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The Promise of Eye-Tracking Methodology for Research on Writing and Reading

THE FIELD OF WRITTEN COMMUNICATION RESEARCH HAD ITS ORIGINS IN DIVERSE methodologies ranging from case studies to longitudinal investigations and ethnographies (see North), and has developed or adapted a number of unique data-collection techniques such as discourse-based interviews (Odell, Goswami, and Herrington), think-aloud protocols (Emig; Flower, Swarts, and Hayes; Hayes and Flower), and keystroke logging (Sullivan and Lindgren). However, over the past two decades, empirically-based studies—those Haswell characterizes as "replicable, aggregable, and data-supported" (201)—have declined in some of the central publications in the field (Anson, "The Intelligent"; Durst; Haswell; see also Juswik, et al.). The reasons for this decline are complex but appear to be related to the "social turn" in composition studies, which has "rejected quantification and any attempts to reach Truth about our business by scientific means, just as we long ago rejected 'truth' as derivable by deduction from unquestioned first principles. For us, 'truth' is rhetorical, dialectically constructed, and provisional" (Fulkerson 662).

We find this suspicion of empirical research methodologies problematic in a field as historically interdisciplinary and open to inquiry as written communication. First, many unexplored questions about writing and literacy processes can be studied using experimental and clinical methods which, while not always employed in naturalistic contexts, still give us data that have both foundational and heuristic value. Second, experimental research can supplement more contextually-rich investigations involving thick description (Geertz), or quantitative and qualitative methods can be triangulated within a research setting (see Charney; Jick). Third, emerging technologies now provide new means of empirical data collection and analysis that allow us to investigate a broader range of questions about the nature and acquisition of written literacy. Text-mining programs, for example, afford analysis of millions of possible patterns and correlations of features across a limitless number of texts in a matter of seconds—analyses that would take humans months or years to conduct. Other technologies that have been available for some time have now become refined enough, and reasonable enough in cost and convenience, to employ in new research on writing.

Computer-assisted eye tracking represents one such technology. Sophisticated eye-

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tracking devices can now capture the exact movements and resting points of humans' eyes as they read text or look at visually presented material. Although eye-tracking devices have been available for many years and have spawned large amounts of research in some areas, particularly reading processes (see Rayner, "Eye Movements [. . .] 20 Years"), they have rarely been used to study writing or the relationships between reading and writing.

In this essay, we focus on the possible uses of eye tracking as a methodology for research in composition. We will first describe what eye tracking has shown us about the processes of human reading. Next, we will demonstrate the potential of eye-tracking methodology for the study of language behaviors through a pilot study of readers' perceptions of written errors embedded in brief texts. Finally, we will suggest some implications for further research on textual processes using eye tracking, with special focus on needed work in the social construction and psycholinguistic effects of error in written texts.

Eye Tracking as a Method for Research on Reading and Writing Processes

It is beyond the scope of the present article to describe the history of eye tracking technology, which has included electro-oculography, scleral contact lenses and search coils, photo- and video-ocularity, and reflective devices (see Duchowski). Mediated by computer technology, today's eye-tracking equipment is highly sophisticated and precise. Most contemporary eye trackers use a video-based system that collects data by measuring movement in the cornea and pupil as a function of reflection. Infrared light is reflected via a mirror into one of the participant's eyes, 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—the gaze trail—and the number of fixations (or pauses in eye movement) that occur as the subject reads text or looks at visually presented material.

Eye tracking has been used to study a wide range of human perceptual processes (see Henderson and Ferreira). In an overview of eye tracking methodology, Andrew Duchowski devotes separate chapters to the adaptation of eye tracking technology to the study of advertising and marketing, neuroscience and psychology, industrial engineering and human factors research (e.g., studies of driving), and computer science. Eye tracking has also been used in disability research (Chapman), in diagnoses of schizophrenia (Campana, Duci, Gambini, and Scarone), and in usability studies (e.g., Web design; see Jepson). Increasingly, eye tracking is being used to study the ways in which learners process visual and textual information in textbooks and in e-learning environments involving multimedia presentations (see Patrick, Carter, and Wiebe; Slykhuis, Annetta, and Wiebe).

In the area of psycholinguistics and language processing, eye tracking has been underutilized in studies of written text production (but is now increasingly employed in some European research; see Alamargot, Chesnet, Dansac, and Ros; Anderson, et al.). In the United States, the only eye tracking study of which the authors are aware in the field of rhetoric and composition examined the relationship between what college students spent time looking at in drafts of their peers' papers and what they subsequently recommended for improvement (Paulson, Alexander, and Armstrong). However, for several decades an extensive body of research on reading processes using eye tracking technology has accumulated. The general results of this research are important to synthesize for purposes of both explaining the pilot study reported here and of suggesting new avenues for the use of this technology in the study of written discourse processes.

Although differing models of reading have been proposed based on close observation and readers' reported experiences, eye tracking has provided researchers with the most accurate pictures of fluent reading. When we read, we persistently make rapid, intermittent eye movements called *saccades*. Between the saccades, our eyes remain comparatively still—that is, they *fixate*—for about 1/4 of a second. During saccades, our eyes move so quickly that all we perceive is a blur. Our sensitivity to visual input is reduced during these quick eye movements, and we do not access any new information. This is called *saccadic suppression*. To maintain a text's coherence, our brains "fill in" information that our eyes skip; that is, although visual information is suppressed during saccades, lexical processing is not. We continue to feel *as if* our eyes have seen every word that our brains piece together into understandable sentences (see Rayner, "Eye Movements [. . .] 20 Years" 373).

When we look straight ahead, the visual field can be divided into three areas: the fovea, the parafovea, and the periphery. The fovea—the central two degrees of vision—has the best acuity. The parafovea extends five degrees to either side; here acuity is less good. The periphery, or the region beyond the parafovea, has the poorest acuity of all. When we read, we move our eyes to locate the fovea on that part of the text we want to see clearly. That central two degrees of focus allows us to see clearly six to eight letter spaces (Rayner, "Eye Movements [. . .] 20 Years" 374). However, the perceptual span for readers extends about 18 or 19 letter spaces beyond that and includes the part of our vision that is off fovea. This span of effective vision is asymmetric, depending on which language we are reading. Because English is read from left to right, we can see 14 or 15 letter spaces to the right of fixation, but only four letters to the left (Rayner, "Eye Movements [. . .] Processing " 82).

The characteristics of what we see in the parafovea or periphery influence whether we need to make a saccade to it in order to identify it. Sometimes we can identify words we see off fovea without having to look at them directly. Largely, this depends on the length of

the word, but we may also be able to identify a word without fixating on it if it occurs repeatedly in the text, if it is predictable from prior context, or if it is a function word (such as a conjunction or a preposition; see Rayner, "Eye Movements [. . .] 20 Years").

When we read English, our eye fixations last for about 200-250 ms (though we can access information during a much shorter fixation), and the mean saccade length is about eight letter spaces. Most words in a text are fixated during reading, but many are skipped over. As the number of letters in a word increases, the probability of fixating the word also increases. Words of eight letters or more are almost always fixated, sometimes more than once. A good place for the gaze to land on a word is about halfway between the beginning and the middle. If the gaze does not land there initially, a word may need to be refixated multiple times in order for processing to take place (Rayner, "Eye Movements [. . .] 20 Years" 386-387).

Although most saccades in reading English are made left to right, about ten to fifteen percent of saccades are *regressions*, that is, right to left—either along the same line, or back to previously read lines. Short, within-word regressive saccades may occur when the reader has made too long a forward saccade or is having difficulty processing the text. Longer regressions (more than 10 letters back, or even back to a previous line) occur because the reader did not understand something in the text (Rayner, "Eye Movements [. . .] 20 Years" 387).

Although average values can be assigned for fixation duration, saccade length, and frequency of regression, there is considerable variability among readers. For example, fast readers make shorter fixations, longer saccades, and fewer regressions than do slow readers (Everatt, Bradshaw, and Hibbard; Everatt and Underwood; Rayner, "Foveal"; Underwood, Hubbard, and Wilkinson). But regardless of the reader's skill, eye movements are influenced by textual variables. As the text becomes more conceptually difficult, fixation duration is prolonged, saccade length shortens, the frequency of regressions escalates, and the perceptual span shrinks (Jacobsen and Dodwell; Rayner and Pollatsek). These values, for example, are likely to be more pronounced for you at this moment than if you were reading a children's book or an article in a popular magazine, but they are likely to be less pronounced for you than for someone who knows little about scholarship on written communication and is unfamiliar with the kind of material published in this journal.

Eye movements are closely related to a reader's cognitive processing. Readers independently decide when and where to move their eyes depending on how easy or how difficult it is to process the word they have fixated (Pollatsek and Rayner; Pynte). Various language patterns also influence readers' decisions about when and where to fixate. For example, if we are reading a story about beavers and we learn that Native Americans called beavers "little men of the woods," every time we begin to encounter that phrase after initial-

ly reading it, we will make a saccade beyond the limits of the phrase because the information is redundant. The same is true of text within logical patterns ("nine or ten," "one hundred to two hundred), expressions ("as a matter of fact"), or information that we do not want or need (such as when we skip over several parenthetical references at the end of a line in a research article). The influence of such textual patterns and information, as well as other forms of prior syntactic, lexical, and world knowledge, has been the source of debate within the study of reading; but it is clear that this knowledge creates a process of reading in which we do not need to see every letter or word on a page; indeed, depending on the text, we may jump over a surprising amount of text that is supplied by our brains and not through our eyes (see Smith, *Reading Without*).

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Because of the close link between complex information processing and the position of the gaze, it is reasonable to deduce moment-to-moment cognitive processing by observing eye movements (Just and Carpenter; McConkie, et al.; Rayner, "Eye Movements [. . .] Developments; Rayner, Sereno, Morris, Schmauder, and Clifton). The mental operations involved in deriving meaning from a text determine our eye movements. If processing difficulty influences eye movement variables, therefore, it is important to understand what happens when error is present. Analyzing the eye movements of a person reading a text containing errors in grammar or punctuation could show us whether (or in what ways) the reading process is perturbed, and the relationship between the strength of that perturbation and the type or nature of the error causing it. Knowing more about these phenomena can help us to refine current models of error in written language production and reception, leading to innovations in pedagogy as well as the presentation of information about error in textbooks and other educational materials currently based on formalist grammar.

Testing the Methodology: A Pilot Study in the Perception of Written Error

Recent research on the nature and effects of error in student writing has used "secondary" methodologies from which conclusions can be derived only tentatively. Researchers have counted errors and instructor marking of errors (Connors and Lunsford), surveyed readers' attitudes towards errors (Hairston; Beason), and interviewed readers about their responses to

writing containing errors (Beason). While these methodologies may be appropriate for determining the average number of errors in student writing (Connors and Lunsford; Lunsford and Lunsford) or the image of a writer that readers create in response to errors in a text (Beason), the data they produce stand at a considerable distance from the cognitive processing of text. That errors have cognitive consequences is, however, the fundamental assumption of most error research. Connors and Lunsford, for example, accept Mina Shaughnessy's claim that errors are "unintentional and unprofitable intrusions upon the consciousness of the reader . . . . They demand energy without giving back any return in meaning" (Shaughnessy, qtd. in Connors and Lunsford, 396). And they assume that errors affect the processing of text: "Nevertheless, very few of us can deny that an outright comma splice, its/it's error, or misspelled common word distracts us" (396).

The speed at which readers process text falls within hundredths of seconds, making text processing a matter of what Anthony Giddens calls "practical consciousness," a level of activity between discursive consciousness and the unconscious (53). Because eye-trackers gather data in the millisecond range, they provide more direct evidence of text processing activities than do even talk-aloud protocols, which require mediation through verbalization, or interview and survey methodologies, which offer retrospective or generalized data (see Tomlinson). In contrast, our ongoing research provides evidence about how errors affect the process of reading. The evidence also suggests that the concept of "severity" of error, treated in a limited number of dimensions in much prior research (especially Connors and Lunsford; Hairston), is multifaceted and based on a number of factors, including the ways in which certain errors do or do not slow down or frustrate the processing of text relative to the reader's context and purposes for reading.

We see considerable potential in the use of eye tracking to identify visual responses to varied kinds of errors in written text, including grammatical, syntactic, punctuation, and usage errors. To illustrate this potential—and the broader potential of eye tracking in research on writing—we describe a pilot eye-tracking study involving a small group of subjects. The results of this study suggest plausible links between visual behaviors and both the psycholinguistic and social consequences of error in written texts. Such results can be useful not only in understanding the nature of error during the evaluation process but also in helping students to learn about error from something more than a traditional grammatical or remedial perspective.

Participants and Measuring Tool

A group of eight subjects at a large, research-extensive university were recruited for this study. All were well-educated and self-described skilled readers. All had at least some college

education, and three had at least some graduate school. Because of technical difficulties, one subject was dropped from the study.

The eye tracking system used in this study was an Applied Science Laboratory (ASL) eye tracker, model 504. The eye tracker collected data 60 times per second on the gaze direction of the left pupil relative to the computer screen. For the purposes of this study, we defined a fixation as lasting at least 200 ms and covering an area of 1.8 visual degrees.

Test Instrument

Six errors "most likely to confuse or irritate readers in the academic community" were selected from Anson and Schwegler's list and crosschecked with Connors and Lunsford's and with Hairston's lists: a status marker (subject/verb agreement); a serious error (fragment); two fairly serious errors (unclear pronoun reference and dangling modifier); a deviation (incorrect apostrophe); and a spelling error.

We excerpted a short article from *The New York Times* on Hong Kong Disneyland, a subject likely to fit into readers' general world knowledge, yet presenting some cognitive challenge. Next, we constructed a parallel text on a likewise common subject, cats, and determined an order in which the errors would be embedded in both texts (see Appendix A). We matched the *Cats* text as closely as possible to the *Disneyland* text in genre, sentence structure, style, grammar, lexis, and length. Each text was prepared in two ways: with and without error. Errors of the same type were placed at the same location in the error version of each text.

We created six multiple-choice comprehension questions relating to information in passages that appeared with and without errors (see Appendix B) in order to measure the possible consequences of error on comprehension. To avoid the confounding effects of text order as well as reading the same passage twice, we employed a two-by-two design; half the participants read an error-free text first, then the alternate error-laden text; the other half read an error-laden text first, then the alternate error-free text. In addition, we prepared a Likert-style adjective rating scale that asked readers to report their estimates of the author in terms derived from Beason's work: hasty to conscientious, uninformed to informed, poorly educated to well educated, and the like (see Appendix C).

Procedure

After providing demographic data, each participant donned the eye-tracking headset. Through trial gaze locations, an assistant calibrated the equipment to ensure it was capturing data precisely. The participant read one text onscreen and answered the multiple choice comprehension questions, then followed the same procedure for the second text. After completing the readings, the participant filled out the rating scale to provide evaluative responses about the authors of the selections. In addition, the eye-tracker produced two visual

records: a movie and a snapshot, both capturing eye movements in relationship to text. The movie showed the complete gaze trail in all its complexities, while the snapshot simplified the gaze trail information, indicating regressions as straight lines and identifying fixations of at least 200 ms.

Analysis

The eye-tracking records of each subject were analyzed independently. Each visual record captured on CD was slowed 32 times using Windows Movie Maker. This procedure enabled us, through multiple viewings of the records, to segment the data for analysis.[1] Results of the eye tracking analysis were then mapped against the results of the questionnaire and the authorial persona surveys.

Results

Effects of Errors on Reading. The data showed a positive correlation between the number of fixations per text and the length of those fixations. Those readers who had fewer fixations also had shorter fixations. Since more fixations meant longer fixations, an even stronger correlation existed between the number of fixations per text and elapsed reading time. All seven subjects made more fixations of longer duration in the error-laden texts than in the error-free texts, resulting in longer readings times when errors were present.

The gaze trails on the non-error texts revealed considerable difference among the normal or regular reading techniques of the subjects, but marked consistency within each subject's behavior. Some subjects read consistently in a linear fashion, left to right, along each line, regressing, most often, back along the lines. Others moved through the text in less linear ways, moving backwards and forwards, fixating on words or clusters of words, yet behaving consistently in this fashion.

The gaze trails for the error-laden texts revealed similar patterns. For example, readers demonstrated markedly different kinds of regression behaviors from each other in response to the errors, yet the regression patterns were consistently different from the reader's typical reading technique. In the case of each reader, therefore, we were able to identify behaviors in response to errors that deviated from the subject's usual reading technique and that we believe provide evidence of perturbation. Most importantly, in almost all cases, eye movements took on perturbed or deviant behaviors at the same points in the error texts: at the point of most, though not all, of the errors.

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1. In much of reading research, a fixation is defined as a pause of 200 ms. or more, but fixations can range anywhere from under 100 ms. to over 500 ms.; "readers typically acquire the visual information necessary for reading during the first 50-70 ms. of a fixation" (Rayner, "Eye Movements [. . .] 20 Years" 378). Thus, applications of this methodology can adjust fixation points to briefer durations in order to register more fixations for faster readers.

In addition to comparisons of the gaze trails (including fixations and regressions) of each subject while reading error-free and error-laden texts, this perturbation could be identified in the length of fixations on specific errors as a function of the subject's average fixation length. For example, Subject 5, who we will call "Lindsay," had an average fixation length (>200 ms.) of 318 ms. Her fixation length at the point of the sentence fragment in *Disney-error* was 946 ms., or approximately three times her normal fixation length. Other errors that also caused greater fixation length included the subject/verb error (706 ms.) and apostrophe (429 ms.). Yet for Lindsay, there was no discernible fixation on the pronoun or dangling modifier errors. Similarly, "Sarah" (Subject 7) had an average fixation length of 328 ms. In *Cats-error*, she fixated for 2330 ms. on the fragment and 766 ms. on the dangling modifier, but there were negligible fixations on the subject/verb agreement and spelling errors.

As illustrated in Table 1, activity around specific errors, as defined by longer fixations on or regressions to the site of the error, was consistently present for sentence fragment errors, dangling modifiers, and apostrophes in both error-laden texts. In contrast, only one subject's reading seems to have been affected by the spelling error or subject/verb agreement error in either text. The pronoun error shows more mixed results.

Table 1

Summary of Readers' Ocular Reactions to Error

Subject	Frag	S/V	Pron	Dang	Apos	Spel
1	✓		✓	✓	✓	
2	✓		✓	✓	✓	
3	✓				✓	
4	✓		✓	✓		
5	✓	✓			✓	
6	✓		✓	✓	✓	
7	✓			✓	✓	✓

One of the most important findings of this pilot study, then, concerned the relative effect of specific errors on subjects' reading. In spite of their usual parallel treatment in writing textbooks and classroom instruction, the errors embedded into the sample texts did not

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affect readers uniformly; rather, for this cohort of subjects, some errors appeared to be more egregious than others. If an error caused confusion in meaning or difficulty for linguistic processing, readers reacted at an ocular level. If an error was present in a text, but the reader had no trouble disambiguating meaning, or if it did not affect text processing, then there was no ocular interference. The passages containing the spelling error were apparently unambiguous to most readers, in spite of the fact that they were homophonous and could be misread phonologically (led/lead). The sentence fragment, on the other hand, caused marked interference that was observable in the gaze trails of all subjects.

Though we believe that the eye movements show evidence of perturbation in text processing, their absence in relation to a particular error does not mean that the error goes unnoticed. An error may have a negative effect on a reader's image of an author, for instance, without significant evidence of a disruption in the reading process.

Effects of Errors on Comprehension. Scores on the multiple choice comprehension measure were approximately the same. Readers of both versions of the *Disney* text answered all the questions correctly. Readers of both versions of *Cats* repeatedly missed three questions, those coincident with passages containing a fragment, a dangling modifier, and a spelling error in the *Cats—error* text. Because readers of *Cats—no error* had comprehension difficulties with the same passages, the errors probably had little or no relationship to the comprehension problems.

Effects of Errors on Writer's Persona. Readers of the error-laden texts gave more negative ratings on all but two items ("sarcastic/sincere" and "caring/uncaring") on the binary adjective scale, with particularly strong differences on the items "careless/careful" and "not a detail/detail person." Differences in the "sarcastic/sincere" item for *Cats* were negligible. *Disney-error* received a slightly higher rating on the "caring/uncaring" item, perhaps because it is not clear whether this item refers to the author's errors or attitude toward the subject. Although it is impossible to know what specific aspects of the texts influenced subjects' judgments about the writers, we believe that the correlation between eye-movement evidence of perturbation in the error-full texts and the stronger negative judgments of the writers of those texts suggest that processing difficulties or frustrations caused by error may contribute to readers' construction of or trust in the writer's ethos and abilities, a possibility that, through further confirming research, could validate a social-constructivist approach to error in classroom instruction and textbook presentation (see Anson, "Response").

Conclusion

Through the use of the eye tracker, this modest pilot study detected processing consequences related to errors. Readers exhibited different gaze trail patterns when reading texts with and without errors, took longer to read the error-laden texts as a consequence of making more (and longer) fixations and regressions, and judged authors' personas more negatively when errors were present than when they were absent. These specific findings suggest some general principles to be tested further through more robust eye-tracking studies with larger numbers of subjects.

- Reading time is generally longer for texts that contain errors than when these same texts error-free.
- Certain errors may cause more gaze disruption than others, although the reasons (syntactic, semantic, lexical, and the like) need further research.
- Perhaps because of the need or tendency to "repair" problems in text processes (resulting in longer fixations and more regressions), even serious errors may not necessarily affect recollection of content; the reader does not necessarily recall the content of an error-laden text any differently than s/he does the same text error-free.
- Readers are more likely to have a negative image of writers who produce error-laden texts, but this may depend on the types, nature, and frequency of the errors and their effects (causing processing difficulties, for example, as opposed to marking the writer as uninformed or unskilled).

Implications of Eye-Tracking for Error Research

Our pilot study suggests several fruitful extensions of eye-tracking methodology for the study of error perception and the social construction of error. First, it is likely that the perception of error is influenced by other textual and contextual factors, such as the writer's persona, the location and types of initial errors in the text, and the genre and physical location of the text itself (e.g., an Internet article vs. a printed chapter in a scholarly book). In the field of written communication, with a few exceptions, scholars of error have tended to view it monolithically or abstractly, disregarding the ways in which errors affect readers depending on other factors such as goals and contexts for reading. Using eye-tracking methodology, it is possible to compare the

"scholars of error have tended to view it monolithically or abstractly"

effects of specific errors on readers when they are reading "natural" texts for the purposes of learning something or being entertained with the effects of these same errors in student texts read by teachers for the purpose of response and/or evaluation.

Our pilot study showed that there is a varied relationship between the presence or absence of error and the reader's construction of the writer's persona and perception of ability. Yet we know almost nothing about the social effects of error—what readers *make* of error when they encounter it, how it affects the construction of broader discursive and rhetorical features such as the writer's ethos, and what role error plays in that construction relative to other variables such as word choice, sophistication of ideas, and the like. When paired with other methodologies such as discourse-based interviews or read-aloud protocols, eye tracking can show us the relationship between frustrations in processing (as measured by excessive fixations or backtracking) and the cumulative impressions readers create about the writer.

The pilot study also showed that certain kinds of errors appear to be responsible for more fixation/regression activity than others. This finding suggests that it may be possible to create an error hierarchy based on the severity of processing effects, effects on comprehension, effects on the construction of the writer's persona, or combinations of these—a hierarchy, that is, based not on what errors teachers mark on student papers or on what errors readers say bother them the most, but on the actual effects of errors on reading. But substantially more research is needed across a much wider range of readers, texts, and contexts in order to discover whether such a hierarchy is statistically possible to create. In addition, variations in the effects of error suggest the need to consider subject background more fully (education, literacy experience/ability, etc.).

The psycholinguistic effects of errors may also vary as a function of textual difficulty, reading role, context, and prior experience with error. The pilot study used simple, journalistic-style stories written at a general reading level for a broad, public audience. When subjects read far more difficult texts for which they may lack certain schemas, or texts that have highly complex syntax, do the resulting constraints on processing cause readers to overlook errors they might otherwise notice or be affected by in simpler texts? In addition to textual difficulty, are readers affected by their knowledge of the context in which a piece of writing appeared? This question is creatively illustrated in an essay by Joseph Williams titled "The Phenomenology of Error." Williams ensured that the final essay, published in *College Composition and Communication,* contained a number of grammatical and other errors. Because to its readers the article is, in Mary Louise Pratt's terms, "preselected"—that is, sanctioned by a complex editorial and publishing process—they are not expecting the errors (117-118). When this fact is disclosed at the end, they discover to their surprise that they overlooked the errors. If error recognition, measured by percentage of errors noticed, is more

prevalent when teachers read student work than when they read professional work, such results could call into question the relationship between pedagogical treatment of writing and how readers and writers behave beyond schooling. In addition, certain roles and "life themes" (Schank and Abelson)—broad schemas readers bring to all reading based on their occupations and interests—could explain variations in readers' responses to errors. English teachers might respond quite differently to the presence of error than lawyers or doctors, or these roles might influence the nature and degree of error recognition based on varying significances relating to broader professional concerns. In addition to such role-influenced behaviors, do individual readers bring idiosyncrasies to texts in the realm of error, perhaps hyper-noticing errors that are the most irksome to them? When accompanied by demographic and personal information from case studies, eye-tracking research can help us to explore these questions more fully across a range of populations.

In the realm of pedagogy, eye-tracking studies of error also hold promise for a much fuller understanding of teacher behavior. Extending the research methods of Paulson, Alexander, and Armstrong, researchers could use eye tracking to capture the effects of error on teachers reading student papers and then study the ways in which teachers communicate with the students—through marginal and end comments or other means—about their writing, focusing especially on how or whether they refer to the errors or their effects. Discourse-based interviews might also discover which of the errors consciously affected the teachers and which remained tacit.

Applications of Eye-Tracking Research in Composition

Based on the explorations described above, as well as the extensive existing research in other areas of language study, we believe that eye tracking holds much promise for further investigations of the relationships between reading and writing. That we could find only one study of writing in the United States that employed this research tool in rhetoric and composition is not surprising in the context of the social turn and a growing aversion, throughout the late 1980s and 1990s, to the assumptions of positivism, behaviorism, and empiricism (see Fulkerson). That this lone study has appeared so recently in one of the field's premier research journals also suggests to us a newly emerging paradigm that allows for the mixing of qualitative and quantitative inquiry, that recognizes the heuristic contributions of clinical and empirical research for broader and more contextually varied studies, and that values the principles of replication, aggregation, and support from data (Haswell) in the creation and mediation of knowledge in composition studies.

Beyond the study of error, eye tracking offers many further possibilities for research on the processes of written language production and reception. Paulson, Alexander, and Arm-

strong's interesting findings that students tend not to focus their oral responses on those features of their peers' texts that they most attended to bears replication and extended exploration. Eye tracking can give us precise information about what students are doing when they read both texts-in-progress and published texts. Such research could be especially useful in furthering our understanding of students' revision processes by revealing patterns in their rereading and rescanning of their own texts and then considering those patterns against specific changes at global and local levels in students' emerging drafts. 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 or digital capture of pen movements) and what they are looking at as they produce these words (through eye tracking; see Alamargot, Chesnet, Dansac, and Ross; Holmqvist, Holsanova, Johansson and Strömqvist).

In the area of writing from sources, eye tracking could be used to study the relationships between the processes students use to read and examine source work and what they do with that material in their own writing. Such research could contrast expert and novice practices in the integration of external material into one's own writing in order to create more effective pedagogies and interventions in the teaching of writing.

Finally, we envision the use of eye tracking in studies of reference materials, instructional guides, and the like. We know little about what students do, for example, when they consult a handbook or other resource in order to make a decision about an ongoing draft. What presentation of textbook material is most effective, based on examinations of students' reading processes and subsequent development of their writing? When students consult material in a handbook, what do they pay attention to? How easily do they process advice and information about language and writing in the materials created for the purpose of helping them improve their work, and what do they subsequently do with this information?

The use of eye tracking, alone or in combination with other research methods, may help us to explore these and many other as yet unanswered questions in the study of writing and reading. With the increasing sophistication of eye-tracking devices, their lowering costs and ease of use, and their potential to be paired with other data-gathering equipment or techniques, we believe that they hold much potential for continued scholarship in written composition.

Appendix A
Texts With and Without Errors

Disney Without Errors

Hong Kong Disneyland, the second Disney venture into Asia, is known to some in the theme park business as Disney Lite. At a little more than 300 acres, it's far smaller than Disney parks in the United States, Japan and France, with fewer of the elaborate signature rides.

But in one area, the Hong Kong park more than holds its own: its long lines.

In several weeks of trial runs leading up to the official opening last week, parkgoers complained of waits of over two hours for some attractions. One visitor said that in 12 hours at the park, he went on only four rides.

The first few weeks of operation are the worst time to visit any theme park, so many problems were no doubt attributable to the newness of the place and its employees.

Still, the waits led some Hong Kong Disney officials to urge Disney to reduce the planned number of daily customers, currently 30,000. Further, the delays sparked cultural complaints in Internet discussion groups. Some Hong Kong residents said that mainland Chinese visitors, who pushed and shoved because they were unaccustomed to orderly waiting, made the problems worse.

There are, in fact, cultural differences in how people behave while in line, according to social scientists and park designers. Those differences have even led to physical changes in so-called queuing areas at some parks.

Disney With Errors

Hong Kong Disneyland, the second Disney venture into Asia, is known to some in the theme park business as Disney Lite. At a little more than 300 acres, it's far smaller than Disney parks in the United States, Japan and France. **Containing fewer of the elaborate signature rides.**

But in one area, the Hong Kong park more than **hold** its own: its long lines.

In several weeks of trial runs leading up to the official opening last week, park employees observed people waiting in line over two hours for some attractions. Park employees said that in 12 hours at the park, **they** went on only four rides.

The first few weeks of operation are the worst time to visit any theme park, so many problems were no doubt attributable to the newness of the place and its employees.

Still, the waits led some Hong Kong Disney officials to urge Disney to reduce the planned number of daily customers, currently 30,000. Further, the delays sparked cultural complaints in Internet discussion groups. **Not accustomed to orderly waiting, Internet**

posts from Hong Kong residents said that mainland Chinese visitors pushed and shoved and made the problems worse.

There are, in fact, cultural differences in how people behave while in line, according to social **scientists'** and park designers. Those differences have even **lead** to physical changes in so-called queuing areas at some parks.

Cats Without Errors

The domesticated cat, a descendent of the African wildcat, is seen by some in the feline world as a miniature Simba. At no more than an armful, it's far smaller than its wild animal cousins in Africa, Asia and North America, but with practically all of the same genes.

But in one area, the domesticated cat more than outpaces its wild counterpart: its sociability.

In casual observations of barn cats spontaneously forming social groups, observers took note of females cooperating in rearing their young. An observer said that in one colony of barn cats, he often saw mothers nursing even unrelated kittens.

The first few weeks of a kitten's life are the most crucial in creating mutual trust, so many antisocial problems are no doubt attributable to lack of early interaction with humans or other cats. In fact, this point led scientists to test how long it would take kittens to approach a seated person from across a room, about eight feet away. Not surprisingly, results showed differences based on cats' early socialization. Scientists said that some kittens, which had not established friendly relations with human beings because they had not been handled till seven weeks old, made the trip more slowly than those socialized earlier.

There are, in fact, marked differences in how domestic cats become sociable while in their kittenhood, according to scientists and pet owners. Those differences have even led to practical changes in training cats by breeders.

Cats With Errors

The domesticated cat, a descendent of the African wildcat, is seen by some in the feline world as a miniature Simba. At no more than an armful, it's far smaller than its wild animal cousins in Africa, Asia and North America. **However, having practically all of the same genes.**

But in one area, the domesticated **cat** more than **outpace** its wild counterpart: its sociability.

In casual observations of barn cats spontaneously forming social groups, observers took note of females cooperating in rearing their young. Researchers said that in one set of observations, **they** often nursed even unrelated kittens.

The first few weeks of a kitten's life are the most crucial in creating mutual trust, so

many antisocial problems are no doubt attributable to lack of early interaction with humans or other cats. In fact, this point led scientists to test how long it would take kittens to approach a seated person from across a room, about eight feet away. Not surprisingly, results showed differences based on cats' early socialization. **Not having established friendly relations with human beings, scientists** said that kittens who had not been handled till seven weeks old made the trip more slowly than those socialized earlier.

There are, in fact, marked differences in how domestic cats become sociable while in their kittenhood, according to scientists' and pet owners. Those differences have even **lead** to practical changes in training cats by breeders.

Appendix B

Comprehension Questions

(Glossed to Type of Error at Site of Information)

Disney

Question 1 [fragment]

How many elaborate signature rides does Hong Kong Disney have compared to other Disney parks?

☐ More ☐ Fewer ☐ Same as

Question 2 [subj/verb agreement]

In what area does Hong Kong Disney hold its own?

☐ Lines ☐ Number of rides ☐ Types of attractions

Question 3 [unclear pronoun reference]

In 12 hours, how many rides did visitors go on?

☐ Only 4 ☐ More than 4 ☐ All of the rides

Question 4 [dangling modifier]

Who pushed and shoved because they were unaccustomed to orderly waiting?

☐ Mainland Chinese visitors ☐ Hong Kong residents ☐ New employees

Question 5 [incorrect apostrophe]

Who believes there are cultural differences in how people behave while they're in line?

☐ Social scientists ☐ People in queing areas ☐ Mainland Chinese visitors

Cats

Question 1 [fragment]

How many of the same genes does the domestic cat have compared to the African wildcat?

☐ Practically all ☐ All ☐ Not many

Question 2 [subj/verb agreement]

In what area does the domestic cat outpace its counterpart?

☐ Sociability ☐ Gene pool ☐ Rearing its young

Question 3 [unclear pronoun reference]

In one colony of barn cats, what did an observer see?

☐ Mothers nursing unrelated kittens

☐ Cats spontaneously forming social groups

☐ Mother cats rearing their young

Question 4 [dangling modifier]

Who established friendly relationships because they had been handled earlier?

☐ 7-week old kittens ☐ Kittens younger than 7 weeks ☐ Kittens older than 7 weeks

Question 5 [incorrect apostrophe]

Who believes there are marked differences in how domestic cats learn sociability while they're in kittenhood?

☐ Scientists ☐ Cat breaders ☐ Seated people in experiments

Appendix C
Author Rating Scale

How do you rate the writing ability of the author of *Disney*?

☐ Awful ☐ Not very good ☐ Average ☐ Good ☐ Great

How do you rate the writing ability of the author of *Cats*?

☐ Awful ☐ Not very good ☐ Average ☐ Good ☐ Great

Please rate the author of *Disney* on the following dimensions. Circle the appropriate number between the two words that best matches your impression of the author:

hasty	2	1	0	1	2	conscientious
careless	2	1	0	1	2	careful
uncaring	2	1	0	1	2	caring
uninformed	2	1	0	1	2	informed
faulty thinker	2	1	0	1	2	good thinker
not a detail person	2	1	0	1	2	a detail person
poor communicator	2	1	0	1	2	good communicator
poorly educated	2	1	0	1	2	well-educated
sarcastic	2	1	0	1	2	sincere

Please rate the author of *Cats* on the following dimensions. Circle the appropriate number between the two words that best matches your impression of the author:

hasty	2	1	0	1	2	conscientious
careless	2	1	0	1	2	careful
uncaring	2	1	0	1	2	caring
uninformed	2	1	0	1	2	informed
faulty thinker	2	1	0	1	2	good thinker
not a detail person	2	1	0	1	2	a detail person
poor communicator	2	1	0	1	2	good communicator
poorly educated	2	1	0	1	2	well-educated
sarcastic	2	1	0	1	2	sincere

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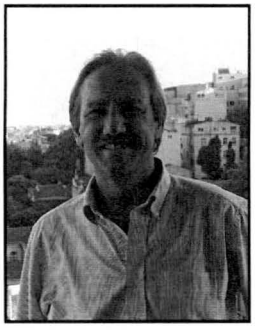

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