Chris M. Anson and Robert A. Schwegler

Tracking the Mind's Eye: A New Technology for Researching Twenty-First-Century Writing and Reading Processes

This article describes the nature of eye-tracking technology and its use in the study of discourse processes, particularly reading. It then suggests several areas of research in composition studies, especially at the intersection of writing, reading, and digital media, that can benefit from the use of this technology.

Using increasingly sophisticated equipment, researchers from several disciplines have studied people's eye movements as they read text or look at still and moving images. In the scholarship on written communication, eye-tracking devices have generated large amounts of research on reading processes (see Rayner) but far less on relationships between reading and writing. With the exception of two studies in North America and some recent interest among European writing scholars, composition researchers have not utilized the method. But today, eye-tracking research has increasing potential for the study of writing, especially in the context of screen-based learning and digital interaction. In this contribution, we argue that a number of questions about the nature of writing and the relationship between reading (screens or texts) and writing

can be profitably studied using eye-tracking methodology, which promises to reveal new insights about the psychological, visual, social, and educational dimensions of literate practice. In addition to revitalizing cognitive research, eye tracking provides ways to understand previously inaccessible dimensions of writing and reading that extend well beyond psychologically based studies of discourse processes. As is the case in many fields of study, a new tool for inquiry and measurement suggests both new directions for investigation and fresh approaches to existing questions.

At this moment, you're engaged in astonishingly complex processes as you read this text—processes that include everything from recognizing minute aspects of letter fonts to applying discursive, disciplinary, and world knowledge to construct meaning.

We first describe the nature of eye-tracking technology and briefly summarize some of the paradigm-forming research it has yielded in the study of reading. We then review the limited North American research that has used the method in composition studies and the psychology of writing, and summarize some of the research that has been conducted in Europe. Finally, we suggest several previously unexplored questions and areas of inquiry in composition studies that can benefit from the use of eye-tracking methodology, including studies of peer review and instructor response; the relationship of visual and textual information in both composing and reading onscreen; the effects of grammatical error or lexical and stylistic choice on teachers or students as readers; and further dimensions of composing processes under a variety of task-, context-, genre-, and knowledge-based conditions.

Eye Tracking: Some Background

At this moment, you're engaged in astonishingly complex processes as you read this text—processes that include everything from recognizing minute aspects of letter fonts to applying discursive, disciplinary, and world knowledge to construct meaning. What you *feel* (or have been taught to feel) is a sort of flow, one word yielding to the next, sentences building on each other, understanding emerging from broad sweeps of your eyes from left to right and back again. In reality, the process is anything but smooth: a series of jerky, erratic movements filled with pauses, false starts, backtrackings, and a lot of guesswork. If we could capture the movements of your eyes across this text, we'd see something more like a subway map than a neat zigzag. The result would suggest not that the text is smoothly offering up its meaning but that you're doing most of the work, actively *constructing* meaning from the words to create a coherent mental representation.

Thanks to new technology, today we can create more accurate maps of what we look at while working with text, with the technology itself helping to alter our understanding (see Figure 1, for an example). Highly sophisticated equipment can now record the exact movements of people's eyes as they read text, look at advertisements, watch TV or computer screens, or drive a car. This technology's development stretches back to the nineteenth century and includes electro-oculography, scleral contact lenses and search coils, photo- and video-ocularity, and reflective devices (see Duchowski for an interesting chronicle). Today, eye-tracking equipment is mediated by computer technology and is extremely accurate.

Most contemporary eye trackers use a video-based system that collects data by measuring movement in the cornea and pupil as a function of reflec-

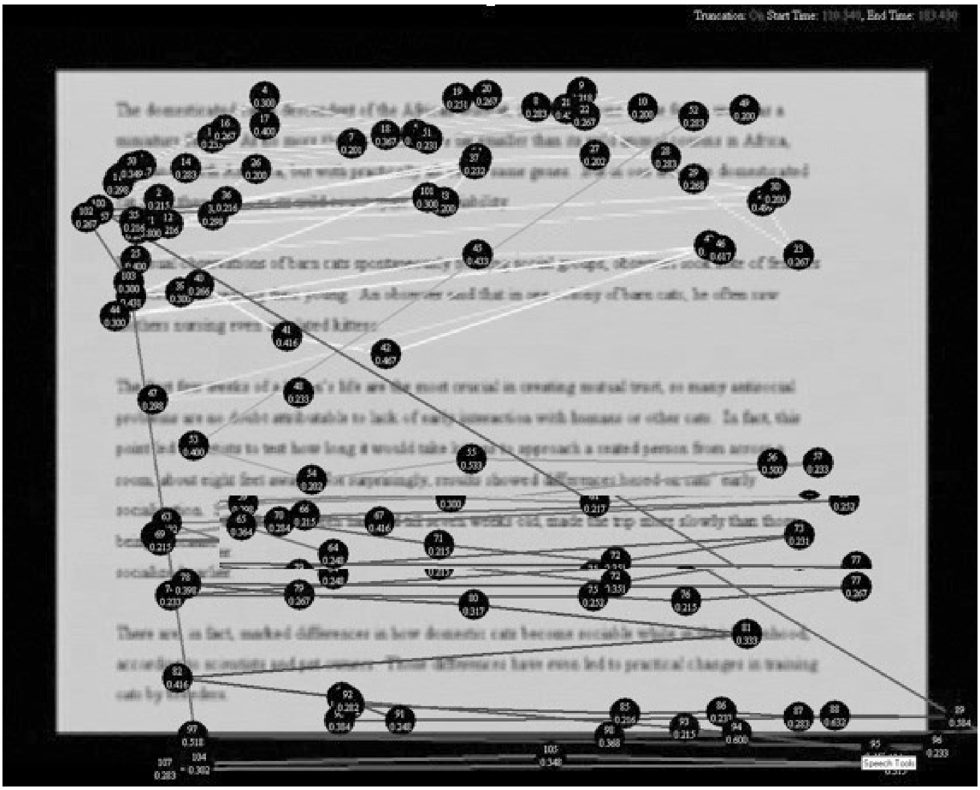

Figure 1. A screen of text showing eye fixations and saccades.

tion. Infrared light is reflected via a mirror into a subject's eye, in turn creating a reflection off the retina and cornea. The corneal glint and the retinal reflection are used to calculate where the participant's eye is focused. The eye tracker measures the eye location and the number of fixations (or pauses in eye movement) that occur as the subject reads text or looks at visually presented material, rendering this in a "gaze trail." Typical eye trackers will collect data sixty or more times per second on the gaze direction of the eye relative to the computer screen or other visual field. The systems can be programmed to capture data at various intervals; for example, a fixation (when the eyes are at rest) can be defined as lasting for at least 200 milliseconds and cover a defined area—say, 1.8 visual degrees.

Until recently, eye trackers were stationary pieces of equipment housed in a lab and usually connected to computer screens displaying visual information such as texts and images. Advances in eye-tracking technology have yielded portable units that subjects can wear on their heads, enabling researchers to capture data as the subjects move freely through space. Figure 2 shows the Applied Science Laboratory Mobile Eye-XG, a unit that "can now collect eye movements and point of gaze information during the performance of natural tasks allowing the use of unconstrained eye, head and hand movements under variable light conditions" (Engineering Systems Technologies).

Figure 2. Applied Science Laboratory Mobile Eye-XG. Photo courtesy ASL Eyetracking, www.asleyetracking.com.

In the context of most composition research, which uses tools that are typically no more complicated than digital video or audio recorders and computer screens, eye tracking may seem highly scientific and expensive. In its earlier development, this was certainly true; institutions procured eye-tracking equipment through large grants, installed the machinery in dedicated lab space, and employed technicians to help prepare for data collection by orienting subjects to the process and calibrating their eye gaze through a series of trials. Researchers from different disciplines frequently relied on a single lab, signing up for and sometimes paying for the use of the equipment.

Today, however, eye-tracking equipment is becoming lighter, more portable, and less expensive, making it easier for scholars to obtain the devices with small grants, department supply and equipment accounts, or even personal funds. For example, the Mirametrix S2 eye-tracking system, which is useful for screen-based eye tracking, takes a few minutes to set up and calibrate and involves only a small visual data-collection bar that sits on a tripod at the bottom of a computer screen. The unit costs about $5,000, minus discounts for academic institutions. Portable eye trackers are somewhat less expensive; EyeGuide, manufactured by Grinbath Technologies, is a wireless system with an elastic headband, a single camera, and a battery pack. The unit and software cost $1,500, and the company also offers educational discounts. These two units are among a dizzying array of eye-tracking equipment on the market, some with price tags of over $40,000. Composition researchers interested in using eye tracking as a method for capturing certain kinds of data are well advised to see if their institution already owns an eye tracker or if there is one for use nearby before spending lots of time researching which equipment to get and finding the funds to get it.

The use of eye tracking to study human perceptual processes and gaze preferences crosses many disciplines. Duchowski provides an overview of some applications of eye tracking in the study of neuroscience, psychology, advertising and marketing (including product packaging), computer science, human factors research, and industrial engineering. Studies of transportation, for example, have used eye-tracking methods to compare what expert and novice drivers focus on as they approach specific traffic situations (see Cohen) and what pilots look at in the cockpit during takeoff and landing. Eye tracking has also been used in disability research (Chapman), usability studies and Web design (Jepson), diagnoses of schizophrenia (Campana, Duci, Gambini, and Scarone), lie detection (J. M. Smith), and studies of the effectiveness of warnings in product owner manuals (Cowley). "Bee swarms," when several or

many records of individuals' eye movements are brought together into a visual "swarm," are often used to analyze what consumers typically focus on when looking at advertisements or commercials. The results can provide clues about the effectiveness of particular images and their relationship to a product, brand name, or other feature, even in video. Multiple eye trackings can be represented in various kinds of visual displays, including "heat maps," which show which areas of a visual draw the most attention; cloud maps, which show what viewers do and do not look at; gaze plots, which show the usual path of a viewer's eyes from point to point in a visual; and zone analysis, which breaks a visual or page into colored zones based on the strongest areas of interest.

In the study of discourse processes, eye tracking has been used most extensively in research on reading. Prior to the advent of this technology, scholars created models of the fluent reading process through a combination of problematic methods that included observations, perceptions, and reports of experience, miscue analysis (mistakes readers make while reading aloud), cloze tests (when every nth word is removed from a text and readers try to resupply the missing words), and various word-identification and visual acuity tests. Because eye tracking provides very accurate representations of what readers do when they read, they have led to important refinements of existing models of the fluent reading process.

Readers may feel as if their eyes have seen every word, but their brains are providing far more information for their comprehension than what's literally on the page.

One important discovery concerns the relationship between the eyes' movements (called *saccades*, the intermittent flick of the eyes between two points on a page or screen) and where they come to rest (called *fixations*, periods between saccades when the eyes are still and focused on a specific place). Between fixations, the information received during saccades is mostly a blur; what comes into the eyes (and brain) during this time is seriously reduced in a process of *saccadic suppression*. Models of reading that assumed readers need to look at most of the text on the page (getting everything "through the eyes") were replaced by models in which readers "fill in" a large amount of information from what they bring to the text (getting much of their understanding from what's "behind the eyes"; see F. Smith). In fact, fixations account for 85 to 90 percent of reading time, while saccades take up only the remaining 10 to 15 percent. In real time, the eyes are still for much more time than they are moving. Readers may feel as if their eyes have seen every word, but their brains are providing far more information for their comprehension than what's liter-

ally on the page (Rayner). These conclusions are also based on studies of what information readers can get from the visual field (the degrees of vision that lie to either side of a fixation). Each saccade provides some information within two to five degrees of vision (the fovea and parafovea), but beyond that, little is seen. In this way, reading proceeds through a focus on bits and pieces of the most important information separated by visual blurs when further information is not needed because it's being inferred or constructed.

Eye movement studies have shown that fixations typically last for about 200–250 milliseconds. Some percentage of saccades are regressions, when the reader moves her eyes back to an earlier point on the line or elsewhere in the text, usually because something isn't making sense (Rayner). The length and frequency of fixations are affected by the difficulty of the text, the nature of the lexis (long words get more frequent fixations), and the relationship of the reader's background knowledge to what the text is providing. Fast readers make longer saccades, shorter fixations, and fewer regressions than slow readers (Everatt, Bradshaw, and Hibbard; Everatt and Underwood; Underwood, Hubbard, and Wilkinson), but "fast" and "slow" are also a function of the text's difficulty (Jacobsen and Dodwell; Rayner and Pollatsek).

An especially interesting phenomenon is how quickly readers make decisions about what to look at and what to skip in the text.

An especially interesting phenomenon is how quickly readers make decisions about what to look at and what to skip in the text—a reflection of their cognitive processing (Pollatsek and Rayner; Pynte). Many elements of discourse contribute to these decisions. For example, imagine reading an article about beavers titled "Little Men of the Woods." The first line of the text reads, "Native Americans called beavers 'little men of the woods.'" Every time the text repeats this phrase (as in "These 'little men of the woods' are busy much of the time"), we are likely to make a substantial saccade over the entire phrase to the next important piece of information. Typically skipped text includes the ends of common phrases such as "as a matter of fact," patterns such as "nine or ten," words not needed to construct the full syntactic elements of sentences, material that can easily be inferred from context, and, in academic writing, periphera such as parenthetical scholarly references. The nature of the relationship between what must be seen in the text and what can be inferred or provided by the reader has been the subject of much debate, especially in the context of reading instruction (see Kim). But there is little question that reading is a constructivist process and that fluent readers jump over surprising amounts of text as they read (Just and Carpenter).

Broadening the Focus: Studies of Writing and Learning to Write

Until recently, eye-tracking technology has not been used extensively in the field of rhetoric and composition. Two studies in the United States bear mention, however. In the first, Paulson, Alexander, and Armstrong were interested in the relationship between what students pay attention to when reading peers' papers and what they subsequently recommend to those peers for revision. Eye-tracking data provided an effective way to begin answering questions about these hard-to-measure behaviors. Using an Applied Science Laboratories Model 504 eye tracker in front of a computer, the researchers recorded the eye movements of seventeen student subjects who read the introduction of a paper written in response to a typical composition assignment. Subjects were given a set of prompts (such as "What advice would you give the author to help him or her improve the introduction?") to focus them on salient aspects of the text in an effort to promote effective revision. After each subject had read the essay introduction, one of the researchers engaged the subject in a discussion, using the four response questions as a guide, to collect the subject's impressions of the text and suggestions for the paper's author. As might be expected, subjects fixated more often and for longer periods of time on the ten sentence-level errors in the text. However, in the discussion period, they tended to talk in generalizations about these errors ("I'd tell them to look at their spelling and punctuation") or not at all (318). Other mismatches also occurred at more global levels between what the subjects looked at and how they responded. The researchers conclude in part that "students are tentative about offering commentary, frequently doubting their ability to provide feedback about the essay despite the fact that eye-movement analysis demonstrates that students clearly identified areas of the text rich with feedback opportunities" (326). These mismatches, revealed by the eye-tracking data, suggested to the researchers several implications for helping to prepare students for peer response activities, including questions about whether moving from holistic to editorial concerns is always the best way for students to critique each other's writing if they are first most affected by—if not consciously aware of—the presence of surface errors. It also provides the beginning of empirical evidence for the need to teach metacognitive strategies—for students to be able to understand and articulate what the eye-movement data show they are actually experiencing. Here, the eye-tracking data help to answer questions about behaviors or cognitive constructs—such as the question "What do students (or other critical readers) notice as they

Until recently, eye-tracking technology has not been used extensively in the field of rhetoric and composition.

read?"—that are likely to be more precise and persuasive than those provided by retrospective account or even protocol analysis, which may be limited by memory or the ability of participants to articulate their reactions or decisions.

The nature of error was the focus of another eye-tracking study designed to explore the effects of certain errors on readers in order to derive principles for writing instruction (Anson, Schwegler, and Horn). In this pilot study, the authors wanted to find out whether the errors commonly made in first-year college writing courses are uniformly noticed by readers and for how long. In a 2X2 design, four subjects read two different texts, one focusing on domesticated cats and one on Hong Kong Disneyland. These two texts were manipulated so that one version contained six errors determined to be among the most frequently noticed by teachers (using Anson and Schwegler's research cross-mapped with that of Connors and Lunsford). Each subject read two different texts (Cats or Disney), one with errors and one without. Errors were placed in similar sentences and in similar locations in both texts. Eye-tracking data showed that in both texts, certain errors had far more dramatic effects on readers' processing and comprehension than others, some of which had almost no effects. The analysis suggested that in contrast to instructional approaches in composition courses that treat all errors the same, it is possible to create a hierarchy of error types based on the severity with which they disrupt the reading process. Such a hierarchy could significantly improve instruction both in the way that students are taught to recognize and avoid error and in the relative emphasis placed on certain errors. The conclusions also have important implications for teachers' response and evaluation practices, in which "error hunting" in students' work can unnaturally replace teachers' usual reading processes.

This study also produced data that call into question some foundational assumptions of writing instruction, particularly definitions of errors as grammatical categories, which are taken for granted in studies like those of Connors and Lunsford. Participants encountering a sentence fragment without a subject paused in their reading after the first few words of the sentence, at the point where a subject might be expected, and searched through prior text, presumably looking for a potential subject. Instead of using broad categorical and metacognitive knowledge (such as "this is a sentence fragment") to repair their reading, it appears that they began a compensatory move based on syntactic experience—a finding similar to what Paulson, Alexander, and Armstrong found in students' *experiences* encountering error and their highly generalized *advice* to their peer writers. While some students may be trained to use concepts like "fragment" in certain kinds of explicit textual analysis, it appears

that such generalizations are less useful in helping students to recognize error than attention to specific sentence patterns that may derail reading, as Anson ("Response") has noted in distinguishing between the "processing" effects of error and those effects that have other sources. Indeed, eye-tracking data may be particularly useful in calling into question long-held assumptions based on lore or textual analysis, and in determining what kinds of metacognitive knowledge are important and what aren't.

Currently, some researchers in educational psychology have taken up eye tracking to learn more about writing behaviors from a cognitive perspective. Hacker and colleagues, for example, have developed a system called "Traktext" that presents writers with several windows onscreen, some containing texts and one containing a word-processing program in which the writer composes his or her original text (Hacker, Keener, and Hirscher). In this way, the writer can freely navigate among windows depending on the nature and demands of the task. Traktext provides a record of everything the writer/reader produces, deletes, or edits (sampled at sixty times per second), along with the amount of time the subject spends at each moment reading, writing, or pausing on any of the multiple screens. Unique to eye tracking is the researchers' analysis of pupil dilation—greater cognitive demands lead to greater dilation, which provides additional insight into moments when the writer is working harder to create or interpret text. In their investigations with this system, Hacker, Keener, and Hirscher have refined our knowledge of the role of metacognition in composing, proposing six distinct processes, some of them control processes and some of them monitoring processes. Advancing earlier models such as that of Flower and Hayes, whose methodology was unable to describe as precisely how writers use a "monitor" to control component processes while writing, the chief contribution of this research is to reconceptualize writing "as primarily applied metacognition in which the production of text is the production of meaning that results from a person's goal-directed monitoring and control of their cognitive and affective states. . . . Online monitoring of writing behaviors reveals rapid and erratic changes from one writing process to another, with variable time courses and fluctuations in cognitive effort" (170). Although Hacker, Keener, and Hirscher offer no implications for instruction, this line of research clearly promises to inform how we teach people to write, including especially what processes must be brought into conscious awareness and how they must be manipulated and deployed while writing.

Currently, some researchers in educational psychology have taken up eye tracking to learn more about writing behaviors from a cognitive perspective.

The orientation of this research is similar to the emerging European interest in the study of writing using eye-tracking technology, especially paired with keystroke logging (records of every keystroke made by a writer; see Leijten and Van Waes for a helpful overview and rationale). This research had its impetus in critiques of previous methodologies whose data were confounded by variables such as subjects' memory limitations or the need to code masses of observational data. As Leijten and Van Waes put it, thanks to eye tracking "it is now possible to collect detailed temporal data that also tell us 'what' writers are reading or looking at during pauses, and how their visual behavior relates to other processes of text production" (6). The aim of this research is to create more sophisticated and accurate models of composing that can improve instruction.

Over the past several years, this interest has yielded a number of conference papers as well as the establishment of an eye-tracking and keystroke-logging training institute at the University of Antwerp. Yet European researchers Torrance and Wengelin note that with the exception of two methods-focused papers, they know of "no journal-published literature exploring where writers look in the text that they are composing," in contrast to the extensive literature on reading. In one of those two existing articles, Alamargot, Chesnet, Dansac, and Ros describe a new device for creating a synchronous recording of eye and hand movements during written composition, which can more precisely map the relationship between the writer's text production and what he or she reads or rescans while writing. This "eye/pen" system is especially useful for studying young children's writing because they are less likely than adults to write on computers. In the second article, Wengelin and colleagues describe two devices, "ScriptLog+ TimeLine" and "EyeWrite," that both collect and analyze eye movements along with logs of keystrokes to "inform understanding of the cognitive processes that underlie written text production" (339).

In their own eye-movement and keystroke-logging research, Torrance and Wengelin point out that during composing, writers' eyes behave differently than when they read because "the text that the writer's eyes move across develops as the task proceeds" (395). Writers' eye movements onscreen are complicated by other factors such as line wrapping and scrolling, which change the location of words on the screen. Using combined keystroke logging and eye tracking, Torrance and Wengelin have identified two kinds of eye activity associated with different cognitive functions: those concurrent with typing (for example, focusing on a word as it's being typed), and those that occur during pauses in composing. Each of these activities can also be classified as "local" or "distant," referring to how close the eyes are to the text being produced. The majority

of subjects in their studies focus on or near the word being produced, while a small percentage frequently look elsewhere (for several possible reasons). In addition, over half of their subjects were "keyboard" composers, meaning that they fixated on their keyboards for much of their composing time, probably because they lacked sufficient typing skills, while the rest were "monitor gazers," focusing on the screen without looking at their keyboards. From their studies, Torrance and Wengelin suggest various hypotheses about the role of visual feedback during writing, the effect of mistyped words, and the nature of fixations during pauses. When such studies compare the processes of novice and expert writers, we can begin to translate the results into potential teaching methods that themselves can lead to additional classroom-based research.

This and other European studies using eye tracking published in edited collections (e.g., Andersson et al.; Wengelin et al.) follow a tradition of highly experimental, cognitively oriented research popular in North America in the 1970s and 1980s. During that period, numerous studies used methods that explore what writers do, say they do, or remember doing while composing, partly in an attempt to create new models that could inform and improve instruction. At the time, these methods offered the only windows into the thinking process of the writer beside the emerging text and revealed complex planning processes at various levels of discourse, including ways in which potential audiences or purposes influenced linguistic and rhetorical decisions. Other studies compared records of novice and experienced writers' text production or used discourse-based interviews (in which writers are asked to consider alterations to their texts and explain why they would or would not make them; see Odell, Goswami, and Herrington) to unearth the writer's often tacit decision-making processes as they composed.

Beginning in the 1990s, the social turn in composition studies and a growing aversion to principles of behaviorism and empiricism may partly explain why U.S. scholars diverged from these lines of inquiry, and why they have not taken up eye-tracking methodology to further our understanding of discourse processes (see Charney; Fulkerson). As this kind of research began to decline, composition researchers were still far from a complete understanding of the cognitive dimensions of writing, and it is these gaps that the European researchers seek to fill. Acknowledging the robust history of process research but pointing to the highly technologized contexts in which writing now takes place, they convincingly argue that "although the general characteristics and cognitive activities that underlie writing are fundamentally the same as in earlier years, these [new digital] contexts create new challenges and certainly

also new opportunities for writing researchers to investigate online writing" (Leijten and Van Waes, 3).

Meanwhile, recent calls in the North American composition community for an increase in data-driven research (Anson, "Intelligent"; Haswell) and an interest in bringing together qualitative and quantitative studies suggest that eye tracking and other technologically driven data-collection methods such as keystroke logging could be increasingly used to study a range of writing, reading, and screen-based processes. Such research does not ignore the social, cultural, and contextual dimensions of writing but supplements and enhances them. As Hacker, Keener, and Hirscher put it, "The very symbols that are used to express ideas, the manner in which the symbols are arranged, and the ways those symbols are interpreted by the writer and reader are socially, culturally, and historically bound. These aspects of writing cannot be ignored. But we also cannot ignore that there is a mind/brain that stores, manipulates, and uses the symbols for oneself or makes them available for others to use. . . . The problem that remains from earlier paradigms is that writing theories have not convincingly described how component processes are coordinated under the direction of a monitor" (170).

The dramatically growing use of computer technology in every part of the educational system starting in the elementary grades has created a need to know much more about what students do when they look at and interact with screens. This activity includes reading, scanning, selecting, and focusing on a range of textual information, still and moving images, and elements of the screen used to control what is seen next.

The dramatically growing use of computer technology in every part of the educational system starting in the elementary grades has created a need to know much more about what students do when they look at and interact with screens. This activity includes reading, scanning, selecting, and focusing on a range of textual information, still and moving images, and elements of the screen used to control what is seen next. Currently, eye tracking is being used to study the ways in which learners process some of that visual and textual information in textbooks and in e-learning environments involving multimedia presentations. Wiebe and Annetta, for example, argue that eye tracking "can be particularly useful for two broad areas of application: 1) general research understanding of how different types of students in different learning situations make use of text and graphics, and 2) applied usability research of instructional materials that will be going into publication for large numbers of students. . . . As in most applied research, eye tracking should be one of many tools the instructional researcher uses to help better understand how a learner

acquires and processes visual information" (Wiebe and Annetta). Wiebe and colleagues' ongoing research includes studying the effects of narration on students' learning from printed text and graphics on PowerPoint presentations, and comparisons of simple two-dimensional and complex three-dimensional graphic representations of DNA in biology instruction (Patrick, Carter, and Wiebe; Slykhuis, Annetta, and Wiebe).

The Future of Eye-Tracking Research

Findings from the few published studies of eye tracking in composition research and the growing interest in screen-based learning and interaction suggest that this methodology holds much promise for further investigations of discourse processes. We see the need for continued study of these processes across a range of task domains, contexts (educational, work, and social or personal), genres, and purposes. We turn, then, to a brief discussion of just a few potential areas of study.

Much scholarship in composition studies has focused on the sources, nature, and evaluation of error in students' writing (Connors and Lunsford; Lunsford and Lunsford; Anson, "Response"; Kroll and Schafer). But aside from survey research (Hairston; Beason) and studies of teachers' correction practices, there has been little investigation of what happens when teachers encounter error in students' writing. Anson, Schwegler, and Horn recruited general readers in their study of the effects of six common errors on reading. Research focusing on various groups of teachers could provide much more insight into the complex processes at work in response to and evaluation of students' writing, both of actual student texts and of texts manipulated to control for kinds and presence of errors relative to other features. Comparisons of what teachers do when they read material such as newspapers or academic articles with what they do when they read student texts could provide insight into the ways that instructional contexts and ideologies influence teachers' practices. The study of these practices in writing courses could be extended to other disciplines in an effort to enhance cross-curricular faculty development and consultation. Such research could also inform large-scale assessment practices, which have been criticized for focusing only on certain aspects of

Research focusing on various groups of teachers could provide much more insight into the complex processes at work in response to and evaluation of students' writing, both of actual student texts and of texts manipulated to control for kinds and presence of errors relative to other features.

texts such as organization and for being subject to the tacit influence of raters by features such as lexis.

Another unexplored area of research in composition focusing on surface features of texts concerns students' recognition of error. At present, we know almost nothing about the relationship between students' abilities to discern error in others' writing and their ability to control or avoid error in their own writing. Unlike methodologies that intrude on students' normal reading and writing processes (for example, by giving them an error-identification task), eye tracking allows students to do what they usually do when reading or writing texts. The data could show us whether and for how long students fixate on words or sentences that contain errors in their own writing and others' writing. A fuller understanding of these phenomena could lead to refinements in our current models of error (and of teaching error), and a fuller understanding of the intellectual processes involved in error detection. Such studies could be expanded into the domains of style, lexis, and syntax, and among different cohorts of students such as ELL (English language learners) writers and those who bring a variety of home and community dialects into academic settings.

Currently, we also know little about what students do when they read texts in progress and published texts—whether, for example, they behave differently knowing that one kind of text is in need of further revision and editing while the other, presumably, is not.

Currently, we also know little about what students do when they read texts in progress and published texts—whether, for example, they behave differently knowing that one kind of text is in need of further revision and editing while the other, presumably, is not. Eye tracking can give us precise information about what students are doing when they read such texts. Paulson, Alexander, and Armstrong's innovative study just scratches the surface of what we might learn about peer response and revision using the kind of precise data that eye trackers provide. For example, areas of students' own texts that they focus on while thinking about possible revisions could be compared with what other students focus on in preparation for peer response. Or data from novice writers' rescanning of their papers could be compared with that of experienced writers, resulting in a matrix of text features associated with effective revision. In addition, further work on composing processes can extend existing research on the relationship between the words writers produce in real time (through keystroke logging) and what they are looking at as they produce these words (see Alamargot, Chesnet, Dansa, and Ros; Holmqvist, Holsanova, Johansson, and Strömqvist).

Recently, a continuously expanding study known as the "Citation Project" has been exploring what students do when they locate, study, and incorporate scholarly material into their research papers (see, for example, Howard, Rodrique, and Service; Howard; Jamieson). Much of the research associated with this project has relied on text analysis rather than the actual processes students use to complete their work. However, paired with screen capture technologies, eye tracking can show us how students access sources during research and how they use those sources in their own writing, considerably expanding the important findings of the Citation Project. Eye tracking may reveal the processes students use to read and examine source work and what they do with that material in their own writing, offering possible contrasts among expert and novice practice. Such studies could prove especially valuable in understanding what happens in the temporal spaces between students' reading of source material and their incorporation of that material (through paraphrase, summary, direct quotation, "patchwriting," or cutting and pasting) into their own emerging texts. In turn, these new insights could have important implications for how we prepare students to conduct secondary research or distill outside sources and incorporate them into their own writing.

Fixed eye trackers can give us very precise records of everything students do as they work and write on computer screens, including the ways they move between their emerging texts and other material onscreen, such as database search engines and scholarly sources.

Related to questions about how students use external source material in their own writing is what they do when they consult reference materials to revise, edit, and proofread their academic papers. Students are constantly admonished to avoid error by reading sections in handbooks or to revise and edit their papers with the advice in writing guides. Yet we know of no studies that systematically examine the processes students use to consult handbooks or other references while writing academic papers, what they pay attention to, and what works most effectively to help them understand the material they are consulting (in terms of layout and design features) and deploy it effectively in their texts. Fixed eye trackers can give us very precise records of everything students do as they work and write on computer screens, including the ways they move between their emerging texts and other material onscreen, such as database search engines and scholarly sources. Mobile eye trackers can do the same when students move between a screen and other print tools and resources such as handbooks, dictionaries, and their own handwritten notes.

Finally, current interest in both the production and reception of genre has raised many new questions about the knowledge students bring to their writing and reading and the extent to which prior experience with genres "transfers" into new experiences (see Bawarshi and Reiff, especially chapter 7). As a textual construct, genre has historically referred to regularized patterns of discourse replicated within and across contexts and internalized through experience. As a newer sociocultural construct, it refers to ever-shifting forms of discourse that emerge from, are shaped by, and are appropriated among various communities. Bazerman describes the methodological challenge of studying genre as trying to make sense of "the complexity, indeterminacy, and contextual multiplicity that a text presents us with" (Bazerman 321). In this context, eye tracking can supplement existing methods of observation, interview, and textual analysis. For example, we can know much more precisely how students read familiar and unfamiliar genres, and we can chart differences in the way they read those genres over time, determining the extent to which familiarity with certain textual and discursive features changes their behaviors. Data from these reading experiences can then be mapped on to students' composing processes to study the effects (and transfer) of genre experience on discourse production as a function of eye-tracked decisions as well as whether students look at reading material to model features of the genre they are producing. Such analyses could begin answering challenging questions about instruction, such as whether explicit genre teaching helps students to write texts that are appropriate to a genre and whether modeling, through exposure to texts, is a useful way to build knowledge that transfers into text production.

As we have suggested, a number of unanswered questions in writing studies can be profitably investigated using eye-tracking technology, whether by itself or combined with other methods. As the technology continues to become less expensive, more sophisticated, and more portable, it will lend itself to wider use and more innovative applications than those we have sketched here, and it promises to bring together interests in the cognitive, social/contextual, spatial, linguistic, and digital dimensions of written literacy.

Works Cited

Alamargot, Denis, David Chesnet, Christophe Dansac, and Christine Ros. "Eye and Pen: A New Device to Study Reading during Writing." *Behavior Research Methods, Instruments and Computers* 38.2 (2006): 287–99. Print.

Andersson, Bodil, Johan Dahl, Kenneth Holmqvist, Jana Holsanova, Victoria

Johansson, Henrik Karlsson, Sven Strömqvist, Sylvia Tufvesson, and Åsa Wengelin. "Combining Keystroke Logging with Eye Tracking." *Writing and Digital Media*. Ed. Luuk van Waes, Mariëlle Leijten, and Chris Neuwirth. North Holland: Elsevier, 2006. 166–72. Print.

Anson, Chris M. "The Intelligent Design of Writing Programs: Reliance on Belief or a Future of Evidence." *WPA: Writing Program Administration* 32.1 (2008): 11–36. Print.

———. "Response and the Social Construction of Error." *Assessing Writing* 7 (2000): 5–21. Print.

Anson, Chris M., and Robert A. Schwegler. *Instructors' Responses to Error: Identification, Clarity, and Emotional Reaction*. Unpublished Ms.

Anson, Chris M., Robert A. Schwegler, and Susan Rashid Horn. "The Promise of Eye-Tracking Methodology for Research on Writing and Reading." *Open Words: Access and English Studies* 3.1 (2009): 5–28. Print.

Bawarshi, Anis S., and Mary Jo Reiff. *Genre: An Introduction to History, Theory, Research, and Pedagogy*. West Lafayette: Parlor P, 2010. Print.

Bazerman, Charles. "Genre and Cognitive Development: Beyond Writing to Learn." *Genre in a Changing World*. Ed. Charles Bazerman, A. Bonini, and Deborah Figueiredo. Fort Collins: WAC Clearinghouse and Parlor P, 2009. 283–98. Print.

Beason, Larry. "Ethos and Error: How Business People React to Errors." *College Composition and Communication* 53.1 (2001): 33–64. Print.

Campana, Arturo, Alessandro Duci, Orsola Gambini, and Silvio Scarone. "An Artificial Neural Network That Uses Eye-Tracking Performance to Identify Patients with Schizophrenia. *Schizophrenia Bulletin* 24 (1999): 789–99. Web. 8 Jan. 2012.

Chapman, J. E. "Use of an Eye-Operated Computer System in Locked-in Syndrome." *Proceedings of the Sixth Annual International Conference on Technology and Persons with Disabilities*. Los Angeles, 1991. Print.

Charney, Davida. "Empiricism Is Not a Four-Letter Word." *College Composition and Communication* 47.4 (1996): 567–93. Print.

Cohen, A. S. "Informationsaufnahme beim Befahren von Kurven [Absorbing Information When Driving on Curves]." *Bulletin der Schweizerischen Stiftung für Angewandte Psychologie* [*Bulletin of the Swiss Foundation for Applied Psychology*] 2 (1983). Web. 8 Sept. 2011.

Connors, Robert J., and Andrea A. Lunsford. "Frequency of Formal Errors in Current College Writing, or Ma and Pa Kettle Do Research." *College Composition and Communication* 39 (1988): 395–409. Print.

Cowley, Jennifer A. "Eye Movements between Text and Warnings in Product Owner's Manuals." M.S. thesis, North Carolina State University, 2009. Print.

Duchowski, Andrew T. *Eye Tracking Methodology: Theory and Practice*. London: Springer, 2003. Print.

Engineering Systems Technologies. "Mobile Eye." N.d. Web.

Everatt, John, Mark F. Bradshaw, and Paul B. Hibbard. "Individual Differences in Reading and Eye Movement Control." *Eye Guidance in Reading, Driving and Scene Perception*. Ed. Geoffrey Underwood. Oxford: Elsevier, 1998. 223–42. Print.

Everatt, John, and Geoffrey Underwood. "Individual Differences in Reading Subprocesses: Relationships between Reading Ability, Lexical Access, and Eye Movement Control. *Language and Speech* 37 (1994): 283–97. Print.

Flower, Linda, and John R. Hayes. "The Dynamics of Composing: Making Plans and Juggling Constraints." *Cognitive Processes in Writing*. Ed. Lee W. Gregg and Erwin R. Steinberg. Hillsdale: Erlbaum, 1980. 31–50. Print.

Fulkerson, Richard. "Composition at the Turn of the Twenty-First Century." *College Composition and Communication* 56 (2005): 654–87. Print.

Hacker, Douglas J., Matt C. Keener, and John C. Hirscher. "Writing in Applied Metacognition." *Handbook of Metacognition in Education*. Ed. Douglas J. Hacker, John Dunlosky, and Arthur C. Graesser. New York: Taylor and Francis, 2009. 154–72. Print.

Hairston, Maxine. "Not All Errors Are Created Equal: Nonacademic Readers in the Professions Respond to Lapses in Usage." *College English* 43 (1981): 794–806. Print.

Haswell, Richard. "NCTE/CCCC's Recent War on Scholarship." *Written Communication* 22 (2005): 198–223. Print.

Holmqvist, Kenneth, Jana Holsanova, Victoria Johansson, and Sven Strömqvist. "Perceiving and Producing the Frog Story." *Perspectives on Language and Language Development*. Ed. Dorit Diskin Ravid, Hava Bat-Zeev Shyldkrot, and Ruth Aronson Berman. Dordrecht: Kluwer, 2006. 289–302. Print.

Howard, Rebecca Moore. "Pedagogical Causes and Rhetorical Consequences of Students' Source Choices." 63rd Annual Convention of the Conference on College Composition and Communication. St. Louis, 23 Mar. 2012. Presentation.

Howard, Rebecca Moore, Tanya K. Rodrigue, and Tricia C. Serviss. "Writing from Sources, Writing from Sentences." *Writing and Pedagogy* 2.2 (2010): 177–92. Print.

Jacobson, J. Zachary, and Peter C. Dodwell. "Saccadic Eye Movements during Reading." *Brain and Language* 8.3 (1979): 303–14. Print.

Jamieson, Sandra. "Statistical Analysis of Students' Source Choices." 63rd Annual Convention of the Conference on College Composition and Communication. St. Louis, 23 Mar. 2012. Presentation.

Jepson, Kevin. "CU Uses Eye Tracking Studies to Create More User-Friendly Website." *Credit Union Journal*, Nov. 2006. Web. Sept. 8, 2011.

Just, Marcel A., and Patricia A. Carpenter. *The Psychology of Reading and Language Comprehension*. Newton: Allyn & Bacon, 1987. Print.

Kim, James S. "Research and the Reading Wars." *Phi Delta Kappan* 89 (2008): 372–75. Web. 8 Sept. 2011.

Kroll, Barry M., and John C. Schafer. "Error Analysis and the Teaching of Composition." *College Composition and Communication* 29.3 (1978): 242–48. Print.

Leijten, Mariëlle, and Luuk Van Waes. "Inputlog: A Multimethod Approach Describing Cognitive Writing Processes Using Keystroke Logging." Unpublished MS. n.d. 5 Mar. 2012. Web.

Lunsford, Andrea A., and Karen J. Lunsford. "'Mistakes Are a Fact of Life': A National Comparative Study." *College Composition and Communication* 59.4 (2008): 781–806. Print.

Odell, Lee, Dixie Goswami, and Anne Herrington. "The Discourse-Based Interview: A Procedure for Exploring the Tacit Knowledge of Writers in Nonacademic Settings." *Research on Writing:*

Principles and Methods. Ed. Peter Mosenthal, Lynne Tamor, and Sean A. Walmsley. New York: Longman, 1983. 249–80. Print.

Patrick, M. D., Glenda Carter, and Eric N. Wiebe. "Visual Representations of DNA Replication: Middle Grades Students' Perceptions and Interpretations." *Journal of Science Education and Technology* 14 (2005): 353–65. Print.

Paulson, Eric J., Jonathan Alexander, and Sonya Armstrong. "Peer Review Reviewed: Investigating the Juxtaposition of Composition Students' Eye Movements and Peer-Review Processes." *Research in the Teaching of English* 41 (2007): 304–35. Print.

Pollatsek, Alexander, and Keith Rayner. "Eye Movements and Lexical Access in Reading." *Comprehension Processes in Reading*. Ed. David A. Balota, Giovanni B. Flores d'Arcais, and Keith Rayner. Hillsdale: Erlbaum, 1990. 143–63. Print.

Pynte, Joël. "Lexical Control of Within-Word Eye Movements." *Journal of Experimental Psychology: Human Perception and Performance* 22 (1996): 958–69. Print.

Rayner, Keith. "Eye Movements in Reading and Information Processing: 20 Years of Research." *Psychological Bulletin* 124.3 (1998): 372–422. Print.

Rayner, Keith, and Alexander Pollatsek. *The Psychology of Reading*. New York: Prentice-Hall, 1989. Print.

Slykhuis, David A., Leonard A. Annetta, and Eric N. Wiebe. "Eye-Tracking Students' Attention to PowerPoint Photographs in a Science Education Setting." *Journal of Science Education and Technology* 14 (2005): 509–20. Print.

Smith, Frank. *Understanding Reading: A Psycholinguistic Analysis of Reading and Learning to Read*. 6th ed. Mahwah: Erlbaum, 1996. Print.

Smith, Jason Matthew. "The Lying Game." *Continuum: The Magazine of the University of Utah* 15.4 (2006): n. pag. Web. 5 Mar. 2012.

Torrance, Mark, and Åsa Wengelin. "Writers' Eye Movements." *Traditions of Writing Research*. Ed. Charles Bazerman, et al. New York: Routledge, 2010. 394–405. Print.

Underwood, Geoffrey, Alison Hubbard, and Howard P. Wilkinson. "Eye Fixations Predict Reading Comprehension: The Relationships between Reading Skill, Reading Speed, and Visual Inspection." *Language and Speech* 33.1 (1990): 69–81. Print.

Wengelin, Åsa, Mark Torrance, Kenneth Holmqvist, Sol Simpson, David Galbraith, and Victoria Johansson. "Combined Eye-Tracking and Keystroke Logging Methods for Studying Cognitive Processes in Text Production." *Behavior Research Methods* 41.2 (2009): 337–51. Print.

Wiebe, Eric N., and Leonard A. Annetta. "Eye Tracking Methods for Improving Engineering Graphics Instruction." Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition. Washington, 2005. Web. 6 Jan. 2012.

Chris M. Anson

Chris M. Anson is University Distinguished Professor and director of the Campus Writing and Speaking Program at North Carolina State University. He has published widely in the field of composition studies, and is currently associate chair of CCCC.

Robert A. Schwegler

Robert A. Schwegler is professor in the Department of Writing and Rhetoric, Harrington School of Communication and Media, at the University of Rhode Island. He studies error, composition, and economics, and is coauthor of the *Longman Handbook for Writers and Readers*.