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The effect of a touch-typing program on keyboarding skills of higher education students with and without learning disabilities

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ABSTRACT

This study examined the effect of a touch-typing instructional program on keyboarding skills of higher education students. One group included students with developmental learning disabilities (LD, $n = 44$), consisting of students with reading and/or handwriting difficulties. The second group included normally achieving students (NA, $n = 30$). The main goal of the program was to increase keyboarding speed while maintaining accuracy. The program included 14 bi-weekly touch-typing lessons, using the "Easy-Fingers" software (Weigelt Marom & Weintraub, 2010a), that combines a touch-typing instructional program and a keystroke logging program, to document the time and accuracy of each typed key. The effect of the program was examined by comparing keyboarding skills between the beginning (pre-test), the end of the program (post-test) and 3 months after termination of the program (long-term). Results showed that at the end of the program, keyboarding speed of the NA students decreased while the speed of the students with LD somewhat increased. In the long-term evaluation, both groups significantly improved their speed compared to pre-test. In both cases high accuracy (above 95%) was maintained. These results suggest that touch-typing instruction may benefit students in general, and more specific, students with LD studying in higher education, which often use computers in order to circumvent their handwriting difficulties.

1. Introduction

The increase of students with specific learning disabilities (LD) studying in higher-education institutes calls for a better understanding of the type of support these students require, to achieve their higher-education academic goals. By definition, students with LD encounter difficulties with academic skills such as reading, written expression and mathematics (American Psychiatric Association [APA], 2013). One of the means that has been found to assist students with LD is the use of digital devices (Seale, 2014) and specifically computers. By using various computer software (e.g., word processor and spell checkers), students with LD may circumvent aspects of their disabilities, such as writing and organization difficulties (Batorowicz, Missiuna, & Pollock, 2012; Lindstrom, 2007; MacArthur, 2009). Moreover, students with LD are often allowed to

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use computers while taking exams, to accommodate for their writing difficulties (MacArthur, 2009). In addition, there is evidence showing that word-processing may have an advantage over handwriting while writing a composition (Berger & Lewandowski, 2013; Lovett, Lewandowski, Berger, & Gathje, 2010). However, efficient use of word processing software requires proficient keyboarding (Connelly, Gee, & Walsh, 2007). Yet to date, there is little evidence as to the process by which higher-education students with LD become proficient typists, and whether this process is similar or different between students with and without LD.

1.1. *Keyboarding proficiency of student with learning disabilities*

Keyboarding is a complex task that requires the orchestration of sensory-motor, linguistic and cognitive skills (Grabowski, 2008; Preminger, Weiss, & Weintraub, 2004; Weintraub, Gilmour-Grill, & Weiss, 2010). Proficient keyboarding is usually demonstrated by the typist's keyboarding efficiency. Efficient keyboarding is the result of the transaction among several factors including typing speed, the number of errors and corrections committed while typing, as well as the amount of attention and motor effort excreted by the typist (Rieger, 2004; Soukoreff, 2010). Often, efficient keyboarding is judged in comparison to handwriting. It is expected that keyboarding will be at least as fast as handwriting (Freeman, MacKinnon, & Miller, 2005). Yet, studies have shown that many students are unskilled typists (Lubbe, Monteith, & Mentz, 2006), and often, their handwriting is more efficient than their keyboarding (Berninger, Abbott, Augsburger, & Garcia, 2009; Connelly et al., 2007).

Non-proficient keyboarding skills may adversely affect the academic performance of students, in general, and specifically those with LD. For example, students with LD may continually need to correct keyboarding errors due to language or motor difficulties, and as a result, their keyboarding speed may be impeded (Berninger et al., 2009). In addition, they may need to allocate their attention to the keyboarding process (e.g., search for keys), and therefore focus less on higher cognitive processes of writing such as generating, planning and organizing ideas and revising the text. As a result the written outputs of non-proficient typists may be of lower quality (Christensen, 2004; Rieger, 2004).

Inefficient keyboarding among students with LD may be due to their deficits. Yet, it may also be related to the fact that keyboarding is not always taught and practiced within the school setting (Trubek, 2011). Thus, perhaps, over the years, due to lack of proper instruction, students have adopted various forms of keyboarding which are not always efficient (Grabowski, 2008). Therefore, one may postulate that systematic keyboarding instruction may improve the keyboarding proficiency of students in general (Britten, 1988), and specifically of those with LD.

1.2. *Touch-typing acquisition*

Keyboarding acquisition is a complex motor learning process. It requires on-going learning of many sequences. One of the ways to become an efficient typist is to learn 'touch-typing'. Touch-typing is based on the use of both hands and all the fingers in a specific manner, mostly using kinesthetic rather than visual feedback (Freeman et al., 2005). As in acquisition of many skills, touch-typing requires explicit instruction and much practice (Rieger, 2007). However, touch-typing is believed to be more efficient than other typing methods (such as "hunt-and-peck"), specifically when the typists are able to look at the monitor while typing, rather than at the keyboard (Johansson, Wengelin, Johansson, & Holmqvist, 2009; Yechiam, Erev, Yehene, & Gopher, 2003).

Based on the basic principles of motor learning, West (cited in Sormunen, 1993) described three phases of keyboarding acquisition. In the first, the 'Cognitive phase', different keystrokes and movement patterns are learnt, while relying on declarative mediation and visual feedback of the keyboard. In the second, the 'Associative phase', the keystrokes and movement patterns acquired, become more internalized, and the typists rely more on kinesthetic feedback (rather than visual feedback). Finally, in the 'Automatic phase', the typists rely primarily on kinesthetic feedback, and are less affected by external processes occurring in parallel. In this stage, the typists invest minimal cognitive effort (attention) in the keyboarding process itself (Grabowski, 2008). The transition to the 'Automatic phase' varies, and depends on the type and complexity of the motor task as well as on the consistency of the task environment. According to Logan (1988), skill acquisition begins with a general algorithm process, that with experience, gradually "speeds-up" and transits into a memory-based process, which reflects the automatization of the skill.

Only few studies examined the efficacy of keyboarding acquisition in improving individuals' skills. Most studies focused on children in elementary school and were conducted early on. The results of these studies showed an improvement in keyboarding skills immediately following an instructional program (Britten, 1988; Nichols, 1995; Sormunen, 1988, 1993). Similar results were reported in a study among higher education students (Yechiam et al., 2003). Alongside these results, absence of sufficient practice following the program led to a significant decrease in keyboarding speed, both among children (Freeman et al., 2005) and among higher education students (Yechiam et al., 2003). This may reflect the complexity of acquiring keyboarding skills. However, the results related to higher-education students may also reflect the fact that most students in the higher-education level have been keyboarding for many years, usually using well established individual typing styles and methods (Grabowski, 2008). Therefore, while learning to touch-type, they are actually learning new (different) motor patterns to perform an activity that they have already acquired (i.e., keyboarding). This process requires a recalibration of neural networks and control (Bastian, 2008), and thus may be more time consuming.

1.3. Touch-typing acquisition among students with learning disabilities

It is reasonable to assume that the complexity of keyboarding and the various processes it requires may affect the acquisition of touch-typing by students with LD, who often manifest difficulties in linguistic, cognitive and sensory-motor skills (APA, 2013). For example, studies have shown that students with LD have difficulties in procedural learning (Lum, Ullman, & Conti-Ramsden, 2013) and in performing complex motor skills such as handwriting (Nicolson & Fawcett, 2011) and other daily living skills (Ase et al., 2012).

The research literature concerning the effect of instructional typing programs on keyboarding skills of students with LD is limited, and mostly refers to children in special education settings. For example, Tenney and Osguthorpe (1990) studied the effect of self-directed versus tutor assisted computer-aided practice while learning to touch-type in a special education elementary school. They found consistent improvement in typing speed and accuracy following 9 h of keyboarding instruction in both methods. In contrast, Koorland, Edwards, and Doak (1996) studied the effect of teaching a systematic keyboarding strategy to children with LD studying in special education classrooms with partial inclusion. They found no improvement in typing speed and accuracy following the instructional program. The researchers suggested that the new keyboarding strategy did not improve the children's former typing abilities, since those were well developed, and the new typing strategy was difficult to implement. It appears from these studies that in general, children with LD can benefit from participating in touch-typing instructional programs. However, the degree of improvement in keyboarding skills and the ability to maintain the effect over time are unknown. In addition, no studies have been found concerning touch-typing acquisition of higher-education students with LD.

1.4. Study goals

The present study examined the effect of a touch-typing instructional program on keyboarding skills of higher education students with LD compared to normally achieving students. The instructional program was designed on the basis of the three motor-learning phases of keyboarding acquisition described above (Sormunen, 1993). The main objectives were: (a) to examine whether there was an overall improvement in keyboarding skills (i.e., speed) following participation in the touch-typing program, while maintaining high accuracy; and (b) in light of the fact that no studies have been found that examined the long-term effects of a typing instructional programs on the keyboarding skills of post-secondary students with LD, we examined the efficacy of the instructional program, both immediately and 3 months after termination of the program among students with LD as compared to their normally achieving peers.

2. Method

2.1. Participants

The study included a total of 74 students, between the ages of 20 and 37, who were recruited from four higher-education institutions in Israel. All students graduated from regular education high-schools. Most of the students (78%) were in their first academic year, studying in the fields of humanities or social science (88%). The other 12% studied in the faculties of mathematics and sciences (3%) or medicine (9%). The sample included two main groups: (a) 44 students with learning disabilities (mean age = 25.30, SD = 2.91) of which 20% were females. This group consisted of students with reading difficulties (25%), handwriting difficulties (40.91%) or both (34.09%); and (b) 30 students without learning disabilities, henceforth normally achieving (NA) (mean age = 25.13, SD = 3.20) of which 60% were females, who served as a control group.

2.1.1. Inclusion and exclusion criteria

The students with LD were included in the study if they (a) had a valid assessment report conducted by a professional diagnostician, showing that they had a learning disability (as defined by the Diagnostic and Statistical Manual of Mental Disorders-fifth edition (DSM-5; APA, 2013), and (b) had a score of 1.5 standard deviations or more below the mean on two or more of the standardized reading and/or handwriting tests (see Section 2.2). Students were excluded from the study if they (a) had a neurosensory loss (e.g., blindness); (b) had a physical disability; (c) took medication that may affect their writing, except for medication for attention deficits, in which case they performed the test battery under the effect of the medication; and (d) knew how to touch-type.

2.1.2. Sample size

Since no previous studies have been found related to touch-typing instruction for individuals with LD, the sample size was calculated based on an earlier study (Preminger, 2002) that consisted of 48 normally achieving fifth-grade students. The students participated in a 14-week typing instructional program. In comparing their pre- and post-test keyboarding speed, estimating an $\alpha < .05$ and a desired power of .80, a sample of 39 students was required. Given the age-difference in the two studies' population, the sample size in this study appears to be adequate.

2.2. Measures

The study included two types of measures: (a) Measures for determining eligibility and group affiliation (henceforth, eligibility measures) and (b) measures for evaluating keyboarding skills (pre- and post-tests).

2.2.1. Eligibility measures

2.2.1.1. Student Background Questionnaire (Weigelt Marom & Weintraub, 2010b). The questionnaire was designed to collect demographic data (e.g., age, gender etc.), previous and current diagnosis of learning disabilities, attention deficits and use of medication. It also related to information concerning usage of the computer (e.g., average amount of hours typing on the computer) and students' motivation to study in the program.

2.2.1.2. The 'Word Attack' test (Shatil, 1997a). This test was designed for adult readers (age 18 and above). Its purpose is to examine graphemes-phoneme conversion skills. The test includes 70 pseudowords that need to be decoded aloud, as quickly and as accurately as possible. Reading speed (in seconds) and accuracy (total number of pseudowords read accurately) are recorded. This test was found to discriminate between university students with and without dyslexia, $F_{(1,116)} = 389.34$, $p < .001$ (Fabian-Zaks, 2010).

2.2.1.3. The 'Word Recognition' test (Shatil, 1997b). This test was designed for adult readers (age 18 and above). It measures the ability to read aloud 44 words that are presented out of context, as quickly and as accurately as possible. Reading speed (in seconds) and accuracy (total number of words read accurately) are recorded. This test was found to discriminate between university students with and without dyslexia, $F_{(1,116)} = 1161.20$, $p < .01$ (Fabian-Zaks, 2010).

2.2.1.4. The 'Handwriting Performance of Post-Secondary Students Evaluation' ('HaPPS'; Weintraub, Israeli-Ovadia, Shoval, & Traub-Bar-Ilan, 2010). This test was designed for higher education students. The test includes three tasks: a 'near-point copying' task, a 'dictation' task and an 'expository writing composition' task based on a selected topic (from three possible topics). In this study, the dictation task was not included. Writing speed (number of characters [letters and punctuation marks] per minute) and legibility (percent of unreadable words) are recorded. The HaPPS was found to have a medium-high and statistically significant inter-rater reliability for legibility: copying; $r = .85$, $p < .01$, and composition; $r = .61$, $p < .01$. In addition, the HaPPS was found to have medium to high and significant ($p < .05$) convergent validity (correlation between performance across the writing tasks) in legibility, $.72 \geq r \geq .80$, and speed, $r = .46$, and to discriminate between students with and without handwriting difficulties both in speed, $F_{(4,112)} = 16.58$, $p = .001$, and in legibility $F_{(4,110)} = 11.80$, $p = .001$ (Yoselis, 2012).

2.2.2. Keyboarding skills measures

2.2.2.1. Keyboarding skills evaluation (KSE; Weigelt Marom & Weintraub, 2010c). The KSE is performed using the "Easy-Fingers" software (Weigelt Marom & Weintraub, 2010a). This software combines a touch-typing instructional program (see Instructional software Section 2.4.1) and a keystroke logging program, to document the time and accuracy of each typed key. The KSE included three tasks of 3-min transcription (copy)-typing of a paragraph. The orthographic complexity of the copied paragraphs was similar. A copying task was selected, because copying a paragraph reduces differences between individuals' spelling and expression abilities (Grabowski, 2008). The text was presented at the top part of the screen, and was copied into a dialog box below. It was only possible to correct typing errors using the back-space key. Keyboarding speed was calculated based on the data gathered in the keystroke logging script (typed and corrected keys), as the number of keys typed per minute. Percent-accuracy (i.e., total typed keys minus typing errors, divided by the total typed keys, multiplied by 100) was calculated based on the printed-screen output of the transcription task. As part of the development of the "Easy-Fingers" software, a Quality-Assurance (Q.A.) was conducted prior to the study, to establish the reliability of the presented and documented data.

2.2.2.2. Keyboarding Observation (Weigelt Marom & Weintraub, 2010d). The 'Keyboarding Observation' measure was designed to document the typists' form of keyboarding. Scoring is based on a 5-level scale of keyboarding: (1) typing with one hand and one finger, and repeatedly using visual-feedback (i.e., visual guidance of keystrokes); (2) typing with two hands, using one finger in each hand, and repeatedly using visual-feedback; (3) typing with two hands, using two to four fingers in each hand, and repeatedly using visual-feedback; (4) typing with two hands, using all fingers of both hands, and repeatedly using visual-feedback; (5) typing with both hands, using all fingers, while looking at the monitor (and relying on kinesthetic feedback).

2.3. Procedure

After obtaining approval from the University's Ethics review boards committee (IRB), notices were posted on the Institutes' bulletin boards on campuses and on the network, inviting students to participate in a touch-typing instructional program as part of a study. Students who expressed an interest in the study were asked to sign an informed-consent form. Then, in order to establish eligibility, the 'Student Background Questionnaire' as well as the reading and handwriting tests were administered by trained occupational therapy students in their senior year. Next, the instructional program was implemented. Prior to, and after termination of the program, three evaluations of keyboarding skills were performed: (a) a pre-test, (b) a post-test, at termination of the program, and (c) a long-term post-test, approximately 3 months following the completion of the program. These three evaluations were administrated by the research coordinator (first author). At each of these evaluations, students were instructed to type in the manner that they preferred.

2.3.1. The instructional program

2.3.1.1. The touch-typing instructional software. Touch-typing was taught using the "Easy-Fingers" software (Weigelt Marom & Weintraub, 2010a). This software was developed due to absence of touch-typing tutorial software in Hebrew that is combined with a keystroke logging program. The touch-typing method taught in this program is similar to that of other touch-typing programs (e.g., in 'TypingMaster' software, Finland, Inc.); namely, systematically learning to move the hands and fingers from the home position on the keyboard (i.e., middle row) to a specific location on the keyboard, and back to the home position (Rieger, 2004). The software's units were developed based on theoretical knowledge in the field of linguistics (e.g., Ravid, 2012; using common words), ergonomics (e.g., Fosnaric & Drnovsek, 2009; ergonomic guidelines for correct seating and upper body position while keyboarding) and teaching strategies for students with LD (e.g., Swanson, Harris, & Graham, 2013; gradual practicing, using short frequent words, and pauses between exercises).

The software includes 18 training units. Upon entering the software, ergonomic recommendations for seating and hands' position while keyboarding (accompanying relevant illustrations) are presented. In each unit, the proper use of the specific hand and fingers for two new keys are practiced (using transcription typing) together with the previously taught keys (which constitute 50% of the practice). The practice is gradual, beginning with copying non-words (i.e., letter sequences that do not maintain a basic orthographic regularity; Arndt, Lee, & Flora, 2008), moving on to words, and ending with copying a paragraph (as recommended by Christensen, 2004). All words presented are frequently used words in Hebrew. During practice of the non-words and words, if an error is committed, an immediate feedback is provided, and the typists cannot continue keyboarding until the error has been corrected.

2.3.1.2. Instructional program's purpose and framework. The purpose of the program was to teach the students to touch-type in an efficient manner and by doing so, to increase keyboarding speed without the loss of accuracy. To this end, the students were instructed to type as accurately as possible (rather than type quickly); assuming that accurate practice will result in better acquisition of the keyboarding skills (Wolpert, Diedrichsen, & Flanagan, 2011), and that speed will increase as the skill becomes more automatic. The program was taught by college teachers or senior occupational therapy students. All instructors received individual training of the instructional program prior to the study. Students learned and practiced the method in 14 lessons (with at least one day interval between the lessons), each lasting up to 45 min. This framework is based on former studies presented in the literature (Freeman et al., 2005). During each lesson, one to two new units from the "Easy Fingers" software (i.e., 2 or 4 new keys) were taught. Lessons took place in computer laboratories allocated for the study by each institution, using standard computers and the QWERTY keyboard that also has Hebrew letters on it (see Fig. 1). Classes were held in small groups (up to 15 students). The instructors individually guided each of the students while using the software (e.g., monitored ergonomic aspects while keyboarding, made sure they are using their fingers properly, answered questions, encouraged and provided emotional support if needed).

2.3.1.3. Instruction fidelity. In order to establish the fidelity of the program (Murphy & Gutman, 2011), the study protocol (described above) was administered in a uniform manner in the various institutions and periods. Additionally, a close follow-up of the lessons was conducted. The research coordinator received reports at the end of each lesson, consisting of information concerning the units that were practiced by each of the participants. In addition, random visits by the research coordinator took place with the purpose of making sure that the lessons were carried out as planned.

Fig. 1. The QWERTY keyboard with the Hebrew letters.

2.4. Data analysis

Statistical analyses were performed using the SPSS statistical software. First, descriptive statistics were used to describe the students' participation in the study. Between-group analyses (i.e., students who did and did not fully complete the instructional program, and students who did and did not participate at the long term post-test), in each study group separately with respect to demographic variables, reading, handwriting and keyboarding skills (at pre-test) were conducted using Mann–Whitney or Chi-square tests. In addition, *t*-test or chi-square analyses were used to compare the groups' daily use of the computer, and a Mann–Whitney analysis was used to compare their typing methods. Next, due to gender variance between the groups, a MANOVA was conducted, comparing gender-differences in keyboarding skills. To assure that there was no change in keyboarding accuracy in the different evaluation points a repeated-measure ANOVA was performed.

In terms of keyboarding speed, first, ANOVA was used to compare the groups' keyboarding performance at pre-test. Then, a repeated-measure ANOVA of group (LD vs. NA) × time (measuring points of time), for keyboarding speed was employed to examine the program's effect. This analysis was conducted twice once, including the first two measuring points of time (e.g., including all participants) and again, including the three measuring points of time (for those who participated at the three tests).

3. Results

3.1. Group description

3.1.1. Participation in the program

Originally, the study included 79 students. Five (6%) students (all from the group with LD) did not complete the instructional program. A comparison between the students who did and did not complete the program (within the group of LD), in terms of demographic background (i.e., gender, faculty of studying, year of studying) and usage of the computer (i.e., average typing hours a day, main use of the computer), as well as reading, handwriting and keyboarding (at the pre-test) skills, showed no statistical differences.

At the long-term post-test, we had data relating to the three points of evaluation on 44 (55.7%) students, of which 24 (48.8%) were students with LD and 20 (66.7%) were NA. A within group comparison (LD and NA, separately), between the students that did and did not participate at the long term, with respect to the students' background information and skills (as described above) showed no statistical differences.

3.1.2. Computer usage and typing method

All participants reported using the computer from adolescence onwards. There were no significant group-differences concerning students' daily average typing hours, and usage of the computer (e.g., using it for browsing the internet or sending emails). The results also showed that upon entering the study, students in both groups used both hands to type, but only a few fingers, while relying on visual (rather than on kinesthetic) feedback. Yet, within the group of students with LD, there were more students (67%) that typed in a less efficient manner (using only one finger in each hand) than within the NA group (42%). However, analysis showed that this difference was not statistically significant.

3.2. The effect of the instructional program

First, an examination of gender differences in each of the keyboarding measures was performed. No statistically significant differences were found. Thus, analysis of the data was calculated for both genders together. A significant group difference in keyboarding speed prior to intervention (pre-test, see Table 1) was found; $F_{(1,72)} = 12.03$, $p < .001$, $\eta_p^2 = .14$, with a medium effect size; keyboarding speed of the students with LD was significantly lower than that of the NA group. Next, an examination of the effect of the instructional program on keyboarding speed of the entire sample, at the end of the program (see Table 1), using a repeated measure ANOVA for group (LD vs. NA) × time (pre-test, post-test), showed a significant time effect, $F_{(1,72)} = 15.21$, $p < .001$, $\eta_p^2 = .17$, with a medium effect size. At the post-test, keyboarding speed significantly decreased compared to that of the pre-test. In addition, a significant group effect was found, $F_{(1,72)} = 6.37$,

Table 1
Means and standard deviations (SD) of keyboarding performance of the entire sample at the pre- and post-testing, by study groups.

Measure	NA group ($n = 30$)		LD group ($n = 44$)	
	Mean	SD	Mean	SD
Pre-testing				
Speed[a]	132.82	55.23	95.33	37.84
Accuracy[b]	96.53	8.46	95.67	7.31
Post-testing				
Speed[a]	95.12	28.35	92.15	38.08
Accuracy[b]	98.82	2.49	98.35	2.96

[a] The higher the score, the faster the typing.
[b] The higher the score, the more accurate the typing.

Table 2
Means and standard deviations (SD) of keyboarding performance of the students who attended all points of time, by study groups.

Measure	NA group (n = 19)[a]		LD group (n = 24)	
	Mean	SD	Mean	SD
Pre-testing				
Speed[b]	125.84	57.98	95.34	38.65
Accuracy[c]	97.06	7.07	97.41	2.51
Post-testing				
Speed[b]	94.03	31.79	98.01	36.84
Accuracy[c]	98.99	1.74	98.97	1.99
Long term post-testing				
Speed[b]	145.79	90.98	125.51	49.42
Accuracy[c]	97.02	9.27	98.47	1.32

[a] One subjects' keyboarding speed data was not documented due to technical reasons.
[b] The higher the score, the faster the typing.
[c] The higher the score, the more accurate the typing.

$p < .05$, $\eta_p^2 = .08$, with a low-medium effect size; keyboarding speed of the students with LD was significantly lower than that of the NA group. Finally, a significant group × time interaction was found, $F_{(1,72)} = 10.85$, $p < .01$, $\eta_p^2 = .13$, with a medium effect size. The interaction stemmed from a sharp decrease in keyboarding speed of the NA group at the post-test, whereas the speed of the students with LD slightly increased.

In order to compare the effect of the instructional program on keyboarding speed of the study groups who attended the three points of time, a repeated measure ANOVA for group (LD vs. NA) × time (pre-test, post-test and long-term) was conducted (see Table 2 and Fig. 2). Results showed a significant time effect, $F_{(2,82)} = 16.50$ $p < .001$, $\eta_p^2 = .29$, with a large effect size. A Simple Effect analysis, comparing each two consecutive points of time separately showed that, similar to the analysis of the entire study sample (as described above), the keyboarding speed of the students who participated at all the measuring points decreased between pre- and post-test, but the decrease was not statistically significant. In contrast, keyboarding speed increased significantly in the long-term compared to the pre-test, $F_{(1,41)} = 12.48$, $p < .001$, $\eta_p^2 = .23$, and to the post-test, $F_{(1,41)} = 32.13$, $p < .001$, $\eta_p^2 = .44$, with a large effect.

In addition, analysis showed no significant main effect for group. However, significant group × time interaction was noted, $F_{(2,82)} = 3.22$, $p < .05$, $\eta_p^2 = .07$ with a small-medium effect size. As presented in Fig. 2, the interaction stemmed from a sharp decrease in keyboarding speed of the NA group at post-test, whereas the speed of the students with LD slightly increased. Further examination (see Fig. 2) also revealed that at pre-test and in the long-term, the keyboarding speed of the students with LD was lower than that of the NA, yet, significant differences between the groups were only noted at the pre-test, $F_{(1,41)} = 4.26$, $p < .05$, $\eta_p^2 = .09$ with a small-medium effect size. In contrast, at post-test, both groups typed at the same pace. In addition to these results, it is interesting to note that, as can be seen in Fig. 2, the keyboarding speed of the students with LD at the long-term was similar to that of the NA group at the pre-test. In other word, following the program, the keyboarding speed of the students with LD was at the same level as that of their peers before participating in the program.

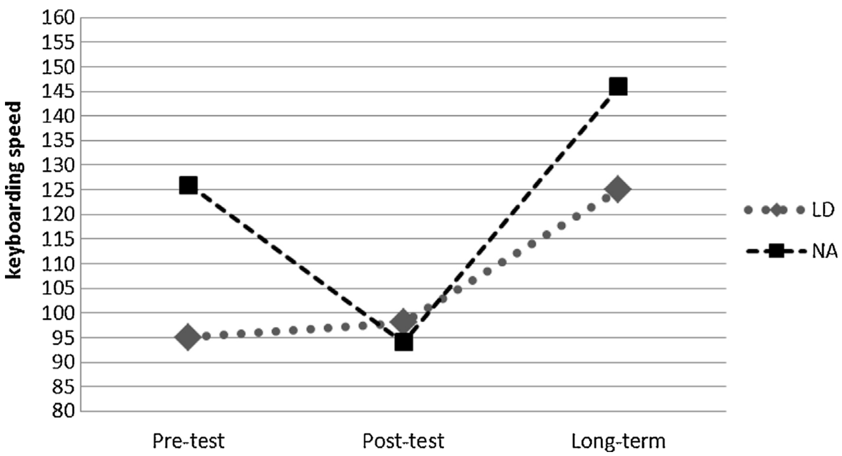

Fig. 2. Differences in typing speed of the LD group (n = 24), and the NA group (n = 19) at the three measuring points of the study.

4. Discussion

In today's world, students are expected to meet the ongoing technology demands, many of which require efficient keyboarding skills. More specifically, these skills are important for students with learning disabilities, since many of them use computers in order to circumvent their writing difficulties. Nevertheless, often, students are not proficient typists. The main objective of this study was to examine the effect of a touch-typing instructional program in improving keyboarding performance of higher-education students with and without learning disabilities, both immediately, at the end of the program, and in the long-term (3 months after termination of the program).

With regard to keyboarding accuracy, both at pre-test and throughout the program students' keyboarding accuracy, in both groups, was very high (above 95%). High accuracy levels of copy-typing were also reported in previous studies with respect to normally achieving students (Baker, Cham, Cidoby, Cook, & Redfern, 2007; Grabowski, 2008; Weintraub, Gilmour-Grill, et al., 2010). However, no similar studies were found relating to students with learning disabilities. These findings support the assertion of Crump and Logan (2013) that typists are aware of the importance of accuracy while copy-typing. Given the fact that during the entire program we emphasized focusing on accurate typing, these findings may not be surprising. One may expect that the accuracy level of students with learning disabilities would be lower than that of their peers (due to their reading and writing difficulties); yet, it may be that this group was more aware of their difficulties, and therefore were careful while typing.

With regards to keyboarding speed, both groups' results showed no significant gains in speed immediately at the end of the program. At this point of time keyboarding speed of the NA group sharply decreased, whereas in the group of the students with learning disabilities keyboarding speed slightly increased. Significant improvement in keyboarding speed for both groups was found only at the long-term evaluation. The finding that at the end of the program, both groups did not significantly improve their keyboarding speed is different from results of previous studies concerning normally achieving students (Britten, 1988; Kahn & Fredy, 1990; Sormunen, 1988; Yechiam et al., 2003) and students with learning disabilities (Tenney & Osguthorpe, 1990).

The difference in the studies' results may have stemmed from several factors. First, it appears that at the end of the program the students in the current study were still at the initial stages of touch-typing acquisition (as described by West in Sormunen, 1993), and did not yet reach an automatic level of typing (Logan, 1988). A possible explanation for this finding may be related to the type of skill that was learned and the structure of the program. Unlike many other skills (Newell, 1991), touch-typing requires the learning of many sequences. In our touch-typing instructional program, as in most traditional programs (Freeman et al., 2005) two new keys were introduced in each lesson, while practicing formerly learned keys. Thus, the keys that were learned at the beginning of the program were practiced more than the keys that were introduced at the end of the program. Therefore, at termination of the program, the students just finished learning the topography of the keyboard and have not yet internalized the new motor patterns they had learned for each key.

In addition, this study population consisted of an older student population (unlike a younger-age population in most former studies) that had already established different forms of keyboarding (as documented in the 'Keyboarding Observation') and was re-learning a skill. Therefore, the acquisition of keyboarding in the touch-typing method was more difficult, and entailed learning new motor patterns for the keystrokes, rather than typing using their previously internalized motor patterns. It is possible that the process of learning new motor-patterns while disregarding earlier habitual patterns slowed-down the acquisition speed of both groups (Schubring-Giese et al., 2007), especially among the normally achieving students, since their original (at pre-test) keyboarding speed was higher and form of keyboarding was more established than that of the students with learning disabilities.

In contrast, at the long-term, both groups showed an increase in keyboarding speed, indicating that the procedural knowledge of touch-typing had been established, and the students entered the 'automatic phase' (Logan, 1988, Sormunen, 1993). This improvement occurred although there was no official keyboarding training between the end of the program and the long-term evaluation. This significant improvement in both groups supports our hypothesis described above suggesting that at the end of the program, the students had still not internalized the newly learned motor patterns. This emphasizes the importance and need for continuous practice of keyboarding after learning the different keys, especially for students with learning disabilities, who most probably need to use the computer as a substitute to handwriting.

Finally, the significantly lower keyboarding speed of the students with learning disabilities prior to the program and the rather lower (but not significantly) keyboarding speed at the long-term evaluation may have resulted from this groups general slower speed of processing (Moll et al., 2014). In addition, their difficulties in decoding words may have affected primary processes while typing words (i.e., the Input and Parsing stages; Salthouse, 1986), and their grapho-motor difficulties may have affected the conversion and implementation of finger movements on the keyboard while typing (i.e., Translation and Execution stages; Salthouse, 1986). Nevertheless, the fact that following touch-typing instruction, the students with learning disabilities were able to narrow the gap in terms of keyboarding speed, as compared to their normally achieving peers is encouraging.

4.1. Limitations and suggestions for further research

The present study has several limitations that need to be acknowledged. First, the relatively low participation rate at the long-term evaluation due to the students' lack of interest or ability to return for reevaluation (as reported by them). This may have limited the effect size and thus calls for an additional study to further examine the long-term effects of keyboarding instruction. In addition, as stated above, perhaps the instructional program's duration needs to be reconsidered given the fact that the keyboarding speed of the students did not significantly increase (LD group) or even deteriorated (NA group). Therefore, further studies should be performed, where the program consists of a practice period following introducing all keys. Prolonging the program, for one group, and comparing it to a similar intervention as described in this study may enable to better understand the results of the current study and the acquisition of touch-typing, in general.

Finally, it is recommended to further study the effectiveness of this program using various groups (e.g., poor versus average typist), to better establish understanding of the program effect.

5. Conclusions and implications for practice

This study is one of the first examining the effect of a touch-typing instructional program for higher-education students with and without learning disabilities. Its results have both theoretical and clinical implications. In terms of theoretical implications, the findings support West's three-stage model of typing skill acquisition (Sormunen, 1993). They showed that immediately following the instructional program, typing skills were not yet established, and students were still in the early stages of acquisition, and the transition to the final acquisition stage ('automatic phase') becomes apparent only over time.

From a clinical point of view, the study's results show that both normally achieving and students with learning disabilities may benefit from learning to touch-type and improve their keyboarding speed while maintaining high accuracy. However, this process takes time and its contribution is seen only several weeks after ending the formal practice of the program. This is an important factor to consider in constructing a touch-typing program. Second, the finding that at the long-term, keyboarding speed of the students with learning disabilities was similar to that of the normally achieving students prior to the participation in the program, is encouraging, showing that students with learning disabilities can benefit from touch-typing instructional program, and almost reach the typing speed of their peers. This is especially important for students with writing disabilities, since they often use the computer in order to circumvent their handwriting difficulties.

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