Overview

Eye-tracking allows researchers to record participants’ eye movements while processing different types of verbal and non-verbal stimuli presented on a computer screen (e.g., written text, pictures, and videos). When reading or looking at static and dynamic images or scenes, peoples’ eyes stop, processing the information at a particular location and then move to another point where other information is available. During fixations, the cognitive system perceives and processes the visual input, as well as plans when and how far to move the eyes next. With eye-tracking equipment and software, researchers can monitor people’s eye movements to determine what they are looking at and for how long. This allows researchers to infer what participants are attending to—which is considered to be what they are looking at—and determine how much cognitive effort they expend processing what they are looking at. In this way, the “eyes provide a window to the mind” (Conklin et al., 2018, p. xiii). The last decade has witnessed an unprecedented increase in the number of studies using eye-tracking in second language acquisition (SLA) research to explore the cognitive processes involved in second language (L2) learning. This research has contributed to our understanding of how L2 learners engage with different input modes (written and/or auditory texts, videos, and multimedia texts) and how they process and acquire information from the various input sources. Undoubtedly, eye movements, as measures of attention and cognitive effort, are affected by individual differences and, in particular, cognitive differences. However, eye-tracking research on the role of individual differences on L2 learning and processing has only recently started to emerge. More research needs to be conducted examining how individual differences affect learners’ processing of different types of input, as well as establishing the relationship with learning outcomes. In addition, in line with pioneering research in other fields, eye-tracking has the potential to be used as a diagnostic tool to identify individual differences. The focus of the discussion of individual differences in this chapter will be on emerging research in this area and the potential ground-breaking direction it could take. The chapter also provides an overview of key features of the technology and the data that it outputs.

Before turning to a more technical discussion of eye-tracking, it is important to consider its potential value to the field. A key advantage of eye-tracking, over other behavior methodologies that measure response times and offline tasks, is that participants do not need to engage in a secondary task (i.e., judgment, decision, button press, ratings), although they can and often do. Thus, with eye-tracking, participants can simply be asked to engage in a task as they normally would from a computer screen: read text, do a computer-based test, look at images or scenes, or watch
video content. While participants are engaged in these activities, eye-tracking technology provides a rich moment-to-moment data source of what people attend to, at which moment in time, and for how long. This allows researchers to determine the amount of attention or processing effort given to regions of interest (ROIs) on the screen: words, phrases, sentences, test options, subtitle regions, people, images, etc. Notably, eye-tracking is already an essential and well-established tool in psychology and psycholinguistics, where it has been said to provide the “gold standard” in research (Rayner, 2009, p. 1474). Over the last 30–40 years, researchers in these fields have established the technical and methodological understanding to employ the technology well. Thus, newcomers to eye-tracking in applied linguistics and SLA have a wealth of knowledge to draw upon. Crucially, like any technical skill, eye-tracking requires knowledge and training to use. Fortunately, there are considerable resources available to SLA researchers wishing to incorporate eye-tracking into their methodological toolkit: two books (Conklin et al., 2018; Godfroid, 2020), two special issues in journals (Studies in Second Language Acquisition in 2013; Second Language Research in 2020), and a number of articles and chapters (e.g., Carrol & Conklin, 2015; Conklin & Pellicer-Sánchez, 2016; Godfroid, 2019; Godfroid & Winke, 2015; Pellicer-Sánchez, 2020; Pellicer-Sánchez & Conklin, 2020; Pellicer-Sánchez & Siyanova-Chanturia, 2018).

Eye-tracking allows researchers to quantify attention, or processing effort, when a word or region on a screen is encountered. They can determine how many times, how long, and when a word is fixated during reading. They can also see where readers go back (i.e., regress) in a text when they are having difficulties. People’s behavior when looking involves a series of eye movements (saccades), which are sometimes back to a previously seen word or ROI (regressions), and brief pauses (fixations). Eye-tracking technology tells researchers where people’s eyes land (fixate), how many times they land in that position or region (fixation/regression count), and how long each fixation lasts (fixation duration), and also measures saccade duration and length. In reading, not all words are directly fixated, which is referred to as skipping. In fact, only about 70% of the words in a text are fixated and the other 30% are skipped (Schotter et al., 2012; and see Rayner, 2009 for a comprehensive overview of the factors that lead to skipping).

Eye-tracking data is described in terms of fixations to an ROI (sometimes referred to as an area of interest, AOI). Data is reported as counts, the duration of fixations, which calculates the amount of time spent in an ROI, and the likelihood or probability of fixating an ROI. Data is often talked about in terms of “early” and “late” measures (e.g., Altarriba et al., 1996; Staub & Rayner, 2007). Early measures (e.g., likelihood of skipping and first pass reading time/gaze duration) tap into automatic processes and the initial stages of processing (e.g., lower-level processes like word recognition in reading). Late measures (e.g., rereading, total reading time, and fixation count) reflect strategic processing and include revisits and reanalysis that result from processing difficulty. Thus, late measures signal more effortful and/or conscious processing (e.g., lexical integration in reading). Sometimes it is difficult to clearly classify an eye-tracking measure as early or late (e.g., regression path duration in Table 28.1). Such measures are thought to tap into early processing as well as late processing; they are indicative of a difficulty integrating a word when it is fixated, arguably an early effect, but at the same time they reflect the time overcoming this difficulty, arguably a late effect (Clifton et al., 2007). When examining regressions (i.e., movements back in a text), it is important to keep in mind that most regressions are short, simply taking the eye back to the previous word, and are likely due to motor programming errors resulting from overshooting the intended word (Rayner et al., 2006). Longer regressions back in a text largely reflect comprehension failures; however, such regressions are far less frequent.

In the reading literature, many different eye-tracking measures have been reported. Some measures are only applicable in certain contexts, while others are common and are generally reported. Some of the more prevalent measures are described and defined in Table 28.1 (a description of a fuller set of eye movement measures can be found in Conklin et al., 2018 and Godfroid, 2020). While studied far less, eye movements can be monitored when participants look at static images,
view visual scenes, or watch videos. Different areas of the screen are defined as ROIs. Data is usually reported in terms of total fixation duration, the proportion of saccades directed to, or the proportion of time spent looking at, a target ROI compared to other ROI(s). For example, Bisson, van Heuven, Conklin, and Tunney (2014) had participants watch a movie under different subtitling conditions and defined two ROIs (the subtitle region and the image region) to see how manipulating the language of the audio and the subtitles influenced looks to the subtitle region. Some of the measures they looked at were total fixation duration, the number of fixations, and the average fixation duration, which were calculated for the subtitle region in different conditions.

In psychology and psycholinguistics, where eye-tracking is well established, L2 research has predominantly focused on word and sentence processing in carefully controlled and manipulated sentences or texts. This level of control allows researchers to attribute the locus of an effect to a particular word or syntactic structure. Because every element of the experiment is the same, other than the variable that is being studied and manipulated, any difference in behavior can be attributed to the variable of interest. While this type of research is still very common, the scope of research has expanded as SLA researchers have made use of the technology. For example, in SLA, eye-tracking is being applied to long and/or authentic materials to capture the dynamics of L2 acquisition and processing in more realistic contexts and has been used to supplement common methodologies such as stimulated recall, interviews, focus groups, think-aloud protocols, and questionnaires (for a discussion, see Godfroid et al., 2020). However, the expansion of eye-tracking into SLA research

### Table 28.1 Common Eye-Tracking Measures

<table>
<thead>
<tr>
<th>Processing Stage</th>
<th>Measure &amp; Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early</td>
<td><strong>Likelihood of Skipping</strong></td>
</tr>
<tr>
<td></td>
<td>• Likelihood that an ROI is skipped (not fixated at all) the first time it is encountered</td>
</tr>
<tr>
<td></td>
<td>• Calculated as number of first fixation durations of 0 ÷ total number of trials</td>
</tr>
<tr>
<td></td>
<td>• Word skipping occurs when words are predictable and when they are short</td>
</tr>
<tr>
<td>Early</td>
<td><strong>First Pass Reading Time</strong> (gaze duration for single words)</td>
</tr>
<tr>
<td></td>
<td>• Sum of all fixations on an ROI before exiting to the right or left</td>
</tr>
<tr>
<td></td>
<td>• Sensitive to semantic and syntactic anomalies</td>
</tr>
<tr>
<td>Early/Late</td>
<td><strong>Regression Path Duration</strong> (or go-past time)</td>
</tr>
<tr>
<td></td>
<td>• Sum of fixations on ROI and any regressions to earlier parts of the sentence before moving past the right boundary of ROI</td>
</tr>
<tr>
<td></td>
<td>• Reflects lexical and integration difficulties leading to regression to earlier points</td>
</tr>
<tr>
<td>Late</td>
<td><strong>Rereading</strong></td>
</tr>
<tr>
<td></td>
<td>• Regression path duration for an ROI minus first pass reading time</td>
</tr>
<tr>
<td></td>
<td>• Provides indication of the time spent resolving a difficulty</td>
</tr>
<tr>
<td>Late</td>
<td><strong>Total Reading Time</strong></td>
</tr>
<tr>
<td></td>
<td>• Sum of durations of all fixations on an ROI</td>
</tr>
<tr>
<td></td>
<td>• Can be impacted by both early and late processing</td>
</tr>
<tr>
<td></td>
<td>• An effect in total reading time, but not early measures, is indicative of a late effect on processing</td>
</tr>
<tr>
<td>Late</td>
<td><strong>Fixation Count</strong></td>
</tr>
<tr>
<td></td>
<td>• Total number of fixations on ROI</td>
</tr>
<tr>
<td></td>
<td>• More fixations typically lead to greater time fixating an ROI</td>
</tr>
</tbody>
</table>
has not (yet) yielded a corresponding growth in individual differences research. This is likely due to the fact that eye-tracking studies are generally time consuming to set up and analyze, as well as requiring participants to come to a lab, which limits the amount of data that tends to be collected. Because of the (relatively) small datasets, it may prove challenging to draw meaningful conclusions about individual differences. This may be why individual differences research using eye-tracking is only in its infancy. As is discussed in the last two sections of the chapter, eye-tracking is beginning to play a role in individual differences research, with a focus on exploring the role of cognitive differences on L2 acquisition and processing.

**Technical Features**

The initial step in eye-tracking research involves understanding the capabilities of the equipment being used; different eye-trackers have different technical specifications, which make them more or less suited to answer particular research questions. For example, researchers interested in investigating the role of working memory on the learning of grammar from written input would need eye-tracking equipment that can record eye movements to small areas of the screen, without compromising data quality. This section provides an overview of the key technical specifications of eye-tracking equipment (both hardware and software) that should be considered when conducting eye-tracking research.

Eye tracking involves recording the eye’s position relative to a visual stimulus. The most common method uses video-based tracking, which records eye movements with an infrared camera that is directed at a participant’s eye. Information about the specific location of the tracked eye(s) on the screen is mapped onto specific regions on the screen (i.e., the stimuli). The eye movements recorded by the system are used to compute the different eye-tracking measures explained in the previous section. Not all eye-tracking systems compute all measures. Thus, it is important to know which measures are most appropriate to answer a study’s research questions and ensure that the system being used outputs those measures.

Eye-tracking systems are usually distinguished based on the position of the camera relative to the eye, the zoom level of the lens, and the algorithms used to parse eye movements. Three main types of eye trackers can be identified based on these criteria:

- **High-precision, head stabilized eye trackers:** The camera and infrared light are positioned remotely near the monitor (desktop mounting) with head support (e.g., SR Eyelink 1000 Plus) or in close contact with the participant (e.g., integrated into a headrest). These eye trackers have a zoomed-in view of the eyes, and their algorithms assume a constant distance and steady illumination.

- **Remote, head-free-to-move eye trackers:** The camera and infrared light are placed remotely, usually on or below the monitor (e.g., Tobii Pro TX 300). No head support is used, and the system allows for a certain degree of head movement. A zoomed-out view of the eye is used. Because of frequent changes in distance and illumination, dynamic algorithms are used to account for this. Some remote systems can be used in both high-precision, head-stabilized and remote, head-free modes (e.g., SR Research 1000 Plus).

- **Head-mounted eye trackers:** The camera and infrared light are placed on the head of the participant in a helmet or cap (e.g., SR Eyelink II) or in glasses (e.g., Tobii Pro Glasses 2).

Experimental stimuli are usually presented on a computer screen that is close to the remote tracking devices. In some setups, an additional monitor is used to process and record the eye movement data (i.e., host PC). This additional computer allows the researcher to monitor participants’ eye movements in real time and identify potential issues with calibration accuracy during the experiment.
Eye-tracking systems vary considerably in their technical specifications. In what follows, some of the key features are discussed: tracking type (monocular or binocular), sampling rate, accuracy, and precision (for a more detailed discussion of these and other key technical specifications, see Conklin et al., 2018).

One of the key technical features is the type of recording: 1) monocular, if the system records from one eye, or 2) binocular, if the system records from both eyes. Some systems offer both tracking options and allow researchers to choose whether they want to perform monocular or binocular recording. When using monocular tracking, the common practice is to track the same eye for all participants. Binocular systems differ in how the eye movement data is outputted. Some binocular systems output separate data streams for each eye, allowing researchers to inspect the data and choose the data from the eye with the best accuracy for analysis. Other binocular systems output an averaged data stream from both eyes. Binocular tracking usually operates at a lower sampling rate, negatively impacting data accuracy. In addition, there is little benefit to tracking both eyes, as they are believed to move in synchrony with very small variation in their position (Liversedge et al., 2006). Thus, monocular recording is common practice in eye movement research (Raney et al., 2014), and in particular in the type of language acquisition and processing research that is relevant for the study of individual differences.

As with other data elicitation techniques, the validity and robustness of the results of an eye-tracking study largely depend on the quality of the data. Data quality is determined by the properties of the eye tracker, including sampling rate, accuracy, and precision, which will briefly be discussed in turn. The sampling rate of a system is the speed with which eye movements are recorded. The sampling rate of current eye-tracking systems ranges from 30 Hz to 2,000 Hz. A sampling rate of 1,000 Hz means that eye movements are recorded 1,000 times per second. A higher sampling rate is preferred in the majority of cases, as it means that any sampling errors (i.e., instances where the eye tracker misestimates the correct point of a particular eye movement) will have a smaller impact on the quality of the data. However, the specific sampling rate needed for a study depends on what is being measured. When examining eye movements to small ROIs, such as words in a reading study, a high sampling rate is needed. However, when examining eye movements to larger ROIs, a lower sampling rate should not be an issue. A sampling rate of 250 Hz is usually considered the threshold between low and high speed (Holmqvist et al., 2011). Using an eye-tracking system with a low sampling rate (i.e., below 250 Hz) does not mean that eye movements to small areas of the screen cannot be recorded. However, in order to compensate for the negative impact of the low sampling rate, a much larger amount of data would need to be collected, which might be impractical (see Andersson et al., 2010 for an explanation on how to calculate the amount of data needed to compensate for low sampling rate).

A second important property of the system that determines data quality is accuracy, defined as the difference between the measured fixation location and the true fixation location. Accuracy is measured in degrees of visual angle. High accuracy is crucial when recording eye movements to small areas. Information about accuracy is usually reported in the system’s technical specifications provided by the manufacturer. It is important to note that the values reported by manufacturers correspond to levels of accuracy measured in ideal conditions. This does not mean that accuracy in an actual experiment will achieve those levels. Accuracy needs to be assessed per participant. Most systems allow researchers to check the accuracy of gaze positions in an initial calibration (see below). The average gaze error should be within 0.5° and 1.0°. In addition, it is important to ensure that accuracy is maintained throughout the experiment. Monitoring eye movements during an experiment is a common way of identifying when accuracy has dropped, and recalibration is needed. Some systems offer the possibility of performing drift corrections throughout the experiment, allowing for potential deviations from the calibrated gaze positions to be corrected. It is important to note that the distance between the eye tracker and the participant impacts data accuracy, making it important to check the distance recommended by the manufacturer.
Another important property, often discussed in relation to accuracy, is precision. Precision refers to the spatial variation between the data samples recorded for a fixation and is calculated as the average root mean square (RMS) (see Figure 28.1 for a depiction of the difference between accuracy and precision). Current eye trackers have RMS values of from 1° to 0.01°. RMS values below 0.05° reflect very precise measurements of fixation durations and saccades (Holmqvist et al., 2011). As mentioned above, the requirements for getting good quality data depend on the experimental design. When examining eye movements to smaller areas of the screen (e.g., in reading research) a system of higher accuracy, precision, and higher sampling rate is needed.

In addition to being well acquainted with the hardware components and technical features of an eye tracker, it is important to be familiar with the software that supports an eye-tracking system, namely the software that is used to build the experiment and to record and process the eye movement data. Some systems have separate software to build the experiment and to record and process the data (SR Research EyeLink systems), while others have a single software package for the whole process (Tobii systems). Although there are differences between the various software packages, most allow researchers to use the main stimulus types that would be of interest in SLA and individual differences studies (i.e., text, images, and videos). Software packages differ in the tools they offer to process the data, with some software offering more sophisticated options for exporting data and calculating eye movement measures. This is an important consideration as it will determine the ease of performing certain types of analyses that might be crucial for a study. For example, a software package may not automatically output regressions. If researchers are interested in determining where learners look back in a text when they encounter a difficulty, the data output by the software might make it challenging to address this. While the majority of systems have the option of producing some descriptive statistics for a recording session (e.g., means), in most cases a full report of the eye movements to the specified ROIs would need to be exported so that more sophisticated statistical analyses can be performed.

High-quality eye-tracking research not only depends on choosing the right equipment and ensuring that the properties of the hardware and software allow research questions to be answered but also on the physical set-up of the system. It is important to ensure that the physical conditions (e.g., position, light, and level of noise) are constant for all participants in a study. As mentioned above, the distance between the participant and the eye tracker and monitor is important for obtaining high-quality data. The optimal distance depends on the screen width. Eye-tracking system user manuals contain specific guidelines on how to calculate the appropriate distance and ensure that it is at its optimum. Finally, it is important to ensure that the system is properly calibrated for each participant. Thus, an initial calibration for each participant is essential to ensure data quality. During calibration, a set of points/crosses are presented on the screen and the participant is asked to fixate them in turn. Although the number of points can be modified, a nine-point calibration is standard. If fewer points are used, data quality may be reduced at certain positions on the

Figure 28.1 Depiction of the Difference Between Accuracy and Precision.
Eye-Tracking

screen. The system provides information about the level of calibration accuracy for a participant and some systems also include a validation procedure to further evaluate the accuracy level. Once the system has been calibrated and the appropriate level of accuracy has been obtained, researchers can start running the experiment. Crucially, head and body movements should be minimized during the experiment as they can impact calibration.

Contributions to ID Research

Having discussed some of the main properties of eye movements and eye-tracking equipment in the previous sections, this section focuses on research that has explored the role of individual differences in eye movement patterns. A major aim of these studies has been to examine the value of individual differences to predict eye movement patterns, in an attempt to determine how individual differences modulate cognitive processes among learners. In this section, we provide a brief overview of the topics and questions that have been investigated in this line of research, as well as some of the main findings.

Most of the recent eye-tracking studies in SLA have focused on reading, exploring learners’ processing of written texts in different instruction conditions. Additionally, there is extensive literature in psychology/psycholinguists making use of eye tracking to explore reading. Empirical evidence showing the effect of lexical and syntactic properties on eye movements during reading abounds (for a review, see Rayner, 1998, 2009). Several studies have attempted to explore the role of learner-level variables on eye movement patterns. For example, studies have examined the effect of age on eye movements during reading by comparing the reading patterns of young and adult readers. Overall, this research has shown that children have a slower reading rate than that of adult readers (e.g., Blythe & Joseph, 2011; Häikiö et al., 2010; Häikiö et al., 2009; Rayner, 2009). In a similar vein, research demonstrates that typically developing children have reduced reading performance compared to adult readers, which is likely a reflection of more effortful word processing (Whitford & Joanisse, 2018). Age differences have also been demonstrated in relation to attention allocation to illustrated texts (e.g., Evans & Saint-Aubin, 2005; Roy-Charland et al., 2007) and to subtitle reading (e.g., D’Ydewalle & de Bruycker, 2007; Muñoz, 2017).

Research has also examined the effect of a range of characteristics of participants’ language background and language experience on eye movement patterns during reading. For example, eye movement measures have been used to examine differences between first language (L1) and L2 reading, as well as between monolinguals and bilinguals. Research has shown that exposure to an L2 can lead to changes in L1 reading (e.g., Titone et al., 2011; Van Asche et al., 2009; Whitford & Joanisse, 2018; Whitford & Titone, 2012). Studies have also shown that, when reading in their L2, bilinguals have longer sentence reading times, more fixations, shorter saccades, and less word skipping than in their L1 (e.g., Cop, Drieghe, & Duyck, 2015). Another feature of language background that has been studied is the level of current L2 exposure, indicating that current L2 exposure modulates different aspects of reading behavior (e.g., Whitford & Titone, 2012, 2015). Eye-tracking studies have also explored how language proficiency modulates eye movements during reading. For example, Muñoz (2017) compared subtitle reading in beginner, intermediate, and advanced learners of English and found significant processing differences among the three groups.

The research discussed thus far demonstrates attempts to explore the effect of a range of learner factors on eye movement patterns. However, only a few studies have explored the influence of individual differences on eye movements. This emergent research has focused on cognitive individual differences, in particular in relation to foreign language aptitude, investigating the influence of traits such as working memory and executive control.

In the cognitive psychology literature, a few studies have examined the mediating role of executive control on eye movements during L2 sentence processing. Pivneva et al. (2014) examined whether individual differences in English–French bilinguals in domain-general executive control
modulated cross-language activation of interlingual homographs and cognates during L2 sentence reading. They found that greater executive control (measured by a battery of tasks) led to reduced cross-language activation of interlingual homographs in both early and late eye-tracking measures, while bilinguals with less executive control exhibited longer gaze duration and total reading time. Greater executive control did not modulate cognate facilitation. Friesen et al. (2020), in their examination of cross-language activation in bilinguals, examined the effect of executive control on homophone activation. In early eye-tracking measures, executive control was not associated with homophone facilitation. In later eye-tracking measures, significant effects of executive control on homophone processing were observed, with greater control associated with larger homophone effects in the total reading time for low-frequency words.

A few studies have also explored the role of working memory on eye movements in different learning conditions. Indrarathne and Kormos (2018) examined the role of working memory abilities on learners’ attentional processing of a target grammatical construction in explicit and implicit instructional conditions. Results showed that memory abilities were highly predictive of how much attention L2 learners paid to the input. Importantly, the findings suggested that the strength of association between the eye movement measures and working memory varied across instructional conditions, with a stronger relationship in the more explicit condition. The authors argued that “those learners who have high WM storage capacity and efficient attention regulation abilities engage in more attentional processing of the input if their awareness of the existence of a target syntactic construction in the input is experimentally manipulated” (p. 370). Revesz et al. (2017) examined the effect that working memory had on learners’ eye movement patterns while completing a writing test. Results showed a relationship between short-term memory capacity and processing patterns, with learners with a larger visual-spatial span looking at the instructions less frequently when pausing. Taken together, these studies provide initial evidence that cognitive differences influence input processing in various L2 learning conditions.

Finally, some eye-tracking studies have explored individual variation in reading caused by deficits, such as dyslexia. Research in this area has demonstrated that dyslexic readers show different reading patterns from normally developing readers of the same chronological age. Some of the main differences include an increased number of eye movements (particularly regressions) and greater variability in the size and duration of eye movements (Pavlidis, 1985). Compared to non-dyslexic matched individuals, dyslexic readers have shown longer fixation durations, shorter saccades, and more fixations in reading (Prado et al., 2007). These eye movement patterns have been reported in studies looking at different languages (e.g., Hutzler & Wimmer, 2004), and when looking at both sentence reading (e.g., De Luca et al., 1999; Hutzler & Wimmer, 2004) and single-word processing (e.g., Hutzler et al., 2006).

While eye-tracking research on individual differences is still scarce, the existing research has shown how cognitive differences lead to important differences in eye movement behavior during reading. Crucially, an examination of individual differences provides a more nuanced understanding of L2 learners and the factors affecting cognitive processes for various types of input and under different learning conditions. An important aim of some recent eye-tracking research in SLA has been to establish a relationship between eye movements and learning gains. For example, research has shown that reading time on novel vocabulary was a predictor of vocabulary gains (e.g., Godfroid et al., 2013; Mohamed, 2018; Pellicer-Sánchez, 2016). Previous studies have also shown that longer processing time for text seems to be related to lower comprehension scores (e.g., Chang & Choi, 2014; Pellicer-Sánchez et al., 2020; Serrano & Pellicer-Sánchez, 2019). However, other studies have reported a lack of relationship (e.g., Elgort et al., 2018) or a significant relationship only in some of the conditions or for some of the target features studied (e.g., Godfroid & Uggen, 2013; Indrarathne & Kormos, 2017; Montero Perez et al., 2015). This points to the need to conduct further research exploring the link between eye movements and performance measures. Crucially, it is likely that individual cognitive differences regulate this relationship and future eye-tracking research should aim to explore their role.
Eye-Tracking

Future Directions

As the previous section demonstrates, eye tracking has been a useful tool for studying the role of cognitive differences on eye movement patterns. Looking to the future, eye tracking might make it possible to differentiate between individual participants. Thus, like in personalized medicine where the goal is to study a patients’ environmental influences and their genetic code to produce personalized diagnoses and treatments (Blix, 2014), educators might be able to use eye tracking to evaluate individual language learners, which would allow them to provide learning experiences that are tailored to an individual student.

In order to begin to use eye-tracking performance as a proxy for individual differences and/or as a diagnostic tool of individual differences, large datasets are needed, akin to what is available for word recognition through the English Lexicon Project (http://elexicon.wustl.edu; Balota et al., 2007), the British Lexicon Project (http://crr.ugent.be/programs-data/lexicon-projects; Keuleers et al., 2012), and the Dutch Lexicon Project (Keuleers et al., 2010). For example, the English Lexicon Project contains nearly four million word recognition trials from lexical decision and word naming from over 1,200 participants. This dataset has been used to explore differences among individuals (e.g., Yap et al., 2012). Importantly, such research demonstrates that large datasets can begin to be used to indicate something about the individuals that make them up.

Unfortunately, in eye tracking there are no comparable databases to those that are available for word recognition tasks (i.e., lexical decision and word naming). As touched on in the opening section of this chapter, this is likely due to the nature of eye-tracking studies, where data collection and analysis are both time consuming. Studies can also be costly; participants are often compensated monetarily in order to ensure a sufficient level of participation, which is particularly true when securing participants from a specific demographic (i.e., L2 speakers). However, eye-tracking researchers are beginning to work with larger datasets both in terms of the number of participants and items that eye movements have been recorded for. This has opened up the possibility of exploring differences between the individuals in a study, as well as the possibility of using eye-tracking performance diagnostically to characterize a particular learner. In what follows, some of these innovative projects are discussed.

Ground-breaking research by Berzak et al. (2017) sought to use eye movements from L2 English speakers to identify their L1. This may seem trivial, as a person’s L1 is often known, or they can simply be asked to provide it. However, the research demonstrates that the reading patterns detected with eye tracking can be used as a diagnostic tool to identify a property of an individual (i.e., their L1). Thus, it is a first step in using eye tracking to identify a particular property of an individual. To achieve this, Berzak and colleagues monitored the eye movements of two groups of participants: 37 L1 English speakers and 145 L2 speakers who had different L1s (36 Chinese, 36 Japanese, 36 Portuguese, and 37 Spanish). The participants read 156 sentences (plus one practice sentence) from the Wall Street Journal portion of the Penn Treebank (Marcus et al., 1993), which is a large, annotated corpus of American English. Of the 156 sentences, 78 sentences were read by everyone in the study and the other 78 sentences were different across individuals. Berzak et al. examined first fixation duration, first pass duration, and total fixation duration. Using the large dataset of eye movement measures, they were able to identify key features that differentiated L2 readers from different L1s. Crucially, this work demonstrates the emergence of eye-tracking technology as an objective means of identifying individual differences.

Using the same dataset in a follow-up study, Berzak et al. (2018) looked at the relationship between an individual’s eye movement patterns and their performance on standardized English proficiency tests. They were interested in whether an individual’s gaze patterns would be a reliable indicator of their proficiency. From the original 145 L2 participants (Berzak et al., 2017), they had scores from the grammar and listening sections of the Michigan English Test (MET; 50 multiple-choice questions) for 88 participants, and self-reported scores from either the TOEFL iBT or the
TOEIC (taken in the last four years) for 53 participants. Berzak and colleagues considered the same eye movement measures as previously (first fixation duration, first pass duration, and total fixation duration) and also included regression path duration. Depending on exactly what was being assessed, the researchers found that gaze patterns correlated weakly to moderately with the test scores. They were also able to use individuals’ eye movement patterns to predict their scores on the two tests. The correlation between prediction and the test scores ranged from weak to strong, depending on the feature being looked at (e.g., reading speed). While the correlations were not necessarily strong, Berzak and colleagues demonstrate the possibility of mapping an individual’s gaze patterns to standardized proficiency tests. Thus, eye-tracking performance while reading sentences from a native speaker corpus had the potential to detect L2 speakers’ proficiency.

Eye-tracking has demonstrated its potential as a diagnostic tool in other participant populations as well. Rello and Ballesteros (2015) were able to detect dyslexia in reading with around 80% accuracy. They point to the future potential of eye tracking to diagnose dyslexia. Similarly, Robertson and Gallant (2019) showed that gaze patterns revealed more differences between children with dyslexia and their typically developing peers than behavioral measures alone. They highlight that, “The sensitivity of eye-tracking identifies group differences in processing that would not otherwise be revealed” (p. 13). Chhaya and colleagues (2018) demonstrated the utility of eye tracking (to images of faces) as a reliable means of evaluating neurodevelopmental risk and disorders in very young children in resource-constrained settings (i.e., HIV-exposed Ugandan infants).

These pioneering studies on L2 speakers, as well as those on other populations, demonstrate that eye tracking has great potential in a number of areas: identifying key individual characteristics, diagnostic assessment of individuals, and mapping individual markers of development. In SLA, future research will likely build on the ground-breaking work and explore how a wider range of L2 individual differences (e.g., working memory, cognitive control, language aptitude, and learner strategies and perceptual styles) interact with and influence gaze patterns in individuals. However, in order to gain a better understanding of individual differences, eye-tracking research is needed that involves a broader range of participants having more varied characteristics and from more diverse backgrounds and contexts. In addition, future research should focus on individual differences in listening comprehension, as the work thus far has concentrated on eye tracking with reading. Further, with longitudinal eye-tracking data, it may be possible to chart a learner’s development over time, without the need to repeat high-stakes proficiency tests. However, to achieve these kinds of goals, researchers will need large and diverse data samples across a wide range of conditions and contexts, which will be challenging to acquire. To track progress over time, large samples of longitudinal data are needed. In other words, in order for eye tracking to provide insight into individual differences, tremendous empirical work is required and would benefit from open science initiatives such as multi-lab collaboration; open-access data repositories akin to the English, British, and Dutch Lexicon projects; and replication research.

References


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