

Visual-Syntactic Text Formatting: A New Method to Enhance Online Reading

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Abstract

A new process, visual-syntactic text formatting (VSTF), transforms block-shaped text into cascading patterns that help readers identify grammatical structure. The new method integrates converging evidence from educational, visual, and cognitive research, and is made feasible through computer-executed algorithms and electronic displays. Among college readers, the VSTF method instantly increased reading comprehension and efficiency of reading online text, while reducing eyestrain. Among high school students, who read with the format over an entire academic year, the VSTF method increased both academic achievement and long-term reading proficiency by more than a full standard deviation over randomized controls.

Introduction

Over the past 30 years, the difficulty of text typically read in the workplace has increased by several grade levels ([Sum, 1999, online document](#); [Sum, Kirsch, & Taggart, 2002, online document](#)). Although more than 60% of U.S. jobs now require proficient reading skills ([Derouzos, 1997](#)), according to statistics related through the [National Center for Educational Statistics](#), the reading proficiency of U.S. high school graduates has not changed significantly over the past several decades. The gap between the proficiency level of workers and the difficulty of the material they need to read is wide and growing.

The nature of text is also changing. Digital text, and the ability to read it well, are a sine qua non for success in the global information economy. Over 60 million U.S. workers now spend more than two hours a day reading directly from a computer display (see, e.g., [Pew Internet & American Life Project, 2005, online document](#); [Regents of the University of California, 2003, online document](#)), and over 70% of college students prefer to conduct their research online, while only 9% prefer going to the library for paper-based publications ([Jones, 2002, online document](#)).

Fortunately, new tools and methods are available to enhance access to and use of digital information—for example, online dictionaries, audio guides to word pronunciation, and the ability to modify presentation of online text. Some webpages are also now being encoded with information to categorize and structure their information, with the goal of creating a “[semantic web](#)” that promises to give readers new power to access, organize, and analyze digital information.

However, when online readers encounter electronic documents that consist of complex expository writing, these tools are not sufficient to facilitate thorough comprehension. New and different digital tools are needed to help today’s readers comprehend this type of material. Visual-syntactic text formatting (VSTF) has been developed to improve reading comprehension of natural language presented digitally.

The VSTF process converts display of text such as this first sentence from the U.S. Declaration of Independence

When in the Course of human events, it becomes necessary for one people to dissolve the political bands which have connected them with another, and to assume among the powers of the earth, the separate and equal station to which the Laws of Nature and of Nature's God entitle them, a decent respect to the opinions of mankind requires that they should declare the causes which impel them to the separation.

into this:

**When in the Course
of human events,
it becomes necessary
for one people
to dissolve the political bands
which have
connected them with another,
and to assume
among the powers
of the earth,
the separate and equal station
to which
the Laws of Nature
and of Nature's God
entitle them,
a decent respect
to the opinions
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requires
that they
should declare the causes
which impel them
to the separation.**

To make these changes in display, the VSTF process exploits two key attributes of digital text. First, computer-executed algorithms can analyze the natural-language content of digital text—primarily syntactic structure, but also such variables as word difficulty and patterns of punctuation use—and then specify formatting patterns (e.g., line breaks and indentations) that optimize perception and linguistic processing of the content. Second, digital text, unlike printed text on paper, can be displayed in a variety of shapes, sizes, and colors with no or negligible increase in the cost of production.

The VSTF method aims to assist with both visual and syntactic processing in reading. Visually, it is known that the eyes can capture only a width of about 9 to 15 characters of text at each fixation ([Legge, Ahn, Klitz, & Luebker, 1997](#); see Figure 1).

Because of this small “soda straw” view, attentional processing is strained as readers try to direct their vision’s “attentional spotlight” across the page and down multiple rows of homogeneous block text ([Henderson & Ferreira, 1990](#)).

The VSTF method ameliorates this problem by

- Breaking text into shorter rows, (usually 8 to 30 characters across), that fit into one or two fixation eye spans
- Using varied indentation patterns that guide the eyes from row to row

Figure 1
The Reading Eye Span



The VSTF method also helps readers identify the syntactic structure of a sentence. Syntax is more complex than a simple, concatenated sequence of one phrase after another; rather, it is hierarchical, much like a set of Russian dolls in which smaller dolls, or phrase-groups, are “nested” inside ever-larger ones. The human mind’s capacity to build sentences through the recursive process of nesting language units inside other units is the essential feature that enables human language to represent an infinite number of meanings ([Hauser, Chomsky, & Fitch, 2002](#)). Therefore, when parsing natural language in written form, the reader’s mind must do more than simply “chunk” the sentence into a string of smaller units. Rather, the reader’s mind needs to determine how each phrase is nested inside larger phrase and clause structures, and how each nested phrase relates to the larger one containing it.

To assist readers with this complex cognitive task, the VSTF method uses algorithms that identify the most important phrase boundaries in a sentence, so that these boundaries are used first when breaking a sentence down into shorter segments. The algorithms include steps that conjugate verbs and identify in which category to place words from multiple possible parts of speech, based on the context of other words and phrases adjacent to it. The algorithms also use rules that cluster words and phrases into larger phrase groups, based on syntactic attributes of each word, with the rules specifying how words with different syntactic attributes may or may not be allowed to form clusters.

Because the spatial lengths of syntactic units can vary widely, the VSTF method integrates visual criteria with syntactic criteria at each step, and repeatedly parses longer segments into ever-shorter segments until the lengths of each segment fit into one or two visual fixation eye spans. As the VSTF method repeatedly examines newly formed segments, levels of syntactic hierarchies between phrases and clauses in the sentence are identified. The VSTF process then uses this hierarchical information to vary the relative horizontal displacement of each segment.

This cascaded-parsing pattern has been designed to enable the reader, when looking at a particular phrase, to perceive simultaneously the relative indentation of the phrases above and below it (Legge, Ahn, Klitz, & Luebker, 1997; [Pollatsek, Raney, La Gasse, & Rayner, 1993](#)). These combined visual and syntactic effects also enable the “mind’s eye” to build and examine a larger and more enduring visual image of the sentence while reading ([Bringuier, Chavave, Glaeser, & Fregnac, 1999](#); [Horowitz & Wolfe, 1998](#); [Vidvasagar & Pammer, 1999, online document](#)).

With the processing power of today's desktop computers, several thousand words (many pages of text) can be converted into the VSTF format within seconds. For professionally composed, expository English writing (e.g., technical and business communication), this software is consistently able to differentiate principal phrases and specify the hierarchical relations between phrases for most sentences. When writing is narrative, personal, or more stylized, phrase groups can still be identified, but clause structure extraction is more difficult; nevertheless, the software is still useful for writers, because it identifies ambiguous expressions and punctuation irregularities that conventional grammar checkers would miss and that the writer may want to address.

Evidence from Prior Research to Support Visual-Syntactic Text Formatting

Converging evidence suggests visual-syntactic text formatting can enhance reading. Readers can sometimes fail to understand a sentence, in particular one possessing a complex syntactic structure, even when they manage to decode all the words it contains ([RAND Reading Study Group, 2002, online document](#)). Although reader differences in working memory affect comprehension in a manner independent of word-decoding skill ([Daneman & Carpenter, 1980, 1983](#)), differences in syntactic processing skill also appear to be an independent factor for comprehension ([Nation & Snowling, 2000](#); [Stothard & Hulme, 1992](#)).

Better readers—children and adult—first gravitate toward the position in a sentence where the subject phrase separates from the subsequent predicate phrase, while poorer readers do not ([Fodor & Bever, 1965](#)). Syntactic awareness in the fifth grade is predictive of the reading proficiency that one will attain in adulthood ([Cupples & Holmes, 1992](#)). There is also evidence that syntactic awareness, relative to phonological awareness, plays an increasingly important role as children progress through the grades ([Roth, Speece, Cooper, & De le Paz, 1996](#)).

Among some poorer readers, metalinguistic awareness, or the explicit knowledge of the structural features of language, is a better predictor of reading performance than tacit lexical knowledge of the language being read ([Gombert, 1992](#)). Moreover, among preadolescents, the more explicit the syntactic awareness tasks, the more frequent and greater their contribution to reading performance ([Gaux & Gombert, 1999](#)).

Nation and Snowling (2000) postulate that syntactic awareness may enhance comprehension in two ways:

- It facilitates text integration and comprehension monitoring, processes that are integral to successful comprehension
- It may also enhance the development of skilled word recognition, by influencing the ease with which children learn to read words they could not read via simple decoding mechanisms

Brain imaging. Recent evidence from neurophysiologic investigations and functional magnetic resonance imaging (fMRI) of the brain also suggests that syntactic processing during reading dynamically collaborates with lexical and higher order cognitive processes performed in separate brain regions ([Friederici, Opitz, & von Cramon, 2002](#); [Keller, Carpenter, & Just, 2001, online document](#)). Brain imaging research has also shown that reading sentences with complex syntactic structure not only activates areas in the left frontal cortex associated with working memory, but also activates large areas in the right cerebral hemisphere associated with pattern recognition; these areas are not activated with syntactically simpler sentences of similar length and semantic content ([Caplan et al., 2001](#); [Patel, 2003](#)). These brain studies suggest that assisting readers' syntactic processing could free up cognitive resources for higher level comprehension activities.

Syntax in non-native language readers. Many U.S. schools now have large populations of students who are English language learners. For these students, the role of syntax in reading performance is especially important. Behavioral studies demonstrate that reading difficulty increases in proportion to the difference between the syntactic rules of the non-native versus native language ([Frenck-Mestre & Pynte, 1997](#)). Limited syntax proficiency also constrains non-native readers' word decoding because the phrase contexts of the words are not easily recognized by the non-native reader. Functional brain imaging studies have also shown that reading in a non-native language activates altogether different patterns of brain activity compared to reading in a native language, which cannot be ascribed to vocabulary or word-decoding differences—and which varied in proportion with proficiency in the non-native language ([Dehaene et al., 1997](#), [online document](#); [Kim, Relkin, Lee, & Hirsch, 1997](#); [Fletcher et al., 2000](#)).

Vision and syntax. Research conducted over the past 20 years shows a tight relationship between eye movements and cognitive processing ([Rayner, 1998](#)). Of the 250 msec (one-fourth of a second) that the eyes typically spend at a single fixation, only 30 msec are required to capture the visual data; the other 220 msec are spent on cognitive processing of the content and deciding whether to go ahead and examine the next word or "regress" and re-examine previously viewed words.

When readers examine sentences in which a subsection is syntactically ambiguous, eye movements frequently regress to previously viewed words, so that readers can revise tentative, earlier syntactic interpretations that, after reading further, are realized to have been incorrect ([Rayner, 1999](#)). Better readers have better memory for the spatial locations of words within a sentence, and they appear to use this knowledge to advantage during visual regressions ([Baccino & Pynte, 1994](#); [Murray & Kennedy, 1988](#)). Thus, cueing hierarchical phrase relations by spatial layout with the VSTF method may help poor readers develop visual-parsing strategies that good readers already possess, and may help good readers develop their use of spatial information even further.

Syntactic cueing in spoken language as a model for written language. The prosodic cues in spoken language are more complex than simple pauses at phrase boundaries; subtle variations in pitch, volume, and the duration of word pronunciation have been shown to convey hierarchical structures in syntax ([Ferreira & Anes, 1994](#)). When these prosodic-syntactic cues of speech are experimentally stripped away from audiorecordings of sentences, listeners' comprehension drops ([Cutler, Dahan, & van Donselaar, 1997](#)). This finding has important implications for reading because, when language is written down, many of these same syntactic cues are similarly stripped away ([Fries, 1963](#)). Although the VSTF method does not extract or directly represent the prosodic features of spoken language per se, it does aim to re-impart to language in its written form a "transparent" multidimensionality for syntactic cueing that its spoken form already contains, in order to engage more efficient comprehension processes.

Research on Visual-Syntactic Text Formatting

Validation research with VSTF has involved college and high school students. These studies both used the direct, unedited output of the currently available visual-syntactic text-parsing engine. The Institutional Review Boards of the universities of the investigators approved both studies.

Laboratory Research With College Readers

We first hypothesized that the VSTF method could immediately enhance retention and comprehension in college readers. Because of the effects that VSTF might have on readers' eye movements, we also hypothesized that it would reduce eyestrain.

Method

Participants. Forty-eight college students participated for extra credit in an Introduction to Psychology course.

Design. In a within-subjects randomized control design, participants read six 500-word expository passages from a computer display: three passages in the standard block format, and three in the visual-syntactic cascading-phrase format. The order of passages and their format were randomized across participants.

Materials. The expository passages consisted of contemporary technical writing obtained from a current online public domain source, the [Federal Register](#). The subject matter was conceptually abstract and unfamiliar to the study participants. In these passages, there was an average of 25 words per sentence, and an average of 197 syllables per 100 words. The Flesch reading difficulty of the passages was rated "very difficult," with an average value of 15.0.

The electronic presentation of both formats (standard and cascaded) used black, monochrome 15-point font, tan background, and single interline spacing; the standard block formatting was approximately 70 characters wide, with left-only justification.

Procedure. Each participant was tested individually in a windowless room. Participants read from a 17-inch computer display, and moved through the text by a "slide show" (not scrolling) method, pressing page-up/page-down keys or clicking an on-screen button. The testing software allowed readers to move back and forth within a single passage, but prevented rereading a passage after leaving it; in this way, overall reading time per passage was also measured. There was no time limit to the reading sessions; readers were instructed to take as much time as they wanted to complete each passage.

Testing and survey data. Immediately after the reading session, participants took a written test with four investigator-prepared, retention and comprehension questions for each of the six passages; these were later graded in a blinded manner following stringent criteria. For each passage, each set of four questions was preceded by the passage title; one test question was of a general nature, two focused on midlevel details, and one focused on specific details. Participants also completed survey questions on whether they experienced eyestrain while reading in each format, and on format preference. A testing session (reading, test, and survey) lasted about 1.5 hours.

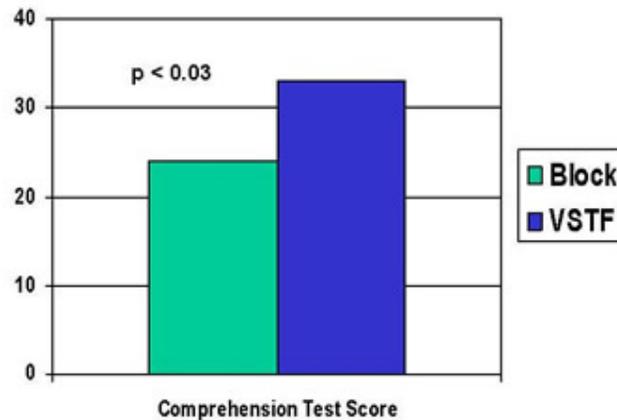
Statistical analysis. One-way ANOVA was used to compare the participants' scores on the reading comprehension test and corresponding reading times for each of the two formats. To assess for a possible speed-accuracy trade-off, reading time was entered as a covariate in a one-way repeated-measures ANOVA that compared comprehension performance between standard and visual-syntactic formatting. Linear regression analysis was used to compare each student's baseline reading aptitude (ACT scores) with gains in comprehension with VSTF. A Chi-squared analysis was used for nonparametric analysis of the response rates to questions on the post-test questionnaire on eyestrain and preference.

Results

Comprehension performance and reading time. Scores on the comprehension tests were 40% higher with the visual-syntactic format ($p = 0.024$, one-way ANOVA, Figure 2). Average reading time was 10% greater in the visual-syntactic format, a difference that did not reach statistical significance ($p = 0.079$); moreover, when reading time was entered as a covariate in a one-way repeated-measures ANOVA, the effect of format on comprehension remained significant ($p = 0.028$). In other words, the increase in readers' comprehension with the visual-syntactic format could not be explained by a speed-accuracy

trade-off. Rather, a higher level of reading comprehension was attained primarily because reading efficiency (comprehension score divided by passage reading time) was 25% higher with the visual-syntactic format. Although more time spent reading may have accounted for some of the comprehension gains, readers may have spent about 10% more time on task reading VSTF passages than block passages because, as is discussed below, they experienced less eyestrain with VSTF.

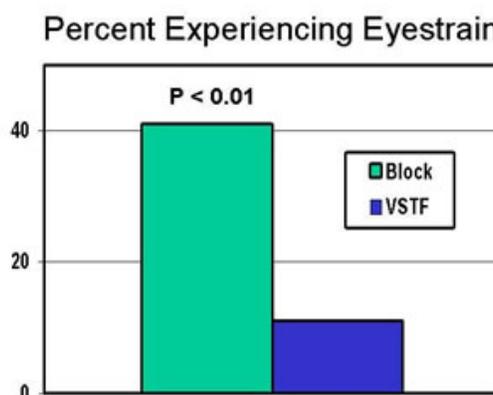
Figure 2
Comparison of Comprehension Test Scores



Impact across levels of reading ability. At the time of written informed consent, study participants gave permission to have their college admissions ACT test scores analyzed anonymously. The ACT reading subsection scores averaged 25.69 (SD = 4.54), ranging from 19 to 36. These data were used in a linear regression analysis as a predictor variable for gains in comprehension scores from the visual-syntactic format. The regression of comprehension gain (visual-syntactic format comprehension score minus conventional format comprehension score) on ACT reading subsection score was not significant ($p = .4103$). Thus, the visual-syntactic format was helpful to readers across the range of reading levels.

Eyestrain and format preference. Forty-one percent reported eyestrain symptoms while reading the conventional format; by contrast, only 11% reported eyestrain symptoms with the visual-syntactic format (Chi-squared, $p < 0.01$) (Figure 3).

Figure 3
Eyestrain Reported for Each Format



Sixty percent preferred the visual-syntactic format to conventional format. Notably, among the 40% of participants who preferred the conventional format, comprehension scores were significantly higher with the visual-syntactic format.

Classroom Research With High School Students

With this assurance that the VSTF method with online text was helpful to most college readers and harmful to none, year-long evaluations of VSTF with high school students were performed. Research questions included the following:

- Among the college students, by definition, reading skills were strong enough to gain college admission. Could the benefits in college readers be replicated among a younger group of readers? How would the VSTF method affect poorer readers with skills far below those of college-level readers?
- Prior research among high school students suggested that reading online text may result in reduced comprehension compared to paper-based publications ([Murphy, Long, Holleran, & Esterly, 2000](#)). Although VSTF may improve comprehension of digital text, would VSTF using digital text actually improve comprehension compared to reading the same material from a printed book?
- Would the observed impact of the VSTF method on short-term reading comprehension be sustained over prolonged use, and would any increased comprehension translate into long-term retention of educational content being read?
- Would the benefits of VSTF, if any, be great enough to justify a school district's investment in technology and digital texts, and the use of valuable class time to implement the method?
- Could the VSTF method, if used for a prolonged time, actually weaken students' skills for reading text in block format?

Pilot Study

In the pilot year study (2000–2001), 50 ninth graders, in two class sections taking a world history course from the same teacher, read their textbooks from computers, using a digital version of the textbook formatted in VSTF. The pilot classes' scores on weekly quizzes, unit exams, and the final exam were compared to those of historical and concurrent control groups (who had used the same texts in paper-based, block form, and taken the corresponding exams); this comparison showed a full standard deviation increase in scores with VSTF.

Randomized, Controlled, Multiple-Instructor High School Study

Methods

Participants. A year-long, randomized control study was performed in academic year 2001–2002, involving two instructors and 100 ninth-grade students in 4 class sections (approximately 25 students per section). Among these 100 students, 73 were native English speakers (41 male and 32 female), and 27 were Hispanic or Latino/a students (14 male and 13 female) for whom English was a non-native language.

Design: Randomized, controlled trial. For each of the two instructors (who each had two sections taking the course), randomization by coin toss assigned one of the instructor's class sections to the intervention group and the other to the control group. Because continued practice with VSTF could result in a change in reading proficiency in standard format during the course of the yearlong study, a within-subjects randomization for text format was not feasible. Likewise, because students would read in a computer lab, and

would be able to see what kind of format their classmates were reading, it was not feasible to randomize format at the individual level.

Procedure and materials. Both the control and intervention groups were informed that they were participating in a research study that was examining the possible effect of completing major reading assignments in class, under direct supervision. In this way, the possibility of a Hawthorne effect was minimized, because both groups believed their classroom procedure was new. Both groups spent 50 minutes a week (averaging 20 minutes in each 90-minute, every-other-day class) reading the same passages from the textbook assigned for the course (ninth-grade world history). Each participant in the VSTF intervention group read from an individually assigned 15-inch computer monitor in a computer lab (Figure 4).

Figure 4
Ninth Grader Reading World History Text in VSTF



For this year-long, curriculum-based evaluation, it was necessary to compare the intervention format to standard, paper-based textbooks to ensure that, if there were any decline in learning or reading proficiency compared to paper textbooks, such a decline would be captured in the study. Because of the prior results in the college-level laboratory study (described above), the randomized classroom-based study did not include an additional control group reading block text from computer displays.

Testing. For reading comprehension and retention, publisher-provided quizzes, unit exams, and a final exam were administered. For reading proficiency, the results from the reading section of the Terra Nova (McGraw-Hill) test were analyzed (national percentile ranking). This test had been administered by the school district at the end of the students' seventh-grade year, and was again administered at the end of the students' ninth-grade year (the grade during which the reading intervention was used).

Students who had been randomized to the visual-syntactic format also completed a survey at the end of the school year, containing 20 questions to be answered "agree," "uncertain," or "disagree"; 8 questions pertained directly to the VSTF format, and the remaining 12 pertained to other aspects of the experiment (e.g., opinions on computer lab distraction, reading aloud, reading with a partner, teacher monitoring, etc.).

Statistical analysis. The two study groups were evaluated at baseline using both the Terra Nova reading proficiency text and a publisher-provided pretest for knowledge of world history; one-way ANOVA and the Levene's Test for Homogeneity of Variance were used for the comparison. One-way ANOVA was also used to compare the difference between beginning-of-year pretest and end-of-year post-test scores on the final exam, and the difference between a student's baseline and end-of-year scores on the Terra Nova reading proficiency test for both groups. Repeated-measures tests were used to assess between-subjects effects for quizzes and unit exams, and to assess within-subjects effects involving time for quizzes and unit exams. Linear regression analysis was used to compare students' baseline reading aptitude with the degree of change observed in reading proficiency at the end of the VSTF intervention. A post hoc Scheffe's Test of Multiple Range was used for descriptive statistics and to compare differences between instructors' results. A sign test analysis was used for nonparametric analysis of responses on the post-test survey given to VSTF groups about the VSTF format.

Results

Baseline scores. There were no significant differences between the study groups in baseline reading proficiency (Terra Nova) or baseline knowledge of world history (publisher-provided pretest) (Table 1).

Table 1

Comparison of VSTF and Control Groups (n=100) at Baseline and End-of-Study in Reading Proficiency and World History Knowledge				
Test	Reading Proficiency (Terra Nova®)		World History Knowledge (publisher-exam)	
Comparison	F _{2,97}	p	F _{2,97}	p
<i>Pre-study, Baseline</i> <i>One-way ANOVA</i>	=0.24	=.79 (NS)	=1.759	=.178 (NS)
<i>Pre-study, Baseline</i> <i>Levene Test for Homogeneity</i> <i>of Variance</i>	=0.30	=.74 (NS)	=1.448	=.240 (NS)
<i>Post-study, End-of-Year</i> <i>minus Baseline</i> <i>One-way ANOVA</i>	=14.11	<.001	=19.65	<.001

Instructor comparison. The two instructors implemented the VSTF method differently (see [Observational Studies](#), below), with one instructor being active with classroom participation with the VSTF method, and the other being passive. Both instructors had significant increases with the VSTF format on both the Terra Nova reading proficiency test and the publisher-provided exams, and there was no significant difference in the scores between instructors for either of the tests. However, for both Terra Nova reading proficiency and publisher-provided exams, the active instructor had relatively larger increases with VSTF than the passive instructor did (Table 2). Unless stated otherwise, the other data presented are for both instructors' results, combined.

Table 2

End-of-Study minus Baseline Scores for Reading Proficiency and World History Final Exam in Active VSTF, Passive VSTF, and Control Groups (n=100)				
Test	Reading Proficiency Percentile Increase or Decrease in National Percentile Ranking		World History Final minus Pretest, Percent Correct	
Group	Mean	SEM	Mean	SEM
VSTF Active	9.566	1.583	77.50	1.78
VSTF Passive	5.900	2.423	71.55	2.02
Control	-1.420	1.270	63.22	1.49

Immediate comprehension. Students who read textbook passages in VSTF had significantly higher scores on publisher-provided quizzes administered after each reading session, averaging 75.6% correct compared to 62.5% correct for the students reading conventional text ($p < 0.001$, ANOVA). There was also a statistically significant increase in quiz scores with VSTF within subjects over time (Table 3).

Table 3

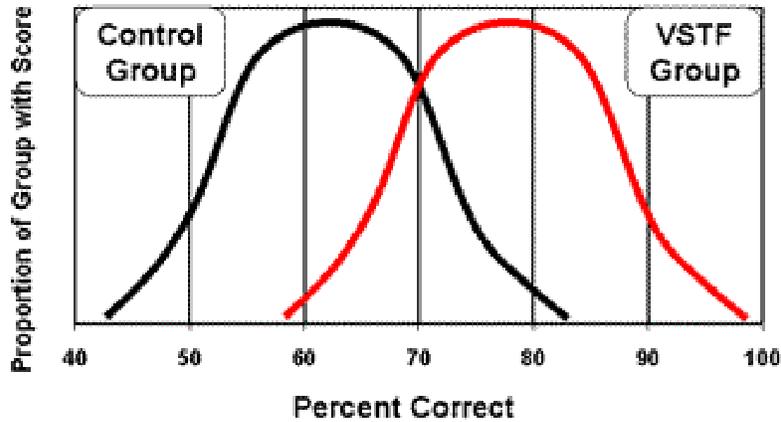
Repeated Measures Analyses for Between-Subjects Effects and Within-Subjects Effects for Tests involving Time for Quizzes and Unit Exams				
Tests	Quizzes		Unit Exams	
Repeated Measure	F	p	F	p
Between-Subjects	$F_{2,97}=22.64$	<.001	$F_{2,97}=35.43$	<.001
Within-Subjects, Time as a Factor	$F_{4,388}=11.57$	<.001	$F_{4,388}=14.48$	<.001
Within-Subjects, Groups by Time Factor	$F_{8,388}=8.09$	<.001	$F_{8,388}=15.96$	<.001

Intermediate and long-term retention. Similarly significant differences between VSTF and block format were found with publisher-provided unit exams that were given approximately every six weeks during the seven-month study. As with quizzes, the within-subjects improvement with VSTF in exam scores increased significantly over time, the difference between VSTF and control being more than two times greater in exams taken at end of the academic year (83% vs. 62%, difference 21%) than at the beginning of the year (71.5% vs. 63%, difference 8.5%).

The final exam contained questions from quizzes given throughout the academic year, representing a measure of long-term retention and learning. Compared to baseline-knowledge pretests given at the beginning of the year, the active VSTF group scored an additional 77.5% correct on the final exam (95% confidence interval [CI] 73.8 to 81.1) and the passive VSTF group scored an additional 71.6% correct (95% CI 67.3 to 75.8), whereas the control group only scored an additional 63% correct (95% CI 60.2 to 66.2). The active and passive VSTF groups were not significantly different from each other, but each had significant differences compared to the control group. In effect, the active VSTF method,

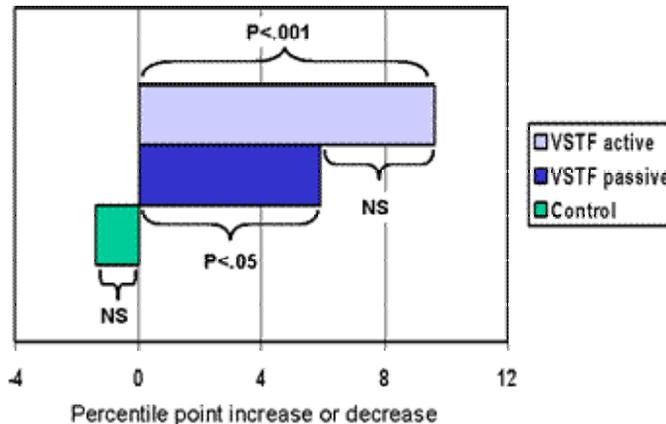
used over the entire academic year, enabled 80% of its students to achieve scores that only the top 20% of the control group achieved (Figure 5).

Figure 5
Distribution of Scores on Final Exam
for the “Middle 95 Percent” in Each Group
 (Mean \pm 2 Standard Deviations)



Impact on long-term reading proficiency in any text format. Before and after the year-long intervention, students took the Terra Nova nationally standardized reading proficiency test, which is formatted in standard block format on paper. At the end of the intervention, the control group’s national percentile ranking on the test was 57.5—not significantly different from its baseline of 59. By contrast, the active VSTF group’s national percentile ranking increased from a baseline of 57 to 66.5—a 9.5 percentile point increase ($p < .001$, one-way ANOVA). The passive VSTF group’s national percentile ranking increased from 56 to 62—a 6 percentile point increase ($p < .05$, one-way ANOVA) (Table 2). The difference between the active VSTF and passive VSTF scores was not statistically significant (Scheffe’s) (Figure 6).

Figure 6
Change in National Percentile Ranking on Reading
Proficiency Test (End-of-Year minus Baseline)



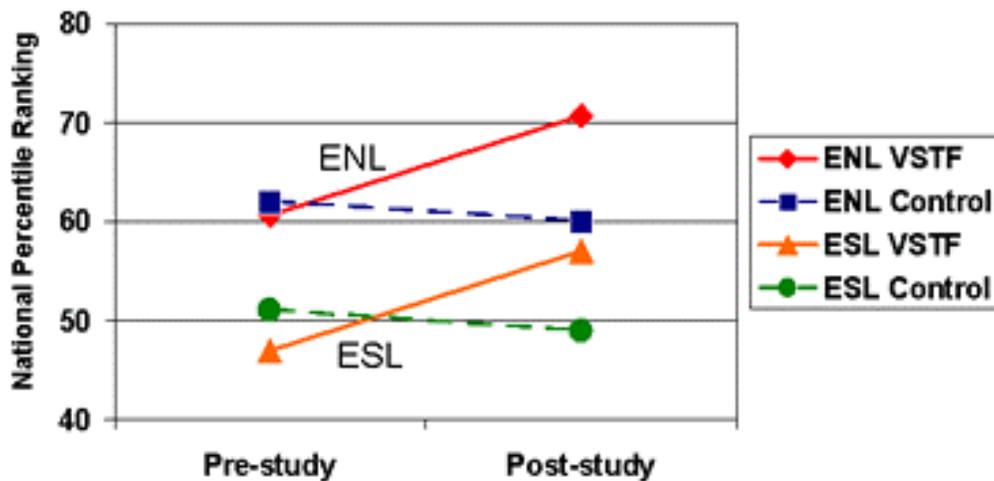
The school district's analysis of these students' annual, state-mandated reading tests showed gains that were similar in magnitude and significance to the Terra Nova results.

Subgroups. Significant benefits from visual-syntactic formatting were seen among both better readers and poorer readers, as stratified by baseline reading aptitude with the students' preintervention Terra Nova scores. However, there was a correlation between the degree of increase in national percentile ranking and baseline reading aptitude, with greater gains seen with lower baseline aptitude (Pearson's correlation coefficient = -0.408, $p < .01$).

Many of the poorer readers who made relatively large gains with VSTF were non-native English speakers. These students gained nearly 10 percentile points in reading proficiency scores ($p < .05$ for growth, one-way ANOVA between groups), having started at baseline at more than 10 percentile points below the native English-speaking students. In effect, with the VSTF method, non-native English readers were able to achieve the same reading proficiency level at the end of the year as the control group of native English-speaking readers (Figure 7).

Figure 7

**Terra Nova® Reading Comprehension Test in Groups
with English as a Native Language (ENL)
and English as a Second Language (ESL)**



Student preference and survey results. A survey on VSTF was given to those who had been in the VSTF groups; the survey and responses are shown in Table 4. "Disagree" versus "agree" responses were compared (omitting "uncertain"); all eight of these survey questions showed a larger proportion having a favorable response to the VSTF format than an unfavorable one ($p < .001$, sign test).

Table 4
End of Year Survey Results for VSTF Students

End-of-Year Survey Computer (VSTF) Students only (n=47)	Percent Responding		
	Disagree	Uncertain	Agree
1. I found it easier to read with the computer-book compared to the regular textbook.	14	26	60
2. Reading the text from the computer-book did not cause eyestrain.	21	16	63
3. I found I did not have to re-read the text as much with the computer-book.	28	23	49
4. Reviewing was easier with the computer-book than with the regular textbook.	19	30	51
5. My grades improved using the computer-book.	28	37	35
6. I did not use the textbook along with the computer-book to study for exams.	26	25	49
7. I would like to read other things using the computer-book (Novels, other texts, etc.)	21	21	58
8. I look forward to reading with the computer-book. It was fun to read this way.	21	18	61

Observational studies. One of the two instructors was active in using VSTF format in the classroom; the other instructor simply used the VSTF for in-class reading sessions, and would perform other activities (e.g., grading papers) as the students read. Both instructors' VSTF groups had significant increases in Terra Nova reading proficiency and examination results, and the difference between the two instructors' VSTF groups was not significant. However, the active instructor also made the following qualitative observations:

- After several students requested to read the syntactically formatted textbooks aloud in a low voice, and were permitted to do so, a majority of students elected, at least from time to time, to read these texts aloud. Although poorer readers in the VSTF group would read aloud regularly, one-fourth of the students in the VSTF group preferred to read silently and alone. This request to read aloud never emerged from the control groups, who, by contrast, generally resisted or declined reading aloud.
- Some of the poorer readers in the VSTF groups also requested to pair up, alternating between reading aloud and listening to a partner read aloud from the same or an adjacent computer. Among Hispanic and Latino/a students, newly immigrated students with lower proficiency would pair up with U.S.-born Hispanic students who were more proficient in English but had not learned English as a first language. Again, this practice emerged spontaneously from the students themselves in the VSTF group, and no such request or practice emerged in the control groups. Not all VSTF students would read aloud or in pairs; one-fourth of the participants (usually better readers) preferred to read silently and alone.
- The computer display of text, which usually showed two or three sentences at a time, would allow a teacher or assistant to monitor student reading activity and engage students with questions about the particular sentences they were reading. This engagement would start with a surface question about why the sentence had a particular shape; then teachers would direct students to examine verbs, using a "verb-chasing" technique that focuses on events and cause-effect relationships. This would be followed by higher order inquiry about the overall significance of the passage.

- The active instructor observed that, through these in-class reading sessions with syntactic formatting, the class became a community, similar to a book club, and would discuss particular passages from the textbook that they had read together.
- Students would vary the appearance of the text depending on their reading goals. First encounters with a passage were usually read with a larger font (25 point or more); in review sessions, students would use smaller fonts and a two-column format, in order to show more sentences (four or five) on the display at a time, thereby analyzing text coherence across multiple sentences.
- The syntactic formatting enabled students to read more difficult texts. Remedial students, who could rarely use the standard textbook, were able to comprehend the same text used by mainstream students when the text was in VSTF. Many students were able to read and understand supplementary text passages from classic authors, such as Plato or Francis Bacon, in VSTF. Syntactic formatting appeared to create a scaffolding of meaning, that expanded the zone of proximal development for many students, thus exposing them to more syntactic variety and complexity than provided by the core textbook alone.
- In additional pilot studies, students used the dynamic parsing software to reformat their own writing, which enabled them to proofread and revise their essays, and build more effective syntactic structure in their writing.

Discussion

In print media, simple phrase cueing was observed as early as AD 400, when St. Jerome (the patron saint of librarians) first noticed that some scribes had placed phrases on separate lines as a way to help poor readers read the text aloud ([Manguel, 1996](#), pp. 48–50). St. Jerome called the method *per cola et commata*, indicating that colons and commas were used to break lines onto new rows. However, even through the 20th century, simple phrase-cueing methods such as *per cola et commata* were never broadly adopted in print because of the costs and production complication of using additional paper ([Geoffrion & Geoffrion, 1983](#); [Klare, Nichols, & Shuford, 1957](#)). With the emergence of electronic text, the cost of paper was no longer an issue, and software was developed that could “chunk” text using common function words; these chunked phrases could then be cued with extra spaces in the lines or with dynamic presentation effects ([Granaas, 1985](#)). However, the impact of chunked phrase cueing on reading performance was irregular and irreproducible, depending on the type of reader and reading material ([Bever, Jandreau, Burwell, Kaplan, & Zaenen, 1990](#); [Chen & Chan, 1990](#)). These mixed results, and the practical restrictions of implementation, prevented broad implementation of simple phrase cueing for improved readability of text ([Conte, Menyuk, & Bashir, 1994](#)).

Visual-syntactic text formatting is more complex than simple phrase cueing because it identifies not only phrases, but also the hierarchical relations across multiple phrases and clauses. The present research demonstrates that VSTF is feasible (using advanced language-processing software), and can help readers across a wide range of reading aptitude. Because this research studied the direct output of the current parsing engine, the observed gains can easily be made available to any reader and for any electronic text.

Visual-syntactic formatting immediately helps college students read challenging material more effectively and efficiently; it may help many college readers, including the 30 to 40% of first-year students who require remedial instruction to be able to read college-level material effectively ([Wessel, 1998](#)).

VSTF also eliminates most of the eyestrain associated with prolonged reading of digital text. This complaint is now the number-one cause of patient visits to eye doctors, accounting for over 15% of such visits, and the U.S. Occupational Safety and Health Administration has issued guidelines to reduce eyestrain from computer display use in the workplace ([Lim, Sauter, & Schnorr, 1999](#)).

For high school students, VSTF directly improves both immediate and long-term retention of content area textbooks, while strengthening reading proficiency—even when going back to other materials that are formatted as conventional block text. This dual benefit for learning and reading proficiency creates an opportunity to enhance literacy skills in content area classes. This intervention can enable more students to pass state-mandated reading and academic achievement tests, and then enter the job market or obtain higher education with stronger reading skills. The ability of VSTF to help non-native English readers is another important educational benefit for U.S. schools.

The direct impact of the visual-syntactic formatting method on reading efficiency is expected. However, the observations that VSTF can help readers across a broad range of reading aptitudes, and can increase longer-term proficiency in any format, have not been described with previous, simple phrase-cueing research.

Possible Alternative Explanations for Reading Proficiency Increase

There are several factors, other than the visual-syntactic formatting itself, that could account for the VSTF group achieving higher reader proficiency scores.

Hawthorne/placebo effect. It is possible that the novelty of reading from computers increased student enthusiasm for the reading activity, which, in turn, generated the observed VSTF effects. As explained in the methods section, there were several reasons for using paper textbooks as the control. To mitigate a potential Hawthorne effect, the textbook control group was informed that they were being evaluated for the impact of in-class reading. Moreover, if there had been such a Hawthorne/placebo effect, one would also expect that the difference between scores in the two groups would narrow over time; however, the opposite trend occurred, with a significantly greater difference between VSTF and control groups found at the end of the academic year than at the beginning.

To evaluate more directly the possibility of a Hawthorne/placebo effect, we conducted a smaller follow-up study, involving two other high school history classes of about 15 students each, in which laptop computers and electronic textbooks were used in both the VSTF class and the control class. The control group's electronic textbooks had a standard block format, using the same character-per-line values and margin justification patterns as in the paper textbook. Both groups used the identical software program for navigation, table of contents, font enlargement, and color control. As in the prior year-long study, students in both groups were always able to open their paper textbooks to review figures and images whenever they desired.

After several months, the vast majority of control students refused to read their computer-based textbooks that were in block text format, citing the lack of images and figures as the problem. However, none of students in the computer-based VSTF group in this follow-up, nor in the prior year-long study, complained of such a lack of figures and images. The results of a survey, given to both the VSTF computer group and the block-text computer group just before the end of the four-month follow-up study, are shown in Table 5.

Table 5
Survey of Participants in Laptop Study

Survey Questions, Follow-up Study. (Both VSTF and Block Groups Using Laptops).	Laptop Format	Percent Responding (n=30)		
		Disagree	Uncertain	Agree
1. It was easier to read with the computer-book compared to the regular textbook.	VSTF	0	8.2	91.6
	BLOCK	77.7	11.1	11.1
2. Reading the text from the computer-book did not cause eyestrain.	VSTF	0	42	58.3
	BLOCK	50	11.1	38.9
3. I found I did not have to re-read the text as much with the computer-book.	VSTF	0	16.7	83.3
	BLOCK	100	0	0
4. Reviewing was easier with the computer-book than with the regular textbook.	VSTF	8.3	25	66.7
	BLOCK	66.6	22.2	11.1
5. My grades improved using the computer-book.	VSTF	0	33.3	66.7
	BLOCK	66.7	22.2	11.1
6. I did not use the textbook along with the computer-book to study for exams.	VSTF	42	15.7	42
	BLOCK	66.7	11.1	22
7. I would like to read other things using the computer-book (Novels, other texts, etc.)	VSTF	25	25	50
	BLOCK	50	22.2	27.8
8. I look forward to reading with the computer-book. It was fun to read this way.	VSTF	8.3	25	66.7
	BLOCK	61.1	22.2	16.6

These results indicate that, in the preceding year-long study (where VSTF readers had computers but controls had paper textbooks), there likely was not a Hawthorne/placebo effect from computers in the VSTF group. Moreover, in the year-long study, 49% of VSTF students reported never using the paper textbook to prepare for exams, but they still scored significantly higher on knowledge acquisition and reading proficiency tests than readers of paper-based textbooks that included images and figures. Combined, the initial college reader laboratory-based experiment, the year-long classroom-based experiment, and the smaller follow-up laptop control study indicate that visual-syntactic formatting in electronic text media, even when lacking images, is superior to both paper-based block text and electronic block text. This follow-up survey also suggests that, in paper-based textbooks, a significant part of the benefit of images and figures is not necessarily informational, but rather is due to the impact of images and figures on breaking up the visual monotony of the block text.

Oral reading. It is also possible that the practice of reading aloud, rather than the VSTF format itself, improved students' reading. The RAND Reading Study Group (2002) report cites "repeated oral-reading exercises" as one of the few methods proven to increase reading fluency and reading comprehension (even for content that was not read repeatedly with the exercise). Developers of repeated oral reading exercises postulate that the exercises enable readers to automate the word-decoding steps of their elocution ([Laberge & Samuels, 1974](#); [Samuels, 1979](#)); then, it is believed that the reader's attention can be directed to imparting proper expression to the phrases and sentences. In other words, repeated oral reading exercises can ultimately help the reader create an acoustic diagram of the sentence's syntactic structure, serving, in effect, as an implicit method to make students aware of syntactic variety.

However, in this study, the practice of reading aloud only occurred in the classroom of the active VSTF instructor, whereas the impact of VSTF on reading proficiency and knowledge acquisition was significantly increased in both active and passive instructors' VSTF groups, with no significant difference between instructors. In addition, even in the active instructor's VSTF class, reading aloud was practiced primarily by poorer readers, whereas

significant increases in proficiency and knowledge acquisition were found not only in poorer readers, but also in better readers, who did not read aloud.

Therefore, although reading aloud may account for some of the gains seen with the active VSTF instructor, and for some of the gains among the active instructor's poorer readers, reading aloud would not account for all of the significant gains observed in this study.

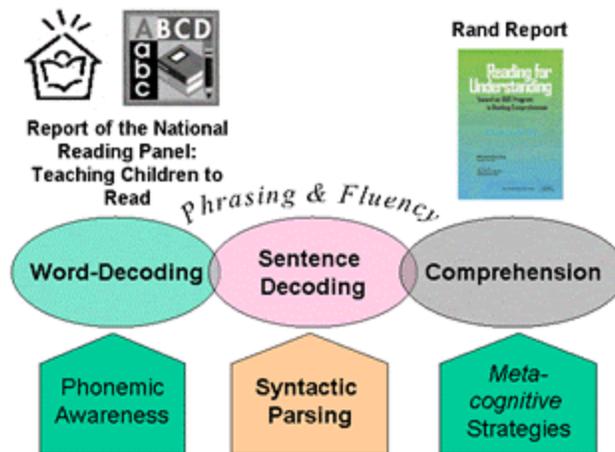
More time spent actually reading. One could also postulate that the control students in this study were merely foraging the textbooks for information and were not truly reading the assignment, whereas the VSTF groups had their reading enforced because their position and progress in the passage were visible on the computer screen. However, the fact that statistically significant improvements in proficiency and knowledge acquisition were found in the passive instructor's VSTF group argues against this possibility; in these relatively unsupervised reading sessions, both the VSTF group and the control group would have had the opportunity merely to forage the text. Moreover, the benefits seen with VSTF in relatively unsupervised settings opens up the possibility that students could read content area text in the VSTF format outside of class time, over the Internet, and still obtain significant benefits.

Possible Model for VSTF: Increasing Syntactic Awareness, Fluency, and Comprehension

Determining how the visual-syntactic formatting method increases reading proficiency (in any text format) will require further study. On the level of phrases, explicit syntactic awareness training has been shown to increase reading comprehension ([Kennedy & Weener, 1973, online document](#); [Weaver, 1979, online document](#)). The mechanism for VSTF may be similar, increasing syntactic awareness on a sentence level—with an explicit syntactic edifice that is relatively transparent (compared to diagramming), and which therefore can be perceived in conjunction with the reading of the text itself. Visual-syntactic text formatting can also present a larger variety of sentences than is feasible in sentence diagramming or repeated oral reading exercises. It may serve as a visual scaffolding to guide reading with syntactic cues, similar to those found in a teacher's modeling of fluent reading ([Armbruster, 2002, online document](#)). However, rather than repeatedly rereading relatively simple texts (as is the current practice to improve fluency), students using VSTF textbooks read ever-changing content, without overt teacher modeling. Moreover, this ever-changing content is not simple, as is text used in repeated oral reading exercises, but is the actual content of the academic curriculum.

The current study provides evidence for a model of syntactic parsing and sentence decoding as key underpinnings of fluency that serve as a bridge between word decoding and higher order comprehension ([National Reading Panel, 2000, online document](#); RAND Reading Study Group, 2002) (Figure 8).

Figure 8
Bridging Decoding and Comprehension



The hypothesis that increasing syntactic awareness can increase reading proficiency has a parallel on the phonemic level of reading. It is known, for example, that even though a heightened awareness of the phonemic substructure of words is not necessary to be able to enunciate the words correctly, such a heightened, “beyond natural” awareness of phonemes does enhance a young reader’s ability to learn phonics rules, and to then apply such rules to the word-decoding steps in reading written language (Ehri et al., 2001, [online document](#)). Likewise, then, while it may not be strictly necessary to have a heightened awareness of syntactic structure to be able to impart syntactically appropriate prosody to one’s elocution of a sentence, it can be postulated that having such a heightened, beyond natural awareness of syntax may similarly assist in the syntactic decoding of written language.

Practical Implementation of VSTF

The VSTF method creates a new paradigm for electronic publishing, and new possibilities for educators. Many electronic publications include an alternative “printer-friendly version” that is just one click away from the original. Using a similar approach, publishers could also very easily include a VSTF format of the text, thereby providing an “online-reader-friendly version.”

In education, the VSTF method can be used at the high school level for in-class reading of social sciences content, replicating the conditions of this study. Additional research is evaluating the impact of VSTF at lower grades and in additional subject areas, such as language arts and narrative literature. This research will also examine the interactions between VSTF and other comprehension strategies, and between VSTF and word decoding.

For school districts with tight budgets, the requirement of computers to use VSTF for students’ textbooks might appear, on the surface, to be cost prohibitive. However, the fall in prices of laptop computers to less than US\$700 per unit, and the ability to easily transport 30 laptops from room to room on a recharging-cart the size of a television stand, make it possible for each laptop to support up to 12 students who read for 20 minutes every other day (the conditions of our study). The cost of the laptop for in-class use, then, if amortized over 4 years, amounts to only US\$15 per student per year. Moreover, content area teachers can easily implement the VSTF method without needing additional training in reading instruction; school districts can therefore use VSTF to help more high school

students attain adequate yearly progress in reading without incurring major teacher-training expenses.

Another potential cost to educators is time: Up to 20% of in-class time was used for the intervention in this study. However, enhancing reading proficiency for expository material in content areas such as social sciences is an important part of preparing students for today's workplace, where over 50% of business and technical writing has complex syntactic structures ([Hindle & Rooth, 1993](#)). Moreover, if students read VSTF texts outside of class time, they can still attain the same results as occurred in the passive instructor's VSTF group in our study. The VSTF method also promises to be a valuable tool for Internet-based research and for analyzing and improving the clarity of writing.

Online Demonstrations

This article concludes with this [link to a Web-based VSTF parsing service \(http://www.liveink.com/LiveInkToGoReadingOnline.htm\)](http://www.liveink.com/LiveInkToGoReadingOnline.htm) that instantly transforms any electronic English text into a VSTF reading page. Through the support of an Innovation Research Award from the U.S. Department of Education, this parsing service will be provided to readers of *Reading Online* for 12 months from the day of publication.

The Internet contains billions of pages of valuable electronic text content. Depending on the subject that you are researching, and your institution's electronic library subscriptions, you and your students can use search engines to find and then instantly parse articles into VSTF as you conduct the research.

Here are some other places to obtain electronic texts to try the VSTF parsing service right now:

- Online newspapers are a great way to engage students in current events. Most local newspapers have an online version. Major national newspapers also have online versions (some will require registration for use, but are free). In addition, newspapers often have education resources, such as the *New York Times Learning Network* (<http://www.nytimes.com/learning/index.html>) that includes free electronic articles, lesson plans, and grade-level guidelines.
- A page at the *University of Kansas website* (http://www.ku.edu/carrie/docs/amdocs_index.html) offers links to many U.S. historical documents.
- Classics literature, including famous children's stories, novels, and essays abound on the Internet. A great example is [Project Gutenberg \(http://www.gutenberg.net/\)](http://www.gutenberg.net/)
- Government sites for children, such as the [one provided by the U.S. General Services Administration, \(http://www.kids.gov/\)](http://www.kids.gov/), also contain helpful information on history, health, and science.

[The VSTF Web-based parsing site](#) provides simple instructions. All one needs is digital text that can be copied to your computer's clipboard. Readers of this article will also have access to over 100 online classic novels that have been reformatted into VSTF. This article will also be made available in VSTF for enhanced online reading. Students may want to use the service to review and revise their own writing (and teachers, if their students submit their reports in electronic form, can read their students' papers).

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About the Authors

Stan Walker is a vision scientist and clinical ophthalmologist involved in the education of medical students and graduate physicians, and in the practice of ophthalmology. As a practicing eye physician, he has evaluated and treated thousands of patients who have complained of visual reading problems, including eyestrain symptoms associated with reading from computer displays. A graduate of Notre Dame and Mayo Medical School, he prepared the visual rationale and the visual criteria that are used in the algorithmic generation of the visual-syntactic text format, and participated in the design of neurocognitive research reported in this article.

Phil Schloss worked for 20 years as a senior software engineer and software system architect at IBM, where he patented 14 inventions, most entailing text-processing methods and Internet protocols, and published numerous technical disclosure bulletins and technical reports. He has also worked in development of natural language translation software and as the architect and lead developer of software development projects. In 1993, he received a special commendation from the governor of Minnesota, in recognition of his contributions to the economy and welfare of the state. He has worked on the visual-syntactic formatting method since 1996, including the engineering and design of computer-executed parsing engines and multidimensional text display methods. The research in the current article was performed using enhanced text that was the direct output of software parsing engines and display modules he developed.

Charles R. Fletcher received his doctorate from the University of Colorado at Boulder in cognitive science. His primary research efforts have been directed toward demonstrating experimentally the existence of three levels of representation in memory for discourse: a surface-level representation, a propositional textbase, and a situation model. This research into the online processing of discourse has focused on the role of memory and attention in understanding the causal structure of narratives; it involves both constructing computer models that simulate the flow of ideas through a reader's awareness during narrative comprehension and recall, and conducting experiments with human subjects to evaluate basic assumptions of those models. Recently, this research has branched off in several directions, including how syntactic and semantic factors interact to control a reader's attention. He has conducted laboratory-based research with the visual-syntactic formatting method among adult readers since 1997, including the work presented in this article.

Charles A. Vogel received his Ph.D. from the College of Education at Denver University; his dissertation research included classroom-based research with visual-syntactic formatting. He has over 25 years' classroom teaching experience in social sciences and language arts at the high school and middle school levels. For the past several years, he has been using visual-syntactic formatting in a wide range of classroom settings, involving several hundred high school students. His ongoing research with the visual-syntactic format includes a further analysis of its impact among non-native English language learners; the use of real-time parsing software by students as a tool to improve their own writing; and the use of visual-syntactic texts and software in preparing high school students for college-level reading.

Randall C. Walker ([e-mail: rwalker@liveink.com](mailto:rwalker@liveink.com)) is an educator and clinician-scientist at a College of Medicine in Rochester, Minnesota. His undergraduate (Notre Dame) and medical (Mayo Medical School) training focused on linguistics, neurology, and internal medicine. His work includes the design and implementation of prospective, randomized, double-blind controlled trials of therapeutic interventions that, similar to the reading research in this article, have involved complex medical conditions requiring special statistical and study design approaches to demonstrate efficacy. Over the past 10 years, Randall has collaborated with his brother, Stan, to integrate current understandings in linguistic and visual processing of reading into a dynamic "cataphorical" model of spatial-syntactic and attentional processing. Randall developed the natural language parsing algorithms and Stan established the visual parameters, which were then combined and encoded by Phil Schloss into the visual-syntactic parsing engines used in this study.

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