

A PERSONAL TAKE ON SYNTHETIC PHONICS

ALEXANDRE V. BOROVIK

ABSTRACT

The author of this paper is a university teacher and a parent of bilingual children. Using his and his children's early reading experiences in Russian and English, he attempts to explain the advantages of using synthetic phonics as a method of teaching to read. The paper is motivated, to some degree, by the recent White Paper on Education [†] where the Government has expressed strong support to synthetic phonics—the position that the author of this text shares and supports in his personal capacity as a parent.

Disclaimer. Needless to say, all opinions expressed here are of the author and no-one else.

1. *English orthography as a metaphor for everything that can go wrong in education*

There once was a man who for hiccough
Tried all of the cures he could piccough,
And the best without doubt,
As at last he found oubt,
Is warm water and salt in a ticcough. ‡

I can only look in horror at the suffering of children taught to read English with its non-phonetic and non-transparent orthography. I am Russian; the way I learned to read, the way my children learned to read without even noticing that—would be impossible if we were English.

In England, the difficulties arising from traditional orthography are, of course, well understood. One of the more dramatic attempts to resolve the problem was the invention and trials of the Initial Teaching alphabet; see Figures 1 and 2.

In my humble opinion, the Initial Teaching Alphabet was doomed to failure because it remained confined to initial teaching. What might really help

2010 Mathematics Subject Classification 00000.

www.borovik.net/selecta

© 2010–13 Alexandre V. Borovik

†The Importance of Teaching. The Schools White Paper 2010. Department for Education, November 2010. <http://publications.education.gov.uk/eOrderingDownload/CM-7980.pdf>.

‡Verses and Limericks collected by Bennett Cerf, Godfrey Dewey and Faith Daltry, and published in Spelling Progress Bulletins. <http://www.englishspellingsociety.org/news/media2006/limericks.php>.

a	ɑ	æ	au	b	c	χ	d
apple	arm	engel	author	bed	cat	chair	doll
ɛ	e	f	g	h	ie	i	j
eel	egg	finger	girl	hat	tie	ink	jam
k	l	m	n	ŋ	œ	o	ω
kitten	lion	man	nest	king	toe	on	book
ω	ou	ɔɪ	p	r	r	s	ʃh
food	out	oil	pig	red	bird	soap	ship
ʒ	t	θ	θ	ue	u	v	w
treasure	tree	three	mother	due	up	van	window
wh	y	z	Σ				
wheel	yellow	zoo	is				

FIGURE 1. *Initial Teaching Alphabet* (Sir James Pitman, 1901–1985).

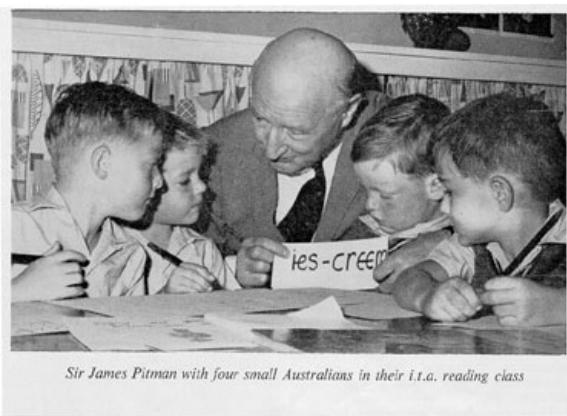


FIGURE 2. Sir James Pitman (1901–1985) teaches children to read the words “ice cream” written in his Initial Teaching Alphabet.

the next generation of children would be a universal reform of English orthography. Of course, such reform would cut off the next generation from the cultural heritage accumulated over centuries. Have I already said clearly enough that I do not propose any reforms?

On the contrary, common sense forces me to accept that a reform of the English orthography is impractical and agree with the anonymous author of this limerick:

It might take a bullett or tu

When reformers have nothing to du
 They might take a shot at the Gnu.
 To nock off the G,
 Would fill them with glee
 And wouldn't embarrass the Nu. †

However, orthography is not a laughing matter.

2. Dyslexia

Indeed the wages of un-intuitive orthography is dyslexia.



FIGURE 3. Vision to the Youth Bartholomew. *Mikhail Vasilyevich Nesterov, 1890. The Tretyakov Gallery, Moscow. Source: Wikipedia Commons. Public domain.* Although an intelligent boy, Bartholomew (who was to become St. Sergius of Radonezh, the most venerated spiritual leader of medieval Russia) had great difficulty learning to read and asked a pilgrim monk to pray for him overcoming his adversity. His Life states that the monk gave him a piece of prosphora (holy bread) to eat, and from that day on Bartholomew was able to read. It has to be added that Cyrillic script of that time was not learner friendly and that this story shows that reading was seen as serious pedagogical problem back in the 14th century.

As a teacher in a university, I have to deal with dyslexic students every

† *ibid.*

working day. For me, dyslexia is a paradigm of the neurological problems of education.

One of the world leading experts on dyslexia, Elena Grigorenko, succinctly summarised the causes of the current epidemics of dyslexia [†]:

The basic dyslexic impairment is caused by a unified mechanism, valid and functioning in all languages in which individuals with dyslexia have been identified. However, the manifestation of this unified mechanism is language- and culture-dependent. Dyslexia is only noted by educators, psychologists, and biologists and then investigated if these three conditions are met:

- (1) the phonological structure of the language must be sufficiently challenging to impose a serious obstacle for dyslexics,
- (2) the frequency of normal reading in society must be high enough to make failures noticeable, and
- (3) there must be a societal demand for mastery of this skill and an adequate number of professionals to support this demand.

3. *Synthetic phonics vs. analytic phonics*

At this point, some theory comparing two competing approaches to reading could be useful—especially since the Government, in its recent White Paper [‡], expressed strong support to synthetic phonics—the point that I happily support.

Synthetic phonics involves the development of phonemic awareness from the outset. As part of the decoding process, the reader would learn up to 44 phonemes (the smallest units of sound) and their related graphemes (the written symbols for the phoneme). One phoneme can be represented by various graphemes, e.g. ‘oa’, ‘ow’, ‘ough’. This is, of course, one of the reasons that the English language can be so difficult to learn to read and spell. The reader would be expected to recognise each grapheme then sound out each phoneme in a word, building up through blending the sounds together to pronounce the word phonetically. This approach works well with phonetically regular words.

Analytic phonics involves analysis of whole words to detect phonetic or orthographic (spelling) patterns, then splitting them into smaller parts to help with decoding, for example onset and rhyme—onset (vowel sound(s))

[†]E. L. Grigorenko, Developmental dyslexia: An update on genes, brains, and environments, *J. Child Psych. and Psychiatry* 42, no. 1 (2001), 91–125. DOI: 10.1017/S0021963001006564. Further discussion and bibliography can be found in J. C. Ziegler, C. Perry, A. Ma-Wyatt, Diana Ladner, and G. Schulte-Körne, Developmental dyslexia in different languages: Language-specific or universal? *J. Experimental Child Psychology* 86 (2003), 169–193. DOI: 10.1016/S0022-0965(03)00139-5

[‡]The Importance of Teaching. The Schools White Paper 2010. Department for Education, November 2010. <http://publications.education.gov.uk/eOrderingDownload/CM-7980.pdf>.

at the beginning of a word or syllable and rime (always beginning with a vowel to form the remainder of that word or syllable).[§]

Basically, synthetic phonics is the standard approach to reading in Russia—it is called there simply звуковой метод, that is, “sound method” or “phonics”[†]; analytic phonics was never seriously considered as an alternative. It is widely accepted that Russian children can be taught (in their families) to read fluently by age of 5 and 6. This was my experience as a child and as a parent.

Finally, one should not forget that there is a hint at something like Initial Teaching Alphabet in Russian approach to reading: books for early reading (by children or for adult learners of Russia as a second language) contained letter ё, which corresponds to a sound different from that of letter e, and stress marks, absent in in “adult” books. If printed for children, the first line of a popular Christmas song may look like

В лесу родилась ёлочка ...

The sound ё does not require a stress mark, it is always stressed.

4. *My first book (and synthetic phonics)*

Figure 4 shows the cover of the first book that I read in my life. Moreover, it was the book that had taught me to read, and it remains the most powerful intellectual experience of my life. The story deserves to be told because it provides the best illustration of the advantages of synthetic phonics. (Of course, the Russian alphabet is more phonetic than English, which makes synthetic phonics much easier to use.)

By the age of 5 or 6 (school in Russia started from 7), I somehow learned the alphabet—mostly by asking my parents and my brothers (who were at the time about 14–15 and 10–11 years old). Crucially, my mother was an elementary school teacher and for that reason, I believe, letters were explained to me by the corresponding sounds, not by their names. No-one, however, taught me to read in any systematic way. For some time the relation between letters on paper and words remained a complete mystery to me. When my brother read me a book, I was very suspicious and occasionally complained to my parents that he was inventing the words.

Then one day I was sitting in a quiet corner with Vladimir Suteev’s book

[§]<http://www.ltscotland.org.uk/5to14/specialfocus/earlyintervention/issues/phonics.asp>. Accessed 30 November 2007.

[†]Phonics was introduced in Russian schools in the late 19th century, adopted from Germany where it was known from early 1800s. Prior to that, children were taught using the horrible буквослагательную методу; first they memorised *names* of letters, the proverbial аз for А, буки for Б, веди for В, etc.; then memorised syllables: буки аз = ба, etc. It took two years to get to basic reading.

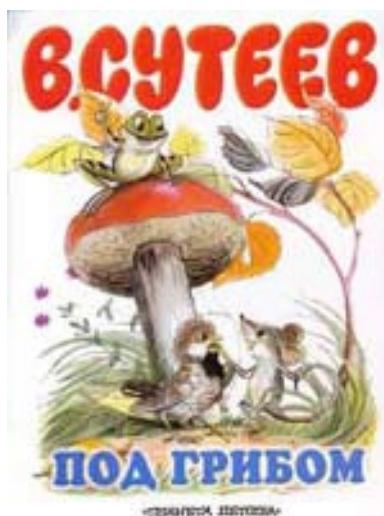


FIGURE 4. *V. Suteev, Under the Mushroom.*



FIGURE 5. *Vladimir Grigorievich Suteev (1903–1993), writer and illustrator of books for children.*

Под Грибом. Looking at the picture of a mushroom (“гриб” in Russian) I suddenly realized that the letters

П, О, Д, Г, Р, И, Б, О, М

on the cover could mean only “Pod Gribom”, “Under the mushroom”, and nothing else. I remember I was surprised by my discovery and decided to check. Under closer examination, it was still

П-О-Д Г-Р-И-Б-О-М.

“So this is how they are doing that”—I thought to myself, then opened the

book and read it in one go, from the beginning to the end. Then I went to the kitchen to report my progress to my mother. “Mom”—said I,—“I read a book”. “Really?”—said my Mom without any sign of surprise. To prove my point, I read the book to her aloud.

Next day, I remember, I went to the village library and enrolled as a borrower.

What I experienced was a classical “AHA” moment, with the same emotional charge as in mathematical discovery. I suddenly discovered that a parser for processing typed text got assembled in my brain and was ready for use. It was exactly the same feeling as in doing mathematics, many years later.

5. *The Tale of the Fisherman and the Fish*

Many years later, my wife Anna and I taught our children to read using a game approach, quite well known in Russia.

First, you ensure an early exposure of a child to letters and letter/sound correspondence (this is the catch: it should exist in the language, this correspondence between letters and phonemes—otherwise the method would not work). This requires some self-discipline on part of a parent: when asked by a child, you should never ever refer to a letter by its commonly used name, only by sound: for the letter “m”, you have to say “mmm”, not “em”.

Then you ensure that small labels with words for usual everyday objects, written in clear block capitals, start to appear overnight on tables, chairs, kitchen utensils, etc.; every morning your child runs around the house collecting these labels and trying to guess what is written on them. In our home, these labels were known as “stickers from Pinocchio”, because of a picture of Pinocchio on a box of pencils.

Then you have to provide your child with proper reading material. And here I reveal the main secret: reading is hard. For a child, to develop interest and commitment to reading, the first texts have to have an exceptional personal and emotional importance—and *nothing can beat a letter from a parent*.

My mother-in-law saved a pile of my wife’s and mine letters to our children. For example, Figure 6 is my version of Pushkin’s *The Tale of the Fisherman and the Fish*, improvised for my son when he was about 5 or 6. Judging by the first lines,

SIT QUIETLY!

I WILL WRITE A TALE FOR YOU.

it was written, most likely, while we were waiting for our turn in a doctor’s reception room.

СИДИ ТИХО !
 Я НАПИШУ ТЕБЕ СКАЗКУ.

СКАЗКА

- О РЫБАКЕ И РЫБКЕ,

- ПОЙМАЛ РЫБАК
 ЗОЛОТУЮ РЫБКУ. РЫБКА
 ЕМУ И ГОВОРИТ:
 "ОТПУСТИ МЕНЯ, Я
 ТВОЁ ЖЕЛАНИЕ ИСПОЛНИО".

- А РЫБАК ЕЙ:
 "НЕ ОТПУСТУ, А
 ПОСАДИЧ В АКВАРИУМ"

ТАК И СДЕЛАЛ,
 ПОСАДИЛ В АКВАРИУМ И
 СТАЛ ЖЕЛАНИЯ ЕЙ ЗАГАДЫВАТЬ.

ЖЕНА У РЫБАКА БЫЛА
 ЖАДНАЯ И ГОВОРИТ: "У НАС
 КВАРТИРА МАЛЕНЬКАЯ. ХОЧУ, ЧТОБЫ
 БЫЛА ИЗ ПЯТИ КОМНАТ"

РЫБКА ТАК И СДЕЛАЛА. СТАЛА
 КВАРТИРА БОЛЬШОЙ И АКВАРИУМ
 ТОЖЕ ВЫРОС - КАК ШКАФ.

ЖЕНЕ ЭТОГО МАЛО,
 "ХОЧУ, ЧТОБЫ НЕ КВАРТИРА
 БЫЛА, А СВОЙ ДОМ, КАК
 ДЕТСКИЙ САД". РЫБКА И

- -3- -4-

- ЭТО СДЕЛАЛА. СТАЛ У
 НИХ СВОЙ ДОМ, В
 НЁМ МНОГО-МНОГО КОМНАТ,
 А АКВАРИУМ УЖЕ ЦЕЛУЮ
 КОМНАТУ ЗАНИМАЕТ.

- ВДОХ РЫБАК ОТКРЫЛ
 ДВЕРЬ В КОМНАТУ К
 РЫБКЕ, А ВОЙТИ НЕКУДА -
 СТЕКАЛО ДО ПОТОЛКА, ЗА
 СТЕКАЛО РЫБКА ПЛАВАЕТ,
 РЫБАК ПОСТУПАЛА ПАЛЬЦЕМ
 В СТЕКАЛО, ПОДОЗВАЛ
 РЫБКУ И ГОВОРИТ:

"ЖЕНЕ ДОМА МАЛО.

ОНА ДВОРЕЦ ХОЧЕТ",
 РЫБКА ХВОСТОМ
 МАХНУЛА - СТАЛ НЕ ДОМ,
 А ДВОРЕЦ. А АКВАРИУМ
 СТАЛ КАК ДОМ. СТЕКАЛО
 У НЕГО БЫЛО ТОНКОЕ,
 НЕ ВЫДЕРЖАЛО ВЕСА ВОДЫ,
 ДОПНУЛО. ВОДА УТЕКЛА
 В ИРТЫШ, И С НЕЙ
 УПЛЫЛА РЫБКА.

FIGURE 6. The Tale of the Fisherman and the Fish. This text was improvised and written down sentence-by-sentence for my son (aged 5 or 6) to read in real time while waiting in a doctor's reception room.

Judging by the free flow of the text from one line to another and even to a new page, this was a text for a relatively late stage of learning to read. Indeed, in our first letters to children every sentence was confined to exactly one line. An example of a letter for earlier stages of learning (from my wife to our daughter, aged 4) is shown on Figure 7.

Figure 8 shows one of the intermediate steps: crosswords and word puzzles.

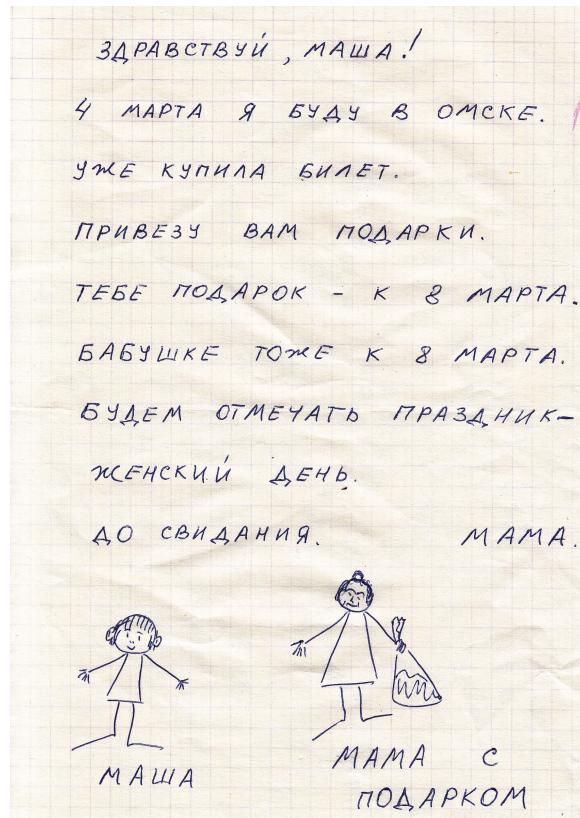


FIGURE 7. A letter from my wife to our daughter (aged 4): every sentence is on a separate line.

This approach to early reading was not our invention. In its many variations and modifications it was widely popularised in mass circulation family magazines, was tried and tested, and worked successfully in thousands of families across Russia—mostly, of course, in families of middle class professionals. It worked for two reasons:

- it exploited a favourable phonological structure of Russian orthography;
- it was done in the family, thus ensuring the strongest possible and unconditional emotional support to the child learner.

No special knowledge was needed—but what required from parents and other members of families was some self-discipline and acceptance of a certain value system. In the pile of letters saved by my mother-in-law the most telling examples were letters sent to my children by their 12 years old cousin who instantly accepted the rules of the game as soon as they were briefly explained to her: she wrote in clear block capitals using only simple



FIGURE 8. A crossword filled by my son (aged 5 or 6). Russian orthography is a trap-door function from letters to phonemes; it is easy to read but pretty hard to write correctly. There is a couple of orthographic errors in my son's writing, but, at that stage, they have to be simply ignored.

words, preferably made of open syllables, in simple short sentences fitting in a single line, etc.

6. *Analytic phonics*

The most bizarre turn of the story is that my daughter, when she came to the USA aged 5, taught herself to read in English using analytic phonics.

This happened when we came to California where my children, as foreigners, benefited from a magnificent Magnet programme of teaching English as a second language. The programme at that time was generously funded by the State of California; classes of 10-15 students were run by two teachers. My son, aged seven, after two or three months of initial introduction to English, was taught to read; my daughter, aged five, was taught only spoken English. My children came to California being fluent Russian readers, and my daughter could not allow that her brother read in English, while she did not. So she started to listen to audiobooks like the one on Figure 9, tracing words in the book and establishing correspondence between combinations of letters and sounds.

In a week, she was able to read *Horton Hears a Who*, in a couple of months she was a fluent English reader—without any help or guidance from

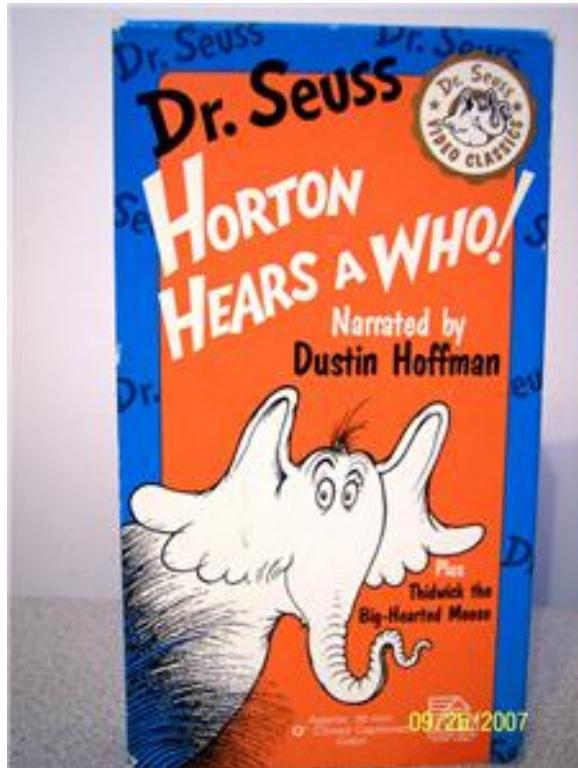


FIGURE 9. *Dr. Seuss, Horton Hears a Who!*

adults except for provision of audiobooks which were actually bought for her brother, on advice from their school. Of course, this was possible only because she could fluently read in Russian. Actually, in Russian she also was a mostly self-taught reader, as it frequently happens with younger siblings in families with a strong reading tradition—the same way as it happened with me. And the audiobooks were real masterpieces: Dr. Seuss narrated by Dustin Hoffman, of all people!

Also it is worth mentioning that rhyming (and who is better in rhyming than Dr. Seuss?) is an important aspect of analytic phonics:

The rhymes of words can be used to help children read and spell by analogy. For example, the right rhyme, once known, can be used to generate another 96 words. It is therefore an efficient way to help children develop a large sight vocabulary for both reading and spelling. It works particularly well for those words that young children cannot work out sound-by-sound, for example 'light', 'through', 'rake'. It is also an effective way of helping children to adopt the common sight words, for example when teaching the

word ‘could’, children would be supported to generate and read the rhyming words that share the same written pattern—‘would’, ‘should’. †

It is an important observation: under favourable circumstances, children could be essentially self-taught readers.

Perhaps I have to reveal at this point that this text is a byproduct of a larger project of mine, a book *Shadows of the Truth* † where I collect and analyse childhood stories of first encounters with mathematics told to me by my colleagues, professional research mathematicians. Quite a number of them could be described, in their pre-school years, as self-taught young mathematicians (or at least arithmeticians). Self-teaching to read deserves a systematic study because it is not something exceptional and because it can shed some important light on early age mastering of basic mathematics.

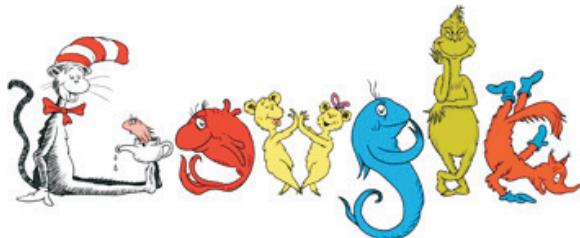


FIGURE 10. *The ultimate accolade: Google's doodle marking the 105th anniversary (2 March 2009) of the birth of one Mr. Theodor Seuss Geisel, better known to the world as the incredible, indelible Dr. Seuss.*

7. Russian orthography and “the language of scum”

This section is basically a disclaimer: Russian orthography and Russian language are not ideal. You may skip this section if you are not interested in statements of obvious.

Russian orthography is not phonetically precise, although it is significantly more precise than English, and sufficiently precise to make reading easy. As a child, I had (and perhaps still have) a noticeable “bookish” accent, a tendency to pronounce words the way they were written (for example, “что” (*chto*) instead of the correct pronunciation “што” (*shto*)); the very existence of the “bookish” accent is the sign that *reading for oneself* is the easiest part of Russian. I have already mentioned that orthographically cor-

†<http://www.ltscotland.org.uk/5to14/specialfocus/earlyintervention/issues/phonics.asp>. Accessed 30 November 2007.

†A. Borovik, *Shadows of the Truth: Metamathematics of Elementary Mathematics*, <http://www.maths.manchester.ac.uk/~avb/ST.pdf>.

rect writing in Russian is difficult; worse, deviations from canonical orthography are (well, at least were in my time) stigmatised. For a very detailed professional analysis, I strongly recommend a paper by Elena Grigorenko *If John were Ivan, would he failed in reading?*[‡]. She explains, in particular:

First, although more phonologically transparent than English, Russian contains a number of letters and letter combinations for which the phoneme-grapheme links are not straightforward.

Second, although the situation is such that, when a word is seen, especially if it is a familiar word, decoding the word is easy, the backward movement from the sound of the word to its orthographical representation can be very difficult. [...]

Third, because the stress is fluid in Russian and its placement can be different for various morphological derivatives of the root, mastering accent is critical[†] [...]

Fourth, the Russian morphology is one of the central pieces of the language, as many roots are used over and over in many derivational formats. [...]

Finally, and especially critical with regard to comprehension of higher-than-word units of the language, the mastery of lexicology is important. The polysemantic nature of Russian vocabulary makes this language heaven for experts and hell for novice writers and readers.

The difficulty of Russian spelling is demonstrated Figure 11: in an exercise from Marina Soloveichik's textbook *Towards the mysteries of our language*: every dot can be replaced by any of the two letters shown above it, producing a readable result—but in each case, only one choice is orthographically correct.[‡]

For me, the most shocking of the recent cultural developments in Russia is the emergence of the “language of scum”, языка падонкоф; it becomes more and more noticeable on the Russian Internet. It is made of Russian words spelled with an exaggerated phonetic precision and intentional (occasionally slightly twisted) deviation from the traditional orthography. It carries a powerful message of unhinged aggression; it is a linguistic equivalent of a shaven head, blood-red eyes, gold teeth and a huge tatoo on a hairy chest. Not surprisingly, язы́к падонкоф has happened to be exceptionally convenient—and much used—for creation of new terms of racist and antisemitic abuse (пейсателя – ф топку!).

[‡]E. L. Grigorenko, *If John were Ivan, would he failed in reading?* In *Handbook of orthography and literacy* (R. Malatesha Joshi, P. G. Aaron, eds.). Routledge, 2006, pp. 303–320. Preview is available at <http://books.google.co.uk/books>.

[†]One should not underestimate the snobbishness of the language culture in Russia: Mikhail Gorbachev was widely ridiculed for pronouncing the word средСТВА with a wrong stress, instead of the correct срЕдСТВА. – AB.

[‡]Source: E. Kerek and P. Niemi, Russian orthography and learning to read, *Reading in a Foreign Language* 21 no. 1 (2009), 1–21. ISSN 1539–0578. Kerek and Niemi quote M. S. Soloveichik, *К тайнам нашего языка*. Москва, Ассоциация XXI век, 2008.

125. Что необычного в этой записи?

П о о о а а я о я и г
 п а а а д . гре л . ч . ик . ч . ии . . .
 и о о и а и г
 и е а а в с . м . ч . . .
 и о и в о а я
 - Пр . х . дит . . се и . ч . и!
 с о а и г о и а
 - . кольк . ч . . ? . тв . ч . и!

FIGURE 11. An exercise from Soloveichik's textbook *Towards the mysteries of our language*.

In English, an intentional deviation from the traditional spelling (“*Krunchy Kream Kookies*”) is not a sign of a break from all social norms. In Russian, it is a deliberate manifestation of an utter contempt to every possible rule and law.

The “language of scum” is a cancer of Russian culture; but it is quite symptomatic and tells a lot about Russia’s hidden cultural tensions.

8. *And finally—a few questions about mathematics*

And now I want to ask some bold questions.

I strongly believe that my experience of learning to read is normal in the sense that this is how children should learn to read. Of course, I had a very supportive environment—and I am painfully aware that millions of children around the world are deprived of the same level of support. But, crucially, it was the Russian alphabet that made my learning natural and easy.

Why are we so sure that the “alphabet” of mathematics, as we teach it—all that corpus of terminology, notation, symbolism—is optimal? It is a result of a long cultural evolution.

Alas, math phobia—like dyslexia—is too common and too widespread to

be ignored. For me, an explanation of its roots lies in Stanislas Dehaene's quip [†]:

We have to do mathematics using the brain which evolved 30,000 years ago
for survival in the African savanna.

There were no books in the savanna, and arithmetic textbooks were even more conspicuously absent. All that stuff was invented and developed later, in a tortuous trial-and-error process spreading over millennia. The results are not perfect, as illustrated by the insane English orthography, which contributes to the epidemics of dyslexia in this country.

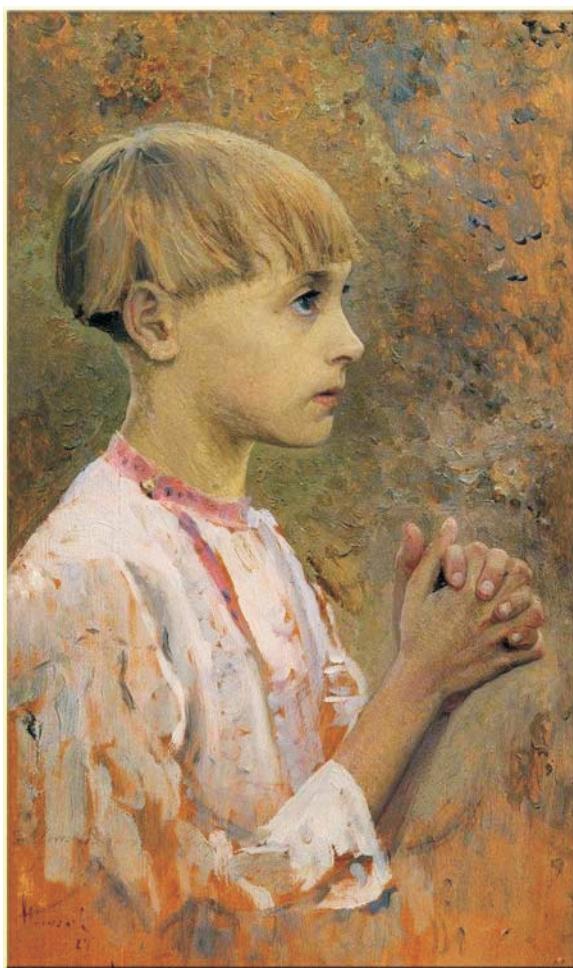


FIGURE 12. M. V. Nesterov, *a study for Vision to the Youth Bartholomew*. Source: Wikipedia Commons. Public domain. Bartholomew is an obvious prodigy; but even a prodigy can be hindered by awkward and pedagogically unsuitable orthography.

[†]S. Dehaene, *The Number Sense*. Penguin Books, 2001.

Indeed orthography, as well as arithmetic notation, is a result of a cultural evolution. By its nature, evolution does not produce optimal results: it produces only survivable results which are forever affected by conditions for survival at the earlier stages of evolution. [†] Over the centuries, selection factors of evolution of orthography or arithmetic did not include suitability for use in compulsory mass education.

English orthography, with English language dominating the world, is definitely survivable—but it is obviously not optimal, for otherwise we would not have the plague of dyslexia. Imagine that there were no other languages in the world—would we suspect that there were problems with English orthography?

Similarly, we have nothing to compare our mathematical language with—how do we know that it is optimal?

About the author

Alexandre Borovik is a professor of mathematics at the University of Manchester, United Kingdom. He has 35+ years of teaching experience in Russia, USA, and UK (in the latter from 1992). His children were born in Russia, started school in the USA, completed secondary school and got university degrees in England. His books and papers can be found at his websites and blogs

<http://www.borovik.net/>
<http://www.borovik.net/selecta>
<http://micromath.wordpress.com/>
<http://manchester.academia.edu/AlexandreBorovik>

Disclaimer

The author writes in his personal capacity and the views expressed do not necessarily represent position of his employer or any other organisation or institution.

EMAIL alexandre.borovik >>>at<<< gmail.com

[†]Only after writing this paper I realised that my thesis is informed by my professional experience of a mathematical study of the so-called evolutionary or genetic algorithms.