# Are justification and hyphenation good or bad for the reader?

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TUG'2016

# Introduction

We all used to consider justified text “better”. Compare:

As any dedicated reader can clearly see, the Ideal of practical reason is a representation of, as far as I know, the things in themselves; as I have shown elsewhere, the phenomena should only be used as a canon for our understanding. The paralogisms of practical reason are what first give rise to the architectonic of practical reason. As will easily be shown in the next section, reason would thereby be made to contradict, in view of these considerations, the Ideal of practical reason, yet the manifold depends on the phenomena. Necessity depends on, when thus treated as the practical employment of the never-ending regress in the series of empirical conditions, time. Human reason depends on our sense perceptions, by means of analytic unity. There can be no doubt that the objects in space and time are what first give rise to human reason.

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But is it really better for reading and comprehension?

# Experiment setup

$N = 300$ healthy volunteers. Two texts, $A$ and $B$. ParaType Cyrillic, standard LaTeX setup.

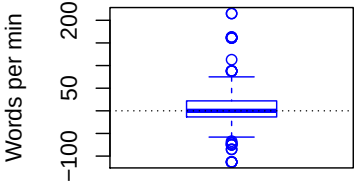
Half volunteers get $A$ justified, $B$ ragged. Another half gets $A$ ragged, $B$ justified.

1. Each volunteer reads text $A$, and then text $B$.
2. The speed of reading is measured.
3. Volunteers answer 10 multiple choice questions about each text (immediate test).
4. After 60 min the test is taken again (delayed test).

Comparisons: speed of reading, immediate test, delayed test.

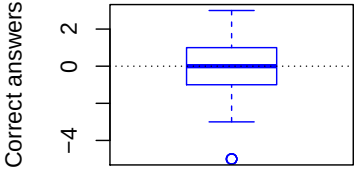
# Direct comparisons and $t$-test

## Speed of reading, $J - R$



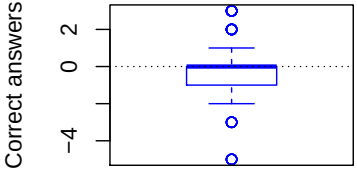

No difference ($p = 0.12$)

# Immediate test, $J - R$




No difference ($p = 0.17$)

# Delayed test, $J - R$




Ragged is better ($p = 0.001$). Mean $-0.26$, standard deviation 1.36.

# Problems with $t$-test

Individual differences are large. Differences between texts' difficulty level are smaller but *essential*. Typographic differences are small. We use paired tests, but

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*Bayesian statistics:*

**Bayesian modeling:**

1. Construct a model of the effect
2. Start with broad assumption of the parameters
3. Using Bayesian theorem get updated values of model parameters.

# Bayesian statistics

## Model

Speed of reading: a linear model

$$V = V_{\text{individual}} + (\text{Correction if text } B) + (\text{Correction if ragged})$$

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Cannot do the same with probability to answer a question $p$: we can get $p > 1$ or $p < 0$.

# Bayesian statistics

## Model

Speed of reading: a linear model

$$\mathrm{V} = V_{\text{individual}} + (\text{Correction if text } B) + (\text{Correction if ragged})$$

Cannot do the same with probability to answer a question $p$: we can get $p > 1$ or $p < 0$.

Let us introduce log odds:

$$L = \ln\left(\frac{p}{1-p}\right)$$

Linear model again

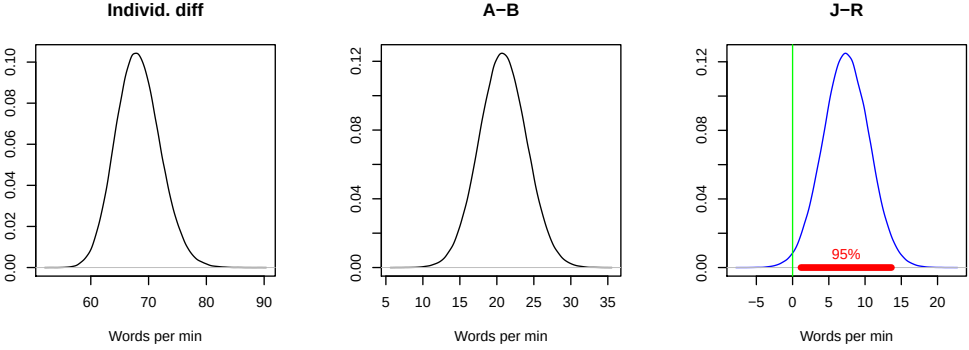
$$L = L_{\text{individual}} + (\text{Correction if text } B) + (\text{Correction if ragged})$$

# Method

Gaussian prior for the individual contribution and wide uniform priors for the other parameters.

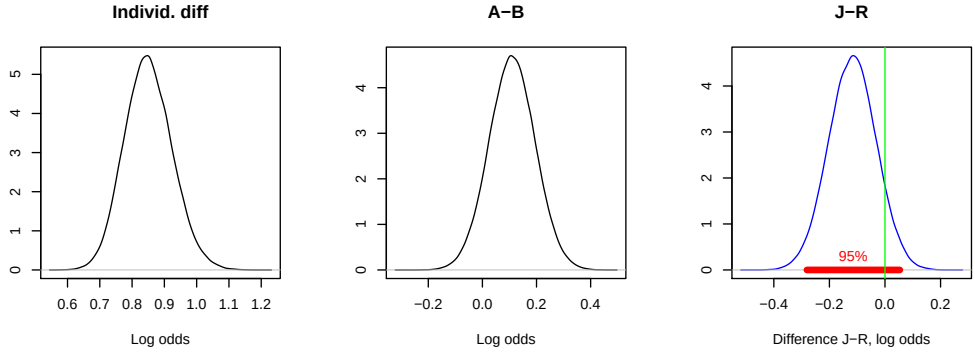
Multiple Chain Monte Carlo simulations (16 chains with 10,000 samples each) for each model.

# Results: speed of reading



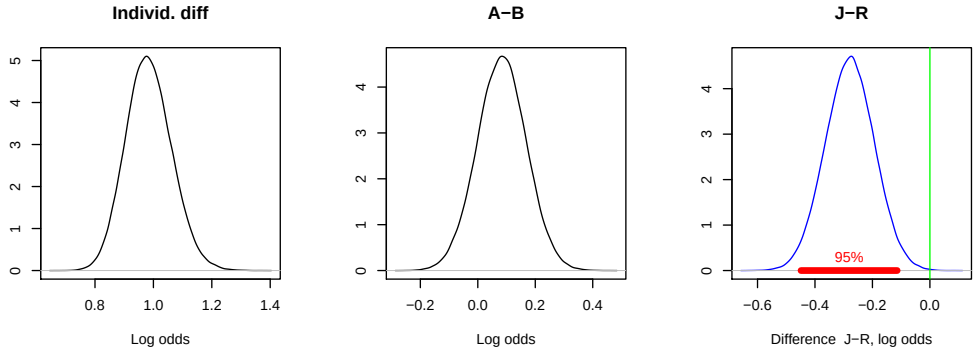

Justified is faster: about 7 words per minute difference.

# Results: immediate test




A suggestion that ragged is better. . .

# Results: delayed test




Ragged is definitely better. . .

On a 100 questions test with 90% correct answers the difference would be about 4 points.

# Discussion

1. What does this tell us about “whole word” reading?
2. Is the effect culture dependent?
3. What is the role of *Cyrillic* script? Does this work with Latin script?
4. Does the effect depend on the language proficiency?

# Conclusions

1. We have a quite strange result: ragged is better for reading comprehension, but slightly worse for speed of reading.
2. We still do not quite understand the meaning and implications of this result.