tracker records eye position. Unlike accuracy, which determines where the participant's gaze is actually directed, precision provides a measure of the spread of measurements in the field of view. Reproducibility indicates eye tracking consistency. Finally, latency is how quickly the system transmits eye position data during recording. Eye trackers are differentiated by their latency – the lower the better: in most systems, latency is 1–3 msec.

Compared to other technologically sophisticated methods used in cognitive and language research (such as electrophysiological or hemodynamic magnetic resonance measurements), eye tracking is relatively easy to learn and use: most modern eye trackers are equipped with user-friendly software (for example, SR Research Experiment Builder and Dataviewer) and their suppliers, as well as the research community, offer comprehensive support to researchers. Several open-source applications for running experiments (Opensesame, PsychoPy) are compatible with many eye trackers. In addition, most eye trackers can simultaneously track eye movements and record reaction time data, as well as integrate them with other types of data acquisition, such as electroencephalography (EEG, more specifically techniques for analyzing event-related potentials), magnetoencephalography (MEG), functional magnetic resonance imaging (fMRI), and various other methods that support the transfer of data and markers through the parallel port of a computer (for a list of supported methods, see [Holmqvist et al., 2011]). Eye tracking equipment is largely "non-invasive" and easy to use, and calibrating and setting up takes 5–10 minutes [Nystrom et al., 2013]. Most eye trackers can record eye movements in free head movement mode, which is especially useful in research on children, for example.

This brief overview explains why eye tracking is currently one of the most widely used methods in cognitive research in general and language research in particular. An important feature of the eye tracking methodology, which must be taken into account when planning studies and analyzing data, and which also explains why it is preferable to combine eye tracking with other methods of cognitive research, should be noted. The next section will explore this feature and give some examples of the use of eye tracking, both on its own and in combination with analysis of event-related potentials.

**Application of Eye Tracking in Psycholinguistics: Eye Tracking in Studies of Reading.** Reading research is the area in which eye tracking is used most extensively. A large body of research has focused on the characteristics of fluent reading using readers' eye movement patterns to identify different stages of the processing of word form and access to the meanings of words [Rayner, 1998; Rayner et al., 1996; see also Clifton et al., 2016 for a detailed review]. Pickering [2004] noted that the use of eye tracking is based on two main principles, like any other measure of reaction time. First, the number and duration of individual fixations on a target word reflect the degree of cognitive effort required to process it [Staub and Rayner, 2007]. Thus, it can be taken that a stimulus word that receives fewer and shorter fixations is easier to process. The second principle is that the stimulus to which the participant's gaze is directed is being processed at that moment – the "eye-mind" hypothesis [Yarbus, 1965; Just and Carpenter, 1980]. This, however, is one of the limitations of the eye tracking technique: the direction of gaze tells us only where the participant is looking while the ongoing processing of the visual stimulus, planning forthcoming gaze shifts, and the mechanisms controlling, maintaining, and orienting attention remain essentially inaccessible when analyzing oculomotor activity.

Thus, in the early studies of Alfred Lukyanovich Yarbus [1965], participants viewed visual stimuli while their field of vision was artificially restricted. Yarbus developed a special system of eyeball suction cups that restricted the foveal region of vision (also known as the central pit of the eyeball, which is responsible for the clearest recognition of stimulus details). Participants could see the stimulus, but not combine the individual "frames" into an overall picture to allow the stimulus to be identified. This was due to the fact that receptor information on eyeball position is insufficient to allow individual "frames" to be linked – information from the parafoveal and peripheral regions of the retina is required for a complete picture of the stimulus to be built. Thus, although eye tracking is a very effective technique, it is important to recognize its weaknesses and, if possible, combine this technique with other methods. Examples of using eye tracking and combining eye tracking with ERP will be considered below.

First, eye tracking is attractive for reading research due to its high temporal and spatial accuracy. Gaze tracking provides access to cognitive processes that unfold "online," in the sense that the process of interest can be studied at millisecond resolution, for example, within a single fixation on a target word (for reviews, see [Henderson et al., 2013; Rayner et al., 2013]). Our eyes move across the page about 3–4 times per second as we read, with an average fixation duration of about 200–250 msec and an average saccade amplitude of eight characters for an experienced adult reader. The latter property roughly corresponds to two degrees of visual angle for normal text at a typical reading distance. It is important to note that readers do not record every word they read: for example, functional and short words are skipped about 70% of the time, while meaningful and longer words are almost always recorded [Rayner, 1998]. Thus, due to its high temporal resolution, eye tracking makes it possible to study low-latency processes with high accuracy.

The two main methods for studying eye movements in reading are (1) the moving window paradigm and (2) the boundary paradigm. These methods provide control of the properties of the text depending on where the reader is currently looking, providing important information about the types of information retrieved at the moment of fixation, both from the word fixed upon and from words in the parafoveal region [Kennedy, 2000; Starr, Inhoff, 2004]. As a rule, existing studies show that readers mainly absorb information from the currently fixed word, and the lexical processing of the fixed word controls the parameters of individual oculomotor events. Furthermore, information on words in the perceptual field zone (4–5 characters to the left of the fixation point and 15–18 characters to the right) also affects the current gaze parameters, pointing to predictive processing during the reading process.

Various studies on visual word recognition and sentence comprehension have documented several factors influencing the reading process. For example, the duration of the first fixation on a word reflects its length and frequency in the corpus [Rayner and Duffy, 1986; Juhaszu et al., 2008], as well as its semantics (for example, the predictability of a word due to contextual constraints, see [Rayner et al., 2011]), syntax (e.g., syntactic complexity and ambiguity, see [Clifton, et al., 2011]), and discourse features (e.g., resolution of anaphora, see [Ehrlich and Rayner, 1983]). High-frequency words are fixed for shorter periods of time or are even skipped, indicating parafoveal access and/or predictive coding. Notably, this difference disappears when the less frequent word is repeated three or more times (see the next section on bilingual studies using gaze tracking). Existing research indicates that fixations, but not saccades, are sensitive to these and other linguistic factors, such as frequency and word knowledge, acquisition age, polysemy, morphological complexity, contextual constraints, and plausibility [Staub and Rayner, 2007]. As a result, fixation analysis is more commonly used in reading research.

There is evidence that the parameters of the subsequent saccade are affected by the length of the currently fixed word. At the same time, readers display a higher probability of creating a progressive saccade and skipping shorter words than longer words [Brysbaert et al., 2005; Rayner et al., 2011]. Most saccades develop in the direction of reading (for example, to the right in English, to the left in Hebrew). At the same time, reverse or regressive saccades are not uncommon, accounting for about 20–25% of all saccades in children during reading and 10–15% in adults. The importance of regressive eye movements is that they often reflect reanalysis of previously encountered material, including general reading difficulties, syntactic and semantic ambiguity, or problems with text integration [Rayner, 1986; McConkie et al., 1991; Blythe et al., 2006; Fan et al., 2009]. In addition, eye movements also reflect the reader's general reading skill, changes in which can be tracked throughout the learning process (e.g., [Huestegge et al., 2009]). Changes in eye movement patterns in this situation reflect the development of reading fluency, starting with reading patterns characterized by a significant number of longer fixations and short saccades, as well as a high proportion of regressive eye movements in the early stages of learning to read, towards shorter and smaller fixations and longer saccades reflecting increases in reading fluency. Like young children, poor and dyslexic readers at all ages show longer fixations, shorter saccades, and greater regression than controls [Ashby et al., 2005; Chace et al., 2005]. Thus, eye tracking is a useful tool for assessing reading fluency both during development and in readers with reading deficits.

***Eye tracking in the understanding of conversational speech.*** Gaze tracking has been found to be useful for studies of language comprehension and retrieval using the "visual world" paradigm (for review, see [Huettig et al., 2011]). In a typical experiment using the "visual world" paradigm, the participant sees an image or set of images and the speaker talks about them. Oculomotor data are captured during the process of listening to the text [Cooper, 1974; Altmann, Kamide, 1999]. The protocol of this paradigm includes a specific image-related task: for example, to find and click on a specific object presented on a computer screen [Tanenhaus et al., 1995; Eberhard et al., 1995; Allopenna et al., 1998]. Results from the first studies using the "visual world" paradigm showed that eye movements are closely related in time to the process of understanding sentences, as listeners tended to fix named referents during access to the corresponding word, even in the absence of a specific image-associated task. These and similar results reflect the impact of visual non-linguistic information on sentence comprehension during interactive processing, the ultimate goal of which is to facilitate comprehension (e.g., [Tanenhaus and Trueswell, 2006]).

Starting with the seminal work of Cooper [1974], Eberhard et al. [1995], and Tanenhaus et al. [1996], the "visual world" paradigm has been widely used in psycholinguistics to address various issues related to how linguistic and visual processing interact during the comprehension and generation of sentences. Eye movement behavior provides detailed evidence for the contributions of both visual context and linguistic/general knowledge to the understanding of language. Many studies have used ambiguity resolution tasks to highlight the steps and features of the process of sentence comprehension. For example, Knoeferle et al. [2005] showed participants images of events 1000 msec before and during comprehension of a heard sentence. The results showed that images contributed to local structural disambiguation in German subject-verb-object (SVO) sentences compared to object-verb-subject (OVS) sentences. In another study [Knoeferle and Crocker, 2005] the gradual integration of image events during sentence comprehension was measured. The results pointed to similar effects of increasing congruence: participants showed longer fixation on the referent in the target sentence when a different referent was used in the priming image.

Other studies have addressed phonological and orthographic processing during spoken language comprehension. Participants were shown images of phonologically/orthographically similar objects or words instead of images, or the two in combination [Huettig and McQueen, 2007; Weber et al., 2007]. For example, Weber et al. [2007] studied spoken language recognition in Spanish: Spanish speakers were asked to click on pictures of objects when they heard their names. When the participants were asked to click on the image of a door ("puerta"), they responded more slowly after the image of a pig competitor ("puerco") due to the phonological similarity between the names of the target and the competitor. A similar effect was observed when participants were presented with printed object names or combinations of images with their names printed underneath. This and similar studies demonstrate that participants' gaze patterns undergo modulation in response to visual stimuli in the "visual world" paradigm, which may be a good indicator of language processing not only in reading but also in comprehending spoken language.

***Gaze tracking in speech generation.*** While studies of sentence comprehension dominate the "visual world" paradigm, this paradigm has also been used to study sentence generation. In the "visual world" version of the sentence generation protocol, participants are asked to describe images presented on a computer screen while eye movements are tracked and recorded. As with studies of sentence comprehension, a typical finding is that the speaker's eye movements are closely related to the sentence generation process. Fixation of the referents that the speaker is about to name slightly precedes pronunciation of the corresponding word [Meyer, et al., 1998; Griffin, 2001; Griffin and Bock, 2000; Bock et al., 2003; Griffin and Weinstein-Tull, 2003]. These results point to a move from conceptualization to lemma extraction, and to open articulation in the sentence construction process.

For example, a series of experiments [Meyer et al., 1998] investigated the relationship between spoken speech and eye movements. In particular, these researchers analyzed the order in which the pairs of objects were named after presentation to determine how object properties (such as recognition difficulty) are reflected in eye movement timing. The results showed that the participants fixed first on the objects they named first. This was due to the location of the objects (the objects were separated by 10–12°), which impelled the participants to fix on the objects in order to recognize them. Eye movements, judging by the results of the experiments, preceded speech: the participants looked at the object at left for about 500 msec and then looked at the object at right, and only then named the object at left. The complexity of the image, as well as the frequency of the object's name, also acted as independent variables in the same study. By removing 50% of the outline (making the image more difficult), the researchers significantly slowed the participants' reactions. The oculomotor data showed that speakers had to exert more effort for visual-conceptual processing of objects, as evidenced by an average increase in the duration of fixation by 15 msec. In terms of frequency effects, shorter naming delays and, more importantly, significantly shorter (by about 35 msec) fixation durations were recorded for objects with high-frequency names.

Another important technique used in eye tracking speech production studies is assessment of the interval between fixation of the gaze on an object and its naming – eye-voice span analysis (EVS). This technique dates back to the early work of Busswell [1920] and Fairbanks [1937] and is still relevant in the study of speech production processes. For example, eye movements precede articulation when reading aloud. Participants in a study reported by Gleitman et al. [2007] described static images of transitional events between animate referents after their attention was manipulated with implicit markers. A marker (a black square presented for 60–80 msec) appeared on the screen in front of the pictures at the location of one of the subsequently presented referents. The overall conclusion of this study was that implicit manipulation of attention has a direct effect on the word order chosen by the speaker. Oculomotor data were collected and then analyzed using utterance and gaze direction analysis, fixation analysis, and EVS analysis. Analysis of first fixations showed that the manipulation of attention using implicit markers affected early eye movements. Thus, speakers more often looked first at marked referents. Analysis of utterances and gaze direction assessed whether manipulation of attention actually affected word order. The researchers compared the choice of word order in sentences where the marker resulted in a gaze shift with those where it did not. This analysis showed that the initial marking of attention on one of the referents affected the order in which this referent was mentioned in sentences. EVS analysis showed, consistently with previous studies (e.g., [Griffin and Bock, 2000]), that people tend to fixate on the object or, in this case, the referent they are about to name. In particular, analysis of eye position dynamics over time showed that fixation on the referent during the first 200 msec after the appearance of the image reliably predicted the speaker's tendency to name this referent first. Overall, these and similar studies show how oculomotor data can be a useful source of information about speech production processes.

***Eye tracking in language learning and bilingualism research.*** Eye tracking has also been used in research on new vocabulary learning in both the first language (L1) and the second language (L2) (see [Conklin and Pellicer-Sanchez, 2016] for a recent review). Learning new words is a process that occurs throughout a person's life, not only during development, but also in adulthood. A typical example of the process is that of learning new words and structures in a foreign language. However, the learning of native language words also never stops, as much new vocabulary is acquired in adulthood through reading and random experience [Bolger et al., 2008; Reichle and Perfetti, 2003]. Existing research analyzing readers' eye movements as a consequence of re-experiencing novel written word forms through sentence context shows how new words are integrated into the L1 spelling vocabulary [Chaffin et al., 2001; Joseph et al., 2014; Li et al., 2019; Lowell and Morris, 2014; Godfroid et al., 2013; Wochna and Juhasz, 2013; Godfroid et al., 2018]. For example, Lowell and Morris [2014] observed adults' eye movements as they read sentences containing new words. First, exposure to new words accelerated the corresponding reading times, with longer words taking longer to encode than short ones. Second, readers looked at the new words longer and also performed more regressive saccades to them, indicating that readers used contextual information from the text to guess the possible meanings of the new words [Chaffin et al., 2001]. Existing data also show that learning L1 spelling occurs at an impressive rate, requiring only a few iterations to fix the meaning of a new word in the existing lexicon. For example, the Chinese participants in Li et al. [2019] showed a significant reduction in the duration of fixation and the frequency of regressive saccades to new pseudocharacters after only five repetitions, with eye movements reflecting the learning process starting as early as the second repetition.

Finally, gaze tracking has been used to study parallel language activation in bilingual speakers in both visual (e.g., [Altarriba et al., 1996; Libben and Titone, 2009]) and conversational (e.g., [Chambers and Cooke, 2009; Ju, Luce, 2004; Marian et al., 2003]) modalities. Researchers have found that the effectiveness of bilingualism is influenced by the presence of cross-lingual competitors (stimuli in an inactive language that have the same orthographic or phonological properties as the currently presented stimuli), which is reflected in eye movement parameters (regression or fixation on irrelevant competitors, saccades, total reading time), thus demonstrating the parallel activation of both languages in bilingual consciousness.

In addition, there is growing interest in psycholinguistic research into the neural mechanisms underlying learning to spell and read fluently in a second language. The proportion of the bilingual population continues to grow as more and more people learn to speak and read two or more languages. This often involves learning a new alphabet, grammar, and vocabulary. Classical oculomotor metrics such as fixations and saccades provide insight into this process and help understand the cognitive mechanisms underlying L2 acquisition and in particular the interaction between language codes L1 and L2. Several studies have analyzed eye movement sequences as indicators of L2 reading acquisition, showing progressive decreases in the number and duration of fixations, as well as saccadic movements and regressions, with increases in L2 reading skills [Balling, 2013; Cop et al., 2015; Elgort et. al., 2018; Godfroid et al., 2018; Godfroid et al., 2013; Koval, 2019; Marian and Spivey, 2003; Marian et al., 2003; Mohamed, 2018; Pellicer-Sanchez, 2016]. As in the L1 studies described above, these changes occurred very quickly, suggesting that the rate at which new words are incorporated into the existing lexicon is the same for L1 and L2. For example, a recent study by Elgort et al. [2018] reported changes in eye movement patterns in a group of Dutch speakers after repeated exposure to new words in L2 (English) embedded in sentences. After very short exposures (eight repetitions), the processing speed of low-frequency English words began to coincide with the processing of high-frequency L2 words (used as control stimuli) in terms of the durations of fixation and gaze and the number of regressive saccades.

**Joint Recording of Eye Movements and Event-Related Potentials.** Despite the many benefits of eye tracking, eye movements alone do not provide direct insight into the underlying neural mechanisms. Many studies use electroencephalography (EEG) to study the neurocognitive mechanisms of language. The EEG has proven to be particularly suited to the study of linguistic processing, providing an extremely accurate record of the order and timing of the cerebral processes associated with use of language. Furthermore, this method is relatively convenient and inexpensive compared to other neuroimaging methods. The existing EEG literature provides ample data documenting electrophysiological potentials, or ERPs, reflecting various language processes (e.g., [Bentin et al., 1999; Coulson, 2007; Kutas et al., 2006]), starting with rapid activation – within 50 msec of word presentation [MacGrego et al., 2012; Shtyrov and Lenzen, 2017] – through components reflecting lexico-semantic access, such as N400, and, finally, to the processes of structural integration and reanalysis, which are reflected in the P600 component (see [Kutas and Federmeier, 2011; Friederici and Weissenborn, 2007] for reviews of relevant components). Thus, the combination of eye tracking and analysis of event-related potentials can provide a unique tool that allows co-recording of eye movements and electrophysiological activity and also offers a single and extremely accurate technique with high spatial and temporal resolution [Sereno et al., 1998; Sereno and Rayner, 2003].

Parallel recording of eye movements and electroencephalographic activity makes it possible to synchronize the analysis of oculomotor behavior, which reflects the perception of visual information, with the analysis of brain reactions associated with analysis of the information acquired, and all this with the same high temporal resolution. The resulting identification of the so-called eye-fixation-related potentials (EFRPs) of EEG components temporally linked to oculomotor events (e.g., fixation or onset of a saccade) provides information on the interaction between information acquisition (eye movements) and information relating to its immediate processing (ERP). In contrast to ERP, EFRP allow ERP potentials to be associated with a specific cognitive process indexed by oculomotor data [Hutzler et al., 2007].

Initially, the paradigm used in psycholinguistics to obtain parallel recording of indicators was word-by-word presentation, as this is the standard procedure performed in ERP research on reading (see [Kutas et al., 2006; Kutas and Federmeier, 2011]). In many early studies using the EFRP approach, words were presented at the center of the screen and ERP acquisition was temporally bound to target fixations (e.g., to a specific word). This approach provided early evidence for a link between oculomotor and ERP data, especially in relation to parafoveal-on-foveal effects, i.e., demonstrated the influence of lexical or semantic information from parafoveal words on the metrics obtained on reading fixed words [Baccino and Manunta, 2005; Simola et al., 2009; Lopes-Perez et al., 2016].

Employment of the paradigm described above led to a partial solution of one of the main problems of combined recording of eye movements and ERP, i.e., detection and removal of oculomotor artifacts [Picton, 2000; Berg and Scherg, 1991]. However, word-by-word presentation lacks the parallel processing of parafoveal information that occurs in natural reading, potentially preventing access to important information on the sequential oculomotor activity performed in the context of natural reading (when the reader makes regressive movements to previously presented words, extracts information from as yet unrecorded words presented in the parafoveal visual field, or makes shorter or longer saccades when skipping words in a sentence). Various algorithms which correct oculomotor artifacts in the EEG signal caused by both blinking and saccadic movements have recently been developed to solve this problem [Ille et al., 2002; Croft and Barry, 2000; Delorme et al., 2007], thus providing efficient co-recording and extraction of interpretable EFRP effects in more natural reading tasks [Henderson et al., 2013; Dimigen et al., 2011; Dimigen et al., 2012; Takeda et al., 2001; Kretzschmar et al., 2009; Kretzschmar et al., 2015; Li et al., 2015]. Similar approaches have recently been used in other areas of the cognitive sciences to study attention [Fischer et al., 2013], memory [Nikolaev et al., 2013, 2011], and emotion [Simola et al., 2015, 2011].

Participants in linguistic studies usually read entire sentences or paragraphs of text. For example, some recent studies using parallel recording provide important details about the timing of changes in signals associated with the cognitive processes of reading [Hutzler et al., 2013; Dimigen et al., 2011]. One such study showed, for example, that word predictability effects in natural reading influence the semantics-related N400 component. Thus, a higher N400 amplitude was seen in the presence of semantically unrelated words in the parafoveal region [Kretzschmar et al., 2009]. In addition, parafoveal presentation (parafoveal-on-foveal) effects on the earlier ERP components, such as N100, have recently been reported, these probably reflecting facilitation of the processing of lower-level verbal cues [Dimigen et al., 2012; Li et al., 2015].

Apart from the use of EFRP, a novel approach to the simultaneous recording of the electrophysiological and oculomotor activity of the brain consists of synchronizing neural oscillations, rather than ERP, with eye movements, thus obtaining a measure of fixation-related oscillations. The oscillatory dynamics of the brain associated with changes in the rhythmic frequency of cortical excitability on different temporal and spatial scales are regarded as informative for models of connections between different areas of the brain during a wide range of cognitive processes [Siegel et al., 2012; Singer, 2011; von Stein et al., 2000; Bressler and Richter, 2015]. Oscillations in the β and γ frequency ranges are especially important for our understanding of language processes [Lewis et al., 2015; Bastiaansen and Hagoort, 2006]. Several recent studies using co-recording of eye movements and brain potentials have provided important insights into online semantic and syntactic processing [Metzner et al., 2015; Vignali et al., 2016; Kornrumpfet al., 2017]. For example, Vignali et al. [2016] identified oscillatory brain dynamics associated with online sentence comprehension, with desynchronization of the lower β range (13–18 Hz) during semantic error detection and increases in the γ (31–55 Hz) and θ ( 4–7 Hz) bands when parsing syntactically correct sentences, but not when word order was randomized to produce syntactic disruption.

Overall, simultaneous recording of eye movements and brain potentials (and note that the same logic applies to a large extent to magnetoencephalography, MEG), especially in free viewing conditions, provides new fundamental information on the neurophysiological basis of processing in natural reading, going beyond traditional verbal processing and word-by-word ERP research. Although parallel recording was previously difficult due to the difficulty in combining eye trackers and amplifiers, the combination of these methods has now opened up a promising avenue of research in the cognitive and neurosciences, providing extremely valuable information on the behavioral and neural correlates of various cognitive processes, with high environmental significance and very low implementation costs.

**Conclusions.** This article provides a brief overview of the methodology of eye tracking, describes its strengths and weaknesses, provides examples of psycholinguistic and neurolinguistic studies, and also presents examples of studies using eye tracking and ERP showing that parallel recording allows the limitations of eye tracking as a technique to be avoided and more detailed and comprehensive data to be acquired.

Our literature search yielded 262 articles in the Russian-language literature for the query "eye tracking and EEG" in Google Scholar. Detailed study of the results showed that there are very few scientific articles describing the use of parallel recording of oculomotor activity and the EEG: there are reports from researchers at Moscow State University (for example, [Anisimov et al., 2019a, 2019b; Serov et al. (2019]) describing the application of EEG and eye tracking to neuromarketing. Otherwise, the search demonstrated the almost complete absence of such studies in Russia, including in psycholinguistics. We hope our review draws the attention of the Russian scientific community to the eye tracking method itself and to the method of parallel recording of ERP and oculomotor activity. We hope that our review will be useful both for young scientists and specialists and for more experienced colleagues.

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