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Salvatore Attardo & Lucy Pickering:
Eye tracking in Linguistics
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Recenzió

Barbara Dervishaj

Salvatore Attardo & Lucy Pickering: Eye tracking in Linguistics

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Eye tracking is a widely used sensor technology that researchers from various fields apply and refer to in their academic work. Although it may sound familiar to linguists, explaining its origin and application or building research based on eye tracking might seem inaccessible or intimi–dating. Initially, eye tracking might appear too complicated technically and methodologically to consider as a research method. This is the motivation behind Attardo and Pickering's recently published textbook: to provide a synthetic roadmap for beginners without advanced psycho–logical, statistical, or biological knowledge. The authors aim to describe the "lay of the land" for newcomers. During their six years of lecturing on eye tracking to undergraduate and graduate students at Texas A&M University-Corpus Christi, they felt the need for a compre–hensive introduction.

With this book, anyone can easily navigate through the basics of eye tracking, its history, achievements and applications. The book is divided into three parts. *Part One* provides a general overview of the historical development of eye tracking, the anatomy and physiology of the eye, and the visual system. It concludes by introducing the terminology and underlying principles of eye tracking. *Part Two* outlines the application of eye tracking in studying reading, the visual world paradigm, social interactions, classroom attention, and other areas. The final, *Part Three*, details the methodological setup for eye tracking research, including planning and statistical analysis. The authors equip the readers with the necessary resources, mentioning comprehensive expert books for well-researched fields and listing all available sources for novice subjects.

In the *Introduction*, Attardo and Pickering identify the reasons for the recent boom in eye tracking research, reflected by exponential growth in Google Ngram since 2000. This rise is due to technological advancements that make eye tracking almost invisible, allowing for natural observation. The evolution of computers has made data collection and pre-processing half-automated, simplifying the researcher's role in setting up variables, running experiments, and interpreting results. Affordable prices have also fostered widespread application, enabling interaction research with data comparison and analysis from multiple devices and subjects.

Part One provides a historical overview of vision studies, reflecting interest from the early 1800s. It begins with the Troxler effect, the fading of the peripheral view if no eye movement occurs. Introspective methods such as afterimages helped establish the extent of eye movement.

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Acoustic methods followed, with William Charles Wells discovering blindness during rapid eye movements. The term saccades, coined by French ophthalmologist Louis Émile Javal, describes these "jerky moves."

From the late 1900s, visual research methods took precedence. Edmund Burk Huey studied reading using a plaster cup attached to the eye. In 1907, Raymond Dodge developed a visual photochronograph to record corneal reflections. Charles Hubbard Judd used a clenching bar and a Chinese white speck to prove binocular convergence. Later, D. A. Robinson developed the scleral lenses with a coil in 1963. Alfred L. Yarbus, in 1967, described microsaccades and drifts using a suction device. These techniques were intrusive, often requiring anaesthetization and chin stands.

Later, in the mid-19th century, applied behaviorist research took over. Guy Thomas Buswell described image perception with short fixations on the main theme and concentrated fixations over a small area. Yarbus's study of analyzing complex scenes, like "An Unexpected Visitor," concluded that fixations changed based on the observer's purpose.

The 1970s brought technological breakthroughs that elevated eye tracking. In 1974, Robert H. Lambert and colleagues used infrared light to enhance the visibility of eye movements. This era saw the first head-mounted cameras. Only a few years later, the year 2000, marked the boom of eye tracking glasses with multiple cameras and recording capabilities.

The next chapter delves into the anatomy and physiology of the eye. The eye functions like a camera, with the sclera as the opaque external part and the cornea as the transparent central area. The iris controls light entry through the pupils by minuscule surface deformation. Hence, uniform light conditions are pivotal during eye tracking experiments. The lens focuses light on the retina, with ciliary muscles adjusting focus. The thus-created four types of Purkinje reflections help calculate eye motion angles. The retina, with photosensitive rods, cones and ganglia, transforms visual input into electrical impulses. Rods perceive light, they are sensitive to six individual photons and saturate at 10,000 photons per second. From this intensity of light, cones take over, which can distinguish different wavelengths of colors. The ganglia control wakefulness and the area where they gather is the blind spot. The image is focused on the foveal region of the retina. If the focus is affected and the image is reflected to another area of the macula, this results in near- or farsightedness.

Shortly, light passes through the conjunctiva, cornea, aqueous humor, pupil, lens, and vitreous humor before reaching the fovea, where it is converted into biochemical information and transported to the visual cortex. Here, it is translated into biochemical information, which is transported by the optic radiation to the visual cortex in the posterior occipital lobe, the visual center of the brain. The ganglion cells with their thin (1 μm) and extremely long (almost 5 cm) axons can individually transmit digital information with a simple yes/no distinction; however, since they are interconnected, complex information can be coded. When inputs reach a threshold, the cell fires at 0.1-10 m/s, repeating after a recharging period.

Next, we learn that three-dimensional vision is enabled by the optic chiasm, an X-shaped crossing of the optic nerve, which provides depth perception. Visual pathways are organized topographically, meaning that associated cells in the retina are paired in the lateral geniculate nucleus (LGN) and visual cortex. Magnocellular cells detect motion and light, while parvocellular cells are responsible for color. The visual cortex processes orientation (V1), form and color (V2-V4), and motion (V5). The Troxler effect results from the specialization of photo-sensitive cells, namely, there are no cells specialized on stationary objects. Microsaccades, un-

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controllable miniature fixational drifts, ensure visibility by causing tiny eye jumps and are also linked to shifts in covert attention.

Chapter Four introduces basic eye tracking terminology. Saccades are broad eye movements measured in angles, often accompanied by head movement if larger than 15°. Saccade planning by the superior colliculus is influenced by new stimuli and peripheral vision, but a saccadic dead time occurs 100 ms before the jump, during which no input can affect the target. Saccadic suppression means the retina cannot process images during jumps, and the brain compensates to provide uninterrupted perception. Researchers establish a velocity threshold for identifying saccades and a movement threshold for fixations.

The principle of eye tracking is that gaze equals attention. However, phenomena like mind wandering, the spillover effect and the "invisible gorilla" effect demonstrate that visual attention is complex, with instances where gaze and attention do not align. Mind wandering is detailed in *Chapter Eight*. The spillover effect in reading is when the processing of complex content continues during the next fixation, thereby extending it. During the invisible gorilla experiment, the subjects were given the task of counting the number of passes in a basketball game. This was enough to create inattentional blindness in the watchers for the gorilla passing through the field, stopping and thumping his chest. Consequently, we can state that attention is finite and when under cognitive load, it may miss even salient and conspicuous stimuli.

Additionally, eye tracking metrics analyze Areas and Regions of Interest (AOIs and ROIs) by measuring the number and length of fixations on specific parts of the visual field. To gather accurate data, the tracker must have 1° accuracy. Fixation metrics include Mean Fixation Duration, Fixation Density, Repeat Fixations, and Regressions (corrective saccades). Visual patterns from scan paths, which consist of fixations and saccades, can be represented by heat maps where colors indicate fixation duration. However, researchers should avoid overgeneralizing data and use advanced visualization software to clarify meanings.

Part Two explores applications in reading, the visual world paradigm, social eye tracking, classroom attention, and related fields. Reading involves perceptual, lexical, propositional, and situational models. Word recognition is influenced by length, familiarity, and age of acquisition, attributed to better brain plasticity at a young age. Ambiguity and opaque spellings hinder processing. Garden path sentences also cause longer fixations but do not need longer reading times. Carpenter's 1980 study suggests a 70 ms period at sentence ends for meaning integration, called the wrap-up effect. However, Stowe et al. (2018) challenge this and support immediate morphological, syntactic and semantic processing.

In reading, the foveal region provides the main information, while the parafoveal region prepares for the next saccade. Proficient readers use 10% of saccades for corrective regressions. Font size and type affect reading, while reducing spaces between characters enhances reading. Better readers have larger perceptual spans and thereby are able to identify more characters at a glance.

The Visual World Paradigm (VWP) studies the interaction between verbal/auditory stimuli and visual displays. Cooper (1974) and Tanenhaus et al. (1995) explored language processing and modularity. Studies show that cohorts and rhymes compete for lexical activation, supporting the continuous-activation model. Sedivy et al. (1999) found shorter latency with contrasting referents. The Stroop and McGurk effects highlight the role of executive control and visual influence on auditory perception. The linking paradigm supports the connection between fixation and language, stating that language and vision are independent but integrated.

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Social eye tracking focuses on social gaze, including mutual gaze and eye contact, which is meaningful and correlates with intimacy and emotional excitement. It studies multiple participants in interaction, using cognitive neuroscience, discourse analysis, HCI (Human-Computer Interaction), and wearable eye trackers. Also, pupillometric data on pupil size can provide insights into cognitive or emotional arousal.

Furthermore, pragmatic aspects are introduced. Joint attention is one-directional when only one subject is aware of both foci, whereas shared attention occurs during a dialogue where both participants are aware of the shared focus, requiring more time and gaze shifts. Gaze aids conversation, disambiguation, and understanding in cooperative tasks. Synchrony refers to the harmony of gestures, body language, and feedback between participants. Gaze aversion can reduce cognitive load, serve as a floor-keeping device, or express irony or deception. In monologues, listeners gaze more at the speaker, while speakers avert their gaze when they intend to continue. At transition points, the current speaker looks at the listener to yield the floor. Process control involves deciding who wants to speak and even unaddressed participants can identify the next speaker. Ruhland et al. (2015) developed embodied agents using gaze and turn-taking cues.

Chapter Eight covers classroom attention and language teaching of Lx, i.e. foreign languages acquired later than one's mother tongue, and how they have leveraged eye tracking to detect mind wandering, optimizing teaching methods by assessing cognitive processes. Digital assistants, individual tutoring systems like Guru Tutor, and smart cars monitoring user alertness can improve performance. Machines can aid learning to read by pronouncing words or showing pictures at certain fixation thresholds.

During mind wandering, eye tracking reports increased blinking, fewer microsaccades, and fixation dispersion. Smallwood (2011) described decoupled covert attention, where tuning out is a deliberate, unrelated cognitive task, and zoning out is unconscious. Mind wandering is more likely with limited cognitive resources, degrading perception and semantic processing, but less likely with self-motivated students and those who take better notes.

In language acquisition, eye tracking evaluates momentary processing during comprehension, aiding educational interfaces. Prosody helps word identification, but learners whose native language lacks contrastive stress cannot use prosodic cues. Bilinguals activate lexical items in all languages. Schmidt (1990) noted that less proficient learners struggle with semantic predictions. Pozzan and Trueswell (2016) supported the cognitive load hypothesis, affecting both children and low-proficiency adult learners with garden path sentences. Eye tracking benefits adaptive e-learning and multimedia learning by establishing the contiguity and signaling principles, which highlight the advantages of proximity of verbal and visual inputs and highlighting, respectively.

Chapter Nine discusses applications in related fields. HCI uses eye tracking for diagnostic assessment and user interaction, such as gaze pointing and eye-typing with a 400 ms dwell time. Visual scene processing differs from reading, with gaze attracted to contrastive areas and borders. Initial fixations fall at the center, followed by a detailed examination based on saliency. The own-race bias shows that it is harder to recognize facial features of another race, indicated by more frequent and shorter fixations.

Eye tracking is widely used in engineering as well. In aviation, it detects fatigue through pupillometry, blink rate, and saccadic velocity. In driving, experienced drivers look at potential threat areas and use peripheral vision for road markers. Inattention has been proven to cause a

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significant portion of accidents. As for neuromarketing research, smartphones are used to gather consumer behavior data, showing frequent digital media checks. In advertising, the arrangement of logos and promotional information affects effectiveness. The gaze cascade effect shows that gaze length increases on the chosen item, and self-reports are unreliable. Impulse purchases are common, and items at eye level sell more. Surprisingly, disorganized displays can increase sales significantly as they urge a sense of limited offer.

Usability studies aim to improve computer interfaces using heat maps and gaze paths. Consumers may develop banner blindness, but changing or flashing banners are hard to ignore. Learning analytics examines interactions between learners and online educational materials, thereby optimizing Massive Open Online Courses such as edX training materials and Learning Management Systems applied by universities.

Finally, *Part Three* covers statistical data processing principles. We learn about descriptive statistics that summarize data and help compare sets and inferential statistics that generalize from a sample to the population, requiring a representative sample. Independent variables are manipulated by the researcher, while dependent variables are the measured outcomes. Confounding variables affecting our conclusions should be avoided by randomization. By all means, consulting a statistical expert can be beneficial when setting up experiments.

When analyzing data, the authors draw our attention to two types of analytical errors. Type 1 error (alpha) happens when a true null hypothesis is rejected (false positive), while Type 2 error (beta) occurs when a false hypothesis is accepted. The alpha level, or significance level, is conventionally set at 0.05. If the p-value is smaller than this, the null hypothesis is rejected, indicating the formulated hypothesis is true. A smaller effect size requires more subjects for the study.

This book, as stated by the authors themselves, is the first of its kind, making its originality unquestionable. As a textbook aimed at an audience needing a summary of the history, of the various applications, and practical advice on the experimental setup advice, it is undoubtedly beneficial. While it provides a helpful summary of eye tracking, it does not introduce any new discoveries in the field. Although no original ideas are presented, the extensive processing work and systematization must be acknowledged. When reading the chapters in order, we encounter a list of seemingly unrelated definitions and concentrated information. This could be improved with a visual correlation map indicating each section’s position and significance as well as showing what the related fields are. However, as the book itself is a content section on eye tracking, cohesion is not its primary purpose.

The clarity is commendable, as no term is left without an explanation or example. If needed, we can find definitions in the book’s eight-page-long *Glossary* starting on page 270. The digital version of the book is impressive, with navigation enhanced by embedded links, making it easy to jump to topics and references with a click. The book’s final section is the *Index*, which is essential for such an expository guide and also includes embedded links for easy reference.

In summary, I highly recommend this book for bachelor or more advanced students who are inexperienced in eye tracking but already have basic linguistic knowledge. This introductory guide is not only easy to handle but is also entertaining with its direct and friendly tone. It occasionally uses humorous language, such as referring to four key statistical terms as the “quartet of doom.” This showcases how much the authors considered the reader in every aspect.

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Barbara Dervishaj
University of Debrecen, Department of English Linguistics
4032 Debrecen
Egyetem tér 1.
vision_hu@yahoo.com