Evaluation of the Readability and Legibility of a Set of Newly Created Japanese Typefaces Designed for Readers with Dyslexia

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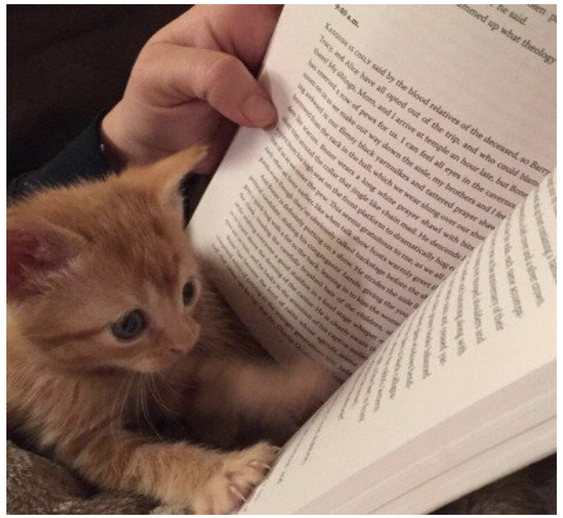
UTLiS
東京大学図書館情報学研究室



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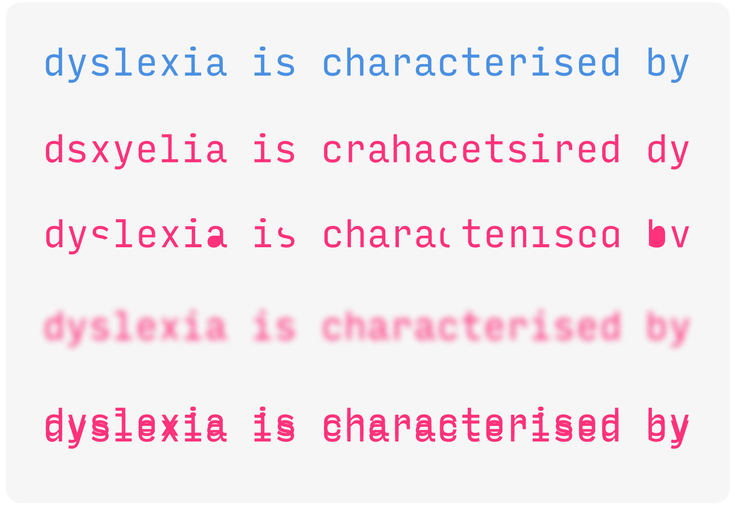
1.1 Dyslexia and Typefaces | 1.2 Aims | 1.3 Framework

Dyslexia and Typefaces

- Developmental dyslexia: difficulties with accurate and/or fluent reading (International Dyslexia Association, 2002)
- 5–17% in English-speaking countries and 3–5% in Japan have dyslexia (Karita et al., 2010)

Dyslexia and Typefaces



- Developmental dyslexia: difficulties with accurate and/or fluent reading (International Dyslexia Association, 2002)
- 5–17% in English-speaking countries and 3–5% in Japan have dyslexia (Karita et al., 2010)
- Letter reversals, distortion, blurring, and superimposition, etc. (Stein, 2008; Kato, 2010)

Dyslexia and Typefaces

Arial
handgloves

Dyslexie
handgloves

Lexie Readable
handgloves

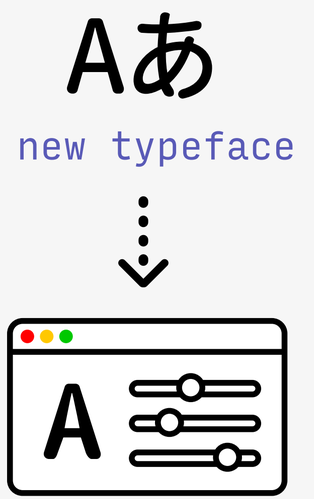
OpenDyslexic
handgloves

- Several Latin typefaces that are designed for readers with dyslexia (Rello & Baeza-Yates, 2013; Zhu, 2016)
- Readers with dyslexia make less errors and/or feel more comfortable (Hillier, 2006; De Leeuw, 2010, Pijpker, 2013)
- Japanese (or Chinese and Korean) fonts not created so far (Tani et al., 2016)

Dyslexia and Typefaces

- Reasons:
  - Problem 1: Characteristics of dyslexia typefaces (both in Latin and in Japanese) were not systematically clarified
  - Problem 2: Japanese contain a large number of complicated characters
  - Problem 3: To create a typeface that fits everyone with dyslexia is not easy

Overall Research Goal



- To create new Japanese typefaces for readers with dyslexia
- To develop a typeface customisation system for readers with dyslexia
- Extend to Chinese and Korean

Framework of Our Research

- Phase 1: Extracting visual characteristics of existing Latin dyslexia typefaces
- Phase 2: Defining requirements for Japanese dyslexia typefaces based on the extracted characteristics
- Phase 3: Creating and evaluating Japanese dyslexia typefaces
- Phase 4: Developing a Japanese typeface customisation system

Framework of Our Research

- Phase 1: Extracting visual characteristics of existing Latin dyslexia typefaces
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Framework of Our Research

- Introducing LiS Font
- Results of Evaluation Experiment

- Phase 1: Extracting visual characteristics of existing Latin dyslexia typefaces
- Phase 2: Defining requirements for Japanese dyslexia typefaces based on the extracted characteristics
- Phase 3: Creating and evaluating Japanese dyslexia typefaces
- Phase 4: Developing a Japanese typeface customisation system

2

Newly Created Japanese Typeface: LiS Font

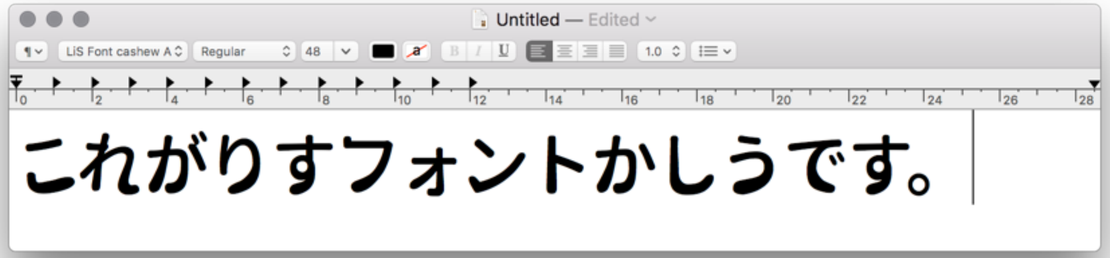
2.1 Introducing LiS Font | 2.2 Creation Process

Introducing LiS Font

LiS Font walnut (2776 characters)

A. Larger characters
B. Maru gothic (rounded sans serif)
C. Bolder strokes
D. Larger height/width ratio
E. Contrast in strokes
F. Larger space between characters
G. Easy-to-distinguish kana characters with similar shapes
H. Easy-to-identify kanji characters
I. Frames added to kanji characters to illustrate radicals

LiS Font cashew (2776 characters)



A. Larger characters
B. Maru gothic (rounded sans serif)
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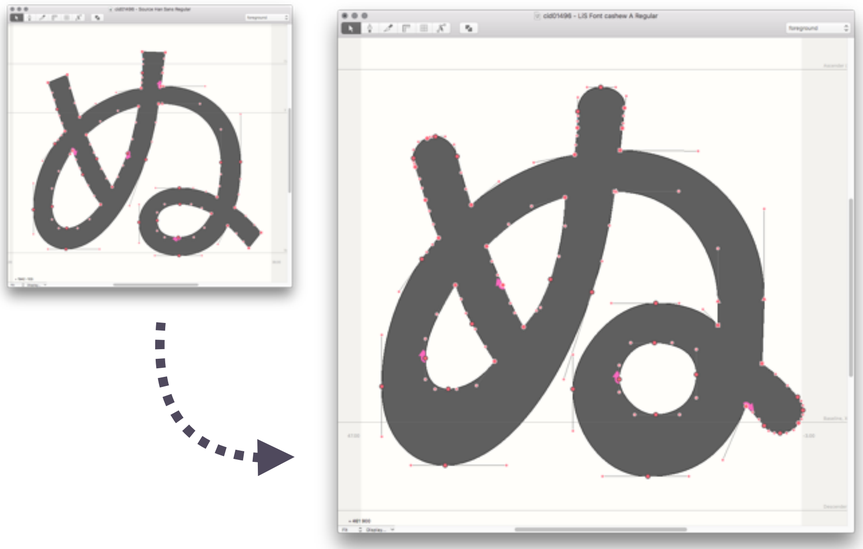
E. Contrast in strokes
F. Larger space between characters
G. Easy-to-distinguish kana characters with similar shapes
H. Easy-to-identify kanji characters
I. Frame added to kanji characters to illustrate radicals

Creation Process of LiS Font

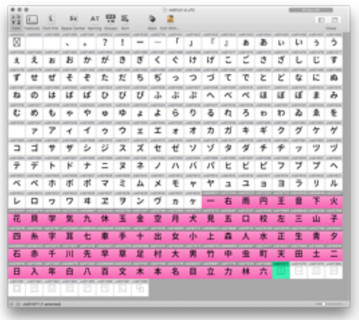
1 Selecting an existing Japanese typeface (Source Han Sans) as a base font

2 Applying the requirements for typefaces for readers with dyslexia

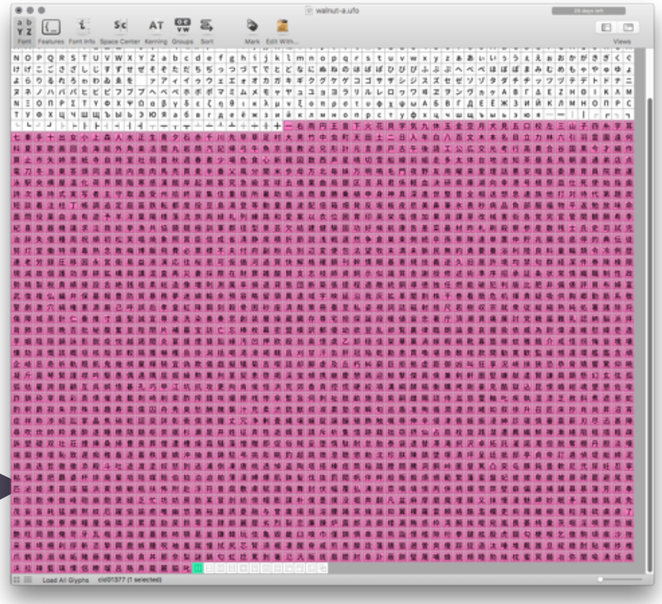


3 Automatically expanding character collections to meet the demands of daily use

274 characters



2778 characters



3 Evaluation Experiment

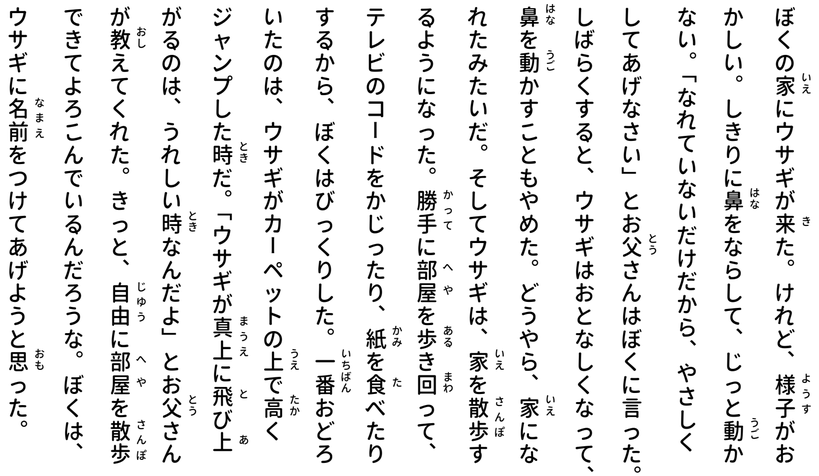
3.1 Methods | 3.2 Materials | 3.3 Participants | 3.4 Results

Methods

- Rapid read aloud task (Tani, 2016)
  - Read aloud the stimuli as rapidly and accurately as possible
- Objective measurements
  - Duration time, number of errors, and number of self-corrections
- Interview (Tani, 2016)
  - Most and least comfortable typeface
  - Subjective readability

Materials

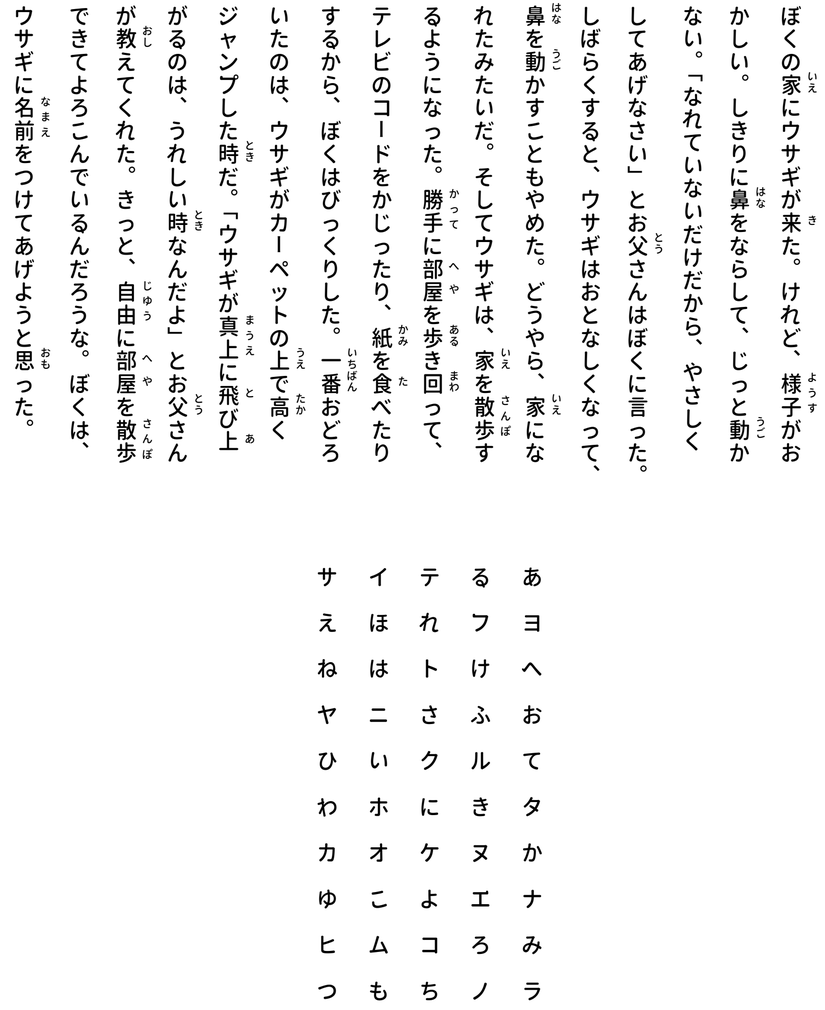
- Two types of written materials
  - Text (Tani, 2016)



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。

Materials

- Two types of written materials
  - Text (Tani, 2016)
  - Random kana characters (Tani, 2016)



Materials

LiS Font walnut (WALNUT)

りすフォントくるみ

LiS Font cashew (CASHEW)

りすフォントかしう

Hiragino Maru Gothic (MARU)

ヒラギノ丸ゴシック

Hiragino Mincho (MINCHO)

ヒラギノ明朝

- Four typefaces
  - LiS Font walnut
  - LiS Font cashew
  - Hiragino Maru Gothic
  - Hiragino Mincho

Participants

		DX	TP
n		20	20
Age	mean	19.05	27.8
	std	11.35	12.78

Readers with dyslexia (DX)

- Children and adults

Readers without dyslexia (TP)

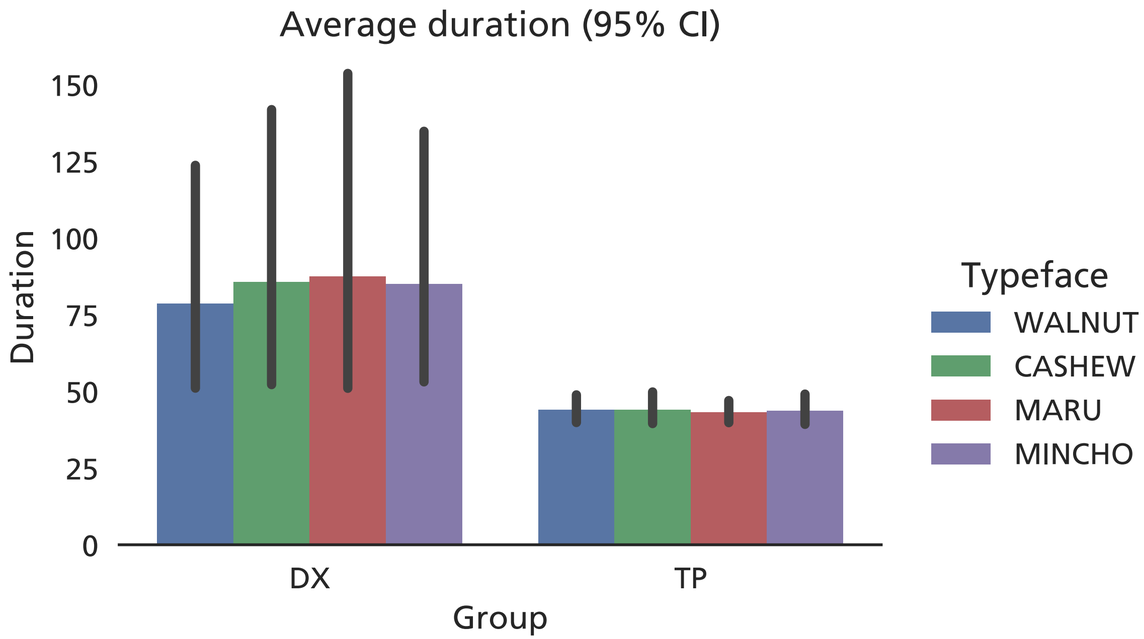
- Children and adults

Results for Text

Results (Text)

Duration Time

		DX	TP
WALNUT	mean	78.60	44.10
	std	88.44	10.32
CASHEW	mean	85.75	44.05
	std	114.25	12.27
MARU	mean	87.50	43.20
	std	129.05	8.71
MINCHO	mean	85.10	43.70
	std	103.45	11.86



- There is no significant in-group difference in duration time between four kinds of typefaces in both groups
- However, there are significant differences between TP and DX group in the same typeface

Results (Text)

Duration Time

- The differences between TP and DX group are resulted from the symptoms of dyslexia
- Good typeface for readers with dyslexia has smaller absolute duration time and smaller effect size (Cliff's d and mean-difference)

	Duration (DX)	Rank	d_s (Cliff's d)	Rank	d_{non} (mean-difference)	Rank	Average rank
WALNUT	78.60	1.00	0.61	1.00	34.50	1.00	1.00
CASHEW	85.75	3.00	0.66	2.00	41.70	3.00	2.67
MARU	87.50	4.00	0.66	2.00	44.30	4.00	3.33
MINCHO	85.10	2.00	0.70	4.00	41.40	2.00	2.67

	Duration (TP)	Rank
WALNUT	44.10	1.00
CASHEW	44.05	3.00
MARU	43.20	4.00
MINCHO	43.70	2.00

Results (Text)

Number of errors

	Duration (DX)	Rank	d_s (Cliff's d)	Rank	d_{non} (mean-difference)	Rank	Average rank
WALNUT	1.55	3	0.41	2	1.30	2	2.33
CASHEW	1.40	1	0.45	3	1.20	1	1.67
MARU	1.75	4	0.33	1	1.50	4	3.00
MINCHO	1.50	2	0.62	4	1.35	3	3.00

	Duration (TP)	Rank
WALNUT	0.25	3
CASHEW	0.20	2
MARU	0.25	3
MINCHO	0.15	1

Number of self-corrections

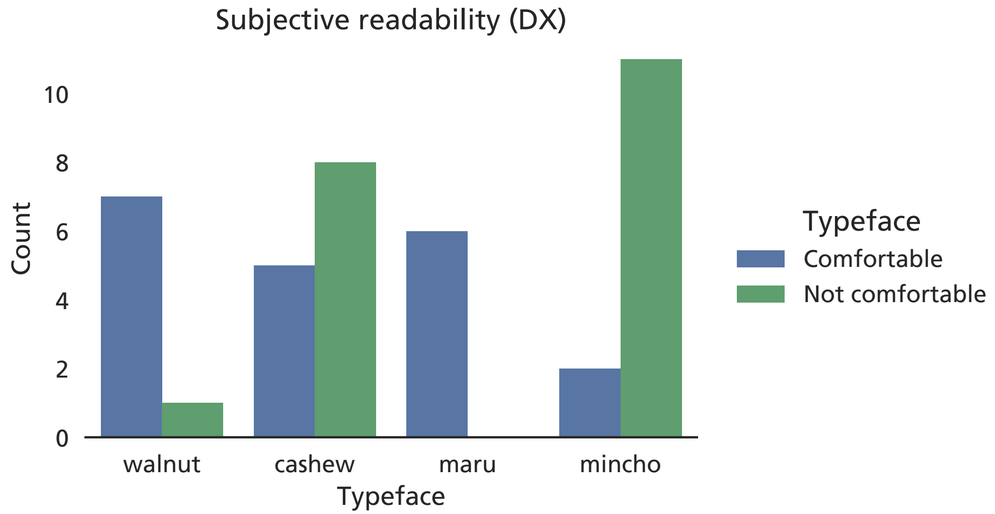
	Duration (DX)	Rank	d_s (Cliff's d)	Rank	d_{non} (mean-difference)	Rank	Average rank
WALNUT	2.45	1	0.40	4	1.90	2	2.33
CASHEW	2.80	2	0.39	2	2.05	3	2.33
MARU	2.95	3	0.10	1	1.75	1	1.67
MINCHO	3.35	4	0.39	2	2.60	4	3.33

	Duration (TP)	Rank
WALNUT	0.55	1
CASHEW	0.75	2
MARU	1.20	4
MINCHO	0.75	2

Results (Text)

Subjective Readability

	Comfortable (DX)	Not comfortable (DX)	Total
WALNUT	7 ▲	1 ▽	0
CASHEW	5	8	13
MARU	6 ▲	0 ▽	0
MINCHO	2 ▽	11 ▲	0
Total	5	8	13

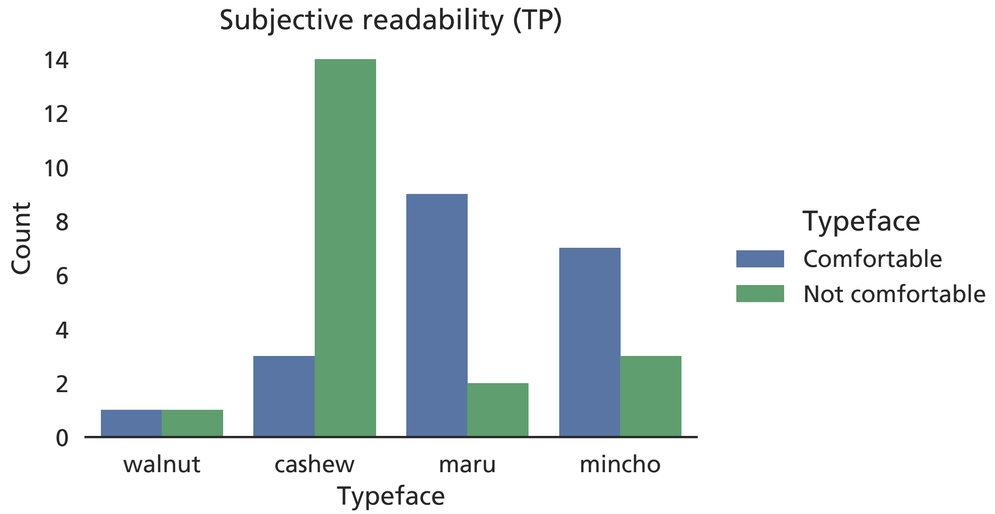


- There are significant differences in subjective readability between different typefaces in DX group
- More readers in DX group consider WALNUT and MARU comfortable and MINCHO not comfortable

Results (Text)

Subjective Readability

	Comfortable (TP)	Not comfortable (TP)	Total
WALNUT	1	1	2
CASHEW	3 ▽	14 ▲	0
MARU	9 ▲	2 ▽	0
MINCHO	7	3	10
Total	8	4	12



- There are significant differences in subjective readability between different typefaces in TP group
- More readers in TP group consider MARU comfortable and CASHEW not comfortable

Results (Text)

Subjective Readability

	Comfortable (DX)	Comfortable (TP)	Total
WALNUT	7 ▲	1 ▽	0
CASHEW	5	3	8
MARU	6	9	15
MINCHO	2	7	9
Total	13	19	32

	Not comfortable (DX)	Not comfortable (TP)	Total
WALNUT	1	1	2
CASHEW	8	14	22
MARU	0	2	2
MINCHO	11 ▲	3 ▽	0
Total	9	17	26

- More readers in DX group consider WALNUT comfortable compared to those in TP group
- More readers in DX group consider MINCHO not comfortable compared to those in TP group
- Readers in DX group prefer dyslexia typefaces to standard typefaces

Results (Text)

Subjective Readability

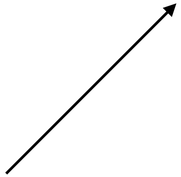
	Comfortable (DX)	Rank	Not comfortable (DX)	Rank	Average rank
WALNUT	7	1	1	2	1.50
CASHEW	5	3	8	3	3.00
MARU	6	2	0	1	1.50
MINCHO	2	4	11	4	4.00

	Comfortable (DX)	Rank	Not comfortable (DX)	Rank	Average rank
WALNUT	1	4	1	1	2.50
CASHEW	3	3	14	4	3.50
MARU	9	1	2	2	1.50
MINCHO	7	2	3	3	2.50

Results (Text)

Subjective Readability

	Comfortable (DX)	Rank	Not comfortable (DX)	Rank	Average rank
WALNUT	7	1	1	2	1.50
CASHEW	5	3	8	3	3.00
MARU	6	2	0	1	1.50
MINCHO	2	4	11	4	4.00



Direction good, customisation needed

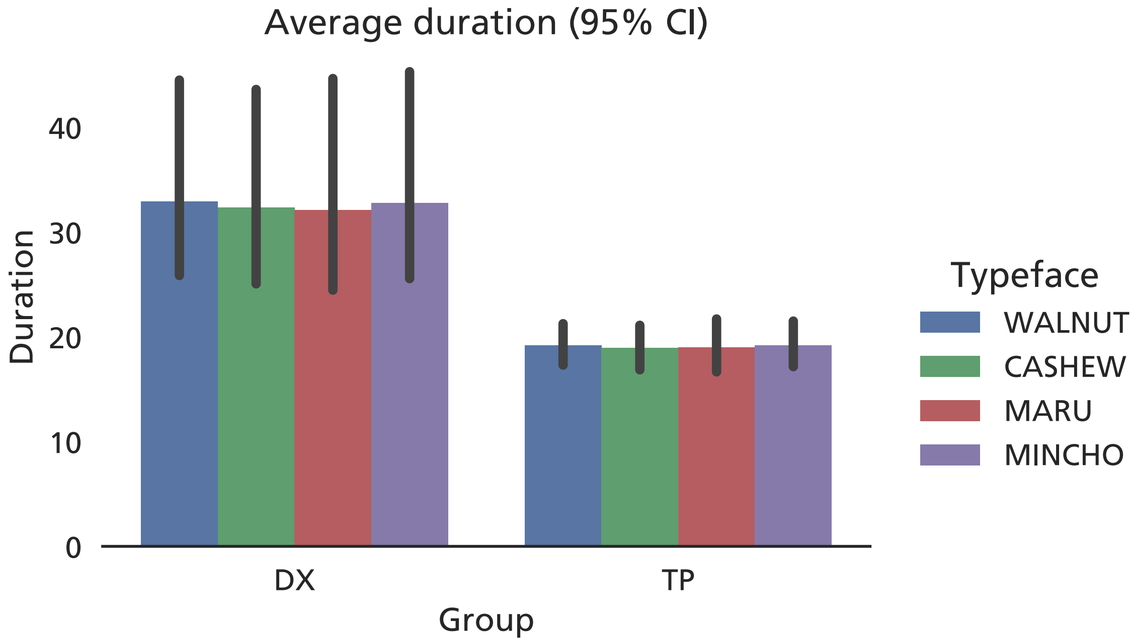
	Comfortable (DX)	Rank	Not comfortable (DX)	Rank	Average rank
WALNUT	1	4	1	1	2.50
CASHEW	3	3	14	4	3.50
MARU	9	1	2	2	1.50
MINCHO	7	2	3	3	2.50

Results for Random Characters

Results (Random Characters)

Duration Time

		DX	TP
WALNUT	mean	32.90	19.20
	std	22.91	4.85
CASHEW	mean	32.35	18.95
	std	22.68	4.97
MARU	mean	32.10	19.00
	std	25.10	5.87
MINCHO	mean	32.75	19.20
	std	23.90	5.20



- There is no significant difference in duration time between four kinds of typefaces in both groups
- However there are significant differences between TP and DX group in the same typeface

Results (Random Characters)

Duration Time

- Differences between TP and DX group are resulted from the symptoms of dyslexia
- Good typeface for readers with dyslexia has smaller absolute duration time and smaller effect size (Cliff's d and mean-difference)

	Duration (DX)	Rank	d_s (Cliff's d)	Rank	d_{non} (mean-difference)	Rank	Average rank
WALNUT	32.90	4.00	0.75	4.00	13.70	4.00	4.00
CASHEW	32.35	2.00	0.71	2.00	13.40	2.00	2.00
MARU	32.10	1.00	0.69	1.00	13.10	1.00	1.00
MINCHO	32.75	3.00	0.71	2.00	13.55	3.00	2.67

	Duration (TP)	Rank
WALNUT	19.20	3.00
CASHEW	18.95	1.00
MARU	19.00	2.00
MINCHO	19.20	3.00

Results (Random Characters)

Number of errors

	Duration (DX)	Rank	d_s (Cliff's d)	Rank	d_{non} (mean-difference)	Rank	Average rank
WALNUT	1.20	4	0.35	3	1.30	2	3.00
CASHEW	0.75	1	0.10	1	1.20	1	1.00
MARU	0.90	3	0.38	4	1.50	4	3.67
MINCHO	0.80	2	0.14	2	1.35	3	2.33

	Duration (TP)	Rank
WALNUT	0.25	2
CASHEW	0.30	3
MARU	0.15	1
MINCHO	0.55	4

Number of self-corrections

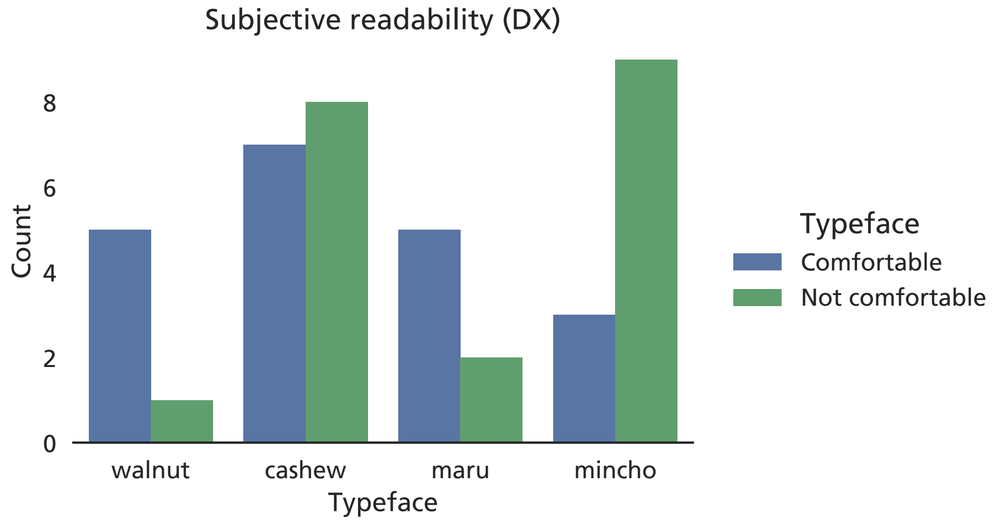
	Duration (DX)	Rank	d_s (Cliff's d)	Rank	d_{non} (mean-difference)	Rank	Average rank
WALNUT	0.55	1	0.00	2	0.00	2	1.67
CASHEW	0.70	4	0.31	4	0.55	4	4.00
MARU	0.55	1	0.04	3	0.15	3	2.33
MINCHO	0.40	3	-0.07	1	-0.10	1	1.67

	Duration (TP)	Rank
WALNUT	0.55	4
CASHEW	0.15	1
MARU	0.40	2
MINCHO	0.50	3

Results (Random Characters)

Subjective Readability

	Comfortable (DX)	Not comfortable (DX)	Total
WALNUT	5	1	6
CASHEW	7	8	15
MARU	5	2	7
MINCHO	3 ▽	9 ▲	0
Total	17	11	28

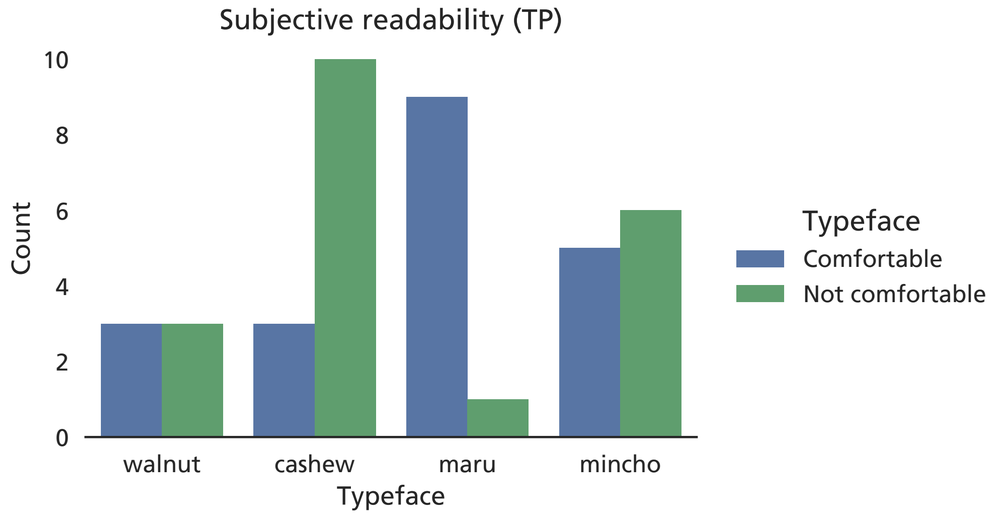


- There are significant differences in subjective readability between different typefaces in DX group
- More readers in DX group consider MINCHO not comfortable

Results (Random Characters)

Subjective Readability

	Comfortable (TP)	Not comfortable (TP)	Total
WALNUT	3	3	6
CASHEW	3 ▽	10 ▲	0
MARU	9 ▲	1 ▽	0
MINCHO	5	6	11
Total	8	9	17



- There are significant differences in subjective readability between different typefaces in TP group
- More readers in TP group consider MARU comfortable and CASHEW not comfortable

Results (Random Characters)

Subjective Readability

	Comfortable (DX)	Rank	Not comfortable (DX)	Rank	Average rank
WALNUT	5	2	1	1	1.50
CASHEW	7	1	8	3	2.00
MARU	5	2	2	2	2.00
MINCHO	3	4	9	4	4.00

	Comfortable (DX)	Rank	Not comfortable (DX)	Rank	Average rank
WALNUT	3	3	3	2	2.50
CASHEW	3	3	10	4	3.50
MARU	9	1	1	1	1.00
MINCHO	5	2	6	3	2.50

Results (Random Characters)

Subjective Readability

	Comfortable (DX)	Rank	Not comfortable (DX)	Rank	Average rank
WALNUT	5	2	1	1	1.50
CASHEW	7	1	8	3	2.00
MARU	5	2	2	2	2.00
MINCHO	3	4	9	4	4.00

Direction good, customisation needed

	Comfortable (DX)	Rank	Not comfortable (DX)	Rank	Average rank
WALNUT	3	3	3	2	2.50
CASHEW	3	3	10	4	3.50
MARU	9	1	1	1	1.00
MINCHO	5	2	6	3	2.50

4

Conclusions & Discussion

4.1 Conclusions | 4.2 Discussion

Conclusions

	Rank in text	Rank in random characters
WALNUT	1.00	3.00
CASHEW	3.00	1.00
MARU	2.00	1.00
MINCHO	4.00	4.00

	Rank in text	Rank in random characters
WALNUT	3.00	3.00
CASHEW	3.00	2.00
MARU	2.00	1.00
MINCHO	1.00	4.00

- Standard typefaces are not the most suitable ones for readers with dyslexia
- Good typefaces for text reading and character reading are different
  - LiS Font walnut is best in text for readers with dyslexia
  - LiS Font cashew and Hiragino Maru Gothic is best in random characters for readers with dyslexia
- Subjective evaluation showed clear difference; objective indices inconclusive

Discussion

- The age gap between the two groups may have affected the results
- Objective indices are inconclusive (duration, number of errors, and number of self-corrections); new indices necessary?
- The results provide hints for further improving Japanese typefaces for readers with dyslexia
  - and necessity for a Japanese typeface customisation system

Thanks: Q & A

LiS Font walnut (WALNUT)

りすフォントくるみ

LiS Font cashew (CASHEW)

りすフォントかしう

Hiragino Maru Gothic (MARU)

ヒラギノ丸ゴシック

Hiragino Mincho (MINCHO)

ヒラギノ明朝

	Rank in text	Rank in random characters
WALNUT	1.00	3.00
CASHEW	3.00	1.00
MARU	2.00	1.00
MINCHO	4.00	4.00

	Rank in text	Rank in random characters
WALNUT	3.00	3.00
CASHEW	3.00	2.00
MARU	2.00	1.00
MINCHO	1.00	4.00