DEVELOPMENTAL DYSLEXIA

(part 2)

Marco Zorzi

Dipartimento di Psicologia Generale
Università di Padova

Remediation of dyslexia

The challenge of dyslexia remediation:

→ increase reading efficiency

The best training? “Reading more” (instructional treatment)

.. a vicious cycle for a dyslexic child ?

Two complementary approaches to remediation:

- Training core cognitive processes (phonological skills, attention, etc.)
- Increase accessibility by manipulating the physical properties of print

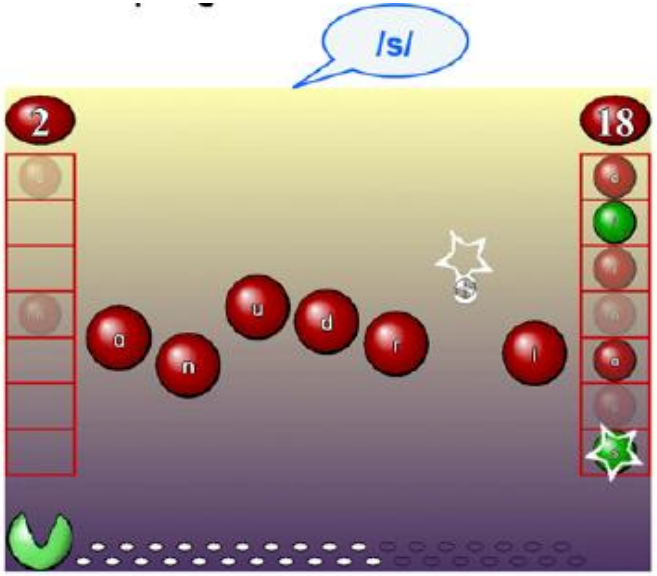
Training core cognitive skills that are ancillary to reading

Pros

- Treatment is theoretically grounded and evidence-based
- Training embedded within computer games (ideal for tablet technology)
- Adaptivity ensures optimal tuning to individual user performance

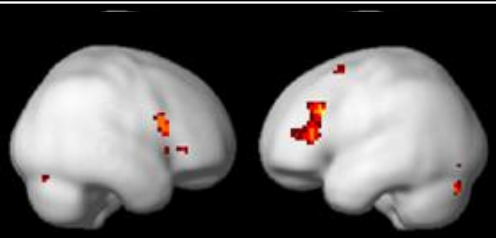
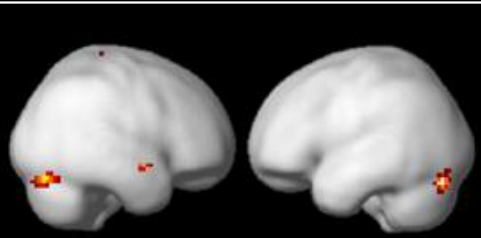
Cons

- Time consuming (but cost is much smaller than instructional treatment)
- Cannot be easily implemented within the school setting
- Improvements do not automatically transfer to reading ability



e.g., GraphoGame, designed to help children learn letter-sound correspondences
first developed and tested in Finland by dyslexia researchers; translated and tested in many other languages
(Lyytinen et al., 2009)

Training with GraphoGame in pre-reading children changes brain reponses to written words

n=15, p<0.001, k=10, uncorr.	Pre GG	Post GG	Post-Pre GG
Words-False fonts	 **No difference**	 **Condition differences**	 **Increased activation in occipito-temporal areas**

Effect of treatment (post- vs. pre-test) on brain activation

(n=15 children; <5 hours total play over 8 weeks)

Brem et al., 2010, PNAS

Increase accessibility of text

Pros

• Computer-based technology allows to reformat text as to match individual preferences and special needs

• E-readers offer accessibility options that are impossible in print

• If reformatting is effective, benefits will be seen “on the fly”

Cons

• Accessibility guidelines for dyslexia (e.g., font type, size, etc) mostly based on common sense or anecdotal evidence; the effect on reading performance is weak

• “Dyslexia-friendly fonts” offered on the market without evidence from clinical trials

• Lack of grounding in the cognitive neuroscience of reading and dyslexia

Learning the visual front-end of reading

1. **Invariance for position, size, case, font**

two four six eight

two four six eight

TWO FOUR SIX EIGHT

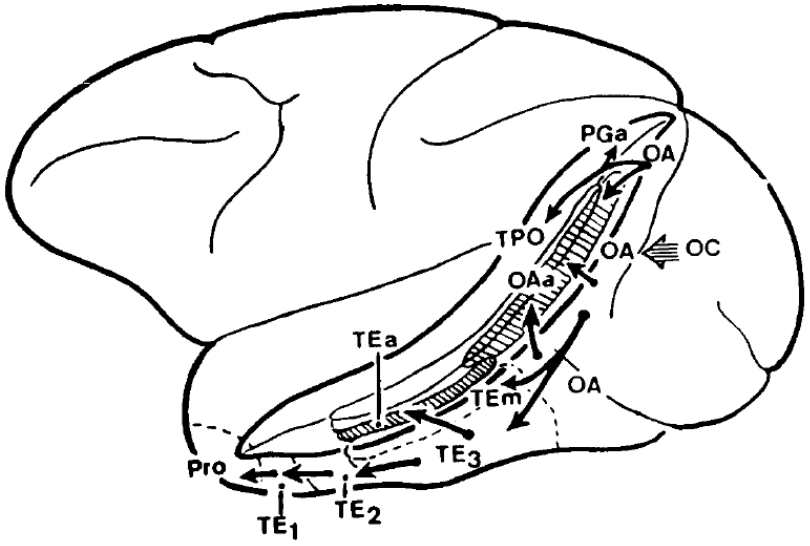
TwO fOuR sIx EiGhT

two four six eight

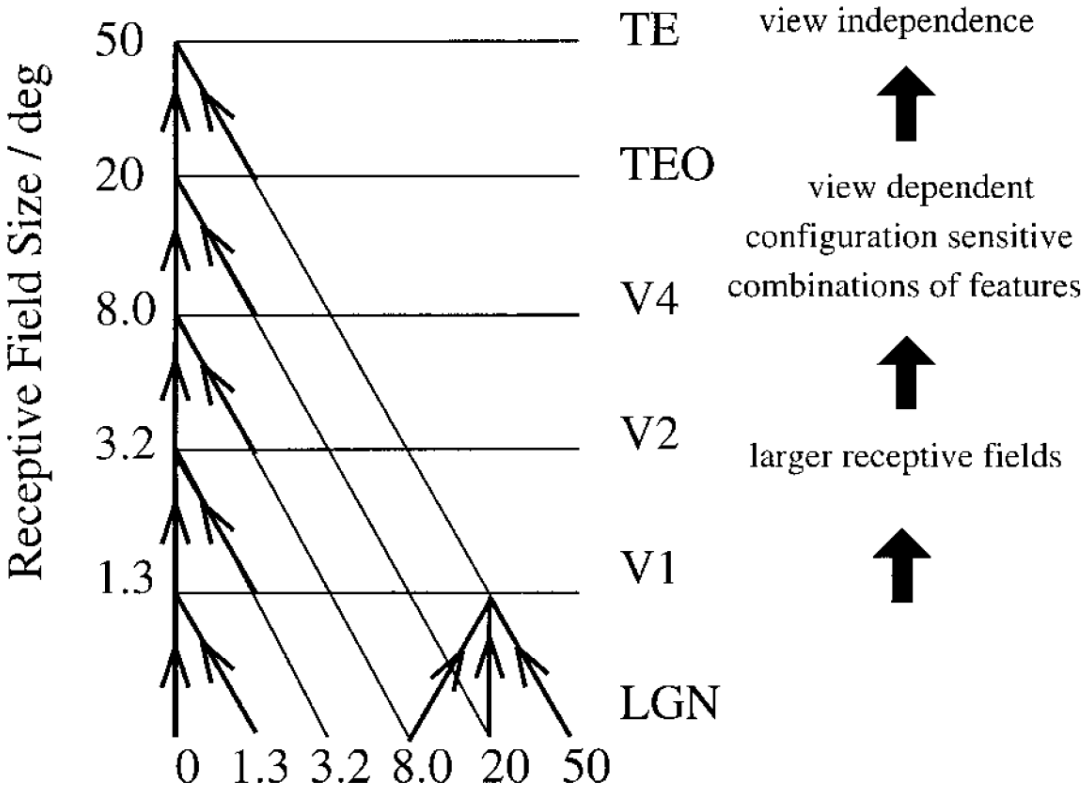
2. Encoding of letter order

range **anger**

3. Cultural « tuning »



A hierarchy of brain areas in the visual system leads to invariance in recognition



Hierarchical visual processing is also crucial for processing written words

Dehaene et al., 2010
Di Bono & Zorzi, 2013

A critical parameter for visual recognition: spacing

Effects of crowding. Fixate the dot in the middle. First line: The R is visible on the right but not on the left because it is surrounded by neighboring letters (i.e., effect of crowding). Second line: Extra-large letter spacing reduces crowding as the middle C is visible on the right side (spaced) but not on the left.

Critical spacing → Minimal spacing above which adjacient items do not interfer

- proportional to eccentricity
- independent from letter size
- not limited by visual acuity

(Bouma, 1970, Pelli et al., 2007)

Reading speed is limited by the number of letters that can be ricognized with a single fixation (Legge, 2001).

Visual span → Region around the fixation point within which all characters can be recognized

Visual span = number of characters that are not subject to crowding

Narrowing of visual span can explain slowing of reading in some conditions (peripheral reading, ambliopia, dyslexia)

Dyslexics show higher susceptibility to crowding (effect is more marked with respect to age-matched controls)

(Bouma et al., 1977; Atkinson, 1991; Spinelli et al., 2002; Martelli et al., 2009)

How does crowding act?

The visual signal in low level visual areas (V1) is intact (Parkes e al., 2001)

Crowding has effect on higher-level visual areas (occipito-temporal cortex)

Features of target and flankers are combined together to form a blurred percept (Pelli & Tillman, 2008)

Extra-large letter spacing improves reading in dyslexia

Hypothesis:
Extra-large spacing between letters --> reduction of crowding --> better reading performance

Study characteristics:
Multi-centric
Cross-linguistic: comparison between consistent (Italian) vs. inconsisent (French) orthographies
Dyslexic sample: unselected (consecutive), 74 children in Exp 1 (34 Italian + 40 French), 20 children in Exp 2

Zorzi et al. (2012, PNAS)

Table S1. Characteristics of Italian and French dyslexic samples

	Experiment 1				Experiment 2: Italian dyslexics (n = 20)	
	Italian dyslexics (n = 34)		French dyslexics (n = 40)			
	Mean	SD	Mean	SD	Mean	SD
Age (months)	129	21	122	15	127	17
Performance IQ	110.3	12.6	99.1	12.2	106.9	7.6
Verbal IQ	107.6	13.4	95.3	10.7	104.7	13.9
Word reading speed (z score)	−4.13	3.00	−2.80	2.83	−3.63	2.10
Word reading accuracy (z score)	−3.94	3.71	−2.30	3.45	−4.28	2.13
Nonword reading speed (z score)	−3.56	2.24	−2.38	1.62	−2.81	2.07
Nonword reading accuracy (z score)	−2.85	2.07	−3.20	2.63	−2.73	1.51
Text reading sill/s	1.72	0.70	1.91	0.71	1.83	0.69
Text reading errors	7.48	7.34	7.27	5.85	9.06	5.26

Effect sizes (z scores) of the word reading deficits were derived from differences between dyslexic readers and population norms expressed in SD units. Text reading performance is averaged across the two test sessions.

A

ando la pera. La bambina asc
ıllo è magro. La quercia si tro
fiore è rosso. La bambina ave
ola. Il ragazzo non ha né capp
stanno saltando sopra il murc
no seduti e guardano verso la
terrazza potrebbero vedere tu
tetto della casa si vede anche
to, ma non il bicchiere. L'elef
o sul ramo dell'albero. La bar
ı è verde. I ragazzi raccolgonc

B

. Il ragazzo che

lo è magro. La q

ella città. Non so

è rosso. La baml

stella, dentro cu

l ragazzo non ha

Character: Times-Roman (most common font), 14 pt (recommended size, British Dyslexia Association).

Extra-large spacing: interletter spacing 2.5 pt, double spacing between words and lines to maintain proportionate appearance

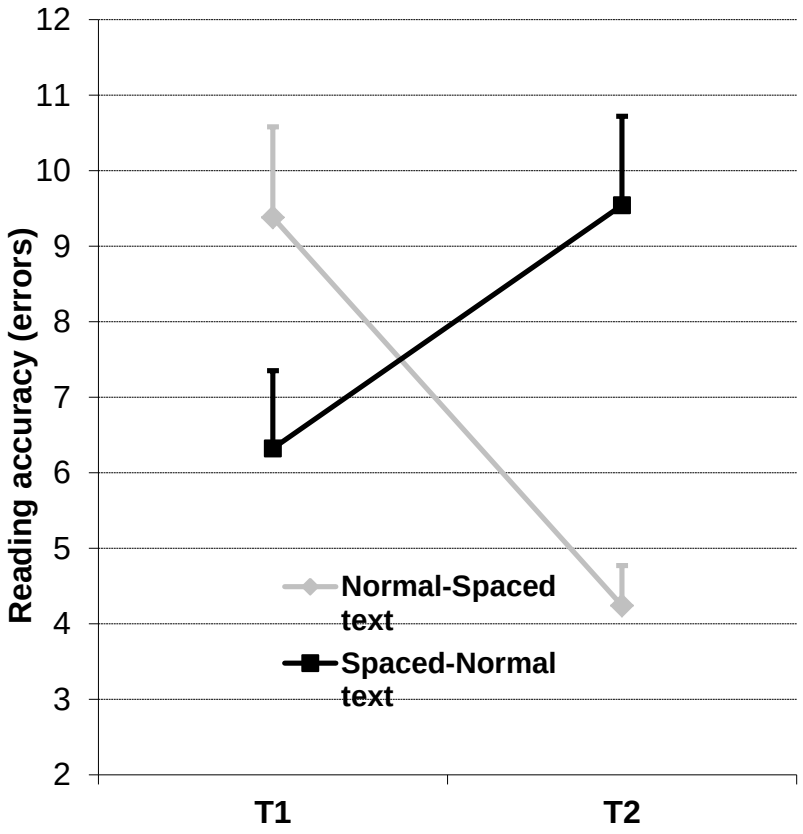
Text: 24 simple sentences, unrelated to each other to avoid contextual cues

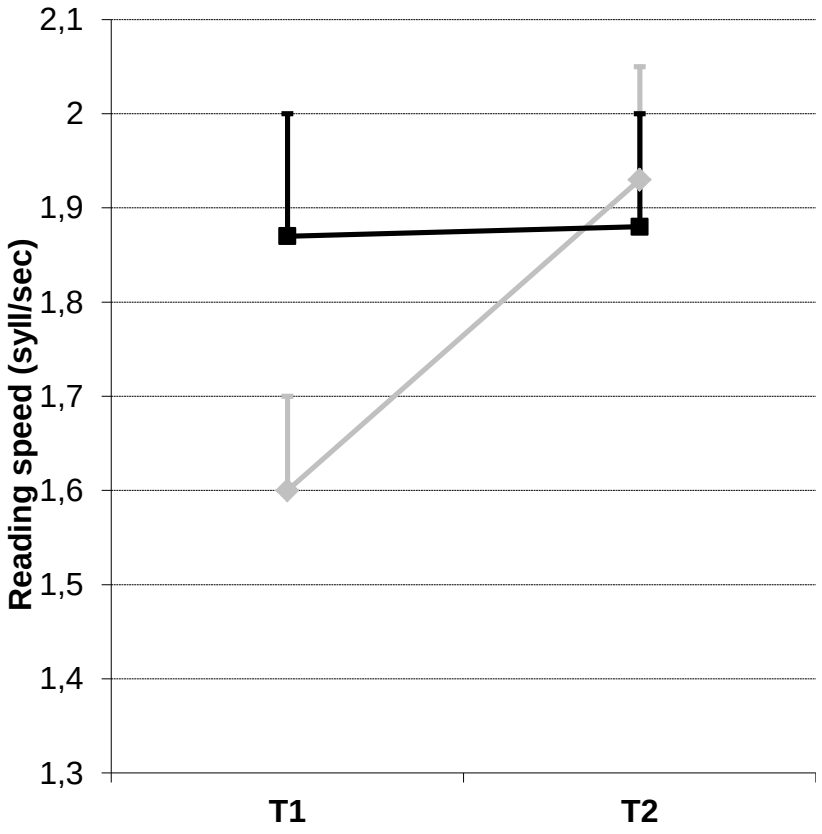
Measures: accuracy (number of errors), speed (syllables per second)

Design:

Random assignment to two groups, test in two sessions (T1 and T2) 14 days apart

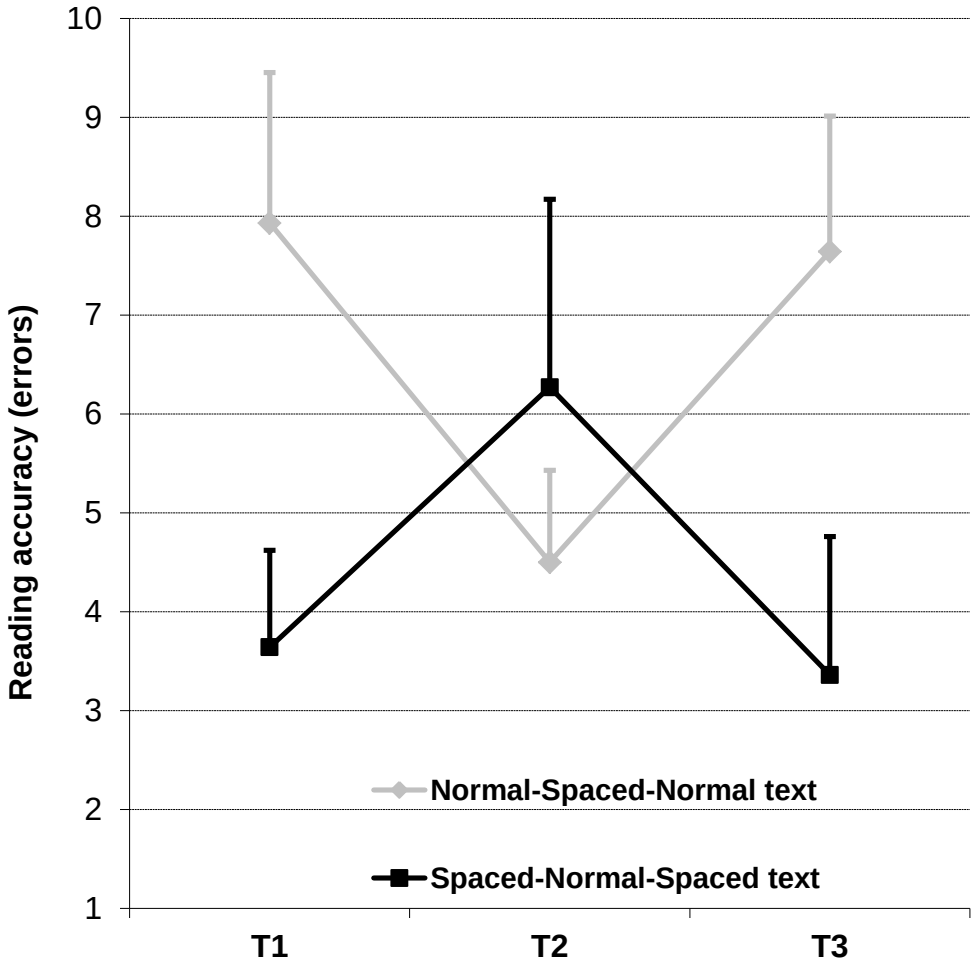
- Normal text at T1, spaced text at T2
- Spaced text at T1, normal text at T2





Errors: decrease of 50% in spaced version

Speed: increase about 20% between groups at T1, T1-T2 difference is masked by repetition effect



Re-test after 2 months (T3) for 25 Italian children

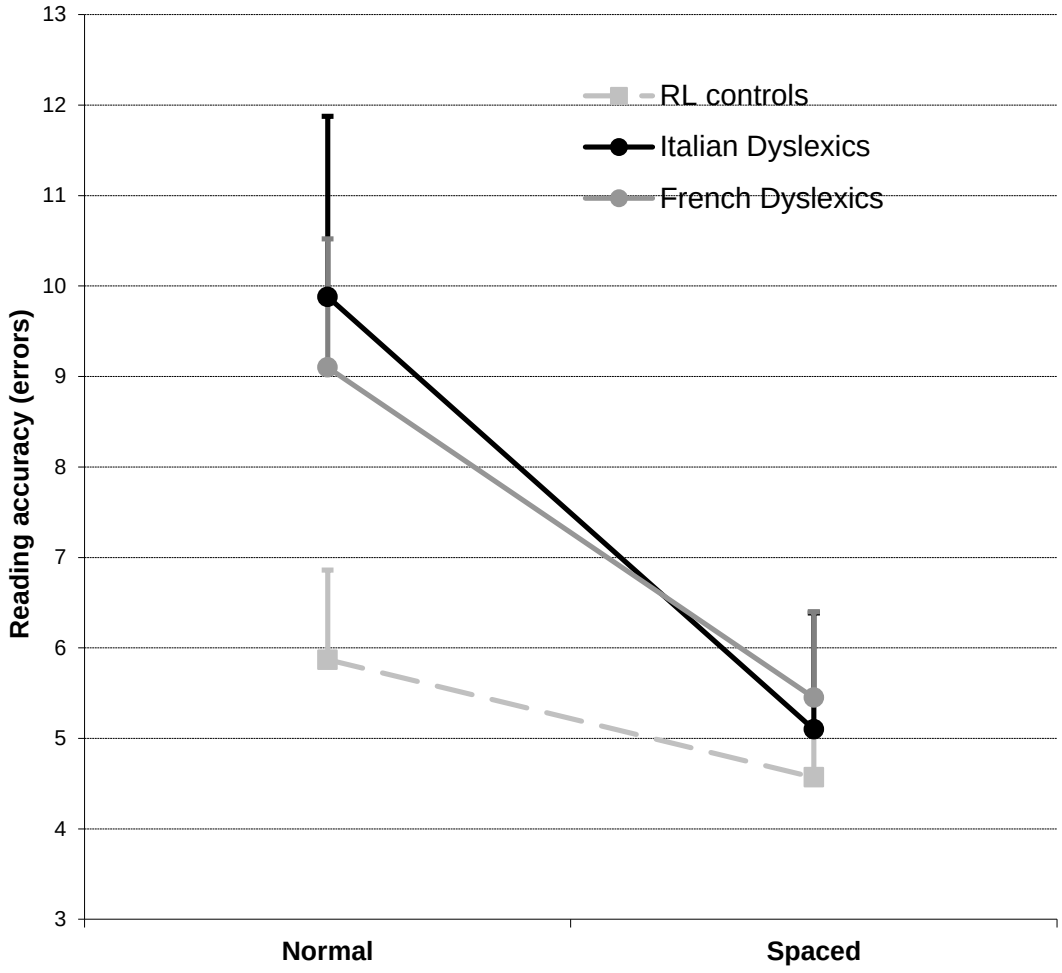
Extra-large spacing benefit is specific to dyslexics?

Comparison with a control group matched for reading level is more conservative and stringent: if the differences persist, they must reflect a fundamental deficit rather than indadequate reading experience (Goswami, 2003)

Table S2. Characteristics of dyslexics and matched reading-level controls

	Dyslexics ($n = 30$)		Controls ($n = 30$)	
	Mean	SD	Mean	SD
Age (month)	131.73	20.50	93.80	4.01
Similarities (WISC-R)	11.53	2.37	11.80	2.40
Block design (WISC-R)	11.17	2.29	10.83	2.36
Word reading speed (z score)	−3.52	2.02	−0.55	0.99
Word reading accuracy (z score)	−3.24	2.45	−0.50	1.05
Efficacy index on word reading	2.70	1.15	2.59	1.02

All z scores reflect differences in performance with respect to age-matched children in the standardized tests.



Dyslexics vs. controls matched for reading performance (younger children)

Experiment 2

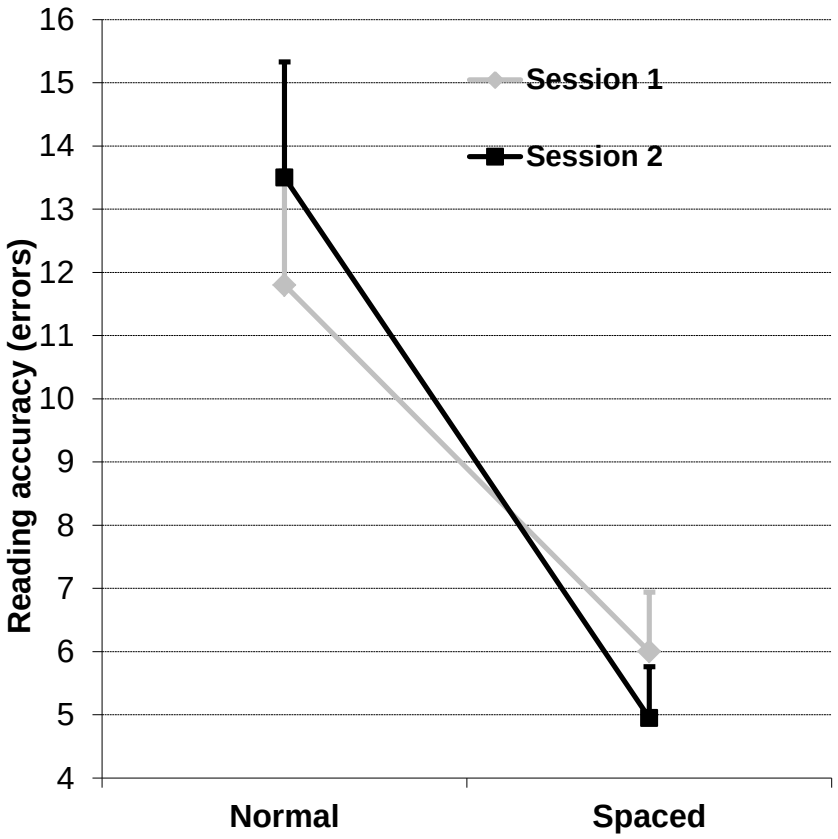
1. Eliminate of repetition effect: use of a second text, identical to the first for number of words, number of syllables, frequency and grammatical class of the words

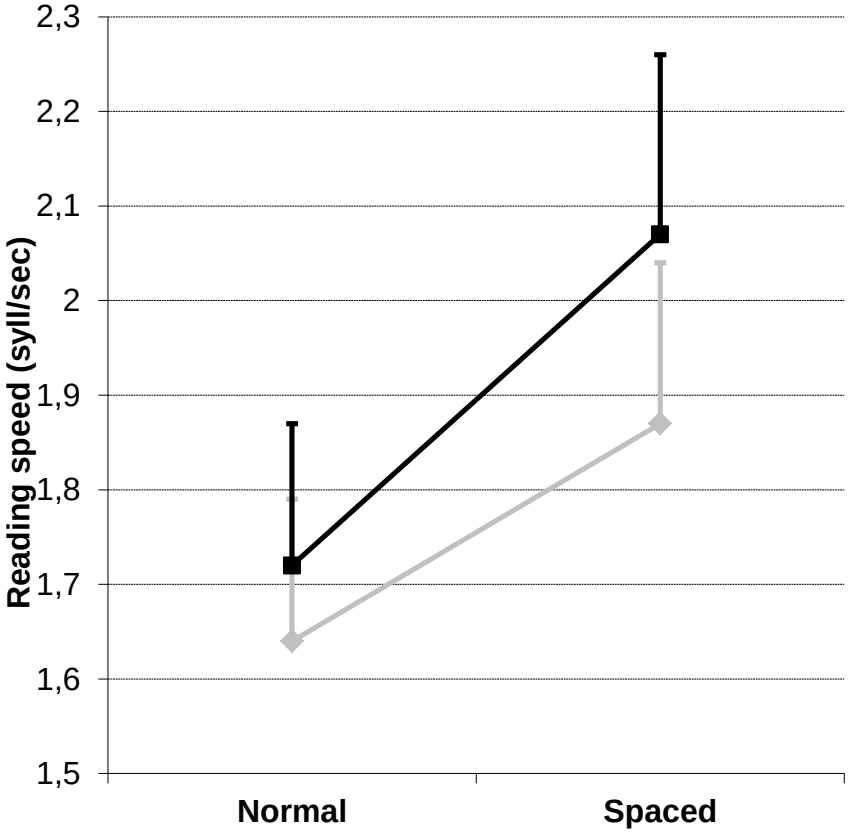
2. Assess if spacing has an effect “on the fly”: comparison within a single session

3. Control for the possible contribution of line spacing: double spacing also in the normal text

Session 1: random assignment text-spacing, reading of normal and spaced text (counterbalanced order)

Session 2 (after 2 weeks): inversion of assignment order, but normal text has single space between lines





Errors: decrease of 50-60% in spaced version

Speed: increase in spaced version of about 20% (0.3 syll/sec)

Conclusions

Extra-large spacing:

- Reduces substantially the number of errors (50%)
- Increases reading speed of about 20% (a third of syllable per second), corresponding to the increase observed across a year of schooling (cf. Tressoldi et al., 2001)
- Effect is on the fly, without training
- No cost, no special (commercial) fonts needed
- Can be implemented in the school setting

- Can be implemented on a large scale in digital printing (tablet, e-reader, e-book, etc.)
- A small increase of spacing has a benefit in normal readers (Perea & Gomez, 2012)