Quarterly of Clinical Psychology Studies
Allameh Tabataba'i University
Vol. 11, No.41, Winter 2021, Pp 83-98.

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Investigating the Efficacy of Implicit Stimulation in Visual Hemisphere-Specific According to the Bakker's Balance Model for the Reading and Writing Skills of Individuals with Linguistic Developmental Dyslexia: A Case Study

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Received: 18 February, 2021 *Accepted: 20 April, 2021*

Abstract

Individuals with developmental dyslexia have difficulties with accurate and fluent word recognition and spelling. Hemisphere alluding stimulation (HAS) is one of the neuropsychological techniques to stimulate cerebral hemispheres through the visual vessel, by word selection with various sizes and fonts. It increases the perceptual traits of the text and balances the reading speed by stimulating the right hemisphere. The aim was to investigate the efficacy of the implicit stimulation in visual hemisphere-specific according to the Bakker's Balance Model for the reading and spelling skills in two students with the linguistic developmental dyslexia. In a single-subject design, two female students (mean age = 9.35 years) were selected through convenience sampling from the 3rd grade in the elementary school. They were diagnosed as having the linguistic developmental dyslexia, evaluated by the Wechsler Intelligence Scale for Children (WISC-IV), who answered the Diagnostic Reading Disorder Test (DRDT) and the Writing Disorder Test (WDT). One student was considered a case subject and the other one a control subject. The case received implicit stimulation in visual hemisphere-specific for 16 sessions (twice a week), but the control subject did not. After the intervention and three months later, the subjects answered the DRDT and WDT again. The results of the visual analysis in

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combination with the non-overlap methods were used to calculate the effect size. The findings showed that the intervention increased the reading fluency (effect size = 90.74%), reading comprehension (effect size = 69.11%), reading speed (effect size = 200%), and spelling mistakes (effect size = 62.5%) of the case subject. The efficacy of the implicit stimulation in cerebral hemisphere was significant ($p < 0.01$), even three months later. We conclude that the implicit stimulation in visual hemisphere-specific is probably an effective method for improving the functioning of the reading and spelling skills in people with the linguistic developmental dyslexia.

Keywords: Developmental dyslexia; Visual Hemisphere Specific; Reading; Spelling

Introduction

Dyslexia is categorized as specific learning disorders according to the Diagnostic and Statistical Manual for the Mental Disorder-5th edition (DSM-5) (American Psychiatric Association, 2013). Developmental dyslexia (DD) is one of the most common learning disabilities. It is considered a neurobiological disorder. Nevertheless, its neurological bases are still under debate and characterized by both deficiencies in accurately and fluently recognizing words, poor spelling, and deficits in decoding (Norton et al., 2015). There is no evidence of its association with any specific sensory, neurological, or intellectual deficiencies. Among the several etiological hypotheses proposed, there is a significant agreement on the literature that DD is related to a specific deficit in the phonological representation of speech sounds (Behrmann & Geskin 2018; Ramus et al., 2013;). At the same time, there are studies focusing on different functions, such as long-term and short-term verbal memory, working memory, visual perception, auditory perception, learning functions, and spatial attention (Heim & Grande, 2012). Many researchers are converging on the idea that several causes and factors interact to contribute to the emergence of reading disorders (Pennington, 2006). This search for DD brain basis is fostering a new wave of innovative treatments aiming at enhancing reading skills in an indirect way, by training the cognitive and perceptual skills potentially involved in the reading process (Frey et al., 2019). Children with developmental dyslexia have many difficulties while reading such as word omission and/or addition or word reversal. Such children have difficulties in separating letters according to their shape and size. In addition, they read slowly with low level of comprehension (Sadock, Sadock, & Ruiz, 2014). Bakker

has stated that the basic reading requires understanding and perceiving letter, word shape, and direction. This perceptual function attributes to the right cerebral hemisphere. In addition, the way for analyzing the perceptual traits and text orientation that each person uses would stimulate the right hemisphere processing. Therefore, the right hemisphere controls the balance of the cerebral hemispheres in basic reading, and then, this responsibility will tend to the left hemisphere in the advanced reading phases. Based on the model, the basic and advanced reading levels are processed by the right and the left hemisphere, respectively, and this shift happens at one stage of the learning reading process. According to the Bakker's balance model, the linguistic developmental dyslexia (LDD) is due to the right hemisphere dysfunction (Robertson & Baker, 2002), and this leads to difficulties in transferring information from the right hemisphere to the left (Huber, Donnelly, Rokem, & Yeatman, 2018). Some children are unable to transfer what they have learned, from the right hemisphere to the left. These groups read slowly, discontinuous and without fluency. They are considered the individuals with perceptual dyslexic (P-type dyslexia) due to paying too much attention to the perceptual traits of the text. The left hemisphere plays an important role in learning to read in some children. Then, they attempt to take advantage of the linguistic strategies relating to the left hemisphere. Furthermore, they ignore the perceptual traits in the text; as a result, they will read rapidly and without accuracy. Bakker described them as individuals with linguistic dyslexia (L-type dyslexia) (Bakker & Hakvoort, 2020).

Nowadays, there are psychological interventions that their efficacy were approved for individuals with dyslexia and learning disorders (Yahyaee et al., 2014; Pahlavanneshan et al., 2015). In addition, there are increasing research evidence about the brain readiness for change through the environmental stimulation (Bakker, 2006; BaEzzat, BaniJamali, & Mo'azzemi, 2006). In other words, the brain is able to change based on the stimulation from the educational, social, and psychological settings. The processing of the text is perceptually demanding at the onset of learning to read. Because of that, the right cerebral hemisphere will have a major share in that process (Cancer et al., 2020). Gradually, the nature of reading changes though. Perceptual analysis of the letters becomes an automatism, the lexicon grows, and the child becomes familiar with the text. Reading no longer proceeds

bottom-up but rather top-down. These are all needed for the child to reach reading with fluency (Peters et al., 2019). Due to its lingual nature, the advanced reading is a primary matter for the left cerebral hemisphere. Some research evidence is available in support of the right-to-left shift in the hemispheric subservience of the process (Medina & Guimaraes, 2021). Therefore, it seems that we can improve the reading performance of children with the type-p dyslexia through stimulating the right hemisphere; On the other hand, it can improve the performance of children with the type-L dyslexia through the left hemisphere stimulation. One of the neuropsychological techniques is hemisphere alluding stimulation (HAS). It stimulates cerebral hemispheres through the visual vessel, by word and text selection with various sizes and fonts. It aims to increase the perceptual traits of the text and balances the reading speed by stimulating the right hemisphere.

As a whole, many studies have confirmed the effect of neuropsychological techniques on the developmental dyslexia (Medina & Guimaraes, 2021; Kuerten,, Mota, & Segaert, 2019; Ramus, 2005; Gibson & Leinster, 2011; Friedmann & Coltheart, 2018), However, the review of the literature in Iran showed that few research studies (Babapour, Porsharifi, & Hamedi, 2015; BaEzzat, BaniJamali, & Mo'azzemi, 2006) have been done on the effect of the hemisphere specific stimulation (HSS) on reading efficacy. Regarding the lack of Iranian research about the technique, the purpose of the present case-control study was to determine the efficacy of the implicit stimulation in visual hemisphere-specific based on the Bakker's balance model for the reading efficacy of the students with dyslexia. In addition, it attempted to answer these questions:

- Will implicit stimulation in visual hemisphere-specific influence the reading fluency of the students with L-type dyslexia?
- Will implicit stimulation in visual hemisphere-specific influence the reading speed of the students with L-type dyslexia?
- Will implicit stimulation in visual hemisphere-specific influence the reading comprehension of the students with L-type dyslexia?
- Will implicit stimulation in visual hemisphere-specific influence the writing performance of the students with L-type dyslexia?

Methods

This study was a single-subject design. The design of AB was (Baseline and Intervention) selected. The AB design includes a two-phase design consisting of a no-intervention baseline phase (A) and an intervention phase (B). It allows for evaluation of the pre-intervention and intervention problem status. The existence of a no-intervention baseline allows for the establishment of a relationship between intervention and outcome. If a change in the dependent measure occurs at the onset of the intervention, a relationship between the independent variables will establish. The study was formally approved by the University of the Social Welfare and Rehabilitation Sciences, Tehran, Iran. Two subjects were selected through convenience sampling from the individuals who referred to a private clinic. The researchers contacted the parents of the participants. The purpose and procedures of the study were explained in detail to both children and their parents. Written parental informed consent of two children who agreed to take part in the study was obtained before the beginning of the intervention. Then, they were matched according to their socioeconomic status and assigned randomly as a case and control subjects. A case subject was 9.2 years old, and a control subject was 9.5 years old with a diagnosis of linguistic developmental dyslexia (LDD). The subjects were recruited from the patients of the private clinic in Tehran, and they were studying at the 3rd grade in the November 2017-2018 school year. Both subjects had to fulfill the inclusion criteria: a) having been previously diagnosed with LDD and of the diagnosis procedure followed in the Iranian practice; b) absence of comorbidity with other neuropsychiatric or psychopathological conditions (whereas comorbidity with other learning disabilities were allowed; c) not having been involved in previous reading intervention programs. In the baseline phase, the reading and writing levels of the subjects were measured. To assess the subjects' reading and writing levels, the Diagnostic Reading Disorder Test (Nasefat, 2001) and the Writing Disorder Test (Fallahchai, 1996) were used respectively before and after the intervention sessions and at the three months follow-up. The Wechsler Intelligence Scale for Children (WISC-IV) was used to measure the subjects' intelligence level.

After evaluating the subjects by the above-mentioned three tests, one subject was considered the case subject and the other the control

subject. The implicit stimulation in the cerebral hemisphere was provided by BaEzzat, BaniJamali, and Mo'azzemi (2006) for the first time in Iran. This was used in present study based on the Bakker's balance model. The case subject participated in 16 intervention sessions (twice a week; 30 minutes per session) and received implicit stimulation in the cerebral hemisphere, and the control subject received the mainstream program (the phonological awareness) in the clinic. During the intervention sessions, the right hemisphere was indirectly stimulated by word selection with different sizes and fonts. Individuals with linguistic dyslexia that read fast make basic mistakes such as word omission and/or addition, replacing the letters and syllables of a word, representing the words and sentences with different sizes and fonts which will activate them to concentrate on the text perceptual traits (the word recognition). Subsequently, they can balance their reading speed (Bakker, 2006). Various lists of words were presented at each session. Although the words had the same font and size, the numbers and length of the words increased at each session sequentially. It began from five to six words at the 1st and 2nd sessions and increased to 15 words at the 16th session. Some letters were presented in a colorless format, and the other ones in chromatic and bold. Subjects were asked to read the colorless letters once, and then, the chromatic and bold letters during each session. The reading mistakes decreased noticeably, and the reading speed of the subject was balanced. In addition, her long pauses for the reading phonemes and words disappeared from the 1st session to the last one. The self-questioning method was used for reducing the spelling mistakes of the student. In this method, a pairs of sentences (which composed of the words with false letters) were presented to the subject, and she was asked to find those words and ask herself these questions: "Do I know this word"? "How many syllables was the word composed of"? "Do I count the syllables in a right way"? "How many letters does this word have"? "Shall I imagine the word"? "Can I remember the word correctly"? "Did I write the word correctly"? "I will read the word loudly, if I write it correctly". At the end of each session, the words and sentences were given to the parents, and they were asked to do such exercises with the child at home and report the results. The words and sentences of the previous session was practiced at the beginning of each session, and then, the content of the next session

was presented to the subject. The content of the intervention sessions is shown in Table 1.

Table 1. The content of the intervention sessions

Sessions	Content of each session
1st to 11th	Presenting self-questioning method including; showing five to six words; recognizing letter numbers in each word; knowing the word and its syllabus; counting the syllabus correctly; writing the word in a correct way; reading the word with loud voice; writing the word correctly; and memorizing the word.
12th to 16th	Above-mentioned method applied for 12 to 15 words.

Wechsler (2003) made the Wechsler Intelligence Scale for Children (WISC) and revised it several times. The WISC-IV is composed of 15 subtests and four indices that provides four intelligent quotient (IQ) and full scale IQ. The indices and its subtests are in respect as follows: verbal comprehension (similarities, vocabulary, and comprehension), perceptual reasoning (block design, picture concepts, and matrix reasoning), working memory (digit span and letter-number sequencing), and processing speed (symbol search and coding). The subtests of information, word reasoning, picture completion, arithmetic, and cancellation are arbitrary subtests and their scores do not contribute to the indices/IQ. To assess the full IQ scale, the scores of the four indices were summed up. In present study, the revised version of WISC-IV, which was normalized for the Iranian children (Razavieh & Shahim, 1992) was used. Test-retest reliability was between 0.58 to 0.87 for the indices and 0.76 to 0.94 for the verbal and performance IQ subscales. Their reliability results estimated through half-split were between 0.67 to 0.79 for the subscales and 0.92 to 0.95 for the verbal and performance IQ subscales (Sadeghi, Rabiee, & Abedi, 2011).

Nasefat established the Diagnostic Reading Disorder Test in 2001 in order to diagnose and measure reading ability. It is composed of one text that is suitable for each grade in the elementary school. It measures three clinical features: reading mistakes, reading speed, and reading comprehension. It considers one point for per mistake in reading, and the mistakes are summed up as total. The correct answer to a comprehensive question, one point is considered and the total considered as reading fluency. Finally, the time that was spent for reading from the beginning to the end of the text was calculated according to the seconds and was considered an indication of the

reading speed. The reliability results were 0.56, 0.61, and 0.68 for the third, fourth, and fifth grades, respectively (Nasefat, 2001).

Falahchai made the Writing Disorder Test for diagnosis and measuring the writing level. It has two texts for each grade, the first one includes 50% of the Persian Reading book, and the last one includes the total content of the Persian Reading book. It has two texts for each grade in the elementary school. The test is arranged based on the age and the grade levels of students. The Chronbach's alpha was 0.80 and its validity was reported to be 0.80 and 0.86 in respect (Fallahchai, 1996). Data was collected and described by frequencies and linear diagrams.

Results

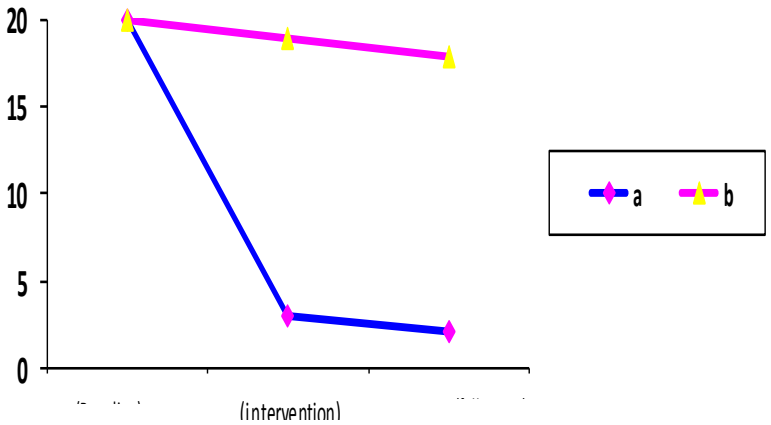
Before selecting the case and control subjects for the intervention session, WISC-IV was administered. One subject got the score of 104 for the full IQ scale, and 90, 88, 94, and 93 in respect for the verbal comprehension, perceptual reasoning, working memory, and processing speed components. She had 32 mistakes in comprehension, one in reading fluency, and read the text in 84 seconds (the reading speed). She also had 18 spelling mistakes in writing. The other subject got the score of 105 for the full IQ scale, and 82, 97, 88, and 90 in respect for the verbal comprehension, perceptual reasoning, working memory, and processing speed components. She had 29 mistakes in comprehension, one in reading fluency, and read the text in 95 seconds (the reading speed). The subject also had 20 spelling mistakes in writing. Table 2 shows the results of investigating the efficacy of Implicit Stimulation in Cerebral Hemisphere for reading fluency, reading speed, reading comprehension, and writing efficacy of the students with L-type dyslexia during different stages of assessment (baseline, intervention, and follow-up).

Table 2. The frequency of reading and writing scores of case and control subjects (a, and b) in baseline, intervention and follow-up

Phase	Subject	Reading			Writing mistakes
		Mistakes	speed	Comprehension	
Baseline	(a)	21	136	1	16
	(b)	20	136	2	15
Intervention	(a)	3	236	5	5
	(b)	19	136	1	14
Follow-up	(a)	2	230	3	6
	(b)	18	137	2	15

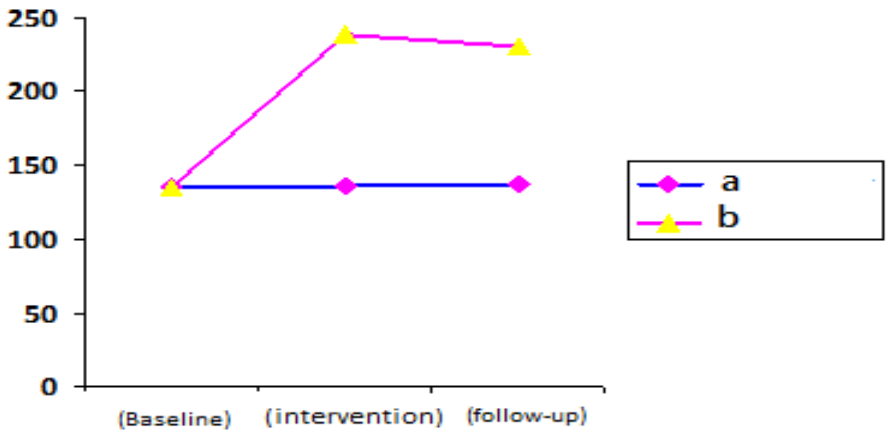
According to the results showed in Table 2, it is obvious that the reading and writing mistakes of the case subject (a) was reduced and her reading fluency and comprehension increased after the intervention in comparison to the control subject (b).

The method of "mean reduction from baseline" was used for computing the effect size. In this method, the observations mean of the intervention or follow-up stages is subtracted from the observation mean of the baseline stage. Then, its result is divided to the baseline observations and multiplies by 100 (Kappers & Dekker, 1995). According to this computation for reading, it is obvious that there is a difference in reading fluency at the intervention and follow-up stages compared to the baseline one. The difference is the result of the efficacy of the implicit stimulation in the cerebral hemisphere. The effect size of the intervention and follow-up stages was 90.47%. In other words, the intervention was effective (Graph 1).



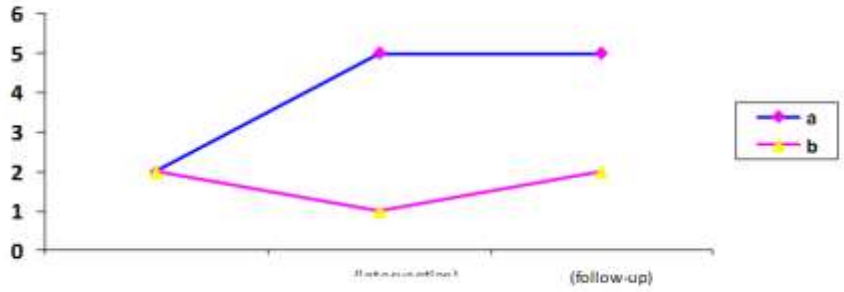
Graph 1. The performance of the subjects (a, and b) in reading fluency

In addition, there was a difference in the reading speed of at the intervention and follow-up stages compared to the baseline one. The effect size of the intervention and follow-up stages was 69.11%. In other words, the difference is the result of the efficacy of the implicit stimulation in the cerebral hemisphere (Graph 2).



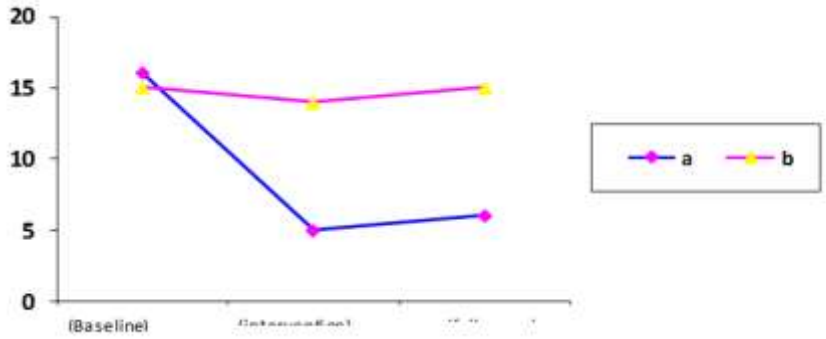
Graph 2. The performance of the subjects (a, and b) in the reading speed

The results showed that there was a difference in reading comprehension at the intervention and follow-up stages compared to the baseline one. The effect size of the intervention and follow-up stages was 200%. In other words, the difference is the result of the efficacy of the implicit stimulation in the cerebral hemisphere (Graph 3).



Graph 3. The performance of the subjects (a, and b) in the reading comprehension

Finally, there was a difference in the writing mistakes at the intervention and follow-up stages compared to the baseline one. The effect size of the intervention and follow-up stages was 62.5%. In other words, the difference is the result of the efficacy of the implicit stimulation in the cerebral hemisphere (Graph 4).



Graph 4. The performance of the subjects (a, and b) in the writing mistakes

Discussion and Conclusion

The findings showed that applying the implicit stimulation in the cerebral hemispheres led to an increase in the efficacy of reading and writing in the case subject with L-type dyslexia. In other words, the implicit stimulation in the right hemisphere increased reading fluency, reading speed, and reading comprehension of the case subject. Also, it reduced her mistakes in writing. These findings are in consistent with the results of some other studies (i.e. Bakker, 2006; Gibson & Leinster, 2011; Kappers & Dekker, 1995; Goldstein & Obrzut, 2001). Considering that developmental linguistic dyslexia is a neurological disorder, it is caused by a dysfunction of the cerebral hemisphere. Bakker and Hakvoort (2020) believed that both hemispheres play an important role in the reading process, because reading requires a perceptual analysis about the letter and word shape and direction at first. If the management of the reading process will transform from the right hemisphere to the left, reading goes on fluently and accurately.

Based on the Bakker's balance model, reading is a function of the right hemisphere occasionally, and then it is performed by the left at the advanced phases. As the right hemisphere involves in spatial thinking and is responsible for extracting the visual-spatial aspects of the written word, the brain should analyze the written word considering its spatial shape and then, associate the shape with its phonemes and meaning in order to understand it. When such transformation is not performed properly, linguistic dyslexia is inevitable. The L-type dyslexia happens when the reader uses early the linguistic strategies of the left hemisphere at the basic phases of the reading development (Vanderauwera et al. 2018). In addition, it is

possible when the left hemisphere has an active functioning at the beginning of the reading development (Bakker & Hakvoort, 2020). In fact, people with L-type dyslexia rely more on their left hemisphere and use less from the strategies of the right hemisphere. Thus, it leads to read faster and inattention to perceiving the text. They are inaccurate and have major mistakes while reading a text. According to the Bakker's balance model in reading, children with L-type dyslexia take less advantage of the right hemisphere; therefore, it seems that implicit stimulation in the right hemisphere is beneficial for them and probably reduces their reading mistakes (Baker, 2004). Applying the implicit stimulation in the cerebral hemisphere can be useful as a complementary method for specialists who provide services to people with learning disorders. The method probably improves reading and writing performance of students with linguistic developmental dyslexia.

Considering that developmental dyslexia is based on a neurological basis, all people with developmental dyslexia have left hemisphere dysfunction despite their language type. Therefore, many researchers coincide that there is a causal relation between brain abnormalities and reading difficulties. In addition, they emphasize these general factors despite the local language at each country.

Our study had some strengths and limitations. The most important strengths of our study was the efficacy of the implicit stimulation of the cerebral hemisphere (hemisphere alluding stimulation; HAS) on the reading and writing performance of an individual with L-type dyslexia. Results from the other studies indicated that L-type subjects treated with HSS (hemisphere specific stimulation) made gains that are more substantial, whereas the P-type subjects made better improvement after HAS intervention (Baker & Vinke, 1985). The limitation of our study was that there is no assessment of phonology. The role of phonology is controversial: The balance model considers the phonological skill as the right-hemisphere activity with the emphasis on the initial visual analysis and the automaticity aspect of the grapheme-phoneme conversion (Baker, Licht, & Kappers, 1995; Campbell et al., 2004). In contrast,, other studies have equated phonology with a primarily left-hemisphere linguistic activity.

In Conclusion, the results showed that implicit stimulating in the visual hemisphere-specific could improve reading fluency, speed, and comprehension in an individual with L-type dyslexia. In addition, it

led to a decrease in her spelling mistakes. The results showed clear variety of studies, and it would be useful to address certain factors in future works; for example, the issue of classification methods, as L-types in one study would not necessarily be L-types in another study, which renders both comparison between studies and differential intervention problematic. It recommends that this method is probably useful for improvement of the reading and writing performance in children with reading disabilities.

Acknowledgement

This article is a part of research project for learning disorder course in Master of Science Degree of University of Social Welfare and Rehabilitation Sciences. We would like to thank the University. We also wish to thank the female students in Tehran for their valuable collaboration with this study. The authors declare that there is no conflict of interest.

Conflict of Interest:

The authors declare that there is no conflict of interest.

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