



# Perceptual and cognitive underpinnings of braille reading

IFLA WLIC 2012  
Preconference  
Tallinn

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# Parallel versus sequential processing in print and braille reading

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# Outline

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- Briefly about reading print
- From reading to Dyslexia
- Briefly about reading braille
- From earlier studies to current research
  - Participants
  - Measures
  - Results
  - Concluding remarks

Briefly about reading print



# Briefly about reading print

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- Writing systems have existed no longer than 5000 years
- Reorganization of the preexisting neural circuitries for spoken language and object recognition



# Briefly about reading print

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- Key feature common to both language and reading development is phonological awareness
  - i.e. the ability to detect and manipulate the component sounds that comprise words at different grain sizes
- Brain develops **phonological representations**



# Briefly about reading print

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Sounds in the spoken word *captain*

Word

captain

Syllable

Cap

tin

Onset-rime

c

ap

t

in

Phonemes

C

a

p

t

i

n



# Briefly about reading print

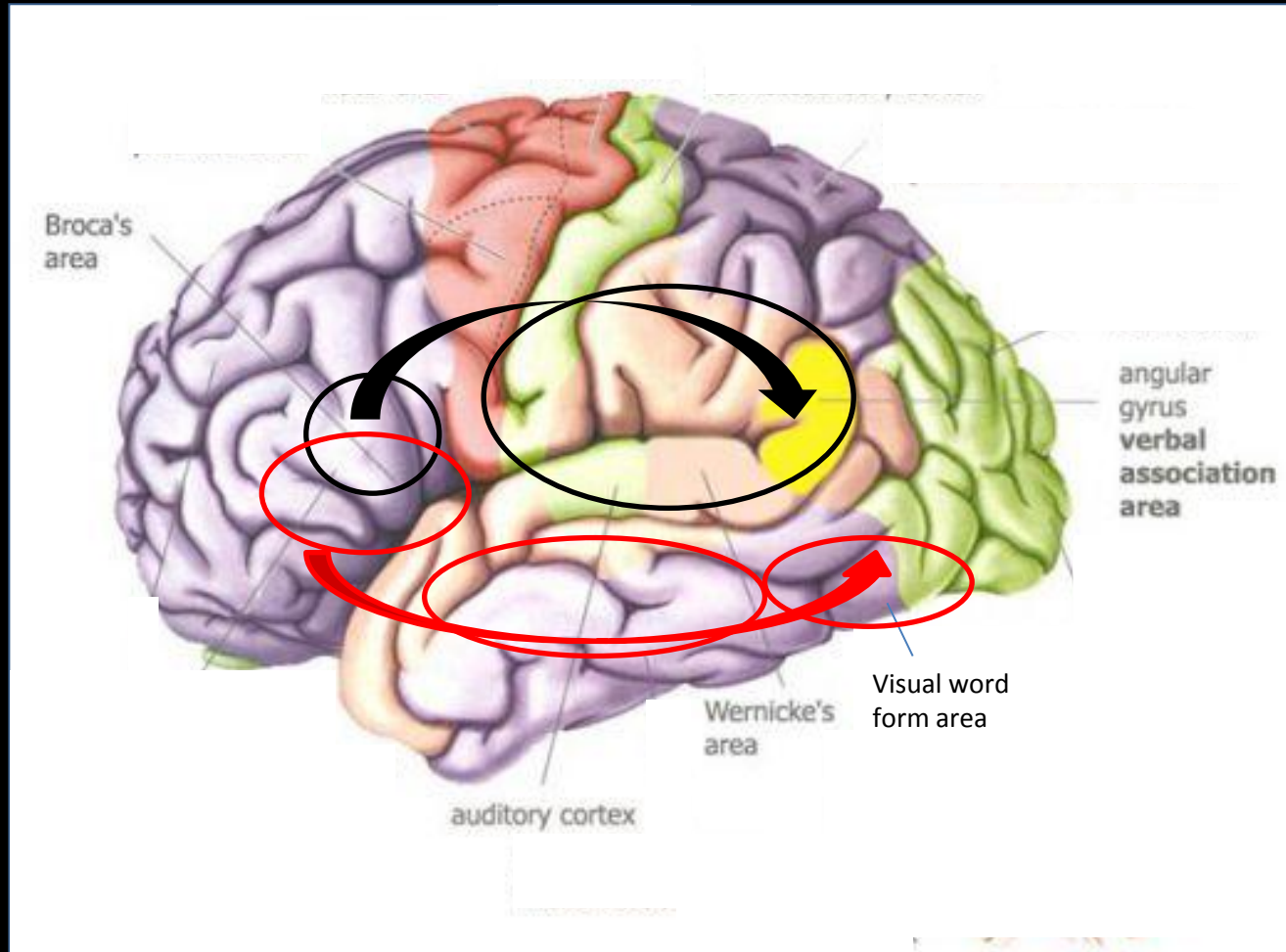
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- Reading model by U. Frith (1986)
  - Logographic stage
  - Alphabetic stage
  - Orthographic stage





# Briefly about reading print



# From reading to Dyslexia



# From reading to Dyslexia

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- Learning to read is a complex task requiring the translation of written symbols (graphemes) into speech forms (phonemes)
- About 5-10% of the population experiences severe and persistent reading difficulties i.e. developmental dyslexia...

...hereditary neurological disorder resulting in failure to acquire age appropriate reading and spelling skills despite adequate intelligence, instruction and remedial efforts



# From reading to Dyslexia

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- Deficit in phonological processing - the primary cause of the reading and spelling difficulties observed in dyslexia
- Phonological processing
  - phonological awareness PA (**recognize and detect**)
  - verbal short-term memory VSTM (**manipulate**)
  - lexical retrieval of phonological codes RAN (**access**)



# From reading to Dyslexia

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- Difficulties with phonological processing are present before the formal onset of reading instruction (at the age of 5)
- Phonological problems embedded in poorly specified **phonological representations**
- Deficient dorsal phonological reading route (**primary**)
- Deficient ventral orthographic reading route (**secondary**)

Briefly about reading braille



# Briefly about reading braille

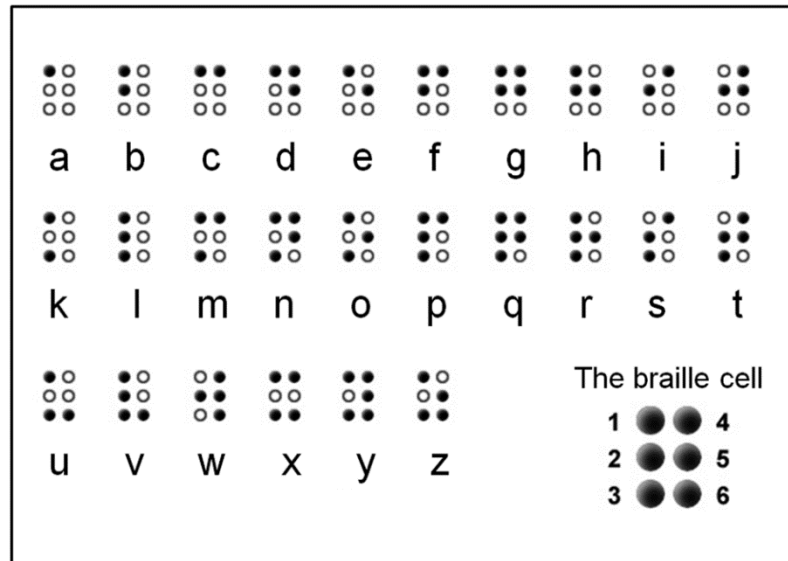
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- Braille is tactile writing system



# Briefly about reading braille

- Braille is tactile writing system
- Braille characters are derived from a six (2 x 3) dot matrix i.e. braille cell







# Briefly about reading braille

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- Uncontracted braille- alphabetic by nature
- Contracted braille- logographic by nature
  - Contractions represent phonetic combinations and letter clusters
  - Contractions represent orthographic rather than phonetic units
  - Different types and quantities of contractions used in different languages (English 189, Dutch 3, Estonian 0)



# Briefly about reading braille

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- Braille reading is a haptic process- information comes from touch, posture and active exploring movements
- Braille reading is sequential rather than simultaneous and exhaustive rather than selective
- Braille reading is considered the most strictly serial mode of language input



# Briefly about reading braille

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## Print reading model

Logographic stage

Alphabetic stage

Orthographic stage

## Braille reading model

No logographic stage

Alphabetic stage

?

From earlier studies to current  
research



# From earlier studies to current research

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- A proportion of blind children have specific difficulties with reading braille which cannot be easily explained
- Very few studies have investigated braille reading difficulties as well as the cognitive and perceptual processes involved in fluent braille reading
- Since print and braille are linguistically identical, the findings and models from print reading research can be used for testing hypothesis about reading braille

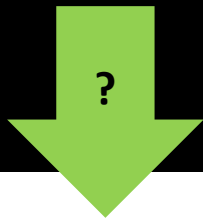


# From earlier studies to current research

## Phonological processing measures

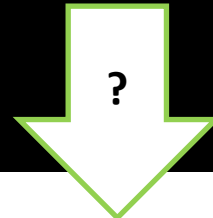
### Phonological awareness

Braille readers perform better, equally well or worse than sighted print readers



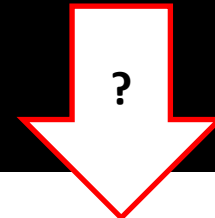
### Verbal short-term memory

Braille readers (congenitally blind) perform better than sighted print readers



### Lexical retrieval

Lexical retrieval speed never measured in braille readers



**Braille reading performance**



# Current research

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Addressing the following questions :

1. Are there significant differences between print and braille readers in their performance on reading and phonological processing tasks? Any developmental aspects?
2. Are braille readers inclined to use the serial grapho-phonological reading strategy similarly for reading words, pseudowords and the story? Any developmental aspects?



# Current research

## PARTICIPANTS

- All the participants had normal hearing and normal intelligence
- Based on sex, age, language and educational level a group of sighted print reading control subjects was composed.

ESTONIA	FLANDERS	+	THE NETHERLANDS
N= 12	N= 12		N=16
11 congenitally blind 1 early blind	22 congenitally blind 6 early blind		
7 light perception 5 no rest-vision	14 light perception 14 no rest-vision		
<b>Unified group (n=12)</b>	<b>Young readers (n=14)</b>		<b>Adult readers (n=14)</b>
<i>M</i> = 14.25 years <i>SD</i> = 3.25	<i>M</i> =12.3 years <i>SD</i> = 1,5		<i>M</i> =18.7 years <i>SD</i> =1.25



Measures



# Current research

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## Reading tests

### Word reading

40 1 syllable words

40 2 syllable words

40 3-4 syllable words

### Pseudoword reading

40 1 syllable pseudowords

40 2 syllable pseudowords

40 3-4 syllable pseudowords

### Story reading

Text on the AVI9 level  
comprising of 223  
words

- Participants were instructed to read the lists of (pseudo)words aloud as fast and accurately as possible
- For each list reading accuracy (number of errors) and time (in seconds) were assessed



# Current research

## Phonological processing tests

### Phonological awareness

Spoonerism task  
(e.g. **S**ILM- **R**IIV becomes  
**R**ILM- **S**IIV)

Phoneme deletion task  
(e.g. MAL**P** without /**L**/)

### Verbal short-term memory

Digit span forward  
27 sequences  
From 2 to 9 numbers

Nonword repetition  
36 nonwords  
Ranging from 3 to 5  
syllables

### Lexical retrieval

Rapid automatic naming  
(RAN) task  
-Letters (d, o, a, s, p)  
-Digits (2, 4, 5, 8, 9)

# Results



# Results

## Group comparisons

### Reading measures in the Estonian group

	Braille readers		Print readers
<b>Word reading accuracy</b>	(1 = 2 = 3-4)	=	(1 = 2 = 3-4)
<b>Pseudoword reading accuracy</b>	(1 > 2 > 3-4)	<	(1 = 2 > 3-4)
<b>Word reading speed</b>	(1 > 2 > 3-4)	<	(1 = 2 = 3-4)
<b>Pseudoword reading speed</b>	(1 > 2 > 3-4)	<	(1 = 2 > 3-4)



# Results

## Reading measures in the Dutch speaking group

	Print readers (PR)			Braille readers (BR)			
	Young PR		Adult PR		Adult BR	Young BR	
<b>Word reading accuracy</b>	(1 = 2= 3-4)	=	(1 = 2= 3-4)	=	(1 = 2= 3-4)	=	(1 < 2= 3-4)
<b>Pseudoword reading accuracy</b>	(1 > 2 > 3-4)	<	(1 = 2 > 3-4)	>	(1 = 2 > 3-4)	>	(1 > 2 > 3-4)
<b>Story reading accuracy (nr. errors) <i>M(SD)</i></b>	2.36 (2.02)	=	1.07 (1.54)	=	2.29 (1.77)	>	7.79 (8.47)
<b>Word reading speed</b>	(1 = 2= 3-4)	=	(1 = 2= 3-4)	>	(1 = 2 > 3-4)	>	(1 > 2 > 3-4)
<b>Pseudoword reading speed</b>	(1 = 2 > 3-4)	=	(1 = 2 > 3-4)	>	(1 > 2 > 3-4)	>	(1 > 2 > 3-4)
<b>Story reading speed (seconds) <i>M(SD)</i></b>	73.82 (16.58)	=	59.90 (9.22)	>	133.61 (28.52)	>	231.4 (102.13)

*Note:* Young BR performed significantly worse than young PR on all the measures



# Results

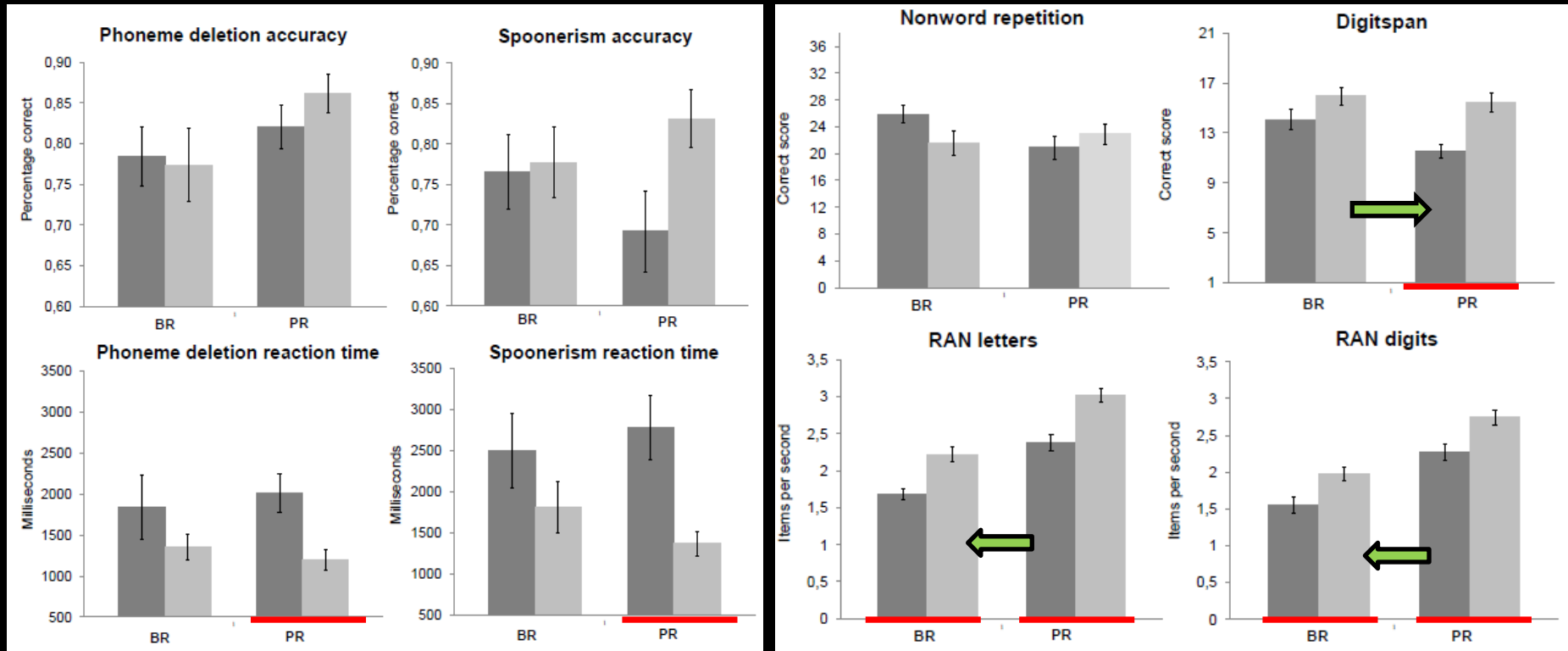
## Phonological processing measures in the Estonian group

	Braille readers		Print readers		Kruskal-Wallis test
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
<b>Composite PA accuracy</b>	0.17	0.65	0	1	$H(1)=.11 p=.74$
Phoneme deletion (% correct)	0.83	0.11	0.83	0.12	$H(1)=.09 p=.76$
Spoonerism (% correct)	0.75	0.11	0.68	0.18	$H(1)=.73 p=.39$
<b>Composite PA speed</b>	-0.71	1.80	0	1	$H(1)=1.07 p=.30$
Phoneme deletion (ms)	2102	1592	1605	895	$H(1)=.36 p=.55$
Spoonerism (ms)	3711	2899	2141	1351	$H(1)=2.49 p=.11$
<b>Composite VSTM</b>	0.29	0.97	0	1	$H(1)=.85 p=.35$
Nonword repetition	27.5	5.7	26.5	3.7	$H(1)=.39 p=.53$
Digit span	15.5	3.3	14.2	4.2	$H(1)=.67 p=.41$
<b>Composite RAN</b>	-0.96	0.65	0	1	$H(1)=7.10 p=.008$
Digits (items/sec)	1.93	0.33	2.53	0.48	$H(1)=7.85 p=.005$
Letters (items/sec)	2.26	0.39	2.63	0.57	$H(1)=2.16 p=.14$



# Results

## Phonological processing measures in the Dutch group







# Results

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1. Are there significant differences between print and braille readers in their performance on reading and phonological processing tasks? Any developmental aspects?
  - Braille readers = print readers on phonological awareness tasks.  
Young readers < adult readers.
  - Braille readers > print readers on verbal short-term memory.  
Young print readers < adult print readers  
Young braille readers = adult braille readers.
  - Braille readers < print readers on lexical retrieval speed  
Young readers < adult readers
  - Braille readers < print readers on reading accuracy  
Braille readers < print readers on reading speed



# Results

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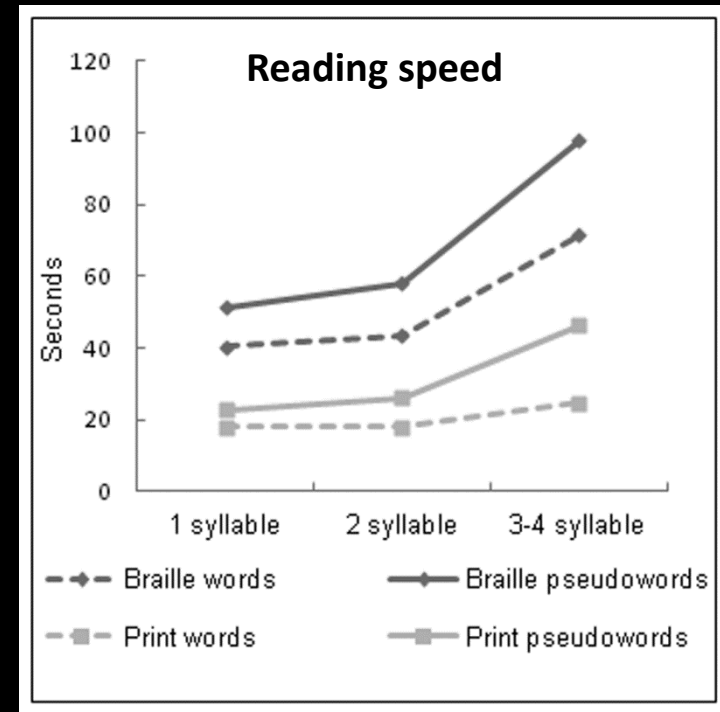
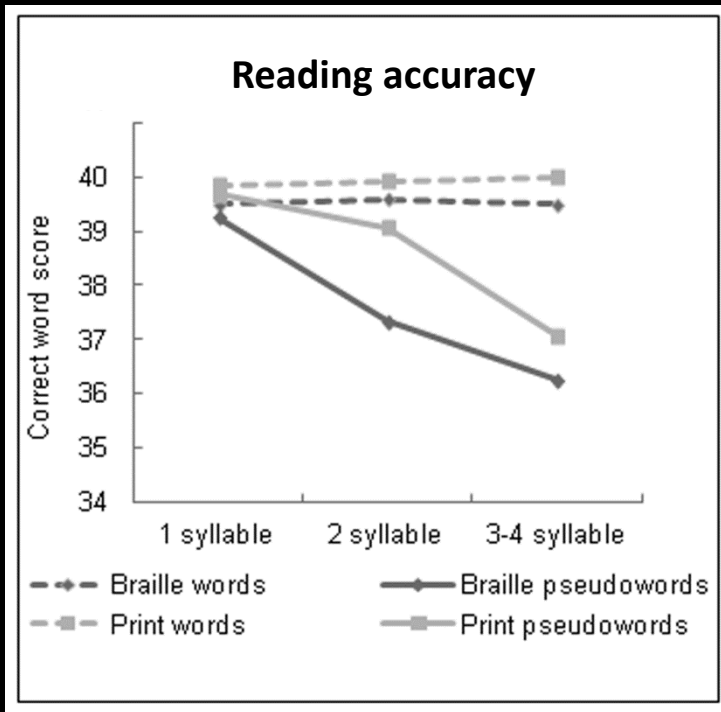
2. Are braille readers inclined to use the serial grapho-phonological reading strategy similarly for reading words, pseudowords and the story? Any developmental aspects?

2.1 Results of the reading tasks → item length effect on reading accuracy and speed



# Results

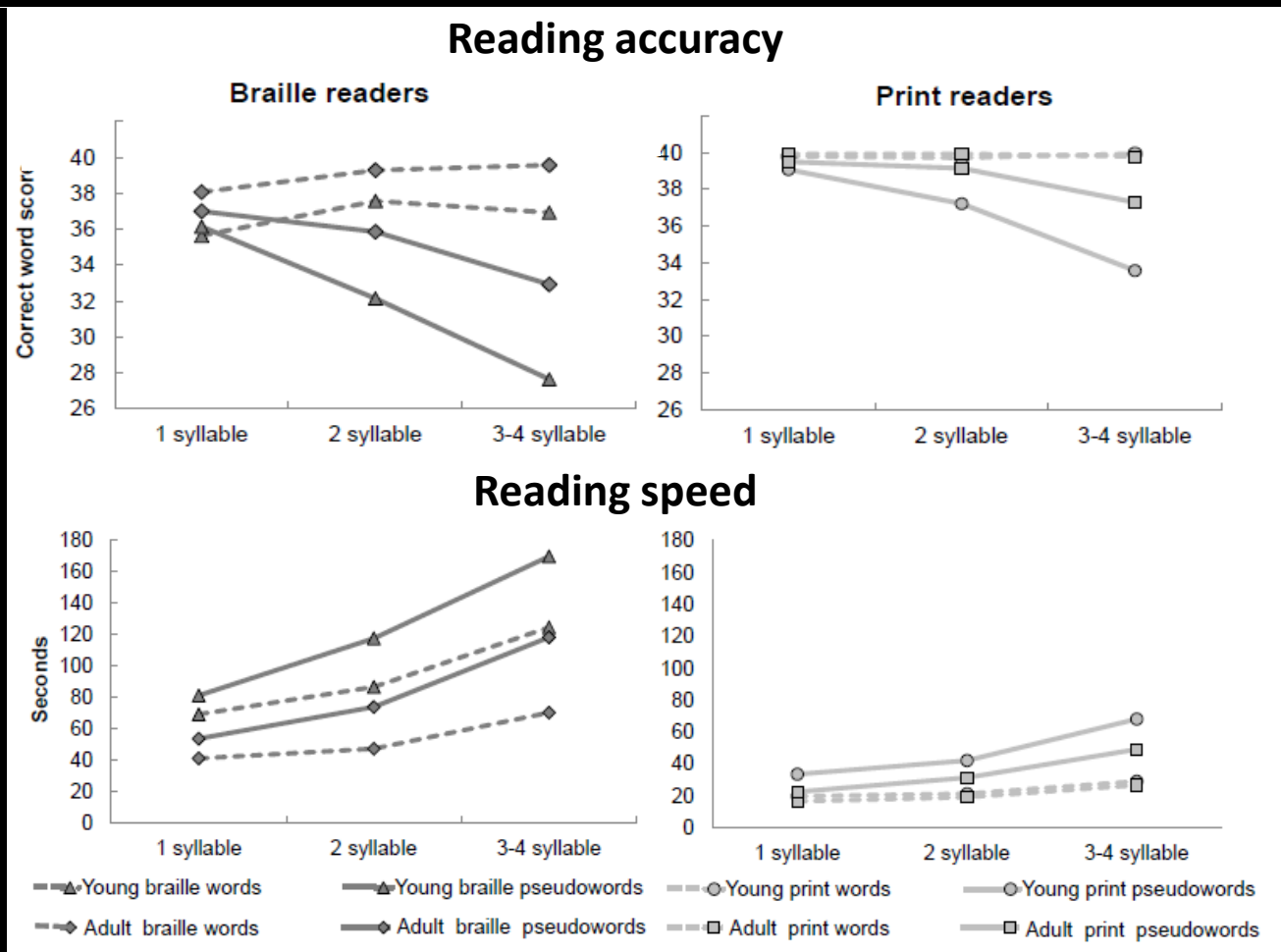
Estonian group of print and braille readers





# Results

Dutch groups of young and adult print and braille readers





# Results

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- In print readers item length effect observable only on the accuracy and speed of reading pseudowords....
  - ... the orthographic strategy for reading words
  - ... grapho-phonological strategy for decoding pseudowords
- In braille readers the item length effect observable on both word and pseudoword reading...
  - ... grapho-phonological strategy for reading both words and pseudowords



# Results

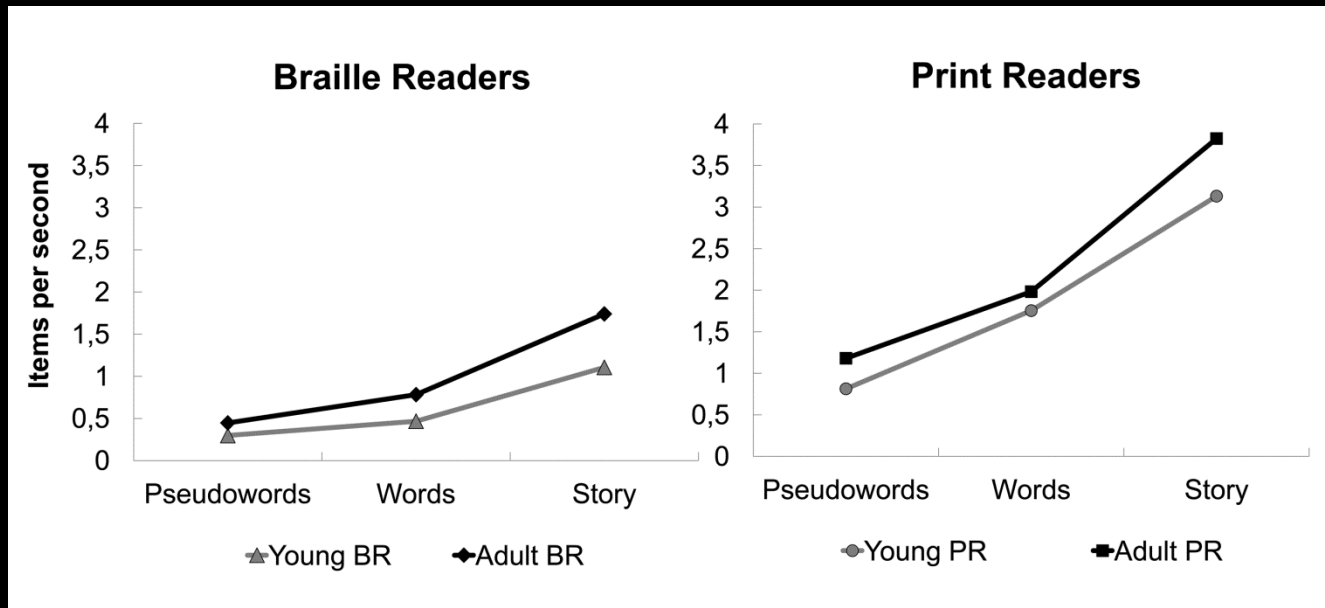
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- Adult braille readers outperform young braille readers on accuracy and speed of reading while the pattern of decreasing accuracy and speed are the same
- ... indicating that the fundamental strategy does not change with development, only becomes more fluent
- **Contradictory findings**
    - Item length effect on words and pseudowords
    - Words are read more accurately and faster than pseudowords
- ... indicating that braille readers benefit from semantic information as well as print readers do



# Results

- Comparing the performance on word, pseudoword and story reading tasks (correctly read items per second)





# Results

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- **Young and adult print readers perform equally on word reading task**  
... indicating further improvement in decoding skills and enlargement of the orthographic lexicon
- **Young and adult braille readers perform equally on pseudoword reading task**  
... Indicating that fundamental decoding skills are comparable and further improvement occurs through semantic top-down processing and contextual cues





# Results

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## 2.2 Relations between reading and phonological processing measures

- **In braille readers** significant correlations between phonological awareness (PA) and all the reading measures
- **In print readers** no correlations (Estonian print readers) or significant correlations only between PA and pseudoword reading measures (Dutch print readers).



# Results

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- **In braille readers** verbal short-term memory (VSTM) significantly associated with all the reading accuracy measures
- **In print readers** no significant correlations between VSTM and reading
- **In braille readers** lexical retrieval speed (RAN) significantly correlated with all the reading speed measures
- **In print readers** RAN significantly correlated with short item reading speed (Estonian print readers) and with all the reading speed measures as well as word reading accuracy (Dutch print readers)



# Results

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- The correlations between reading and phonological processing measures support the hypothesis of the constant use of the sequential grapho-phonological reading strategy in braille reading
- Results also suggest that the serial versus parallel nature of language input determines the extent and the intensity of the recruitment of phonological processing skills in support of reading rather than the transparency of the language's orthography alone

Conclusion



# Main conclusions

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- While print readers skillfully switch between grapho-phonological and orthographic reading strategies dependent on the familiarity, type and length of the words, braille readers are inclined to constant decoding
- The benefit in reading for experienced braille readers is achieved through semantic top-down processing and lexical predictions used in a systematic manner.
- Braille readers are highly dependent on the effective use of phonological processing skills and hence... they are also more vulnerable to the reading difficulties resulting from shortcomings in the phonological domain.

Thank you!



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