Review of Attardo & Pickering (2023): *Eye-tracking in linguistics* (London: Bloomsbury Academic)

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Eye-tracking in linguistics by Salvatore Attardo and Lucy Pickering provides a comprehensive introduction to this methodology based on capturing eye movements for the purposes of studying human behaviour. Eye-tracking has gained increasing popularity over the past 20-30 years, as a result of fast advances in the technology supporting this method, with increasing accuracy and precision and an increase in the speed of capturing gaze. In addition, the prevalence of various eye-tracking devices has made eye-tracking technology more accessible, even though research based on eye-patterns is still largely skewed across continents and countries (Angele & Duñabeitia, 2024). What makes eye-tracking a suitable and versatile method is the underlying idea of a tight association between gaze behaviour and attention, the eye-mind hypothesis. The eye-mind hypothesis, originally proposed for the study of reading, is a theoretical framework which exploits eye movements as a window into cognitive processes (Rayner, 1977; Just & Carpenter, 1980; Rayner, 1998). Since, eye-tracking has proven a widely applicable method for the study not only of text decoding and comprehension, but also attention, semantic processing, violation processing, prediction in both spoken and written language (e.g., in the Visual World Paradigm), differences between populations of speakers, such as e.g., native speakers vs. second language users, typical readers vs. readers with learning and developmental disorders, children vs. experienced readers (adults). More recently, technological advances have made it possible to study dyadic and triadic communication and interaction, as well as human-machine interaction. The versatility of eye-tracking resides in the fact that it allows for capturing real-time language and information processing and the moment-to-moment deployment of participants' attention to target aspects of the visual or auditory stimulus. While there exist a number of excellent sources on the tradition and details of the methodology (e.g., Rayner, 1998; Roberts & Siyanova-Chanturia, 2013), as well as comprehensive, but more specialised resources on specific fields of study, e.g., second language and bilingualism (Godfroid, 2019), the current volume aims to cover a wider spectrum of applications and is meant for an audience with little or no experience in the field. This is also rooted in the authors' experience teaching a beginner's graduate course for a variety of students.

Part I of the book (*Basics*) presents the historical, physiological, neurological, and theoretical foundations of eye-tracking in four chapters. Chapter 1 (*Historical Development*) gives an outline of the historical development of research on eyes and eye movements. The chronological organisation is established by a four-way periodisation: an early phase (up to 1920) of observational, acoustic and visual methods for capturing eye movements; a phase of applied behaviour-oriented, mainly psychological, research (until the mid-1970s), during which the first systematic studies on reading and image perception were carried out; a further phase of technological improvement (1970–2000), for example the use of infrared light, and the emergence of the first head-mounted cameras; a current phase of development of several different methods of eye-tracking (2000–present), such as video-oculography, electro-oculography, electromagnetic and contact lenses, along with a more recent application of deep learning to eye-tracking.

Chapter 2 (*Anatomy and Physiology of the Eye*) deals with the anatomy of the human visual system, covering the structure of the various organs and its physiology, namely the functioning of the system. Although the visual system is technically part of the central nervous system, this chapter is mainly concerned with the anatomy and physiology of the eye. The anatomy of the eye is introduced with basic terms, such as sclera, cornea, conjunctiva, iris, pupil, lens, aqueous and vitreous humour, retina, fovea centralis, optic nerve, and photoreceptor cells. Chapter 3 (*The Visual System in the Brain*)

is the continuation of Chapter 2, in which the neurological basis of the visual system is described. The chapter provides an overview of the physiology of the visual system in the brain and introduces its vital components: the optic nerve, chiasm and trait, the lateral geniculate nucleus, the optic radiation, and the visual cortex. The authors also briefly discuss other neural structures in the brain that have a significant influence on vision and eye movements, such as the intraparietal sulcus, the superior colliculus, and the frontal eye field, as well as lateralisation and hemispheric specialisation.

Chapter 4 (*Eye-tracking Basics*) explains the basic constructs in eye-tracking research, such as eye movements (saccades and fixations), compensatory movements (vergence and pursuit movements), and miniature (fixational) eye movements that occur within a fixation (microsaccades, drifts and tremors). The authors provide an overview of some of the approaches to attention, in particular distinguishing between overt and covert attention, namely the spotlight theory, bottom-up and top-down attention, and the eye-mind theory. The last part of the chapter presents various eye-tracking metrics that are regularly collected and analysed by eye trackers, for example areas/regions of interest, fixations (fixation/dwell time, time to first fixation, mean fixation duration, fixation density/coverage, repeat fixations, regressions), gaze paths, heat maps, saccadic measurements, pupil dilation, and other non-eye-related metrics (galvanic skin response, electroencephalography (EEG) and fMRI).

Part II of the book (*Applications*) discusses some of the applications of eye-tracking and their findings. One of the areas of research where eye-tracking has been applied most successfully is in the study of reading.

Chapter 5 (*Reading*) deals with the mechanics of reading as the main channel of cultural transmission in literate societies. First, a brief and simplified overview of the process is given by introducing the hierarchical model of reading, followed by a detailed description of what happens during reading. In this context, the most important reading-specific phenomena are discussed, such as perceptual-level phenomena, visual acuity, visual and perceptual span, saccades and fixations during reading, saccade latency, parafoveal preview, and targeting movements (where to fixate next and when to move, regressions, skipping). The authors then explain the factors that influence eye movements during reading, drawing on previous findings from eye-tracking research. Lexical influences include factors that affect lexical processing, such as frequency, word length, predictability, familiarity, complexity, age of acquisition, ambiguity, orthography, phonological similarity, etc. Syntactic influences refer to the effects of processing syntactically ambiguous sentences, such as garden-path sentences. The contextual influences are explained in terms of predictability or cloze probability, whereby a distinction is made between transitional probability and contextual probability. This chapter also describes the wrap-up effect, a common phenomenon when reading. After summarising the factors that influence reading, the main methods (the moving window paradigm, the priming paradigm, the boundary paradigm) and reading-specific measurements (single-word measures, measures of areas of text) are presented. The last part of the chapter introduces models of eye control during reading (EZ Reader, SWIFT and Rational Models).

Chapter 6 (*The Visual World Paradigm*) contains a thorough description of the visual world paradigm, an experimental method that is widely used in eye-tracking research. First, the historical development of the visual world paradigm is presented by introducing the foundational studies using this method (Cooper's 1974 study, Tanenhaus et al.'s 1995 study). The authors then review a selection of studies in which the visual world paradigm has been used, with the aim of illustrating the versatility of this approach, from comprehension studies dealing with lexical activation, the influence of context on sentence processing, predictive understanding, pragmatic influences (implicatures) and dialogue, to production studies and prosody studies dealing with contrastive stress. This is followed by a discussion of the interplay between visual and linguistic systems, which aims to explain interference phenomena such as the Stroop effect and the McGurk effect. The chapter concludes with a summary of the basic components of a visual world paradigm to illustrate the versatility of the experimental design used in this approach and explains the linking paradigm.

Chapter 7 (Social Eye-tracking) introduces social eye-tracking, a new sub-field of eye-tracking for observing and analysing interaction between participants, which has existed for about ten years and

has currently made remarkable progress towards becoming a fully-fledged field. The chapter begins with a description of the origins of social eye tracking, explaining it as a convergence of four different fields of study and paradigms: the cognitive neuroscience approach to social gaze, the discourse analysis or ethnomethodological paradigm, human-computer interaction, and the introduction of wearable eye trackers and automatic recognition of images and gaze. The authors then discuss factors that affect the use and, respectively, results of social eye-tracking, such as dyadic and polyadic interactions, the different social functions of gaze superimposed on the physiological function of seeing, joint attention, collaborative tasks, mutual gaze, synchrony, gaze aversion, conversational organisation (engagement, turn-taking), and embodied conversational agents.

Chapter 8 (*Classroom Attention and Lx Teaching*) reviews the extensive literature on the use of eye-tracking in teaching, namely in classroom interaction, with a particular focus on mind wandering and its detection. The chapter begins with an overview of studies on the use of eye-tracking in a live face-to-face classroom setting. In the next part of the chapter, the authors describe the phenomenon of mind wandering in the study of attention in the classroom. They discuss the effects of mind wandering, mind wandering in lectures, mind wandering and eye-tracking, mind wandering in reading and the automatic detection of mind wandering using eye-tracking technology. Furthermore, a comprehensive overview is given of the aspects that have been investigated by Lx acquisition researchers using the eye-tracking method, such as prosody, vocabulary, syntax, prediction, reference, and captioning. The chapter concludes with an overview of the applications of eye-tracking to the study of adaptive e-learning, multimedia learning and learning strategies.

Chapter 9 (*Applications in Related Fields*) describes the application of eye-tracking outside the field of linguistics, not only in neighbouring fields, such as psychology and computer science, but also in more distant fields, such as engineering and marketing. These applications are potentially related to linguistics because language is ubiquitous and plays an important role in mediating communication, even in non-linguistic systems. The chapter takes an in-depth look at eye-tracking in human-computer interaction, in particular the use of eye-tracking as part of the interface and the use of eye-tracking in augmentative and alternative communication (AAC) devices. Various aspects of visual scene processing are explained, such as saliency maps, top-down and bottom-up features and the role of the gist of an image, followed by an overview of studies dealing with the face and facial expression. Next, the study of eye- tracking in engineering (aviation, driving) and marketing (advertising, point of purchase) is discussed, concluding with an overview of usability studies focusing on pragmatic goals, for example the case of web page or graphical interface.

Chapter 10 (*Planning an Eye-Tracking Study*) is intended to familiarise the reader with how to set up an eye-tracking study. It contains a detailed description of the various steps required to design a study using an eye-tracking methodology, for example reading the relevant literature to find out how scholars have dealt with a particular topic and establish a relevant topic/gap in the literature, formulating research questions, and choosing the appropriate methodology. Afterwards, the authors explain the planning phase for conducting an experimental study, for example manipulating variables, dealing with human subjects' compliance and ethical treatment guidelines and obligations, open science, and data sharing. The chapter also includes practical tips on data collection and validation, as well as how to efficiently write an eye-tracking based paper.

Chapter 11 (*Principles of Statistical Analysis*) describes how to set up a study, so that it is suitable for statistical analysis. The authors address readers who have no prior knowledge of statistics and explain why statistical analysis is necessary in an eye-tracking study. The basic statistical concepts are introduced (sampling, variables) and guidelines for testing the normality of distribution are given. The chapter also deals with the process of determining the appropriate statistical test, followed by a detailed description of the factors that determine the quality of the data, such as sample size, error types, alpha, aka, significance level, beta and power, effect size. Finally, the use of R, a software package for statistical analysis, is discussed.

By offering a gradual progression from the history of the field to eye/gaze physiology onto research traditions and paradigms, as well as fields of application and practical advice on basic design

and aspects of data quality, reliability and validity, data analysis and scientific writing, the book is a valuable resource for the beginner in the amazing world of eye-tracking.

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