Chapter 1

Assistive Technology for Writing: Tools for Struggling Writers

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Individuals with learning disabilities (LD) and others who find writing challenging often struggle with basic transcription processes, including handwriting or typing, spelling, capitalization, and punctuation. Problems with transcription affect motivation and interfere with students’ ability to attend to higher order processes such as planning and evaluation. Computer tools, including word processing, spelling and grammar checkers, speech synthesis, word prediction, and speech recognition software, offer support to writers, but they also have limitations. This chapter analyzes the growing body of research on the benefits and limitations of these tools with students with LD and other struggling writers. In addition to research on specific types of assistive technology, the chapter discusses general issues such as the inevitable tradeoff of burdens when adopting new writing tools and the need for instructional methods designed to take advantage of the power of particular writing tools.

1 Introduction

Mark, a fourth-grade student with dyslexia, struggles with both reading and writing. In his classroom, students write back and forth with the teacher in dialogue journals. The teacher has difficulty reading Mark’s entries because of his severe spelling problem, and Mark has difficulty reading her responses. Word prediction software with speech synthesis helps him to participate independently in this class activity without direct teacher support.

Marcia, a high school student with a learning disability who is probably college bound, reads with good comprehension, though slowly, but struggles to meet school demands for writing reports and essays. The combination of a planning strategy and speech recognition software enables her to write longer and better quality papers.


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These two examples, both actual cases from my research, illustrate the potential of computers to support writing and writing instruction for students with learning disabilities (LD) and other struggling writers. For these students, the basic transcription processes of getting language on paper — particularly, handwriting, spelling, and overall fluency — create significant barriers to effective writing. Problems with transcription affect motivation and interfere with students’ ability to attend to higher order processes such as planning and evaluation. Computer tools, including word processing, spelling and grammar checkers, speech synthesis, word prediction, and speech recognition software, have considerable potential to reduce these barriers. However, there are also significant limitations to this potential. This chapter reviews the research on the benefits and limitations of computer tools to support transcription. Most of the research has been conducted with students with LD, though it is probably applicable to other struggling writers. The term assistive technology is used here to refer to technology that supports individuals in overcoming barriers due to a disability.

As prelude to the review, I would like to comment on three general issues that affect interpretation of any findings regarding the use of assistive technology to support struggling writers. First, it is important to keep in mind issues of motivation, burden on working memory, and training in the use of the tool (MacArthur, 2000). All transcription tools remove one burden but impose some additional burden on working memory or require additional training. For example, word processing removes concerns with handwriting, but requires typing, which may slow text production and take attention away from the content of writing, unless the student has developed fluent typing skills. Whether a new tool will increase or decrease the overall cognitive burden depends on the skills of an individual student and the quality of training. Furthermore, the value of accurate text in a given social context and the motivation and cognitive ability of a student determine how much burden is acceptable. For example, an elementary school student whose teacher encourages students to write first drafts without concern for spelling, may not benefit from software that increases spelling accuracy but slows the writing process. On the other hand, a college student with LD who is expected to produce accurate work may need to expend the extra effort to produce correct text. Thus, findings must be interpreted with an eye on context and individual characteristics, and both benefits and limitations should be analyzed.

Second, technology by itself is unlikely to produce major improvements in students’ writing. Good instruction takes advantage of the capabilities of the technology to improve students’ abilities to plan, revise, and write fluently. While there is a place for direct comparisons of technologies (e.g., handwriting vs. word processing), research investigating combinations of technology and instruction is also important. Thus, it is important to consider the specific writing tasks and related instruction used in research in interpreting the findings.

The third point hardly needs to be mentioned in a book such as this. Technology and the familiarity of students with technology change rapidly. The design details of computer tools can make a significant difference, as Haas (1996) has shown in her studies comparing older 40-line monitors with larger, higher-resolution monitors for word processing. Researchers can deal with the rapid change, first, by designing studies to investigate basic capabilities of technology and, second, by attending carefully to how the details of the technology affect users. Even so, the rapid development of technology creates an inherent limitation for research on technology and writing.
The chapter is organized as follows. First, as background, the chapter provides a brief overview of research on the writing problems of students with LD including correlational studies and dictation studies supporting the claim that transcription difficulties contribute to the poor quality of their writing. Second, studies of word processing are discussed including studies of the overall impact of word processing on written products and studies of the combination of revising instruction and word processing. The remaining sections focus on specific assistive technology tools that can support accurate transcription. The third section discusses research on the benefits and limitations of spell checker and on instructional methods to help students use them more effectively. Fourth, the chapter considers whether speech synthesis can assist in editing by reading text back to students. Fifth, several studies demonstrating the benefits and limitations of word prediction with students with severe spelling deficits are analyzed. Word prediction software predicts what word the user intends to write based on initial letters and syntax and presents a list of words for the user to select; thus, it can support spelling in ways different from spell checker. Finally, the chapter reviews research on dictation using speech recognition software, including research on its use to compensate for poor transcription skills on writing tests.

2 Writing of Students with Learning Disabilities

Students with LD have difficulty with both the composing processes of planning and revising and with the transcription processes of getting language onto paper (for a review, see Troia, 2006). First, they have less knowledge of the characteristics of good writing and the requirements of various genres (Englert, Raphael, Anderson, Gregg, & Anthony, 1989). Second, they engage in relatively little planning, and have few strategies for generating or organizing content (Graham, Harris, MacArthur, & Schwartz, 1991). Third, their revising is limited primarily to correction of errors and minor changes in wording that do not affect meaning; often, they introduce new errors in the process of recopying a paper to fix previous errors (MacArthur, Graham, & Schwartz, 1991). Finally, they have difficulty with the transcription processes required to get their sentences into print — spelling, handwriting, capitalization, and punctuation (Graham, Berninger, Abbott, Abbott, & Whitaker, 1997). As a result of these difficulties, their written products, in comparison to those of their normally achieving peers, contain more errors of spelling, handwriting, and other mechanics and typically are shorter, less coherent and organized, and lower in overall quality (Graham et al., 1991).

Transcription problems are important both in their own right and because of their impact on the overall writing process. They are important in their own right because errors distract readers from the message that a writer is trying to communicate and, in extreme cases, render the message incomprehensible. On writing tests, errors influence judgments about overall quality of writing.

Perhaps more important, transcription problems interfere with the overall composing process and affect both overall quantity and quality of writing. Evidence from correlational studies demonstrates that proficiency with transcription affects the quality of writing at least through elementary school. For example, in a study involving 600 students in grades 1–6, Graham et al. (1997) found that handwriting fluency and spelling explained a sizable
proportion of the variance in length of composition (41–66% across the grades) and in quality (25–42%). In addition, studies using interference with reaction time to study attention processes (Olive & Kellogg, 2002) show that handwriting demands interfere with composing for children but not adults.

Another way to investigate the impact of transcription is to compare dictation and handwriting. For primary grade children, dictated compositions are longer and higher in quality than handwritten papers (King & Rentel, 1981). However, for upper elementary, middle school, and college students, dictated compositions may be longer than handwritten ones, but are generally not higher in overall quality (Hidi & Hildyard, 1983; MacArthur & Cavalier, 2004; Reece & Cummings, 1996; Scardamalia, Bereteit, & Goelman, 1982). In contrast, for middle and high school students with LD and other poor writers, dictated compositions are both substantially longer and qualitatively superior to compositions written via handwriting or word processing (Graham, 1990; MacArthur & Graham, 1987; Reece & Cummings, 2004). Differences between dictation and handwriting for children but not adults have also been found using contrived writing tasks (Bourdin & Fayol, 1994).

Computer tools that support transcription may directly support writers with LD as compensatory tools, as when they help writers avoid and correct their errors. They may also enhance instruction and the development of transcription skills by freeing writers to focus on higher level composing concerns, by motivating practice, and by providing models of correct form.

### 3 Word Processing

Word processors are flexible writing tools that can support struggling writers with many aspects of writing, especially transcription and revision. The ability to produce an attractive final publication with the errors corrected can be highly motivating for students who struggle with spelling and handwriting. Word processing makes it easier to separate composing and transcription concerns by focusing on planning and ideas in a first draft, secure in the knowledge that errors can be fixed later without tedious recopying.

Although it facilitates transcription, word processing also introduces the new burden of typing. Unless students have received typing instruction, the attention required by typing and the slower rate of production may negatively affect the length and quality of writing (Graham, 1990). One study comparing handwriting and word processing on test essays (Russell, 1999) found that the effect of word processing depended on typing skill; it had a positive effect on quality for high school students with above average typing speed (20+ wpm) but a negative effect for students with below average typing.

Word processing appears to be especially beneficial for struggling writers. A meta-analysis (Bangert-Drowns, 1993) found that use of word processing in writing instruction programs produced a positive though small impact on the quality of students’ writing. However, this small effect is better viewed as a combination of a moderate effect size ($d = 0.49$) for nine studies of ‘basic’ writers and a non-significant effect size ($d = 0.06$) for 11 other studies. One study that focused specifically on students with LD (MacArthur, Graham, Schwartz, & Shafer, 1995) evaluated the effectiveness of a model of writing instruction that integrated word processing and instruction in planning and revising strategies. Students in
12 experimental classes made greater gains in the quality of their narrative and informative writing than students in 10 control classes who received a process approach to writing without computers or strategy instruction. This study did not isolate the effects of word processing. Rather, it demonstrated the effectiveness of writing instruction that included word processing and strategies designed to take advantage of word processing capabilities.

The effects of word processing have also been studied in short-term experiments comparing word processing and handwriting as means of producing text. Vacc (1987) found that middle school students with mild disabilities wrote more slowly, made more revisions (mostly mechanics), and produced shorter texts with word processing; no differences in quality were found. MacArthur and Graham (1987) found that middle school students with LD wrote more slowly with a word processor and made more revisions during the first draft but fewer revisions between drafts; no differences were found on the final papers in length, syntactic complexity, vocabulary, errors, or overall quality. Limited typing skill may have influenced the results of these two studies. However, another study (MacArthur et al., 1995) used students who had participated in a full year curriculum with regular instruction and practice in typing and word processing; no differences were found between handwritten and word-processed compositions in overall quality, length, or spelling, capitalization, and punctuation errors. Note the similarity in results in the two studies despite the improvements in technology and the greater experience of students in the later study.

The limited evidence with students with LD indicates that word processing by itself may affect rate of composing (depending on typing skill) and the amount and timing of revision, but that it has little impact on written products. However, word processing in combination with instruction designed to take advantage of its capabilities may have positive effects on the quality of writing. Word processing may facilitate instruction about writing processes and enhance motivation in ways that improve students’ writing achievement over time.

One particular area in which word processing may facilitate instruction is revising. Skilled revision involves identification of problems, diagnosis, and either revision or wholesale rewriting to fix the problems (Flower, Hayes, Carey, Schriver, & Stratman, 1986). Word processing does not directly help students learn how to evaluate their writing, diagnose problems, or fix those problems. However, word processing does reduce the physical burdens of revising and provide a clear copy of the revised text and, thus, may increase motivation for learning about revision. Three related studies investigated whether a combination of word processing and instruction in revising strategies would increase the amount and quality of revision and improve the overall quality of writing by students with LD. The first study evaluated a solo revising strategy (Graham & MacArthur, 1988). The other two studies investigated peer-revising strategies with instruction provided by research assistants (Stoddard & MacArthur, 1993) and by teachers in classrooms (MacArthur, Schwartz, & Graham, 1991). Research has demonstrated the value of peer response in improving revision (Rijlaarsdam, Couzijn, & Van den Bergh, 2004). In all studies, students wrote all drafts and made revisions on a word processor without a spell checker. In all three studies, instruction had positive effects on the number and quality of revisions, improvement from first to final draft, and quality of the final draft. In the classroom study (MacArthur et al., 1991), the control condition included word processing and peer response groups but not instruction in specific revising strategies, thus, supporting a
conclusion that specially designed instruction is needed to help students take advantage of the power of word processing to improve revision.

4 Spell Checkers

Not surprisingly, spell checkers are helpful to students with spelling problems. In a study of young adolescent students (ages 11–14) with LD who had moderate to severe spelling problems, students corrected 37% of the spelling errors in their compositions with a spell checker, compared to 9% unaided (MacArthur, Graham, Haynes, & De La Paz, 1996). College students with LD (McNaughton, Hughes, & Clark, 1997) used a spell checker somewhat more effectively, correcting 60% of their errors using a spell checker compared to 11% with handwriting.

The interesting question about spell checkers is not whether they can help students to correct their errors, but what the limitations are and how those limitations might be reduced. The most serious limitation is that they fail to detect spelling errors that are other words, including homonyms and other real words (e.g., sad for said). In the MacArthur et al. (1996) study, 37% of students’ misspellings were not detected for this reason. A second serious limitation is that the correct spelling may not appear in the list of suggestions, especially when words are severely misspelled (e.g., fernitcer for furniture). In the same study, the spell checker failed to suggest the correct spelling for 42% of identified errors. Other limitations of spell checkers, which accounted for smaller numbers of uncorrected errors, include the possibilities that students may not recognize the correct spelling in the list of suggestions and that proper names may be falsely identified as errors.

Students can learn strategies to use spell checkers more effectively. McNaughton, Hughes, and Ofiesh (1997) taught high school students with LD to (a) generate additional suggestions when the intended word was not in the list of suggestions (e.g., try a phonetic spelling) and (b) proofread a hard copy looking for errors the spell checker missed. The strategies helped the students to identify and correct substantially more of their errors.

The design of spell checker software can also make a difference. For students with LD, it is important that the spell checker include phonetic rules in generating suggestions. Smaller, or adjustable-size, dictionaries can reduce the number of errors that are not detected by flagging uncommon words. Some spell checkers also flag homonyms, asking the user to consider whether the correct word was used. Finally, the addition of speech synthesis can help some students to select the correct word from the list of suggestions. However, no experimental evidence supports the effectiveness of these design features.

5 Speech Synthesis

Most research on speech synthesis for students with LD has studied its use as a support for reading (for a review, see MacArthur, Ferretti, Okolo, & Cavalier, 2001). However, it might also help students in revising. By listening to their text, students might be able to use their oral language skills to identify and correct errors they would miss by reading. Very limited evidence is available on this possibility. In one study (Borgh & Dickson,
1992), elementary school students wrote on a special word processor that prompted them to check for errors; half of the students used speech synthesis along with the prompts. No differences were found in overall amount of revision or on the length and quality of papers. Raskind and Higgins (1995) asked college students to detect errors in their papers under three conditions — speech synthesis, human reader, and no assistance. Students detected more errors in the speech synthesis condition, but the differences were not large in absolute terms (35% vs. 25% detection), and data on actual correction of errors were not reported. For additional discussion, see Quinlan (this volume).

6 Word Prediction

Students with severe spelling problems may have difficulty using spell checker successfully. The spell checker may not be able to help with badly misspelled words, or the students may not be able to read their own writing after finishing. Word prediction software offers another option for spelling support. Word prediction was originally developed for individuals with physical disabilities to reduce the number of keystrokes needed. It works by predicting what word the user intends to type based on the first letter(s). For example, if I have typed, *Pears are my f*, the program might offer a list of predictions including *friend, favorite,* and *first.* If I continue by adding an *a* to the *f,* the program would update the list, eliminating words that do not start with *fa* and adding new words. I could then insert the word in the text by typing the number of the word or clicking on it. Most word prediction systems also provide speech synthesis to help students read the list of words. Depending on the sophistication of the program, predictions will be based on syntax and recently used words as well as spelling.

Newell et al. (1992) reported case studies of 17 students using word prediction. Most of the students had physical disabilities, primarily cerebral palsy, though students with visual and hearing impairments, developmental delay, language disorders, and LD were also included. Of the six students who had mild to moderate language and LD, five showed improvements in accuracy of spelling, quantity of writing, and motivation.

MacArthur (1998, 1999) conducted three related studies of word prediction with 9- and 10-year old students with severe spelling problems, using single-subject designs that support causal conclusions about the effects of treatment on individual students. In the first study (MacArthur, 1998), five students wrote dialogue journals with their teacher, using a word processor in the baseline condition and word prediction with speech synthesis in the treatment condition. The word prediction program began with a vocabulary of 300 common words to which were added all words used by the teacher and student in their dialogue. In this study, the software was well adapted to the writing task. The speech synthesis made it possible for the student to read the teacher’s entry fluently. The vocabulary was relatively small and targeted on the words used in the dialogue. The treatment had a substantial effect on the legibility and spelling of writing for four of the five students. During baseline, the writing of these four students ranged from 55 to 85% legible words (i.e., readable in isolation) and 42 to 75% correctly spelled words. All four increased their percentage of both legible and correctly spelled words into the range 90–100%.
The other two studies (MacArthur, 1999) used word prediction software with a larger vocabulary and a more sophisticated prediction algorithm that used information on syntax and frequency of use by individual users. Effects of word prediction were limited to an improvement in spelling for one of three students. More detailed analysis of process data showed that students had difficulty using word prediction to find the correct word. In order to accommodate a large dictionary, the program used a fairly complex interface to predict words. For example, the word list changed as each new letter was typed, making it necessary to monitor the list continuously. Students also had difficulty when they did not type the initial letters correctly. The writing task and the software were not well matched because the journal-writing task did not demand the large vocabulary that made the program difficult to use. In a follow-up study with the same students, the writing task was changed to a controlled task demanding a larger vocabulary. Students wrote from dictation using selections from graded reading passages at their instructional reading level. Under these conditions, word prediction clearly improved legibility and spelling for two of the three students. Error rates were still high, but were substantially better with word prediction than with word processing or handwriting.

A more recent study (Handley-More, Deitz, Billingsley, & Coggins, 2003), which also used a single-subject design with students with LD and severe spelling problems, found similar effects; two of three students made substantial improvements in legibility and spelling. Thus, the available research supports the use of word prediction software with students with severe spelling problems. The studies also revealed that design issues, such as the size of the vocabulary, its match to the writing task, and the complexity of the interface, make a difference in the impact. Further research is needed to replicate and extend the findings to other groups and to investigate the potential impact on vocabulary use.

7 Speech Recognition

Dictation using speech recognition software represents potentially the most complete solution for students who have difficulty with handwriting, spelling, and overall fluency. As summarized above, the dictated compositions of students with LD are substantially longer and qualitatively superior to compositions written via handwriting or word processing (Graham, 1990; MacArthur & Graham, 1987; Reece & Cummings, 1996). However, despite dramatic improvements in the quality of speech recognition software in recent years, it still has important limitations in comparison to dictation to a person. First, accuracy is limited, even after training the system to understand an individual voice. Second, users must articulate carefully, must dictate punctuation and formatting, and must avoid extraneous vocalizations. Third, users must learn to recognize and correct new types of mistakes; in place of the spelling errors in handwritten or word-processed texts, users need to search for incorrect words in texts dictated using speech recognition. All of these limitations represent new cognitive burdens in place of the old burdens of handwriting and spelling.

On the other hand, speech recognition has an important advantage over normal dictation to a tape recorder in that the writer has access to the text already written (Reece & Cummings, 1996). Leijten and Van Waes (this volume) address this issue thoroughly.
A few studies of speech recognition with students with LD are available. Higgins and Raskind (1995) studied the effects of speech recognition with college students with LD. Students wrote essays under three conditions: speech recognition, dictation to a human who transcribed via handwriting, and unassisted (i.e., handwriting or word processing without a spell checker at the student’s choice). Quality ratings were significantly higher in the speech recognition than the unassisted condition. Quinlan (2004) selected middle school students who had significantly lower written language than oral language scores and compared them to students without such a discrepancy. All students composed four brief narratives using handwriting and speech recognition. Students with writing problems, but not the average writers, wrote longer papers using speech recognition. However, the poor writers’ dictated papers were not rated higher in quality than handwritten papers.

MacArthur and Cavalier (2004) investigated the feasibility and validity of speech recognition software and dictation to a scribe as accommodations for tests involving extended writing. By law, students with disabilities are entitled to accommodations, or modified test procedures, to remove barriers due to their disabilities, as long as the accommodations do not change the construct measured by the test. The study compared the effects of speech recognition, dictation to a person who typed on a visible screen, and handwriting on the writing of high school students with and without LD. In a repeated measures design, all students received training in speech recognition and then wrote essays in all three conditions. The students with LD made fewer total errors with speech recognition than handwriting. Students with LD produced higher quality essays using speech recognition than handwriting, and even better essays when dictating to a person. No statistically significant differences of condition were found for students without LD. The differential impact on students with and without disabilities was interpreted as support for the validity of the accommodation. See Quinlan (this volume) for a more complete discussion of research on speech recognition and developing writers.

8 Concluding Comments

Although the research on assistive technology for writing is not extensive, it does provide evidence that computer tools can offer significant support to writers who struggle with the basic mechanics of writing. Word processing, in combination with instruction designed to take advantage of its capabilities, can help students learn to revise and improve their writing overall. Spell checker clearly help students with spelling problems, and their limitations can be at least partially overcome with special instruction. Word prediction appears to be of value for students with severe spelling problems. Speech recognition has, perhaps, the widest applicability as it addresses concerns with handwriting, spelling, and fluency.

However, each of the tools has limitations and imposes new cognitive burdens on users. Word processing requires typing. Word prediction requires careful attention to word choices and slows the writing process. Speech recognition requires training, careful articulation, and new editing skills. Consequently, the tools will be useful for some struggling writers and not others. The implication for research is that more work is needed to determine which users are likely to benefit from particular tools. The immediate practical implication is that individual assessment of skills and trials with various computer applications
are needed to match students and tools. A related practical concern is the use of these technology tools in schools and other environments. Students and teachers need training and support, and some of the tools pose practical problems for use in school settings (e.g., dictating in classrooms).

Except for word processing, which has been studied in combination with instruction, these applications have been investigated as compensatory tools, which support production of text but are not designed to improve the user’s skills. However, Raskind and Higgins (1999) argued that regular use of technological tools might have transfer effects on skills. They presented preliminary evidence that regular use of speech recognition improved the reading skills of high school students with LD. Further research is needed to investigate transfer effects for tools such as spell checker, word prediction, and speech recognition. It is likely that obtaining transfer effects will require the development of instructional methods that use the capabilities of the tools with the goal of increasing students’ independent skills.

Fifteen years ago, most word processors used in schools did not have integrated spell checker or high-quality screens; high-quality speech synthesis required special hardware; word prediction was available only in specialized augmentative communication devices; and speech recognition required users to dictate isolated words. The rapid changes in technology present significant problems to schools and researchers. Schools have difficulty updating their technology and training their staff. Researchers are challenged to design research that will have meaning beyond the current status of the technology. Research and development is needed to understand the benefits and limitations of these tools with various students and to develop and evaluate models for use of the tools in classroom situations.