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Research on Japanese Typefaces and Typeface Customisation System Designed for Readers with Developmental Dyslexia

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This research aims to create Japanese typefaces and a Japanese typeface customisation system for readers with developmental dyslexia. In previous research, we have defined the requirements for Japanese typefaces for readers with dyslexia and created a set of new Japanese typefaces, *LiS Font*. This paper reports the evaluation experiment conducted regarding the readability and legibility of *LiS Font*. The results indicate that typefaces have impacts on both objective and subjective measures of readability, and readers with dyslexia consider *LiS Font* more readable compared to existing Japanese typefaces. In addition, the results imply the necessity of meeting the needs of readers with different symptoms of dyslexia. Hence this paper also reports our progress with developing a Japanese typeface customisation system for readers with dyslexia by introducing an initial prototype.

Keywords: typeface; customisation; Japanese characters; developmental dyslexia; readability; legibility

1 Introduction

This paper introduces our research which aims to develop a set of new Japanese typefaces specially designed for readers with developmental dyslexia and a Japanese typeface customisation system for readers with developmental dyslexia.

1.1 Background

Developmental dyslexia, or dyslexia, is “a specific learning disability that is neurobiological in origin. It is characterised by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities” (International Dyslexia Association, 2002). Evidence shows that 5–17% of the population in English-speaking countries (Reid, Fawcett, Manis & Siegel, 2008) and 8% of the population in Japan (Japan Dyslexia Research Association, 2018) have developmental dyslexia. It is essential to provide readers with developmental dyslexia with an assistive environment.

There is a wide range of assistive tools for readers with dyslexia (Smythe, 2010) and in this research, we focus on typefaces as a visual assistive tool for the readers.

Several Latin typefaces that are specially designed for readers with dyslexia have been created over the years and some research shows that readers with dyslexia are able to read with fewer errors or are more comfortable reading in these typefaces compared to standard typefaces (Hillier, 2006; Marinus et al., 2016; Zikl et al., 2015). With regard to Japanese language, recent studies indicate that typefaces have effects on reading performance of readers with dyslexia in Japanese (Okumura et al., 2018; Tani, Goto, Uno, Uchiyama & Yamanaka, 2016). These results imply that Japanese typefaces designed for readers with dyslexia would be effective.

1.2 Problems

However, Japanese typefaces for readers with dyslexia had not been created so far due to the following problems.

1. The characteristics of typefaces designed for readers with dyslexia (both in Latin and Japanese) were not systematically clarified,
2. Japanese typefaces contain a large number of complicated characters which makes creating new typefaces expensive,
3. To create a typeface that fits every reader with dyslexia is not easy.

1.3 Research Objectives

In our research, we aim to solve the first problem by (i) clarifying the characteristics of Latin typefaces designed for readers with dyslexia and mapping them to Japanese typefaces to define the requirements for Japanese typefaces designed for readers with dyslexia, to solve the second problem by (ii) creating a Japanese typeface for readers with dyslexia by programmatically manipulating glyphs of open source typefaces, and to solve the third problem by (iii) creating a Japanese typeface customisation system that enables readers with dyslexia to adjust typefaces within a certain range to fit their symptoms. This research, thus, consists of the following three phases:

- Phase 1: Defining the requirements for Japanese typefaces designed for readers with dyslexia by mapping the characteristics of the Latin typefaces designed for readers with dyslexia,
- Phase 2: Creating a set of Japanese typefaces based on the requirements defined in Phase 1 and evaluating the typeface,
- Phase 3: Developing a Japanese typefaces customisation system for readers with dyslexia.

This paper reports the results of the evaluation experiment of Phase 2 and our progress with Phase 3.

2 LiS Font: New Japanese Typefaces Designed for Readers with Dyslexia

LiS Font, as shown in Figure 1, is a new set of Japanese typefaces designed for readers with dyslexia that we have created in this research. *LiS Font walnut* and *LiS Font cashew* are two variations of *LiS Font* and each of them contains 2776 characters including Japanese kana characters and Jōyō kanji (common-use Chinese) characters.

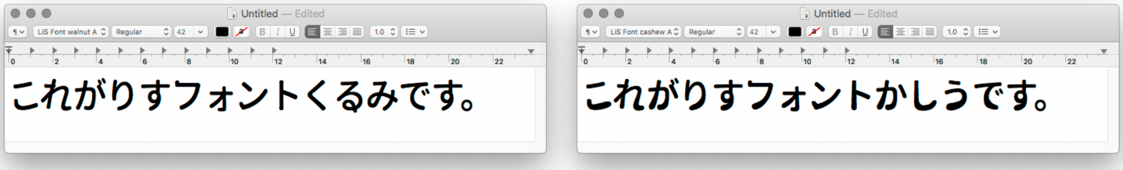

Figure 1. LiS Font walnut (left) and LiS Font cashew (right).

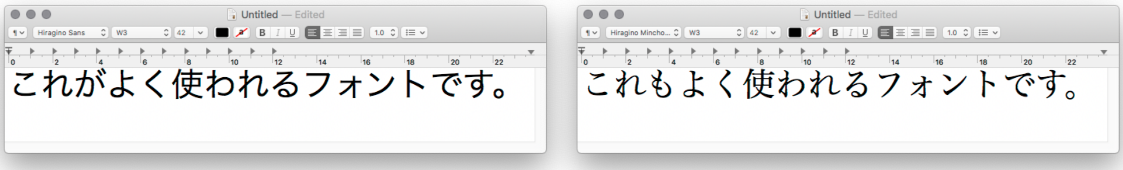

Figure 2. Standard Japanese typefaces, sans serif style (left) and serif style (right).

In this section we will report the definition of the requirements for Japanese typefaces for readers with dyslexia and the creation of *LiS Fon*t in brief and report the results of the evaluation regarding the efficacy of *LiS Font* in detail.

2.1 Requirements for Japanese Typefaces for Readers with Dyslexia

As is mentioned in Section 1.2 and 1.3, we extracted visual characteristics of the existing Latin typefaces designed for readers with dyslexia by comparing their elements quantitatively and qualitatively to those of standard typefaces (Zhu, 2016). As a result, we obtained 9 characteristics of Latin typefaces designed for readers with dyslexia.

On the basis of the characteristics extracted, we defined the requirements for Japanese typefaces designed for readers with dyslexia by mapping those characteristics to typographic elements in Japanese (Yamada & Zhu, 2018). It is reasonable to assume that the characteristics of the Latin typefaces designed for dyslexia can be mapped to Japanese typefaces because research shows that character recognition process is similar across the languages and writing systems (Dehaene, 2009) and moreover, similar visual symptoms of dyslexia such as letter reversals, distortion, blurring, and superimposition are reported in both Japanese and English (Stein, 2008; Stein & Walsh, 1997). As a result, we defined 9 requirements for Japanese typefaces designed for readers with dyslexia as below.

1. Larger characters,
2. Maru gothic (rounded sans serif),
3. Bolder strokes,
4. Larger height/width ratio,
5. Contrast in strokes,
6. Larger space between characters,
7. Easy-to-distinguish kana characters with similar shapes,
8. Easy-to-identify kanji characters,
9. Frames added to kanji characters to illustrate radicals.

2.2 Creation

In order to create Japanese typefaces that fulfil the requirements defined above, We combined programmatic methods of manipulating glyphs of an existing typeface, or the base font, with manual adjustments.

We selected Source Han Sans JP as the base font for the reason that it is an open source project of CID-keyed OpenType fonts and its character collection is large enough for Japanese typefaces. Tools adopted during the process include RoboFont, Glyphs, and Adobe Font Development Kit for OpenType (AFDKO).

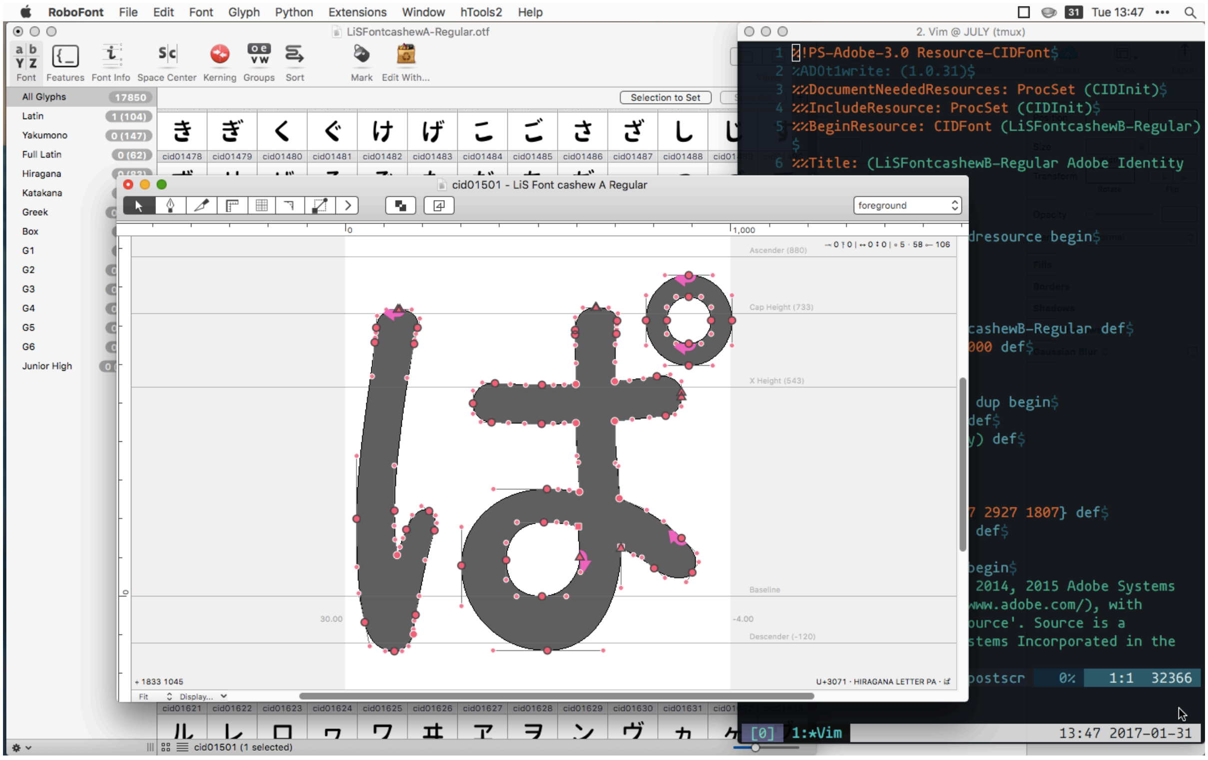

Figure 3. Creation process of LiS Font.

The results of this process are *LiS Font walnut* and *LiS Font cashew*. *LiS Font walnut* fulfils the requirements 1--4, 6, 7, and 9 while *LiS Font cashew* fulfils the requirements 1--7, and 9.

2.3 Evaluation

We conducted an evaluation experiment on readability and legibility of *LiS Font.* Twenty participants with dyslexia (DX group) and 20 participants without dyslexia (TP group) participated in the experiment. Table 1 shows age of the participants.

Table 1 Age of the participants

Group	N	Age			
		mean	*SD*	*min*	*max*
DX	20	19.05	11.35	10	53
TP	20	27.80	12.78	8	47

2.3.1 Procedures

The experiment consists of rapid reading tasks for objective measures and interviews for subjective measures. In rapid reading tasks, we asked the participants to read aloud 2 kinds of materials (short random characters and random kana characters) typeset in 4 different typefaces (*LiS Font walnut*, *LiS Font cashew*, Hiragino Maru Gothic, and Hiragino Mincho, in which Hiragino Maru Gothic and Hiragino Mincho are commonly used Japanese typefaces that bundled with macOS.), and recorded the duration of reading, number of errors, and number of corrections. In interviews, we asked the participants about the most and worst readable typeface in their point of view and recorded the answers. Figure 4 shows the typefaces used in the experiment.

Figure 4. Typefaces used in the experiment.

2.3.2 Results

2.3.2.1 Objective measures

Figure 5, Figure 6, and Figure 7 show the results of objective measures of the participants reading text.

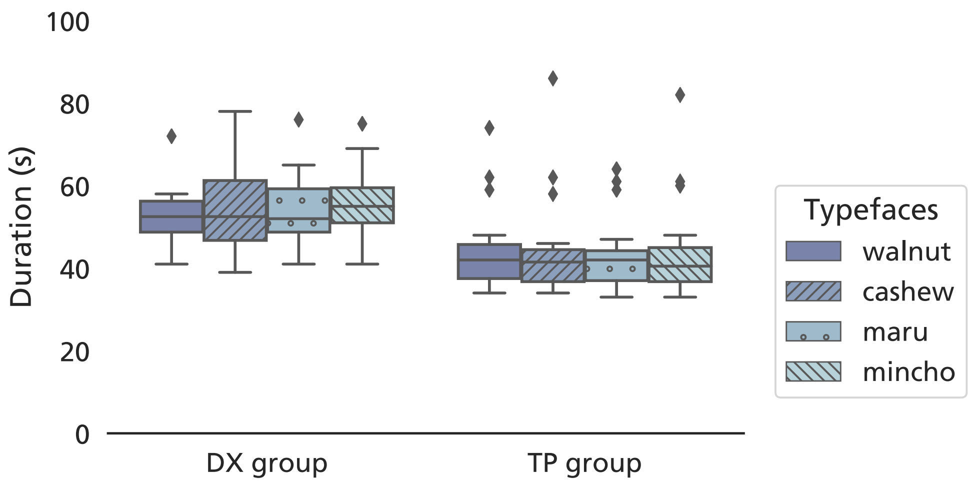

Figure 5. Duration of reading text.

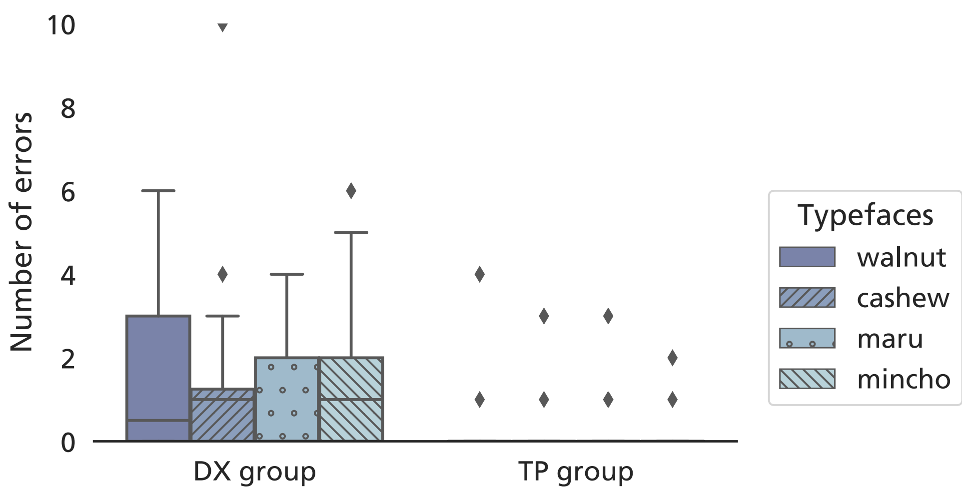

Figure 6. Number of errors of reading text.

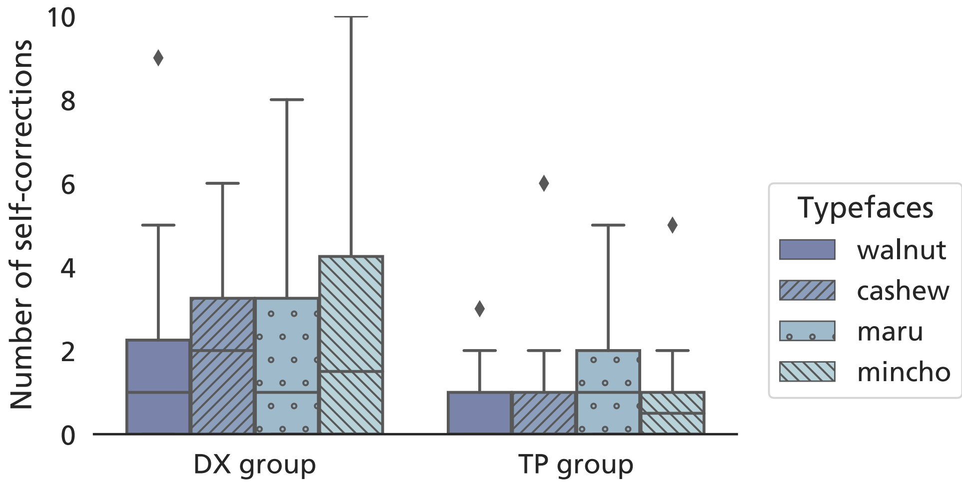

Figure 7. Number of self-corrections of reading text.

Figure 8, Figure 9, and Figure 10 show the results of objective measures of the participants reading random characters.

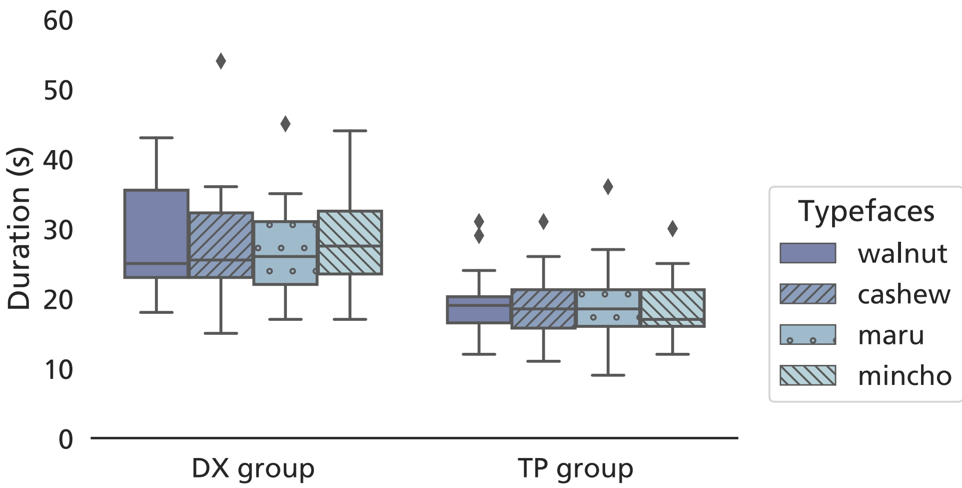

Figure 8. Duration of reading random characters.

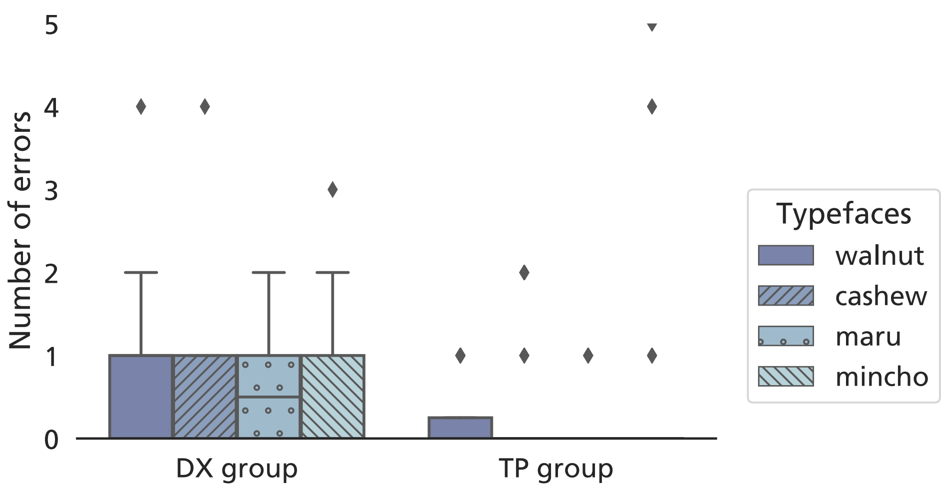

Figure 9. Number of errors of reading random characters.

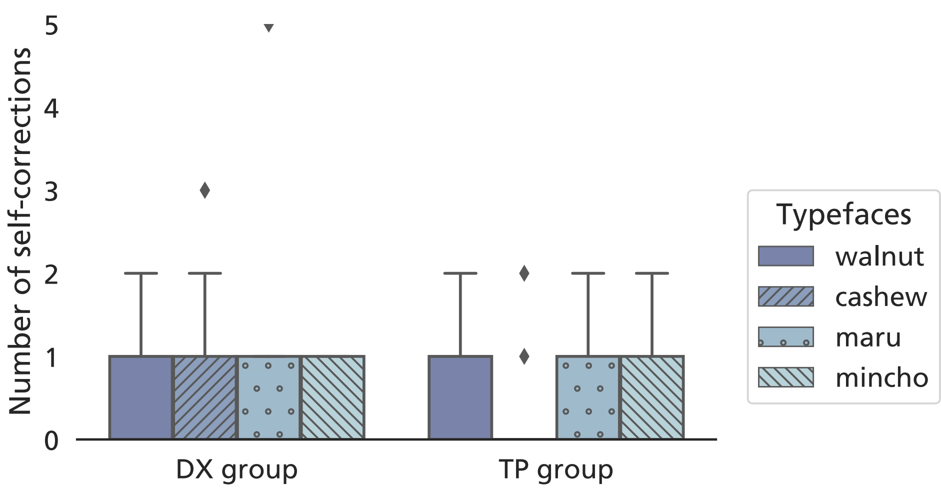

Figure 10. Number of self-corrections of reading random characters.

We conducted Friedman test on the results. As Table 2 shows, although no significant differences were detected between 4 typefaces in all the measures, small to medium effect sizes (η^2) were observed for all the measures except for the duration of reading random characters.

Table 2 Results of Friedman test

Material	Measure	Group	$\chi^2(3)$	η^2	p
Text	Duration	DX	2.862	0.048 *	0.413
		TP	1.737	0.029 *	0.629
	Number of errors	DX	2.395	0.040 *	0.495
		TP	1.286	0.021 *	0.733
	Number of self-corrections	DX	0.886	0.015 *	0.829
		TP	6.094	0.102 **	0.107
Random characters	Duration	DX	0.452	0.008	0.929
		TP	0.223	0.004	0.974
	Number of errors	DX	5.764	0.096 **	0.124
		TP	1.357	0.023 *	0.716
	Number of self-corrections	DX	1.268	0.021 *	0.737
		TP	6.780	0.113 **	0.079

In Friedman test, the effect size can be calculated by the formula $\eta^2 = \frac{\chi^2}{N(p-1)}$, in which N is the total sample size and $p-1$ is the degree of freedom (Morse, 1999). Interpretations of the effect size are shown in Table 3. Since effect sizes “provide an objective measure of the importance of an effect” (Field, 2009) regardless of sample sizes, it is safe to conclude that typefaces do have impacts on objective measures of readability and legibility in readers with and without dyslexia.

Table 3 Interpretations of the effect size

Interpretation	η^2	Cramer’s V
Small	0.01	0.10
Medium	0.09	0.30
Large	0.25	0.50

Source: Mizumoto & Takeuchi (2008)

We will conduct further analysis of multiple comparisons in future research.

2.3.2.2 Subjective measures

Table 4 and Figure 11 show the result of subjective readability recorded from the interviews. Figure 12 shows this result in proportion of all the answers.

Table 4 Subjective readability

Material	Typeface	DX group		TP group	
		Readable	Not readable	Readable	Not readable
Text	walnut	7	1	1	1
	cashew	5	8	3	14
	maru	6	0	9	2
	mincho	2	11	7	3
Random characters	walnut	5	1	3	3
	cashew	7	8	3	10
	maru	5	2	9	1
	mincho	3	9	5	6

Figure 11. Subjective readability.

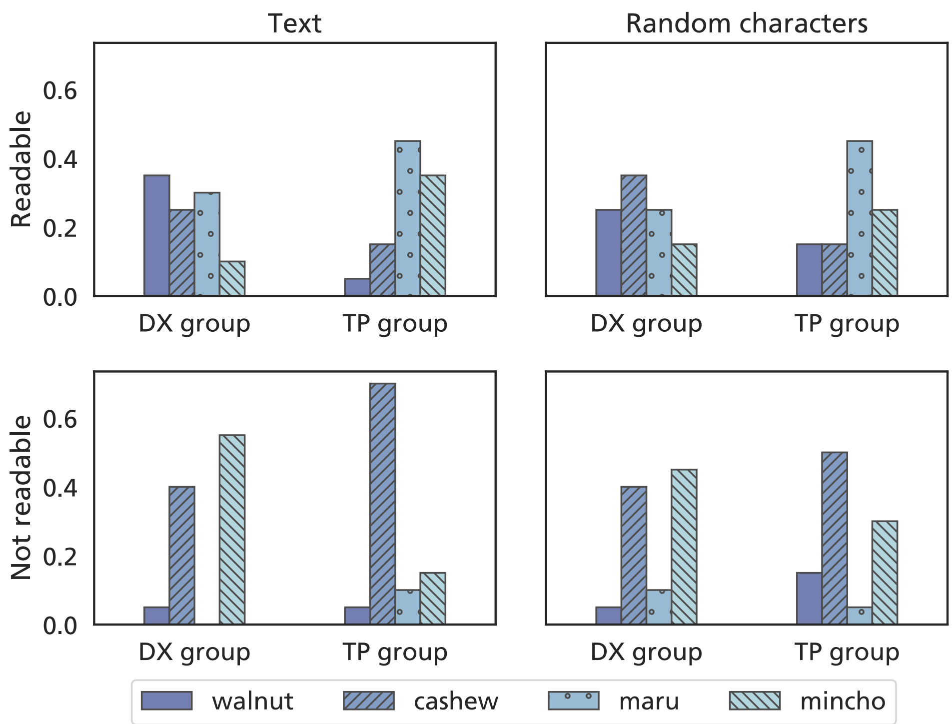

Figure 12. Subjective readability in proportion of all the answers.

The result of subjective readability indicates that readers in DX group tend to consider *LiS* Font more readable in both text and random characters compared to standard typefaces and readers in *TP* group consider the opposite.

We conducted χ^2 test on the result of subjective readability for each group in each material. The results are shown in Table 5. From the table, we can see that typefaces have large or medium effect sizes (Cramer's V) in the reading of text and random characters in both groups. This indicates that the effects of typefaces are easier to observe in subjective measures than objective measures.

The results also indicate that readers in DX group consider *LiS Font walnut* more readable in both text and random characters and readers in TP group consider *Hiragino Maru Gothic* more readable in both text and random characters. As for *LiS Font cashew*, while most readers in TP group found it less readable, the answers were divided into two for readers in DX group. It is possible that this result was caused by the difference in symptoms of dyslexia and we will investigate into this in future research.

Table 5 Results of χ^2 test

<table>
<tr><th rowspan="3">Material</th><th rowspan="3">Typeface</th><th colspan="3">DX group</th><th colspan="3">TP group</th></tr>
<tr><th colspan="2">Residuals</th><th rowspan="2">Cramer's V</th><th colspan="2">Residuals</th><th rowspan="2">Cramer's V</th></tr>
<tr><th>Readable</th><th>Not readable</th><th>Readable</th><th>Not readable</th></tr>
<tr><td rowspan="4">Text</td><td>walnut</td><td>2.372 *</td><td>-2.372 *</td><td rowspan="4">0.660 ***</td><td>0.000</td><td>0.000</td><td rowspan="4">0.574 ***</td></tr>
<tr><td>cashew</td><td>-1.013</td><td>1.013</td><td>-3.518 **</td><td>3.518 **</td></tr>
<tr><td>maru</td><td>2.657 **</td><td>-2.657 **</td><td>2.479 *</td><td>-2.479 *</td></tr>
<tr><td>mincho</td><td>-3.038 **</td><td>3.038 **</td><td>1.461</td><td>-1.461</td></tr>
<tr><td rowspan="4">Random characters</td><td>walnut</td><td>1.771 +</td><td>-1.771 +</td><td rowspan="4">0.419 **</td><td>0.000</td><td>0.000</td><td rowspan="4">0.506 ***</td></tr>
<tr><td>cashew</td><td>-0.327</td><td>0.327</td><td>-2.363</td><td>2.363</td></tr>
<tr><td>maru</td><td>1.248</td><td>-1.248</td><td>2.921 **</td><td>-2.921 **</td></tr>
<tr><td>mincho</td><td>-2.070 *</td><td>2.070 *</td><td>-0.354</td><td>0.354</td></tr>
</table>

In summary, the following conclusions are drawn from the evaluation experiment for now.

- Typefaces affect both objective and subjective measures of readability and legibility,
- Impacts of typefaces on subjective readability are easier to observe,
- Readers with dyslexia consider *LiS Font walnut* more readable in both text and random characters,
- Readers without dyslexia consider Hiragino Maru Gothic more readable in both text and random characters,
- Symptoms of dyslexia may affect subjective readability of readers with dyslexia.

These conclusions indicate the efficacy of *LiS Font* and the validity of the requirements for Japanese typefaces designed for readers with dyslexia. In the meantime, the results show that readers with different symptoms of dyslexia may perceive varying characteristics of typefaces as readable and/or legible, thus implying the necessity of a typeface customisation system in order to meet the needs of readers with different symptoms of dyslexia.

We will report our progress regarding the customisation system in the next section.

3 A Japanese Typeface Customisation System for Readers with Dyslexia

The aim of our research in this phase is to develop a Japanese typeface customisation system that enables readers with dyslexia to adjust the elements of typefaces within a certain range to fit their own symptoms.

At the moment we are at an early stage of this phase and are conducting a review on related studies and projects. Also we have made an initial prototype of this system, which will be developed as a cross-platform web application, with Python.

3.1 Related Work

The history of programmatic type design goes back to the fifteenth century (Knuth, 1999), and the practice flourished after the invention and spread of computers as Amado (2013) pointed out in his work of the timeline of font formats and production software.

We reviewed all the parametric systems for designing typefaces and 4 software for font production that can be extended by scripting (FontLab Studio, FontForge, Glyphs, and RoboFont) listed in Amado (2013) along with more recent projects (RoundingUFO, Metaflop, Metapolator, Project Faces, Variable Fonts, and FontLab IV) and projects regarding Japanese typefaces (Tanaka (1992), Yamamoto (2003), Kamichi (2007)). Table 6 shows a list of projects we reviewed.

Table 6 Related work

Year	Work	Developers	Approaches
1967	ITSYLF	Mergler and Vargo	Outline and skeleton (Mergler & Vargo, 1968)
1975	CSD	Coigneaux	Outline and skeleton (Ruggles, 1983)
1979	METAFONT	Knuth	Skeleton (Knuth, 1986)
1991	Multiple Master	Adobe Inc.	Outline (Adobe, 2004)
1992	Font Chameleon	Ares Corp.	Outline
1992	Tanaka (1992)	Tanaka	Skeleton and parts (Tanaka, 1992)
1993	InfiniFont	McQueen and Beausoleil (ElseWare Corp.)	Outline (McQueen & Beausoleil, 1993)
1993	FontLab Studio	SoftUnion and Pyrus (now Fontlab Ltd.)	Outline
1994	TrueType GX	Apple Inc.	Outline (Rickner, 2016)
1996	Metatype	Vakulenko	Skeleton (Vakulenko, 2003)
1996	RoboFog	Petr van Blokland, van Rossum, and Erik van Blokland	Outline
1997	LiveType	Shammir and Rappoport	Outline (Shamir & Rappoport, 2006)
1998	DaType	Schneider	Outline and skeleton (Schneider, 1998)
2001	CPFPage	Hu and Hersch	Outline and skeleton (Hu & Hersch, 2001)
2001	FontForge	Williams	Outline
2002	Meek FM	Meek Design	Outline
2003	Elementar	Ferreira	Parts
2003	Font Remix Tools	Ahrens (Just Another Foundry)	Outline
2003	RoboFab	Erik van Blokland and van Rossum	Outline
2003	Yamamoto (2003)	Yamamoto	Skeleton (Yamamoto, 2003)
2006	Kalliculator	Berlaen (TypeMyType)	Skeleton (Berlaen, 2006)
2006	GlyphWiki	Kamichi	Skeleton and parts (Kamichi, 2007)
2007	Font Constructor	Berlaen (TypeMyType)	Parts
2007	Superpolator	Erik van Blokland (LettError)	Outline
2008	UFOstretch	Berlaen (TypeMyType)	Outline
2009	LetterModeller	Blokland (Dutch Type Library)	Skeleton (Blokland, 2016)
2009	Prepolator	Leming (Type Supply)	Outline
2009	RoundingUFO	Berlaen (TypeMyType)	Outline
2009	Glyphs	Seifert	Outline and skeleton

2011	RoboFont	Berlaen (TypeMyType)	Outline and skeleton
2011	Prototypo	Mathey and Babé (Prototypo)	Skeleton and outline
2012	Metaflop	Reigel and Müller (Metaflop)	Skeleton
2013	Metapolator	Egli and Crossland (Metapolator)	Skeleton
2015	Project Faces	Adobe Inc.	Skeleton and outline
2016	Variable Fonts	Adobe Inc., Apple Inc., Google LLC, and Microsoft Corp.	Outline
2017	FontLab VI	Fonrlab Ltd.	Outline and skeleton

From the review, it is revealed that each system adopts one or two approaches among three approaches, namely, manipulating outlines, manipulating skeletons, and assembling the parts, to designing glyphs. The review also shows that recent projects tend to adopt skeleton-based approaches, that theoretically originated from Noordzij (2005) and technically originated from Knuth (1986), and in regard to projects of Japanese typefaces, all of them adopt skeleton-based approaches.

Therefore the skeleton-based approaches will be the major candidate for developing the Japanese typeface customisation system for readers with dyslexia in our research.

3.2 Prototype

An initial prototype adopting skeleton-based approaches has been written with Python in DrawBot (van Rossum, van Blokland & Berlaen, 2019), as shown in Figure 13. The skeleton data of Japanese characters are from KanjiVG project (Apel & Quint, 2004), an open source project that describes skeleton of Japanese characters in vectorial data. We adopted a simple conversion algorithm of Beziér curves to give outlines to the skeletons.

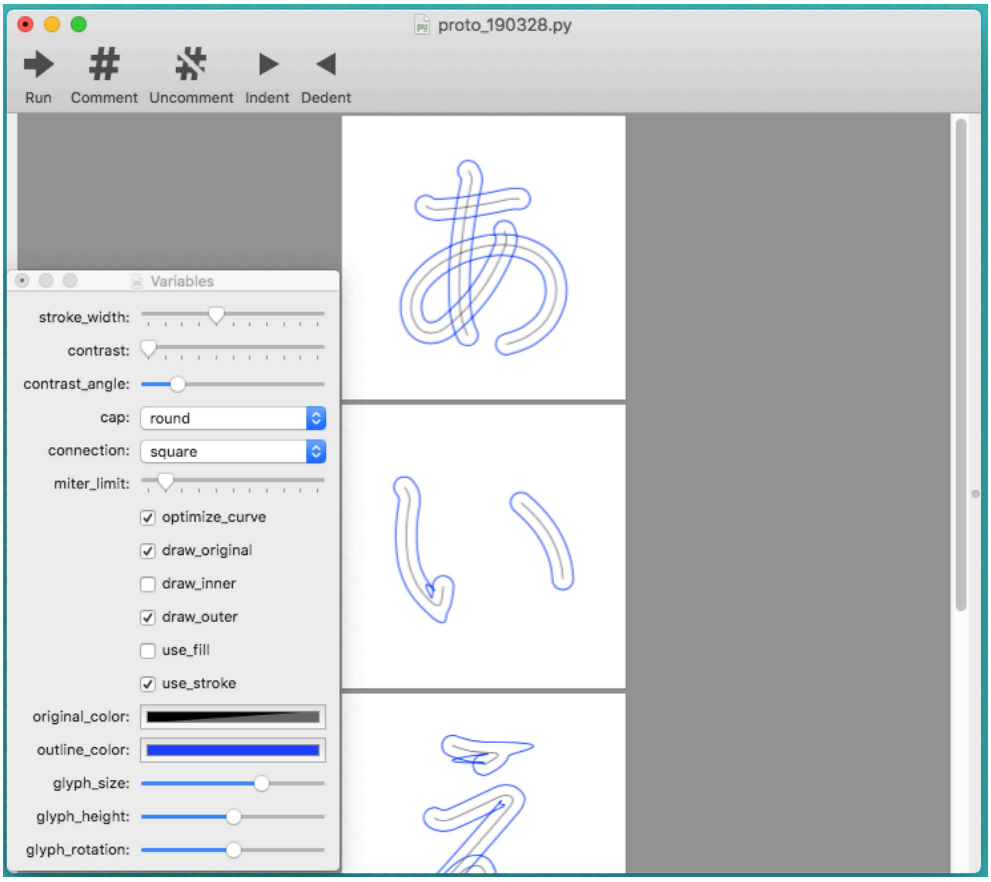

Figure 13. An initial prototype.

There is much to be done to develop the typeface customisation that truly helps readers with dyslexia.

4 Future Work

We intend to continue developing the typeface customisation system in future research, especially focusing on implementation of better conversion from skeletons to outlines. In the meantime, we will look into algorithms of manipulating glyph outlines in a typeface while keeping the characteristics of the typeface consistent, such as Campbell & Kautz (2014).

As for the requirements of Japanese typefaces for readers with dyslexia, besides continuing on evaluating their validity with empirical experiments and machine learning approaches, we will improve these requirements based on opinions from professional type designers.

Since the method of our research has good compatibility with other languages of East Asia and any languages with syllabaries or/and logographic writing systems, we have the intention to extend our research to those languages in future research.

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