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# Benefit of Typoscope on Transcription in Children with Writing Difficulties: A Study of Three Cases

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## Abstract

*The typoscope has been considered as an important aid for children with learning disabilities (LD) who struggle with reading. It is also believed to be helpful for children with writing difficulties who struggle with copying tasks. Surprisingly, however, no academic evidence has yet been found that the typoscope works for these children. This study aimed to analyze the effects of typoscoping in three Japanese children with writing difficulties for the task of copying Japanese character lines using eye-tracking glasses. A copying task was presented to three children with LD and three with typical development (TD). This consisted of copying 22 target letters (characters) of the hiragana (Japanese phonogram), randomly arranged on a sample sheet, onto a blank 18 mm square grid sheet. Children with LD took longer to complete the copying task without using a typoscope than children with TD. In the copying task with the typoscope, their time was similar to children with TD. The eye-tracking data showed that all three children with LD tended to lose targets in the copying task without the use of a typoscope but were less likely to lose targets if they used a typoscope. In conclusion, this study demonstrated that the use of typoscope effectively reduced the target search load and shortened the transcription time for the children with LD.*

## Introduction

According to the DSM-5 diagnostic criteria, specific learning disorders (also known as learning disabilities) are neurodevelopmental disorders typically diagnosed in young children. They are characterized by persistent impairment in at least one of three major areas: reading, written expression, or math. This excludes intellectual, visual, or hearing impairments and disabilities caused by educational environment factors (American Psychiatric Association, 2013). Causal elements or factors for these disorders are believed to be related to a central nervous system disorder (Fletcher & Grigorenko, 2017).

There are many challenges involved in handwriting for children with LD. These include illegible handwriting, slow sentence transcription, character writing errors, improper postpositional particle usage, and insufficient expression of thoughts in writing. Furthermore, a specific disorder in writing *kanji* morphograms is an issue particular to the Japanese language (Bureau of Social Welfare and Public Health Tokyo Metropolitan Government, 2015).

Children with dysgraphia complain about difficulties copying from blackboards and textbooks during class. They commit many typographical errors or take extended periods for copying tasks. Diverse support systems are provided as reasonable accommodations for school children with these difficulties. Examples of supports include: a colour filter is used with a reading ruler, a typoscope which is a sheet with a slit is used to read only 1-3 lines at a time, taking pictures is permitted, printed materials are distributed to students instead of needing to transcribe from a blackboard, letters are enlarged, and spaces between lines are adjusted in the printed materials, notes can be taken using amanuensis, keyboard input and audio recorders are permitted during classes, technological tool for voice input is used to assist with note-taking, highlighting function in an electronic book helps with reading and writing (Japan Student Services Organization, 2018; Tsuchida, 2019).

Typoscopes or “reading slits” are common reading support tools (Kouno, 2012), widely used for children with impaired vision (Ghosh, 2017). Typoscopes are not only made available in special education school libraries (Noguchi, 2016) but also in other libraries as a universal design tool. Furthermore, typoscopes are used for school children who tend to have a problem skipping words or lines (Tsuchida, 2019).

Some studies on the digital text highlight function, inspired by typoscopes, revealed favorable effects for children with dyslexia. Okumura et al. (2011) studied the effective use of digital textbooks in children with reading disabilities. They found that simultaneous highlighting of the phrase being read out in the sentence was more effective for understanding and memorizing than audio or visual presentation. Kanamori et al. (2017) reported positive effects of the highlight function through experimentation using an eye tracker, they suggested that when reading digital material, the highlight function enabled children with reading difficulties to read more quickly with sentence flow and with less sporadic eye movements.

Transcribing sentences from a blackboard or textbook into a notebook requires a heavier cognitive load than reading alone. Children need to look at the target and then notebook for transcribing alternately. They tend to lose their visual orientation compared to a simple reading task. From this perspective, highlighting and typoscoping reduce the cognitive load for this complex task, shorten the time required, and improve the transcription accuracy. However, no academic reports have examined whether highlighting or typoscoping would reduce difficulties in copying tasks. Therefore, further empirical studies are warranted.

This study aimed to examine the impact of typoscoping on difficulties in transcribing characters for children with writing difficulties.

## Materials and Methods

### Participants

The participants of this study were six Japanese schoolchildren in the fourth, fifth, and sixth grades of an elementary school. Three were boys with learning disabilities (LD), and three were boys with typical development (TD) **(Table 1)**. The three schoolchildren with LD had writing difficulties and received support from the elementary school, the afterschool service, and university experts. Before participation in this research, one child was diagnosed with LD by a pediatrician, and two were diagnosed with LD by a developmental clinical psychologist.

### Ethical Approval

This study was conducted with the approval of the Research Ethics Committee of the university to which the authors were affiliated (#1805-04, 5/8/2018), in accordance with the principles of the Declaration of Helsinki as revised in 2013. All participants and their parents expressed their willingness to participate in the study. Written informed consent was obtained from all participants and their parents under the guaranteed right of refusal.

### Measurements

All three children with LD had academic scores less than the mean minus 1.5 standard deviation (SD) of the mean values of children in their grades. This was based on the Standardized Test for Assessing the Reading and Writing (Spelling) Attainment of Japanese Children and Adolescents: Accuracy and Fluency (STRAW-R, Uno et al., 2017).

Visual function and automatization skills related to writing skills were assessed (Uno, 2016). Eye movements were examined using the Developmental Eye Movement test (DEM, Richman, 2016). Rapid Automated Naming (RAN) of STRAW-R was performed to assess automatization skills. In the DEM results, LD participants A and C showed +1.5 SD or more in H/V ratio (the correction score of the time required for and the number of errors in the horizontal reading test divided by the time required for the vertical reading test) which indicated increased accuracy in saccadic eye movement. LD participants A and B showed +1.5 SD or more in the number of errors. All three participants with LD showed RAN values of +1.5 SD or more.

In addition, IQ tests were performed using the Wechsler Intelligence Scale for Children-IV or III (WISC-IV; Wechsler, 2003, or WISC-III; Wechsler, 1991) and Raven's Colored Progressive Matrices (RCPM, Raven et al., 1993), which correlated with WISC-III (Uno et al., 2005). Results of the IQ tests confirmed that two children with LD had scores of 85 or higher in Full scale intelligence quotient (FSIQ), Verbal comprehension index (VCI), Perceptual reasoning index (PRI), Working memory index (WMI), and Processing speed index (PSI) in WISC-IV or Full intelligence quotient (FIQ), Verbal intelligence quotient (VIQ), and Performance intelligence quotient (PIQ) in WISC-III. IQ scores in RCPM were greater than -1 SD compared with other children in their grades. In contrast, one child with LD scored 85 or higher in FSIQ, VCI and WM though he scored 78 for PSI in WISC-IV and RCPM IQ scores of less than -1.5 SD for his grade. Based on these data, their learning support conditions, and the DSM-5 criteria, the three children were considered to have LD with writing disabilities.

STRAW-R writing and RCPM tests were also given to the children with TD. It was confirmed that none of these children had a developmental delay in writing ability, or an IQ score of less than -1.5 SD, compared to other children in their grade.

Visual acuity in both eyes was measured using the new standard near vision chart (Kozaki, 2002). There were no problems with eyesight (or corrected eyesight) in all participants.

**Table 1**

*Characteristics of Participants*

| | | Participants with LD | | | Participants with TD | | |
|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F |
| Age (years) | | 10 | 9 | 12 | 10 | 11 | 11 |
| Grade | | 4 | 4 | 6 | 4 | 5 | 5 |
| Dominant hand | | R | R | R | R | L | R |
| WISC-IV (WISC-III) | FSIQ (FIQ) | 99 | 86 | 88 | - | - | - |
| | VCI (VIQ) | 101 | 99 | 95 | - | - | - |
| | PRI (PIQ) | 96 | 89 | 85 | - | - | - |
| | WMI | - | 85 | 91 | - | - | - |
| | PSI | - | 78 | 91 | - | - | - |
| RCPM | | 29/36 | ***25/36*** | 32/36 | 36/36 | 36/36 | 36/36 |
| STRAW-R Writing | Hiragana words | ***16/20*** | 20/20 | 20/20 | 20/20 | 19/20 | 20/20 |
| | Katakana words | ***9/20*** | 17/20 | ***10/20*** | 20/20 | 18/20 | 19/20 |
| | Kanji words | ***7/20*** | ***3/20*** | ***0/20*** | 19/20 | 17/20 | 17/20 |
| DEM | H/V Ratio | ***1.93*** | 1.35 | ***1.66*** | 1.29 | 1.26 | 1.10 |
| | Errors | ***10*** | ***27*** | 3 | 0 | 1 | 4 |
| RAN | Average time (s) | ***16.57*** | ***15.63*** | ***13.18*** | 11.56 | 9.23 | 11.10 |

*Note. Results below the criteria are shown in bold italics.*
*WISC- IV/III: Wechsler Intelligence Scale for Children-Fourth Edition/Third Edition.*
*RCPM: Raven's Colored Progressive Matrices.*
*STRAW-R: Standardized Test for Assessing the Reading and Writing (Spelling) Attainment of Japanese Children and Adolescents: Accuracy and Fluency.*
*DEM: Developmental Eye Movement Test.*
*H/V Ratio: The correction score of the time required for and the number of errors in test C which is a horizontal reading task, divided by the time required for test A and B which are vertical reading tasks.*
*RAN: Rapid Automatized Naming.*

## Tasks and Procedure

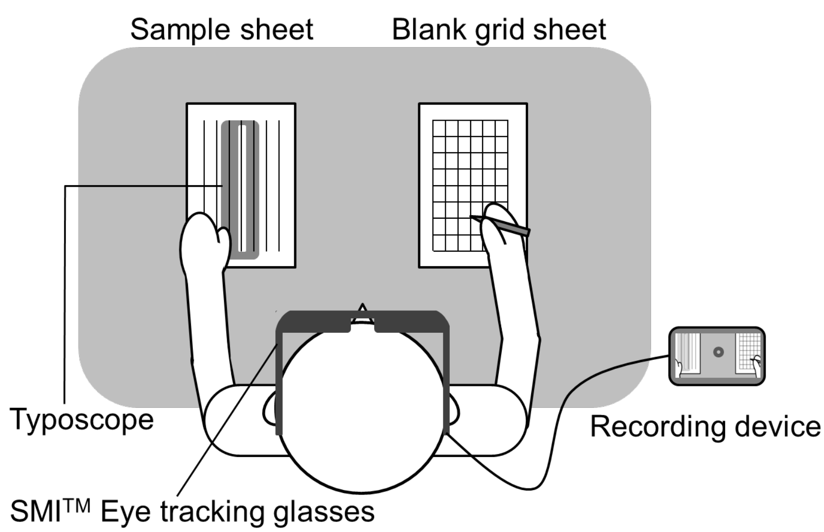
Participants were equipped with SensoMotoric Instruments (SMI$^{TM}$) eye-tracking glasses to measure eye movements and sounds during the transcribing task. The task was to copy 22 target letters (characters) of *the hiragana* (Japanese phonogram), randomly arranged on a sample sheet, onto a blank 18 mm square grid sheet.

In Japan, *hiragana*, *katakana*, and *kanji* are used as characters in daily reading and writing. *Hiragana* is the set of characters that children are expected to learn first, and it is the minimum necessary basic set. Therefore, the *hiragana* sample was used in the copying task of this study. Also in Japan, scientific, arithmetic and social studies texts are written horizontally, but Japanese language study texts are written vertically, so the sample strings were written vertically. In this study, in order to prevent the practice effect of using the same meaningful character lines in each trial and the variation in difficulty by using different meaningful character lines in each trial, meaningless character lines were used.

In the copying task, a sample sheet was placed on the non-dominant hand side, and a blank grid sheet was placed on the dominant hand side of the participant (**Figure 1**). The desk and chair heights were adjusted to ensure participant comfort. The participants used a pencil and were asked to write letters as quickly and neatly as possible. When characters were miswritten, they were asked to rewrite them on the next square. The font size was 15 points, and three types of line spacing (15, 7.5, and 0 points) were prepared. Six operations were performed randomly depending on the six conditions—three types of line spacing with and without a typoscope (**Figure 2**).

The typoscope was made of a colored and semi-transparent plastic film and had a slit with one line width. The copying task without a typoscope started after indicating the first letter of the target lines on the sample sheet. In the copying task using a typoscope, the typoscope slit was placed on the first letter line of the target lines before pointing as the start signal.

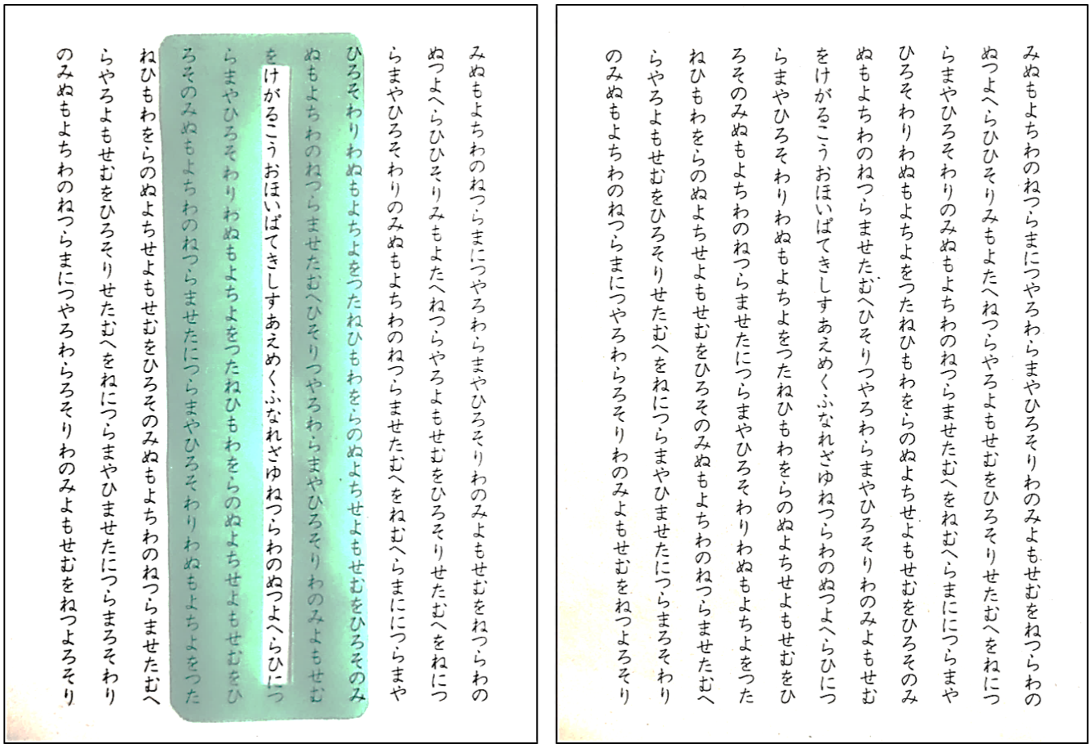
**Figure 1**
*Schema of Copying Task*




*Note. Created by the authors*

**Figure 2**

*A Sample Sheet with and without Typoscope*



### Data analysis

We used a reference value of mean +1.5 SD or more to determine the degradation of performance scores in DEM and RAN based on previous studies by Goto et al. (2010) and Sambai et al. (2016).

The number and time data for saccades and fixations during the copying tasks were recorded using eye-tracking glasses and analyzed at a sampling frequency of 60 Hz. A fixation occurs when a gaze is held on an object or location within 3° of visual angle for 100 ms or longer (Vickers, 2007). Eye mark data, which indicated positions seen by participants, were collected from when the first target letter was written to when the last target letter was written. This period indicated the total duration of the copying tasks. In the copying task, the eye movements of a participant indicated an interaction between the sample sheet and a grid sheet as the participants looked at the target letters, remembered them, and transcribed them on the grid sheet. Therefore, when a visual fixation moved from the sample to the grid sheet, it was counted as a reference to the sample sheet.

The duration from the first visual fixation to the last visual fixation for every sample sheet reference was recorded as the text reference time. In the copying task, participants occasionally had irregularly long reference times. An extremely long reference time (ELRT) was calculated to account for this irregularity, which was an index based on the operational definition of this study. It was noted as exceeded time duration. ELRT was calculated as the mean value +4 SD or longer for TD participants' text reference times without a typoscope.

Furthermore, based on the text reference time of all TD participants without a typoscope, the average total text reference time +1 SD (ATTRT+1 SD) was calculated to estimate the standard time required for the copying tasks for children without LD. Subsequently, the number of letters written during one text reference was counted. When writing a letter requiring multiple text references, one was divided by the number of text references for that letter.

The number of errors was subtracted from the number of written letters to assess transcription accuracy. Errors consisted of four types: mistake, omission, correction, and addition. The sample consisted of 22 characters, but the total number of transcribed letters may have increased or decreased due to incorrectly copied letters being included in the analysis.

## Results

The total time of the copying tasks for all participants under both conditions (with and without typoscopes) can be found in **Figure 3**. For all three participants with LD, the total time of copying tasks using the typoscope was shorter than without the typoscope. Furthermore, typoscope non-use and use differences were the largest, especially in the 0-point line spacing copying tasks. Copying time differences between participants A, B, and C were 149.99, 121.84, and 82.56 seconds, respectively. There were no remarkable differences between typoscope non-use and use in TD participants D, E and F. Among them, the most considerable difference was 23.36 seconds in participant E (TD) for the 7.5-point line spacing copying task.

**Figure 3**
*Total Times of Copying Tasks in 15, 7.5, 0 Point Line Spacing with and without Typoscope*

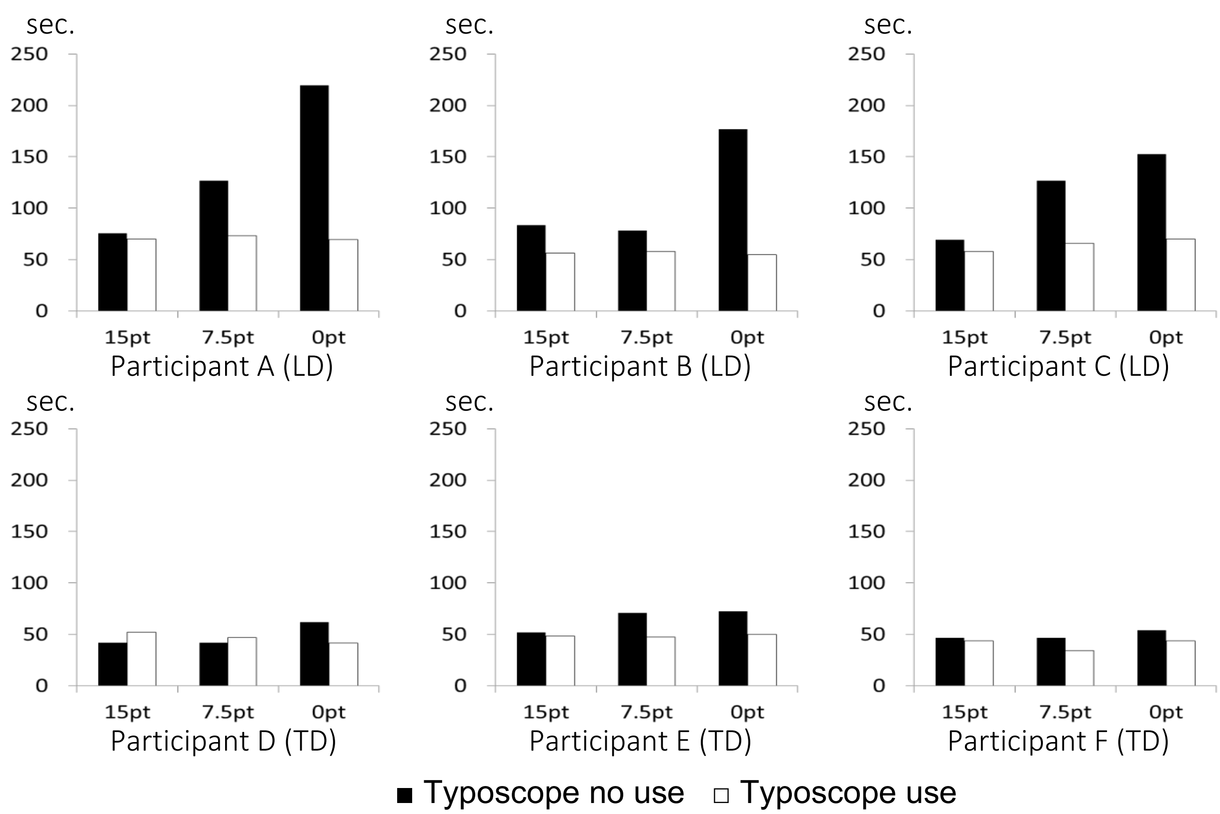
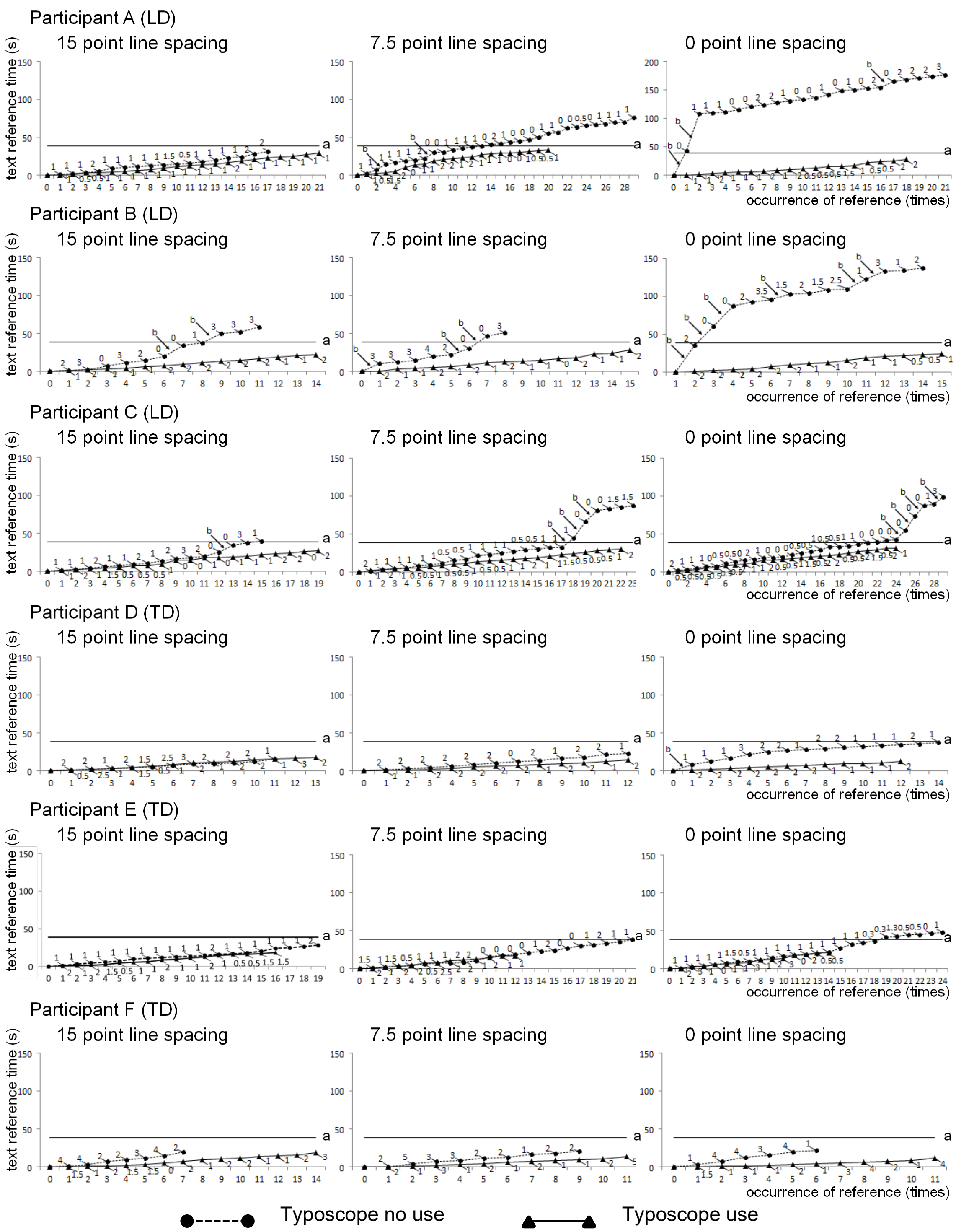


**Figure 4**

*Total Text Reference Times when Participants Transcribed the Text in 15, 7.5, 0 Point Line Spacing with and without Typoscope*




*Note. Numerals with short lines indicate the number of letters written after a reference. 'a' indicates the Average of Total Text Reference Time+1SD (ATTRT+1SD) of TD participants when not using typoscope. 'b' indicates the Extremely Long Reference Time (ELRT).*

**Figure 4** shows text reference time, reference occurrence, and the number of letters copied during one reference in the copying tasks with and without a typoscope. The ATTRT+1 SD of all TD participants without a typoscope was 38.56 seconds.

The total text reference time at a 15-point line spacing of participant A was 31.68 seconds without a typoscope and 29.11 seconds with a typoscope. There was no considerable difference between the two categories. Differences in the 7.5-point line spacing task were 75.97 seconds for non-use of a typoscope and 33.46 seconds for the use of a typoscope. Differences in the 0-point line spacing task were 175.40 seconds for non-use of a typoscope and 28.12 seconds for the use of a typoscope. The total text reference times for 7.5- and 0-point line spacing greatly exceeded ATTRT+1 SD in the copying tasks without a typoscope. The total text reference time with a typoscope was shorter. ELRTs were detected multiple times in the 7.5- and 0-point spacing copying tasks without a typoscope.

The total text reference time for participant B's 15-point line spacing task was 58.31 seconds without a typoscope and 21.65 seconds with a typoscope. The total text reference time for the 7.5-point line spacing task was 51.98 seconds without a typoscope and 28.38 seconds with a typoscope. The total text reference time for the 0-point line spacing task was 136.06 seconds without a typoscope and 23.79 seconds with a typoscope. The total text reference time without a typoscope for all three-line spacing tasks was considerably longer than ATTRT+1 SD, and ELRTs were detected multiple times. In contrast, for the copying tasks with a typoscope, the total text reference times were within ATTRT+1 SD, and no ELRT was detected.

The total text reference time for participant C's 15-point line spacing task was 39.20 seconds without a typoscope and 27.59 seconds with a typoscope, showing no remarkable difference. The total text reference time for the 7.5-point line spacing task was 87.02 seconds without a typoscope and 30.10 seconds with a typoscope. The total text reference time for the 0-point line spacing task was 98.21 seconds without a typoscope and 31.25 seconds with a typoscope. The total text reference time without a typoscope was remarkably longer for the 7.5- and 0-point line spacing tasks than ATTRT+1 SD. The total text reference time for the same tasks with a typoscope was shorter than ATTRT+1 SD. ELRTs were detected once in the 15-point line spacing task and multiple times in the 7.5- and 0-point line spacing copying tasks without a typoscope.

From the above results, we can see that all participants with LD required longer reference times with their sample sheet without a typoscope. Using a typoscope in copying tasks helped them reduce the total text reference time to less than ATTRT+1 SD. Participants with TD showed little difference regarding the total text reference time between typoscope use and non-use in the copying tasks. Only participant E exceeded ATTRT+1 SD at 47.36 seconds in the 0-point line spacing task without a typoscope. Participant D also had only one ELRT in the 0-point line spacing task.

The number of participant mistakes, omissions, corrections, and additions in the three-line spacing copying tasks with and without a typoscope is shown in Table 2. Participants with LD made more errors than participants with TD. There was no remarkable difference in the frequency of errors between the use and non-use of a typoscope or between the three variable line spacing categories.

**Table 2**

*Number of errors in copying tasks in 15, 7.5, and 0 point line spacing with and without typoscope*

| Participants | | Typoscope no use | | | Typoscope use | | |
|---|---|---|---|---|---|---|---|
| | | 15pt | 7.5pt | 0pt | 15pt | 7.5pt | 0pt |
| LD | A | O 1 | C 1 | - | M 1 | M 1 | - |
| | B | - | O 1 | M 1 | C 1 | C 1, O 1 | - |
| | C | O 1 | O 1 | O 2 | O 2 | - | A 4 |
| TD | D | - | - | - | - | - | - |
| | E | M 1, O 2 | - | - | - | - | - |
| | F | - | - | - | - | - | - |

*Note. M: mistake, O: omission, C: correction, A: addition*

## Discussion

Children with dysgraphia have various writing speed and accuracy challenges while transcribing written characters (Levine, 1990). This study confirmed that in the copying tasks with typoscope, the total task duration and overall text reference times were reduced in participants with LD. Furthermore, there were fewer instances of ELRTs for text references compared to copying tasks without a typoscope. Eye-movement observation data during ELRTs—primarily during transcription tasks without typoscopes—indicated that participants with LD often lost the target in the sample sheet when the eye moved from the grid sheet to the sample sheet. At that point, the eye searched the sample sheet, requiring a longer time for the target search. Participants remarked that they could not find the target. However, when the typoscope was used, they did not lose the target as easily and needed a shorter target search time to complete the task. The total text reference times for the tasks with typoscopes were within ATTRT+1 SD. This was at the same level as the participants with TD without typoscope.

Furthermore, it was observed that the total duration and text reference time were shorter for all participants with LD during the 15-point spacing tasks than during the 0-point line spacing tasks. It follows that an appropriate line spacing adjustment could also reduce the target search time.

This study showed no remarkable difference in the number of errors between typoscope use and non-use or between the three types of line spacing. Kanamori et al. (2017) reported that reading latency decreased for children with dyslexia using the highlight function, but there was no effect on reducing misreading of the text. The findings of this study are similar to Kanamori et al. (2017). The present study shows that using typoscopes shortened the target search time but did not improve character transcription accuracy. Further studies are required to develop support systems for children with writing difficulties and to improve copying accuracy.

## Conclusion

This study demonstrated that children with LD frequently lost targets and took longer to complete a copying task without using a typoscope than children with TD, but the use of typoscope effectively reduced the target search load and shortened the transcription time in children with LD. Especially when the text had narrow line spacing, a typoscope was highly effective for improving speed in a copying task.

## Conflicts of Interest

The authors declare that the study was conducted without any commercial or financial relationships that could be construed as potential conflicts of interest.

## Key Messages from This Article

**People with Disabilities:** When transcribing sentences from a text into a notebook, using a typoscope reduces the chance of losing sight of the target word, and shortens the transcription time.

**Professionals**: Children with learning disabilities should be encouraged to use typoscopes, as these may help them transcribe text sentences more efficiently. In addition, when they transcribe sentences from a virtual display, consider using a highlight function to assist them.

**Policymakers**: Policy supporting access to and skill teaching with typoscopes is recommended because they are a useful tool for children with learning disabilities, enabling them to better read and transcribe texts. Furthermore, line spacing is an important consideration when printing textbooks and documents, to ensure accessibility for all types of learners.

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