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Original Paper

The Effects of Font Type on Reading Accuracy and Fluency in Japanese Children with Developmental Dyslexia

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Abstract

We administered rapid reading tasks in Japanese children (32 with typical development and 24 with developmental dyslexia), and investigated the effects of two different font types: Rounded-Gothic and Mincho style font. In the experiment, we used four kinds of stimuli: two scripts (paragraphs and random kana character non-words) in two font types (Rounded-Gothic and Mincho style font). In this experiment, the duration time, the number of errors and the number of self-corrections were measured during reading. Participants were asked which font type was easier to read. There was no significant difference in the duration time, the number of errors and the number of self-corrections between two types of fonts among the 56 participants. On the other hand, regarding subjective readability, the developmental dyslexia group reported that the Rounded-Gothic font was easier to read. There was a difference between objective and subjective readability. In this study, there was no difference in reading performance of Rounded-Gothic and Mincho style fonts in Japanese children with developmental dyslexia.

Keywords

developmental dyslexia, font type, reading accuracy, reading fluency, readability, Japanese speaking children

1. Introduction

Developmental dyslexia was defined by the International Dyslexia Association (IDA) (Lyon et al., 2003) as follows: "Dyslexia is a specific learning disability that is neurobiological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities".

One hypothesis for the onset of developmental dyslexia is the phonological deficit (Shaywitz & Shaywitz, 1999; Skeide et al., 2015), which is currently supported by most researchers. Although studies on the relationship between phonological skill and reading performance are relatively consistent, other research suggests a relationship between reading skill and visual processing (Stein, 2001; Winner et al., 2001; Pache et al., 2004; Gotoh et al., 2010).

In recent years, due to their visual processing deficits, there has been increased attention on the use of specific font types to improve the reading performance of children with developmental dyslexia. In English-speaking countries, font types appropriate for children and adults with developmental dyslexia, such as Open Dyslexic (Gonzalez, 2014) and Dyslexie (Boer, 2016) have been designed. For example, in response to the complaints that "letters appear blurry" and "letters appear inverted" from individuals with developmental dyslexia, Open Dyslexic (Gonzalez, 2014) designed letters to be thicker at the bottom so that the top and bottom of the typeface are clear. The British Dyslexia Association (BDA) (2012) recommends the use of a simple and monospaced sans-serif font. Rello and Baeza-Yates (2013) investigated the influence of different Latin fonts such as Helvetica, Courier, Arial, Verdana, and Computer Modern Unicode (CMU), on the reading of adults with developmental dyslexia and indicated the possibility of increasing the reading performance of children and adults with developmental dyslexia.

In Japan, however, there are no font types that are considered to be easy to read for Japanese-speaking children and adults with developmental dyslexia. Organizations supporting individuals with developmental dyslexia in Japan (NPO EDGE, 2019; Eigo Kyoiku Universal Design Kenkyukai, 2019) recommend the use of the monospaced Gothic and/or Rounded Gothic fonts, although no scientific evidence for this recommendation has been presented. Furthermore, little research has been conducted regarding the effect of different Japanese font types on the reading abilities of Japanese speakers with developmental dyslexia.

The purpose of this study was to clarify the effects of different types of Japanese font (Rounded Gothic and Mincho) on reading accuracy and fluency in Japanese-speaking children with developmental dyslexia.

2. Methods

2.1 Participants

2.1.1 Children with Typical Development

The participants with typical development comprised 32 children from 4th to 6th grades who attended a regular school (age: 11.0 ± 0.36 (mean ± standard deviation) years; 12 boys, 20 girls). All these children scored higher than -1SD of the mean in all of the tests of Raven's Coloured Progressive Matrices (RCPM) (Raven, 1976), the Standardized Comprehension Test of Abstract Words (SCTAW) (Haruhara et al., 2002), and the Kanji writing accuracy task in the Standardized Tests for Assessing the Reading and Writing (Spelling) Attainment of Japanese Children and Adolescents (STRAW-R) (Uno et al., 2017), and the children scored within +1 SD of the mean in the reading fluency tasks in the STRAW-R, showing that their general intelligence and spoken language development were within the normal range and they did not have any delay in reading and writing attainment.

2.1.2 Children with Developmental Dyslexia

The participants included 24 children with developmental dyslexia from 4th to 6th grades in elementary school [age: 11.1 ± 0.79 (mean ± standard deviation) years; 18 boys, 6 girls; 22 right-handed, 2 left-handed]. The results of cognitive tests and tests related with reading and spelling observed from the first examination of the 24 children with developmental dyslexia are shown in Table 1.

The children in the developmental dyslexia group met the following three conditions: (1) They scored 85 or above in the Verbal Intelligence Quotient (VIQ) or Performance Intelligence Quotient (PIQ) of WISC-Ⅲ (Wechsler Intelligence Scale for Children-Third Edition) or in the Verbal Comprehension Index (VCI) or Perceptual Reasoning Index (PRI) in WISC-Ⅳ (Wechsler Intelligence Scale for Children-Fourth Edition), or had a score of at least -1.5 SD in RCPM (Raven, 1976). (2) They scored under -1.5 SD of the mean in reading accuracy of any one of the Hiragana words, or Katakana words, or Kanji words, or had a duration time of longer than +1.5SD of the mean in reading either Hiragana and Katakana words or Hiragana and Katakana non-words or sentences in the reading fluency tasks in the STRAW-R (Uno et al., 2017). (3) (a) They scored below -1.5 SD of the mean in the number of correct answers in the non-word repetition task or word repetition in reverse order, the time it took to correctly answer the word repetition in reverse order was +1.5 SD of the mean or longer, or (b) the duration in the Rapid Automatized naming task (RAN) (Kaneko et al., 2004) was +1.5SD or longer, or (c) below -1.5SD in the number of correct answers or over +1.5SD in the number of errors and reaction times in the Matching Familiar Figures Test (MFFT) (Yokoi et al., 2014), or they had a score of under -1.5 SD either in the copy task, immediate recall task, or 30-minute delayed recall task in the Rey-Osterrieth Complex Figure Test (ROCFT) (Osterrieth, 1993).

Twelve out of the 24 children with developmental dyslexia (age: 11.2 ± 0.90 years; 9 boys, 3 girls; 11 right-handed, 1 left-handed) had a score of below -1.5SD of the mean in the number of correct answers in the visual perception tasks of the MFFT (Yokoi et al., 2014) and/or the copy drawing task in the ROCFT (Osterrieth, 1993). Thus, this group was designated as the developmental dyslexia with visual

perception deficits group.

There was no statistically significant difference in chronological age ($\chi^2 = 2.066$, $df = 2$, $p = .356$) among the typical development group (n = 32, 11.0 ± 0.36 years), the developmental dyslexia group (n = 12, 11.1 ± 0.79 years) and the developmental dyslexia with visual perception deficits group (n = 12, 11.2 ± 0.90 years).

2.2 Procedure

An oral reading task was administered to the participants. Afterwards, the participants were asked which font was easier to read. Because the Japanese organization that specifically supports developmental dyslexia recommends Gothic and Rounded Gothic fonts (NPO EDGE, 2019; Eigo Kyoiku Universal Design Kenkyukai, 2019), one font that was used in this study was the Rounded Gothic font. In addition, Mincho was used because it is a contrasting font. Whereas the Rounded Gothic font features lines of uniform thickness, the lines in Mincho are dynamic. Furthermore, the stops and hooks are simplified in Rounded Gothic; in Mincho, the application and withdrawal of pressure are expressed (Appendix 1 and 2).

The stimuli for the oral reading task had a 2 × 2 design in terms of script (i.e., paragraphs of 320 characters each and non-word strings of 50 characters each) and font type (i.e., Rounded Gothic, Mincho). The paragraph task used vertical writing and mixed Kanji and kana. Only Kanji that would have been learned by grade four were used, as Kanji included Ruby text. Non-word strings were composed of Hiragana and Katakana. To eliminate the effect of the width of inter-character spaces, each character was provided within the same space. For both the paragraphs and the non-word strings, the character size was 16 pt; 32 pt was left between consecutive lines. The font types used were Rounded Gothic (Hiragino Rounded Gothic W3) and Mincho (Hiragino Mincho W3). The same 320-character paragraphs and the same 50-character non-word strings were presented in the Rounded Gothic and in the Mincho fonts. We administered the four stimuli with a counterbalanced design to offset order effects.

Participants were instructed as follows: “Please read the characters and paragraphs we show you as quickly as possible without making mistakes”. After the experimenter gave the signal to “start”, each stimulus was presented on the paper. The oral reading of the participants was recorded using a digital voice recorder, and the time required for oral reading was measured with a stopwatch. For each stimulus, we analysed the duration of reading, number of errors and number of self-corrections. After completion of the oral reading task, each stimulus was presented a second time, and the participants were asked which font was easier to read. Statistical analyses were performed using wilcoxon signed-rank test and chi-squared test (IBM SPSS Statistics ver.23, Tokyo, Japan).

Table 1. Results of Cognitive Tests and Tests Related with Reading and Spelling in the Children with Developmental Dyslexia (n=24)

		DD (n=12)	DD +VPD (n=12)
General intelligence test			
Wechsler Intelligence Scale for Children-Third Edition (WISC-III) or Wechsler Intelligence Scale for Children-Fourth Edition (WISC-Ⅳ)		**mean±SD**	**mean±SD**
Verbal IQ (VIQ) or Verbal Comprehension Index (VCI)		99.1±18.4	97.3±10.7
Performance IQ (PIQ) or Perceptual Reasoning Index (PRI)		105±27.7	85.8±14.4
Full scale IQ (FIQ)		97.9±21.1	90.4±8.91
		mean z scores	**mean z scores**
Raven Coloured Progressive Matrices (RCPM)	(n=36)	−0.14	−1.25
Vocabulary test			
Standardized Comprehension Test of Abstract words (SCTAW)	(n=45)	0.65	0.32
Reading and writing tests			
Standardized Tests for Assessing the Reading and Writing Attainment of Japanese Children and Adolescents (STRAW-R)			
Reading accuracy			
Hiragana words	(n=20)	−1.36	0.06
Katakana words	(n=20)	−3.01	−1.04
Kanji words	(n=20)	−2.62	−1.06
Writing accuracy			
Hiragana words	(n=20)	−1.86	−0.33
Katakana words	(n=20)	−1.80	−2.65
Kanji words	(n=20)	−3.21	−2.25
Reading fluency			
Hiragana words		4.08	2.96
Katakana words		4.84	2.86
Hiragana non-words		3.15	1.66
Katakana non-words		2.79	1.45
Paragraph		3.69	1.37
Phonological ability tests			
Nonword Repetition	(n=10)	−0.57	−0.59
Word Repetition in Reverse Order			
Number of correct answers	(n=20)	−0.99	−1.48
Duration (s)			
Three-morae words	(n=10)	4.12	0.79
Four-morae words	(n=10)	4.01	0.89

Visual cognitive ability tests			
Matching Familiar Figure Test (MFFT)			
Number of correct answers	(n=12)	0.71	−1.40
Number of errors		−0.63	1.62
Reaction time (s)		1.59	0.06
Rey-Osterrieth Complex Figure Test (ROCFT)			
Copy drawing		−0.38	−1.13
Immediate recall		−0.84	−1.24
Delayed recall		−1.07	−1.49
Automatization test			
Rapid Automatized naming (RAN)			
Duration (s)		2.06	1.10

Note. DD, Developmental dyslexia group; DD+VPD, Developmental dyslexia with visual perception deficits group, WISC-ⅢorⅣ indicates mean±SD and all other tasks indicates mean z scores.

Participation by subjects in this study was determined based on the informed consent of both the child and his/her parent or guardian. After explaining the outline of the study, the tasks were performed only if both the child and his/her parent or guardian gave their approval. Sufficient explanation was also provided regarding the fact that participants could drop out of the study at any time and that they would suffer no disadvantages by doing so. This research was conducted after obtaining approval from the University of Tsukuba Art Research Ethics Committee (Issue Number Arts 26-2).

3. Results

3.1 Duration of Reading, Number of Errors and Number of Self-Corrections

Table 2. Results of Reading Tasks

Task			TD (n=32) mean (SD)	Z	*p*	DD (n=12) mean (SD)	Z	*p*	DD+VPD (n=12) mean (SD)	Z	*p*
Paragraph	duration (s)	Round Gothic	45.2 (8.2)	-1.72	.085	70.2 (24.6)	-.235	.814	49.2 (12.2)	-1.37	.170
		Mincho style	43.4 (6.0)			68.2 (26.7)			53.9 (10.8)		
	number of errors	Round Gothic	2.38 (2.2)	-1.02	.310	6.25 (3.7)	-1.43	.152	4.58 (3.3)	-1.54	.123
		Mincho style	2.66 (2.0)			4.92 (4.2)			6.33 (4.3)		
	number of times of self-correcting	Round Gothic	1.97 (1.5)	-.665	.512	4.17 (1.9)	-.154	.887	2.83 (1.9)	-1.15	.251
		Mincho style	1.78 (1.6)			4.00 (2.7)			3.33 (1.9)		
Random kana character non-word	duration (s)	Round Gothic	23.3 (4.4)	-.729	.466	31.3 (8.1)	-.941	.347	22.9 (4.7)	-.784	.433
		Mincho style	23.0 (5.6)			33.6 (10.9)			24.1 (6.7)		

number of errors	Round Gothic	0.72 (1.0)	-.211	.833	1.25 (1.2)	-.787	.431	0.67 (1.0)	-.276	.783
	Mincho style	0.78 (1.2)			1.58 (1.9)			0.83 (1.2)		
number of times of self-correcting	Round Gothic	1.28 (1.5)	-1.05	.295	1.08 (1.4)	-.879	.380	0.33 (0.5)	-1.73	.083
	Mincho style	1.03 (1.4)			1.50 (2.2)			0.92 (0.8)		

Note. TD, Typical development group; DD, Developmental dyslexia group; DD+VPD, Developmental dyslexia with visual perception deficits group, Statistical analyses were performed using a wilcoxon signed-rank test.

The results of the reading tasks are shown in Table 2. There were no significant differences between the two font types (Rounded Gothic and Mincho) in the duration of reading, the number of errors and the number of self-corrections in the typical development group, developmental dyslexia group, or the developmental dyslexia with visual perception deficits group in both the paragraph task and the non-word strings task.

3.2 Participants' Opinions about the Oral Reading Tasks in the Two Fonts

The participants were asked which font was easier to read during the oral reading tasks. On two-way chi-squared test, a significant difference was found ($\chi 2 = 5.03$, $df = 1$, $p < .024$). There were significantly more children in the developmental dyslexia group than in the typical development group who felt that the Rounded Gothic font was easier to read (Table 3).

Table 3. Results of Participants' Opinions

	Which font type is easier to read ?		χ^2	p
	Round Gothic	Mincho style		
DD (n=24)	17	7	5.03	.024*
TD (n=32)	13	19		

Note. TD, Typical development group; DD, Developmental dyslexia group, and the Developmental dyslexia with visual perception deficits group, Statistical analyses were performed using a two-way chi-squared test. *p <.05.

4. Discussion

4.1 Effects of Japanese Font Type on Duration of Reading, Number of Errors and Number of Self-Corrections

In this study, there were no significant differences in the duration of reading, the number of errors and the number of self-corrections between the two font types in the typical development group, developmental dyslexia group, or the developmental dyslexia with visual perception deficits group.

Our study showed that in children with developmental dyslexia, a difference in font type was not linked to an objective improvement in reading speed or a reduction in the number of errors. As font type is

thought to have an effect on visual processing, an analysis of children with developmental dyslexia who had visual perception problems was conducted in this study as well. However, there were no significant differences in the duration of reading, the number of errors and the number of self-corrections between the two font types in each group.

De Leeuw (2010) had Dutch university students with and without developmental dyslexia perform two reading tasks (i.e., word reading and non-word reading). They were asked to read both tests in Arial font as well as in Dyslexie font. Her conclusion was that no differences in reading errors and speed between the tasks presented in Dyslexie font and Arial font emerged for either the students with or students without developmental dyslexia. Rello and Baeza-Yates (2013) conducted a paragraph silent reading task in adults with developmental dyslexia; the researchers investigated the ease of reading 12 Latin fonts such as Helvetica, Courier, Arial, Verdana, and Computer Modern Unicode (CMU), and acknowledged the potential of improving reading performance of children and adults with developmental dyslexia. But, regarding the duration of paragraph silent reading, a significant elongation was observed in Arial italic font only (compared to the other 11 Latin fonts), and significant differences among the other 11 Latin fonts were not observed. Thus, clear evidence has not been offered to support the claim by Rello and Baeza-Yates (2013) that there is a font with the potential to improve reading performance in children and adults with developmental dyslexia. Our results were mostly in line with De Leeuw (2010) and Rello and Baeza-Yates (2013). On the other hand, Marinus et al. (2016) reported that the efficacy of font types appropriate for children and adults with developmental dyslexia were not because of its specially designed letter shapes, but because of its particular spacing settings. In fact, it has been shown that children with developmental dyslexia benefit from increased spacing with standard fonts (O'Brien et al., 2005). Therefore, we think that it is necessary to clarify the effects within-word spacing and between-word spacing of on reading accuracy and fluency in Japanese-speaking children with developmental dyslexia.

Regarding the claim of dyslexia-related parties and support organizations in Japan that Gothic and Rounded Gothic fonts are easy to read for children with developmental dyslexia, the present study did not find scientific evidence for this in neither reading accuracy nor fluency.

4.2 Children's Opinions on Font Types

In the present study, in the subjective assessment, significantly more children in the developmental dyslexia group reported that the Rounded Gothic font was easier to read than Mincho. In interviews with Japanese speakers with developmental disorders who used large-print textbooks (Nakano, 2011), all participants agreed that normal textbook fonts and Mincho were difficult to read; they also agreed that the Universal Design (UD) font was easy to read. The UD font is a font with a twist, designed to change characters with similar shapes into different shapes, widen character spaces, increase the size of the letter surface, and remove Kanji's foot (Hakamada et al., 2002). Additionally, in these interviews (Nakano, 2011), regarding the reason UD is easy to read, the assessment of "because the width of the lines making up the characters is fixed" was received. Rounded Gothic font was identified by children

with developmental dyslexia in this study as easy to read; this font has lines characterized by a fixed width, similar to the UD font, and it is thought that there is possibly a tendency for children with developmental dyslexia to feel that a font is easier to read when it has a fixed line width.

Nonetheless, in the present study, when compared with Mincho, there were no significant effects of the Rounded Gothic font on duration of reading, number of errors and number of self-corrections. Regarding the fact that the objective assessments of reading fluency and accuracy and the subjective assessments had differing results, it was unclear if the objective evaluation was not reflected in the subjective assessment or if the relationships were independent because of their different natures.

5. Conclusions

In the present study, the effect of different Japanese font types (Rounded Gothic and Mincho) on reading by Japanese-speaking children with and without developmental dyslexia was investigated in a group study. As a result, it was revealed that the children with developmental dyslexia felt subjectively that the Rounded Gothic font was easier to read; however, there were no significant differences in the duration of reading, the number of errors and the number of self-corrections between the two font types in the typical development group, developmental dyslexia group and the developmental dyslexia with visual perception deficits group. This finding suggests that the use of Rounded Gothic font could decrease the "mental burden of reading" even though it did not improve reading accuracy and fluency in Japanese-speaking children with developmental dyslexia.

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Appendix

Appendix 1. Stimuli of the Oral Reading Task: Paragraphs

Rounded Gothic font

ぼくの家にウサギが来た。けれど、様子がおかしい。しきりに鼻をならして、じっと動かない。「なれていないだけだから、やさしくしてあげなさい」とお父さんはぼくに言った。しばらくすると、ウサギはおとなしくなって、鼻を動かすこともやめた。どうやら、家になれたみたいだ。そしてウサギは、家を散歩するようになった。勝手に部屋を歩き回って、テレビのコードをかじったり、紙を食べたりするから、ぼくはびっくりした。一番おどろいたのは、ウサギがカーペットの上で高くジャンプした時だ。「ウサギが真上に飛び上がるのは、うれしい時なんだよ」とお父さんが教えてくれた。きっと、自由に部屋を散歩できてよろこんでいるんだろうな。ぼくは、ウサギに名前をつけてあげようと思った。

Mincho font

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Appendix 2. Stimuli of the Oral Reading Task: Kana Non-Word Strings

Rounded Gothic font

わ イ き あ
カ ほ ヌ ヨ
ゆ は エ へ
ヒ ニ ろ お
つ い ノ て
ホ テ タ
オ れ か
こ ト ナ
ム さ み
も ク ラ
サ に る
え ケ フ
ね よ け
ヤ コ ふ
ひ ち ル

Mincho font

わ イ き あ
カ ほ ヌ ヨ
ゆ は エ へ
ヒ ニ ろ お
つ い ノ て
ホ テ タ
オ れ か
こ ト ナ
ム さ み
も ク ラ
サ に る
え ケ フ
ね よ け
ヤ コ ふ
ひ ち ル