Word Processing as an Assistive Technology Tool for Enhancing Academic Outcomes of Students with Writing Disabilities in the General Classroom

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Abstract

This study investigated the use of a word processor for enhancing the academic outcomes of three students with writing disabilities in a junior high school. A single-subject ABAB design was used to compare academic output produced during class time with and without a computer equipped with a word processor. The number of spelling errors, the number of reading errors, and the number of words used per text were counted, and the overall structure and organization of text were examined across all in-class materials. The data demonstrated a clear difference between handwritten and computer phases. In traditional paper-and-pencil phases, students produced outcomes that had more spelling mistakes, more reading errors, and lower overall quality of organization and structure in comparison with the phases in which a computer equipped with a word processor was used. The results did not indicate any noticeable difference in the number of words per text. Implications and future research directions are discussed.

Students with learning disabilities (LD) experience significant difficulties with the writing process (Bahr, Nelson, & Van Meter, 1997; Newcomer & Barenbaum, 1991). A significant portion of school time (i.e., 30%–60%) is dedicated to various writing assignments (McHale & Cermak, 1992). Whereas most of the students cope with the writing tasks, students with LD have difficulties in fulfilling their demands (Graham & Weintraub, 1996), resulting in reduced academic achievement throughout the school years (Deuel, 1994; Wong, 1996).

Written language disorders have been referred to as failures in developmental output (Berninger, 1994; Deuel, 1994). Written language problems usually occur in the context of reading or of arithmetic and mathematics (Siegel, 1999). Some individuals have difficulties only with writing or spelling. Spelling difficulties can occur also in the absence of severe reading disabilities; however, this form of isolated writing disorder is relatively rare (Berninger, 1994; Siegel, 1999). The term *dysgraphia* refers to a childhood disorder of written language expression (Deuel, 1994). Developmental dysgraphia is described in conjunction with dyslexia, motor clumsiness, or spatial difficulty (Deuel, 1994). Students with dysgraphia write slowly, they form letters incorrectly, and their final product is messy and often illegible (Lewis, Graves, Ashton, & Kieley, 1998). Their errors may include errors in handwriting, illegible letter formation, spacing errors, margin errors, and punctuation and spelling errors (Schumaker, Nolan, & Deshler, 1985; Wong, 1996).

A major goal for educators working with students with LD is to provide appropriate support to enhance their opportunities to achieve academic and social skills (Villa, Thousand, Stainback, & Stainback, 1993). Lewis et al. (1998) indicated two major approaches to the writing problems of students with LD. The first centers on modification of the traditional instructional procedures used to teach writing skills, and the second on using word processing for improving writing skills.

In the last decade, technological advances have provided new opportunities for individuals with LD (B. R. Bryant & Seay, 1998). Assistive technology (AT) is a tool for making the learning environment more accessible and for enhancing individual productivity (Day & Edwards, 1996). Although AT is recognized in the area of rehabilitation for persons with physical disabilities, it has also received attention as a tool for helping individuals with LD and other specific cognitive deficits (Day & Edwards, 1996; MacArthur, 2000; Raskind & Higgins, 1998).

The majority of reports involving students with LD using AT have investigated written language difficulties (Day & Edwards, 1996). An early study investigating the use of a word processor as a tool for improving writing skills in elementary school–age children with LD and mild mental retardation found that they improved their writing skills once they learned keyboarding (Margalit & Roth, 1989). Langone and Willis (1994–1995) compared the use of a computer-based word processor with the use of a paper and pencil for teaching writing skills to elementary school students with LD. An alternating treatment design was used to compare the relative effects of each instructional strategy. The results indicated that both strategies were effective for teaching writing skills, with individual differences between the students (Langone & Willis, 1994–1995). A longitudinal study comparing two groups of elementary school students with and without access to a word processor found that the students who were using word processing demonstrated significantly greater writing competence in meaning, in content quality, in writing form, and in surface features (Owston & Wideman, 1997). Students with LD can derive great benefits from using word processors. The ability to produce a product that can be edited, spell-checked, read, and presented to the teacher can increase motivation and encourage writing, because specific problems with handwriting and spelling can be circumvented (MacArthur & Graham, 1987; MacArthur & Shneiderman, 1986).

Research comparing the abilities and the outcomes of students with LD and those of typical students revealed that although the receptive vocabulary and oral language abilities of students with learning disabilities were similar to those of students with typical abilities, the written outcomes (i.e., spelling and perceptual–motor skills) of the students with LD were significantly lower (Johnson & Carlisle, 1996; Newcomer & Barenbaum, 1991). Johnson and Carlisle (1996) reported that the ability to produce improved written material may be enhanced once the students use word processing. They also indicated that the use of word processing might enable individuals with LD to focus on issues such as structure, organization, and clarity of writing, which would also assist them in reading their own products (Johnson & Carlisle, 1996).

An overview of research on the use of AT by postsecondary students with LD revealed that AT was effective for some of the students in compensating for specific deficits in areas such as reading and writing (Raskind & Higgins, 1998). It allowed them to compensate for reading, organization, memory, or math problems and to enhance their functionality within their environment (Day & Edwards, 1996). Raskind and Higgins (1998) questioned if the use of a word processor as a compensatory tool during the writing process would enhance the productivity of secondary and postsecondary students and produce better outcomes.

A 3-year project investigating the effects of AT on the performance of postsecondary students revealed that AT can be effective in compensating for specific deficits in areas such as reading and writing by college students with LD (Raskind & Higgins, 1998). However, the compensatory effectiveness of select technologies needs to be evaluated for specific difficulties, for contexts, and for outcomes (Raskind & Higgins, 1998). A study involving elementary and secondary students with and without LD investigated the use of spell checkers and grammar checkers and found that for mechanical errors, spell checkers were useful (Lewis, Ashton, Haapa, Kieley, & Fielden, 1999; Lewis et al., 1998). However, results on the use of grammar checkers were mixed (Lewis et al., 1999). It has been recognized that students with LD need to acquire specific competencies necessary to meet academic demands in the secondary-level classroom (Anderson-Inman, Knox-Quinn, & Horney, 1996). These competencies may be acquired by using word processing to compensate for their deficits and enable them to produce better academic outcomes using their strengths and skills (Anderson-Inman et al., 1996). A meta-analysis of studies involving the use of word processing by K–12 students found that word processing improved writing quality especially for students with LD who were receiving remedial intervention in writing (Lewis, 1998; Lewis et al., 1998). However, general education students wrote higher quality compositions at both pretest and posttest than students with LD. The meta-analysis also revealed that most of the use of word processing involved instructional strategies (Lewis, 1998; Lewis et al., 1998).

Illegible handwriting, spelling mistakes, and lack of text organization skills affect the academic outcomes of students with writing disabilities (Berninger, 1994; Graham & MacArthur, 1988; Johnson & Carlisle, 1996; MacArthur & Graham, 1987). Two main areas have been found to be impaired: (a) the students' ability to read the written outcomes, and therefore their teachers' capability to read it as well; and (b) a decrease in the text length as a result of fine motor fatigue (Berninger, 1994; Johnson & Carlisle, 1996) and the difficulty of revising the written draft (Graham & MacArthur, 1988; MacArthur & Graham, 1987). These two academic areas were found to have a great impact on the students' academic functioning during class activities and home assignments. However, the assessment of those activities within the classroom and the ability to read the written outcome produced by the students in the classroom were not investigated. The integration of technology into classroom instruction is recognized as an important element that can meet the needs of students with LD and solve authentic problems on a regular basis (D. P. Bryant & Bryant, 1998). As students become involved in higher level educational activities, writing in the classroom becomes an essential tool for academic achievements. Difficulties in completing regular classroom tasks may impair the accomplishments of students with dysgraphia. Exploring accommodations and tools that can compensate and assist the students in the classroom are critical.

The purpose of this study was to investigate the effects of AT as a compensatory tool on the written outcomes of students with writing disabilities produced in the classroom during regular classroom activities in a junior high school. A computer equipped with a word processor was used as the compensatory AT tool.

Method

Participants

Participants were selected for the study based on the following criteria:

1. a formal diagnosis of learning disability obtained from school records;
2. a consistent school record of underachievement attributed to illegible handwriting;
3. age-appropriate reading abilities according to school records and a systematic reading evaluation (see description);
4. IQ scores in the average range based on formal school records;
5. basic knowledge in using a word processor as established by an informal evaluation;
6. motor dysgraphia assessed according to Deuel's (1994) guidelines as follows: (a) illegible penmanship; (b) written spelling errors; (c) illegible handwriting and incomplete results of written text even when copied; (d) incomplete and combined letters and words; and, (e) difficulties and compromising in drawing; and
7. difficulties in text organization.

Participants selected for the study—Olli, Al, and Dan—were three male students, 12 to 13 years old, enrolled in two seventh-grade general education classrooms in a junior high school. They all showed numerous spelling errors, illegible penmanship, and difficulties in copying text, and tended to write incomplete and combined letters and words. Olli, Al, and Dan were characterized as being of middle class socioeconomic status, and their native language was Hebrew.

All participants had typical reading abilities based on school records and teacher reports. An informal reading assessment, which included reading and comprehension tasks, confirmed the evaluation. The systematic reading evaluation was based on an age-appropriate text and evaluated the following measures:

1. percentage of words correctly read aloud (Olli 99.75%; Al 96.5%; Dan 98.2%);
2. vocabulary (i.e., ability to define words from the text; Olli 100% correct; Al 75%; Dan 90%);
3. identifying the main idea (all students successful);
4. describing the chronological order of topics in the text (all students successful);
5. answering content questions (Olli 100%; Al 75%; Dan 100%); and
6. ability to draw conclusions based on the text (all students successful).

The students performed at an independent reading level for their level of word identification (Duffy, 1990; A. J. Harris & Sipay, 1979; L. A. Harris & Smith, 1986). Both Olli and Dan demonstrated an independent level of comprehension with a score of 100%, which ensured that they were using an automatic and fluent decoding level (Samuels & Farstrup, 1992). Al demonstrated an instructional level of comprehension, with a score of 75% (Duffy, 1990; Samuels & Farstrup, 1992).

The three students demonstrated basic knowledge of keyboarding and word processing with an ability to create, open, and save documents. Olli and Dan tended to use two hands for typing on the computer keyboard. They also knew all the needed word-processing functions and demonstrated a high general level of skills when working on the computer. Al tended to use only one hand for typing on the keyboard. He knew only some of the basic word-processing functions and demonstrated only a limited general ability in word processing.

Setting and Materials

All students participating in the study worked in their classroom at their regular desks using paper-and-pencil materials or a laptop PC computer according to research condition. No other differences existed in the setting between the two research conditions. One investigator sat by each student during all sessions.

Pencils, pens, markers, and a ruler were provided for Phases A1 and A2 of the study. A PC-compatible laptop computer equipped with a commercially available word processor (Word 2000®) was used for Phases B1 and B2 of the study. These conditions served as the independent variable in the study.

Design

A single-subject research design was used for this study. An ABAB design, with a withdrawal between Phase B1 and Phase A2, was implemented. A training phase was implemented between Phases A1 and B1 (Kazdin, 1982; Kratochwill & Levin, 1992).

Dependent variables included the following:

1. percentage of spelling errors taken from all final products and calculated as the number of errors divided by the number of words and multiplied by 100 (repeated mistakes were not counted);
2. percentage of errors in the oral reading of final products was calculated by counting the number of errors in reading and dividing them by the number of words in the text and multiplying by 100 (repeated mistakes were not counted);

3. total number of words in the text taken from all final classroom products (regardless of the spelling errors); and
4. text structure and organization (checked for existence regardless of the number of items in the text).

Text structure and organization included the following variables: (a) existence of underlining or other special features (such as WordArt®) for emphasis of the title, a sentence, or a word in the text (regardless of the number of items per text); (b) existence of color or highlighting under a title, a sentence, or a word (regardless of the number of items per text); (c) existence of a title (regardless of the number of words in the title); (d) existence of text organization (defined as the organization of paragraphs according to titles, subtitles, bullets, numbers, tables, or schemes); and (e) existence of drawings or pictures (such as clip art) in the final product. The existence of each variable was checked at the end of each session. All items in the text structure and organization variable were counted, divided by the number of sessions in each phase, and multiplied by 100.

Procedure

A junior high school located in a major city in Israel was selected for the study. After an explanation of the research and goals, the school identified several students as potential participants in the study. Once consent forms were signed, all potential participants were interviewed and evaluated on the selection criteria of the study. Language arts and Bible were selected as the target classes due to the variety of activities offered in the classroom (i.e., copying from the blackboard, dictation, and creative writing tasks). The language arts teacher and the Bible teacher taught the three students. During the lessons, the students were requested to fulfill all in-class assignments. These products were evaluated at the end of each session.

The experiment began after all assessments were obtained and participants were selected. To ensure appropriate use of the materials, one investigator sat by each participant twice a week for 1 hour per session during the whole experiment. Each session was 45 minutes long (total duration of a lesson in Bible and language arts classes). The examiner sat by the student during the whole lesson. The typical lesson included a 10- to 15-minute lecture by the teacher, followed by a 10- to 15-minute discussion, which was accompanied by writing on the blackboard. After reading a segment from the textbook, the teacher wrote the main ideas on the blackboard, followed by the composition of an independent creative summary by the students. Furthermore, the students were often expected to write answers to questions presented during the discussion. At the end of each lesson, the students were requested to copy all homework assignments, which were also written on the board. All students were expected to copy all information from the blackboard, regardless of the time needed to finish the task.

All written and printed materials produced during in-class activities were collected from the students at the end of each session and evaluated for the percentage of spelling errors, the number of words written in the text, and the existence of structuring and organization items in the text. Moreover, the students read their written output at the end of each lesson, and the percentage of reading errors was recorded. This evaluation was used during all phases of the study, and for all in-class material written by the participants.

Phase A1 was used to establish a baseline and to monitor the use of traditional paper-and-pencil materials. During this phase, one of the investigators came to the classroom and sat by each participant as determined in the agreement with each participant and teacher.

Once a clear baseline pattern was established, the first phase ended, and a training session was implemented. The criterion for terminating the baseline phase was established based on a clear, unstable pattern of baseline, as Phase B1 was expected to create a substantial increase in the stability of the data and in the trend and level of the data collected (Kazdin, 1982; Richards, Taylor, Ramasamy, & Richards, 1999). Basic functions of word processing were introduced and explained, including underlining, shortcuts, implementing graphics, and importing clip art. Students were also provided with an opportunity to practice using the portable computer. As in the previous stage, the same investigator sat by each student, collected all output products, and graphed the results. Training lasted four sessions in order to provide sufficient practice time. Once the training ended, Phase B1 began, and the participants started to use the computer independently for all in-class activities.

During Phase B1, a portable computer was brought to the classroom by the investigator for each session. The investigator continued to sit by the student during all sessions. No further training was provided. The written output was evaluated and graphed at the end of each lesson. The criterion was set to approximately seven sessions per phase. The change from Phase B1 to A2 was determined according to the stability of the data. Stability was defined as three consecutive sessions in which the data did not alter more than 10% from the mean of all previous days of that phase (Kazdin, 1982).

Phase A2 included a withdrawal procedure. Participants were informed that the computer would not be available for a period of time, due to maintenance needs, and that they should go back to their previous method of using paper-and-pencil materials. The investigator continued the same procedure of sitting by the student and collecting all materials at the end of the class and recording all reading errors. Once the pattern of behavior was apparent, the data points became unstable again, and the level and the trend changed, intervention resumed.

Phase B2 began, and the laptop computers were brought back to the classroom. Students returned immediately to using the computers independently for all in-class activities. Intervention terminated when stability returned and eight sessions ended.

Interobserver agreement was obtained for 20% of all permanent products. An observer recorded all errors independently. Interobserver agreement in the area of reading errors was not measured due to the agreement permitting only one investigator each time in the classroom.

Results

Interobserver agreement data were obtained for 20% of permanent products. An observer recorded spelling errors, number of words in text, and structural and organizational features. The data were collected during all phases and analyzed independently by the two observers. The comparison of both observers' recordings resulted in interobserver agreement of 95%, 94%, and 95% for Olli, Al, and Dan, respectively.

The graphed data indicated a clear difference between Phases A and B across all participants and across all variables (see Figures 1–3). The means showed similarities within phases and a clear difference between Phases A and B (see Tables 1–3). Statistical analysis of the findings for the three participants included the following variables: percentage of spelling errors, percentage of reading errors (counted only for reading errors regardless of the spelling errors in the text), number of words that were written in the text, and percentage of organizing and structuring elements (see Tables 1–3). A simple *t* test was used to obtain the statistical information regarding the dependent variables for the three students.

The visual examination of Olli's results suggests a decrease in spelling mistakes and reading errors in the B phases, when he used a word processor (see Figure 1). Although there is a slight increase in the number of words in the text in Phase B2, it does not portray a clear difference in the pattern. Phase A1 lasted eight sessions due to instability in the baseline data. An example of the instability in the results is clearly depicted in the data displaying reading errors. A clear 15% drop from the last point of Phase A1 to the first point of Phase B1 and a 5% change in the mean demonstrate the difference between the first two phases. Phase B1 lasted five sessions, with reading errors stable across all data points (range 0%–1%). Although the increase from the last data point in Phase B1 to the first data point in Phase A2 was only 3%, during the seven sessions in this phase, the mean was 8% and the difference from the last point of Phase A2 to the first point of Phase B2 reached a difference of 21%. Phase B2 lasted nine sessions, in which all data points indicated 0% reading errors.

The statistical analysis of the data obtained for Olli is summarized in Table 1. Significant differences were found in the percentage of spelling errors and in the percentage of reading errors between the A and B phases, but no difference was found within those phases. An indefinite conclusion is drawn regarding the number of words written in the text, as the measurement tool was not designed to measure copied written output. However, standard deviation data indicated stability in the text length in the word-processing phases as opposed to wide dispersion in the paper-and-pencil phases.

Descriptive and statistical analyses indicate a significant difference in Olli's use of text organization and structuring elements in the word-processing phases versus the paper-and-pencil phases (see Table 1). The quality and quantity of text structure and organizational elements changed significantly between the phases. Underlining changed from 75% use in Phase A1 to 100% in Phase B1. Although colors were available across both phases, there was no use of color in the paper-and-pencil phases and 100% use of coloring features in the texts produced using word processing. The existence of a title was 100% in both intervention phases. The existence of a title varied in the paper-and-pencil phases, with an average of 75% in Phase A1 and 50% in Phase A2. Text organization was visible in 50% of the phases using handwriting, compared to 100% in the computer phases. The use of pictures and other graphics increased from 0% in both Phases A1 and A2 to 50% in Phase B1 and 33% in Phase B2. Thus, there was a significant difference between the A and B phases, $p = .0038$, and no significant difference within the phases, $p = 1$ for Phase A, and $p = .84$ for Phase B.

Al's number of spelling mistakes, number of oral reading errors, and number of words written in the text are portrayed in Figure 2. A clear decrease in spelling mistakes and reading errors was noticeable in the B phases. No differences were detected in the number of words used in the text between the two phases. As in Olli's baseline, Al's baseline data demonstrated instability. The B phases demonstrated a clear, stable line both in reading errors and in spelling mistakes.

Table 2 summarizes the statistical analysis of the data obtained for Al across all conditions. The two phases were significantly different in the percentage of spelling errors and in the percentage of reading errors. No difference was detected for the number of words in the text for Al between phases. Significant differences were found in all elements of text structure and organization for Al in quality and amount between phases (see Table 2). Underlining changed from 43% in the handwritten text to 87% in the word-processing text, then decreased to 60% in Phase A2, and increased in Phase B2 to 100%. As with Olli's results, colors were available across all conditions, yet there was no use of colors in the paper-and-pencil phases, and colors

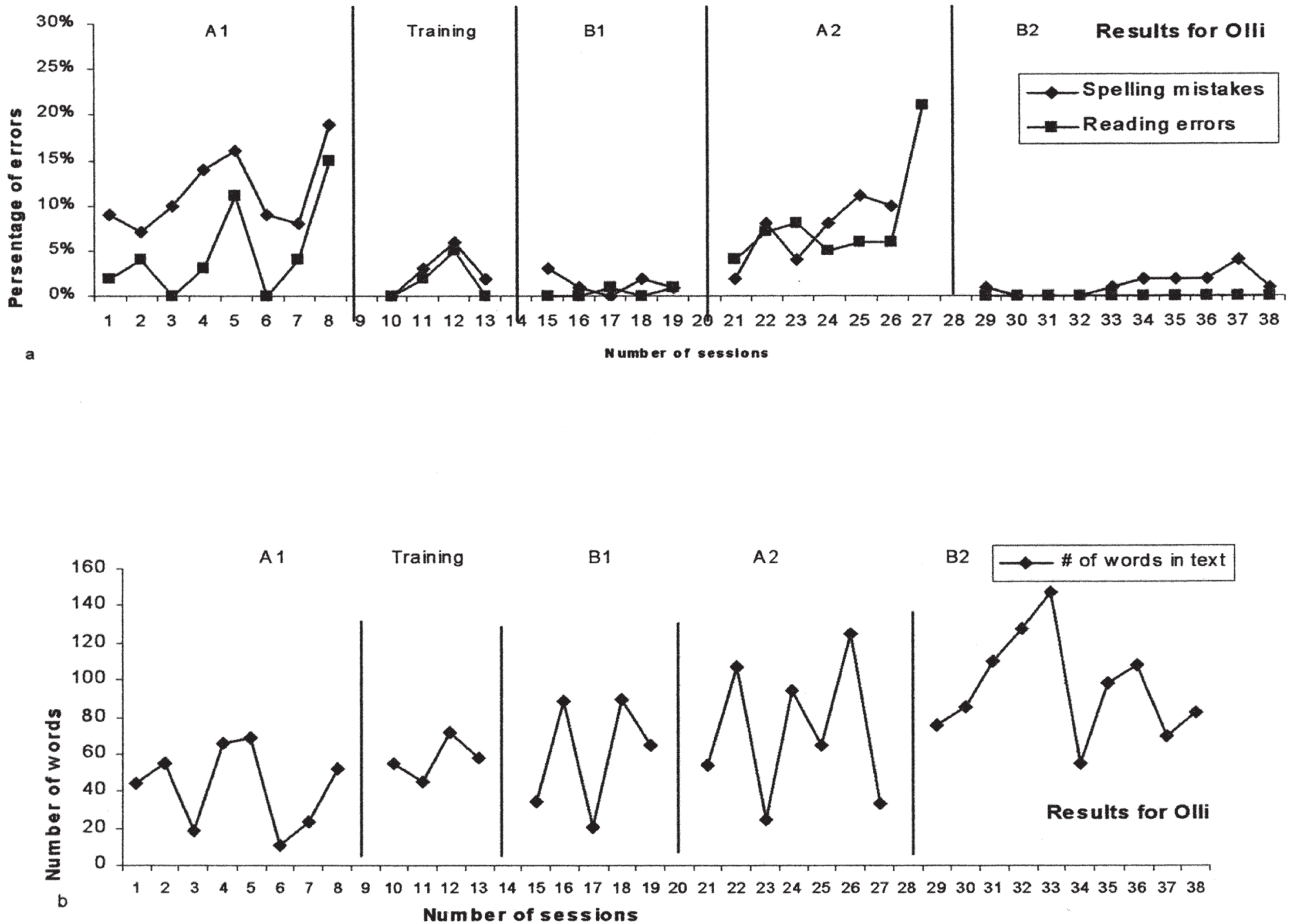

FIGURE 1. Results for Olli across spelling errors, reading errors, and number of words per text for all experimental sessions.

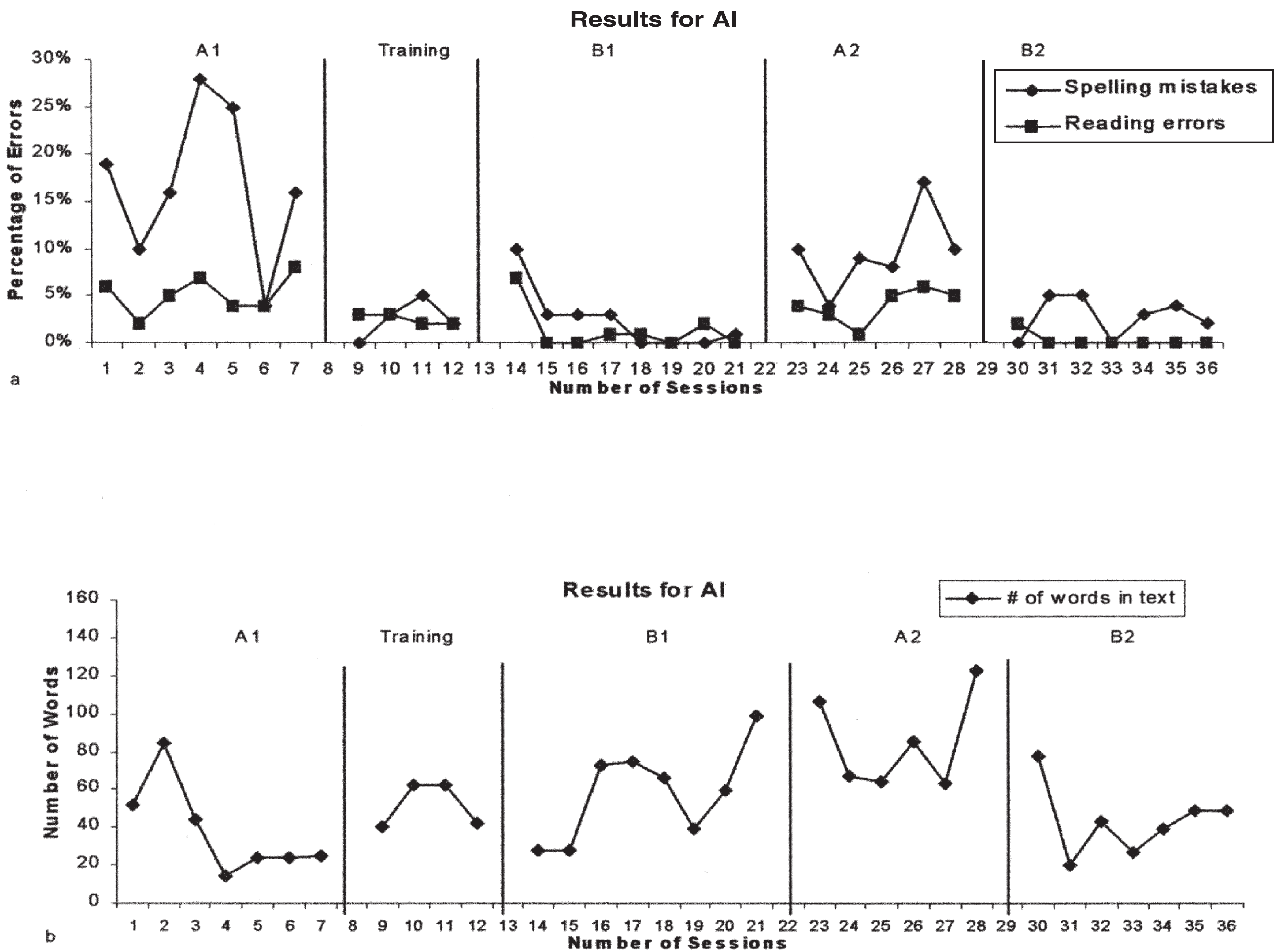

FIGURE 2. Results for AI across spelling errors, reading errors, and number of words per text for all experimental sessions.

TABLE 1
Results of Statistical Analysis for Olli Across Variables

Measure	Phase			
	A1	B1	A2	B2
Spelling errors (%)				
M	12	1	7	1
*SD***	4.30	1.13	3.48	1.25
Reading errors (%)				
M	5	0	8	0
*SD***	5.35	0.54	5.81	0
Number of words per text				
M	43	59	72	96
*SD**	22.00	31.00	37.90	27.97
Organization and structure (%)				
Use of underlining	75	100	100	100
Use of color or highlighting	0	100	0	100
Use of title	75	100	50	100
Text organization	50	100	50	100
Drawings or pictures	0	50	0	33
*SD***	37.91	22.36	41.83	29.96

*$p < .05$. **$p < .01$.

TABLE 2
Results of Statistical Analysis for Al Across Variables

Measure	Phase			
	A1	B1	A2	B2
Spelling errors (%)				
M	17	3	10	3
*SD***	8.25	3.33	4.22	2.13
Reading errors (%)				
M	5	1	4	0
*SD***	2.05	1.92	1.92	0.70
Number of words per text				
M	38	58	85	44
*SD**	24.10	25.12	25.03	18.68
Organization and structure (%)				
Use of underlining	43	87	60	100
Use of color or highlighting	0	100	0	100
Use of title	86	100	80	100
Text organization	71	100	20	100
Drawings or pictures	0	100	80	50
*SD***	39.64	5.81	36.33	22.36

*$p < .05$. **$p < .01$.

were used in 100% of the text produced with a word processor. Title existence was 100% when using a word processor (Phases B1 and B2), and 86% and 80% for the paper-and-pencil phases (Phases A1 and A2). Use of underlining and color, use of titles, text organization, and use of graphics and pictures were significantly different between the phases, $p = .0018$, and not significantly different within the phases, $p = .75$ for Phase A, and $p = .23$ for Phase B.

Figure 3 depicts the results for Dan for the number of spelling mistakes, the number of errors in reading, and the number of words written in the text (see Figure 3). A noticeable decrease can be detected in the percentage of spelling mistakes and reading errors from the A phases to the B phases. Although there was a noticeable increase in the number of words per text in Phase B1 and a decrease in the transition to Phase A2, there was no clear difference in the transition back to Phase B2. All phases seemed to be unstable, although the mean of the number of words in the B phases seemed to be higher.

Statistical analysis demonstrates significant differences in the percentage of spelling errors and the percentage of reading errors between the A and B phases, and no difference within those phases, for Dan (see Table 3). No significant differences were found for the number of words in the text. The descriptive and statistical analysis of the organizational and structural variables indicates a significant difference between the paper-and-pencil condition and the word processing condition (see Table 3). The quality and the quantity of the structure and organization variable changed significantly between phases. Underlining changed from 37% in Phase A1 to 100% in Phase B1, and from 86% in Phase A2 to 38% in Phase B2. Although colors were available for Dan during the whole study, he added color only during the word-processing phases. Titles were also 100% existent only during the intervention phases and decreased to 75% and 43% in Phases A1 and A2, respectively. Text organization was visible in 60% of the material in the handwriting phases and 100% during the word processing phases. The use of pictures and other graphics increased from 0% in both A phases to 40% and 25% in Phases B1 and B2, respectively. The difference between the A and B phases was significant, $p = .008$, whereas the difference within the phases was not significant, $p = .92$ for Phase A, and $p = .48$ for Phase B.

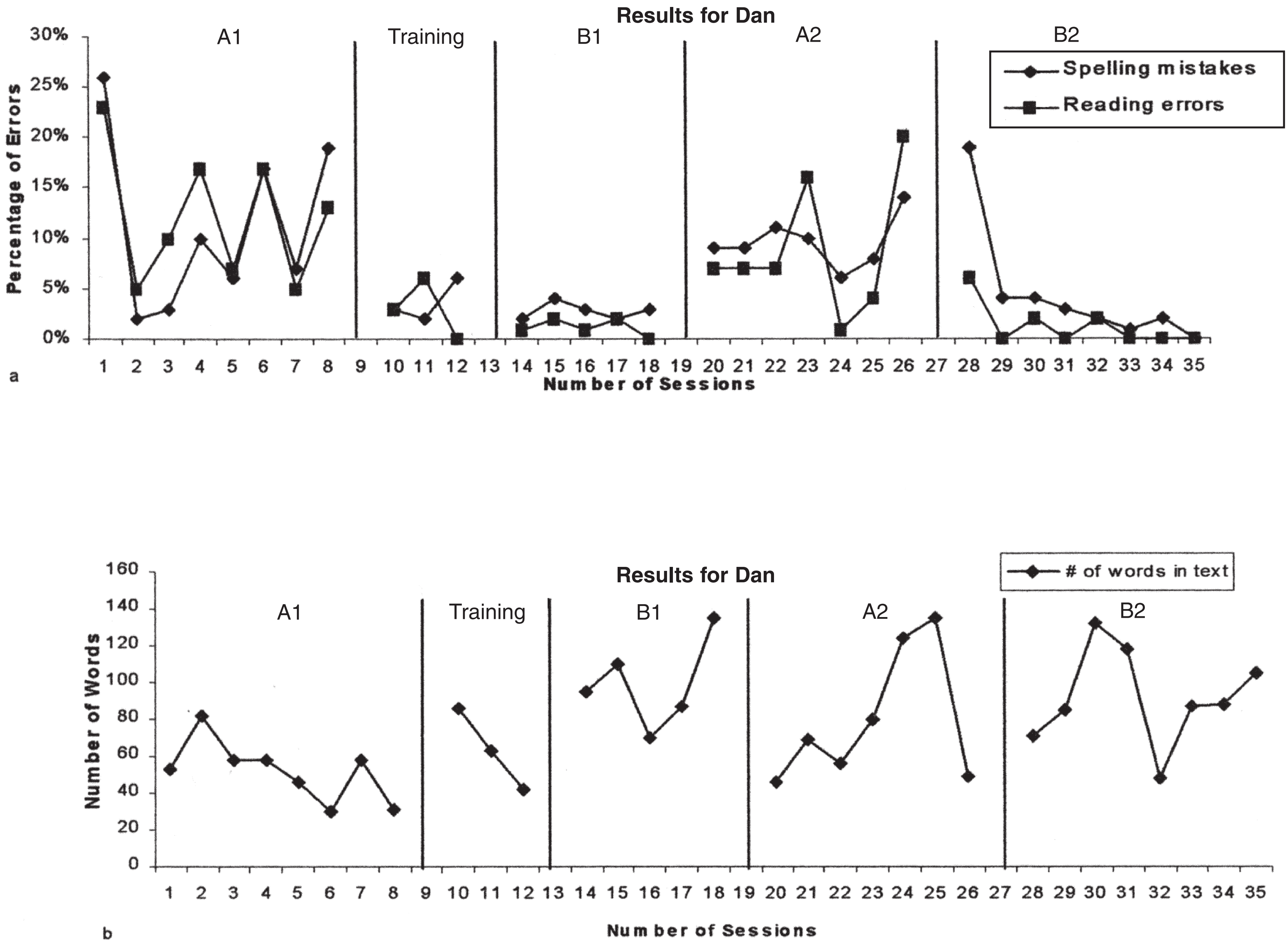

FIGURE 3. Results for Dan across spelling errors, reading errors, and number of words per text for all experimental sessions.

TABLE 3
Results of Statistical Analysis for Dan Across Variables

Measure	Phase A1	Phase B1	Phase A2	Phase B2
Spelling errors (%)				
M	11	3	10	3
*SD***	8.54	0.83	2.50	3.05
Reading errors (%)				
M	12	1	9	1
*SD***	6.53	0.84	6.74	2.12
Number of words per text				
M	52	99	80	92
*SD**	16.77	25.58	35.99	26.48
Organization and structure (%)				
Use of underlining	37	100	86	38
Use of color or highlighting	0	100	0	100
Use of title	75	100	43	100
Text organization	63	100	57	100
Drawings or pictures	0	40	0	25
*SD***	34.77	26.86	37.33	37.79

*$p < .05$. **$p < .01$.

A comparison of the direction and number of spelling errors during Phase A2 indicates that the number of spelling errors (4.6%, 7.6%, and 9.6% for Olli, Al, and Dan, respectively) in the first third of Phase A2 was smaller than the number of spelling errors (9.6%, 11.6%, and 9.5% for Olli, Al, and Dan, respectively) in the third part of Phase A2.

Discussion

The purpose of this study was to examine the effects of word processing on the academic outcomes of students with LD with specific writing disabilities. The results provide support for the effectiveness of a computer-based word-processing system for enhancing classroom academic outcomes. The study suggests that these three junior high school students who were using a word processor in the classroom were able to produce material that was more acceptable by class standards. They made fewer spelling mistakes, used more organization and structure, and made fewer reading errors when reading their own written outcomes. For example, with the assistance of the computer, participants were able to produce results that increased the use of titles, underlines, and other text organizing features. Most of all, students were able to read their own material with fewer reading errors. These results concur with the results of previous studies that found that the use of the spell checker feature in the word processor reduced the number of spelling mistakes made by children with LD (Graham & MacArthur, 1988; Lewis, 1998; Lewis et al., 1998; Margalit & Roth, 1989; Raskind & Higgins, 1998).

Through the use of the word processor, all participants reduced spelling errors by using the spell checker feature of the word processor and by keeping spaces between letters and words. The use of the red underline feature of the word processor and the availability of the spell checker increased their awareness of the existence of their errors in the text. From the comparison of the first and third parts of Phase A2, it seems that during the withdrawal phase, students initially checked for spelling mistakes, but after a while the spelling errors increased again. This could be the result of a loss in their awareness or of fatigue from the continuous search for the correct spelling. This issue should be further investigated to enhance the understanding of such spelling mistakes in the handwriting of students with writing difficulties.

Variability of spelling errors across the handwritten phases in comparison with the stability of the low number of errors in the word-processing phases could be a result of the type or length of text written or fatigue or concentration level of the student. The reasons for this instability in spelling mistakes may be investigated in future research.

This research found variability in reading errors in the A phases and a stable, low number of errors in the B phases. These results coincide with the variability detected across spelling errors. Thus, the lower number of spelling errors found in the text produced by the students could be the primary cause for the fewer errors detected during oral reading. The results indicate that when the three students read their own handwriting, many errors were detected; they were reading with only 87% and 91% accuracy in Phases A1 and A2, respectively. All students read their written output with an accuracy level of 98% in both B phases. These results demonstrate that in the A phases, the participants were performing at a frustration level of reading (Duffy, 1990; L. A. Harris & Smith, 1986; Samuels & Farstrup, 1992). These results were noticeable especially with Dan (see Table 3). Although comprehension was not investigated in this study, research has demonstrated that reading at a frustration level may affect comprehension (e.g., Samuels & Farstrup, 1992). Further research may assist in understanding this possible relationship between the two variables.

The number of words produced per output was chosen to detect an additional variable in identifying the differences between handwriting and word-processing phases for in-class academics. Because the results of previous studies investigating the effects of word processing on the length of the text were mixed (Graham & Mac-

Arthur, 1988; MacArthur & Graham, 1987), it was interesting to investigate the influence of word processing on the length of the text. The rationale for choosing this variable is the notion that students who tire easily from writing would write fewer words when possible (Deuel, 1994). This could not be investigated appropriately in this study, as most of the written output produced in these classes was dependent on the teacher's instructions to copy from the blackboard. The opportunities the participants had to produce independent written materials were few and insignificant for the study. Thus, the number of words per text was not an appropriate tool for measuring differences in classroom activities across phases. This variable should be reinvestigated under different conditions that enhance independent, self-initiated text production.

The use of text organization and structure, however, was significantly different between the two phases across all variables investigated. The ability to organize and to use the tools that a word processor provides with great ease could be the reason for those differences. Thus, although the tools were available across both phases, they were used almost entirely during the word-processing phase. The ability to produce drawings and pictures, incorporate color, and organize the text to satisfaction without the need to erase, plan, and use too many tools could be the reason for the use of those materials. Lack of knowledge and limitations in using the tools could have made a difference between the first two phases in the study. However, during the withdrawal phase, students again reduced their use of organizational tools. Thus, the word-processing tools were used more often than the traditional tools even after learning their potential effects. These results support the results reported by Owston and Wideman (1997), who found that while students with LD were using the computer, the clarity of the output and their ability to organize the text improved, their motivation to write increased, and their frustration diminished. The novelty effects could have decreased as the research continued for several months, but the ability to demonstrate the results to teachers and peers remained over time. The effects of the ability to show the written material to peers and teachers should be further investigated.

The word processor increased the students' awareness of spelling and grammatical errors and helped them distinguish between different kinds of errors. It enhanced the students' ability to read their own written product. This may have improved their academic functioning as expressed in the ability to use written output for independent learning, for homework assignments, and for various assessment/testing situations (MacArthur, 1997).

The use of word processing may allow junior and senior high school students with LD to take control over their assignments while using their strengths instead of their deficits (Anderson-Inman et al., 1996). The use of the word processor increased the readability of the written output for participants and for their teachers and peers. As a consequence, it may enhance the outcomes that students are able to produce and motivate them to take control of the text. This process might also foster their confidence in their written work and may result in changing their peers' and teachers' attitudes toward their written output. It may also facilitate the revising and editing process during writing. These issues should be further investigated in future research.

In summary, the use of word processing improved written outcomes produced in the classroom for students with writing disabilities and allowed them to structure and organize the text, decrease their spelling errors, and reduce their reading errors when reading their own written output. Significant differences in text length were not found because the measurement tool was not suitable for investigating texts that were dependent on copying the assignments from the blackboard. The use of a word processor enhanced the writing performance of these students with writing difficulties, which was apparent by the reduction of writing and reading errors and the improvement of text structuring and organization. Thus, the ability to produce texts with a reduced number of spelling mistakes and the ability to read the output with higher accuracy point to a possible improvement in academic functioning in the general education classroom.

This study demonstrates the use of a compensatory tool for enhancing the acceptability of the performance of these three students with LD and points to the advantages of using a word processor to compensate for their writing difficulties during class sessions. Further studies could extend these research findings and explore whether there is a connection between improvement in the technical aspects of writing (i.e., spelling, grammar, format) and improvement in the content of the writing when students with writing disabilities use a word processor in the classroom. Moreover, the implications of the students' writing improvement for their academic achievement in the classroom might be investigated in future research.

These research findings should encourage educators to allow students with writing disabilities to have free access to a word processor in their classroom and to encourage their using the computer for home activities as well. The word processor could be considered a writing tool for those students who have writing difficulties, especially in junior high and senior high school, where compensation for disabilities becomes more appropriate. Further research could increase the understanding of the significance of this tool for high school–age students. Further research should investigate the relationship between the improvement of AT-based academic outcomes and the improvement of academic skills across the curriculum.

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