



Progression in Materials for Learning to Read and Write - a Cross-Language and Cross-Century Comparison of Primers

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Abstract

This work is part of a larger effort about understanding the effects of didactic materials on acquisition of reading and writing in German. In this paper, the focus is on progression in primers (beginner readers). Texts in various languages are analyzed in terms of complexity, as measured by entropy between letters and phonemes, from the point of view of reading or writing that text. The assumption is that a good teaching text would start low and increase gradually in complexity. At the same time, languages have different requirements on progression depending on their orthographic depth. The goal of this work is to compare German primers to various other languages for the beginning stages of reading skill acquisition. We show that there are difference across languages and a large span of approaches in primers of presenting material to the learner.

Index Terms: orthography acquisition, text analysis, entropy, orthographic depth, text difficulty, text progression

1. Introduction

Acquisition of reading and writing are interrelated. Over the years, a number of studies have looked at the basal abilities needed to predict these skills in children to obtain early diagnostics. In this area, publications for English language have dominated the research, exemplified by [1, 2, 3]. This focus may be problematic, since English orthography presents an outlier for readers and writers [4] due to its orthographic depth [5, 6] and the results may not be generalizable to other languages. Depending on the language, reading and writing can be more or less difficult to acquire [7, 8]. Dyslexia, and some reading or writing difficulties manifest themselves differently depending on orthographic depth [9]. Deeper orthographies take more context at phoneme, syllable and morpheme or even sentence grammatical knowledge into account to understand the relationship between phoneme and grapheme sequences. Some studies regarding reading and writing acquisition exist that compare the process across languages [10, 11, 12, 13, 14, 5]. Few authors look at spelling acquisition particular to German [15] and more work is needed to focus on detailed interaction between the reading and writing acquisition processes [16, 17].

For German, Fricke [18] looks at basal skills that can predict both reading and writing. Landerl [19] looks at specific orthographic pattern acquisition for spelling in German and Dutch. Roth [20] looks at long-term effects on orthographic skills for German after training basal skills. Suggate [21] studies long-term effects of intervention on reading. Röber-Siekmeyer [22] focuses on orthographic acquisition process in multilingual children. Similar studies are reflected in the liter-

ature for the French language [23] and Italian in comparison to English [24].

The lack of detailed understanding of the reading and writing skill acquisition is reflected in the inability to prevent the so-called Matthew effect [25], the so called separation of learners at a very early stage (Kindergarten) into those that excel versus those that stagnate. Early diagnostics, improved learning materials and early training in basal skills are repeatedly shown to be of importance, though the effect has remained [26, 27].

Two important lines of thought in the literature lead us to examine reading materials for first graders. Firstly, the self-teaching theory that builds on a strong interaction between reading and writing process based on the textual interactions. The theory states that through reading, orthographic skills and reading skills are self-taught with practice. Some of the key literature in this area over the years has been [28, 17, 29, 30, 31, 32]. It is therefore important to study the reading materials that are supplied to children in the first years of their schooling. In fact, the study by Ziegler [29] seems to suggest that bad reading materials (just like learning impediments) will have a long-term negative impact on skill acquisition in the same way that inherent learning disabilities have. Bad learning material may simulate a disability and could lead to negative acquisition effects in the same way as inherent learning disabilities. Apart from [33, 34] we are not aware of any other related work that analyzes progression in reading materials at the early stages of acquisition in a quantitative manner.

The second very important strand of thought in the literature relates to the regularity in learning material that are required to support optimal learning [35, 36, 2, 37]. This includes training or drill as an important component [38, 39]. A look at the reading materials for regularity and incremental learning is therefore an important step towards evaluating the quality of learning materials. The National Reading Panel [40] and more up-to-date studies by Galuschka [41] have published meta-reviews of major comparative and quantitative studies, realizing that 'Phonics'¹ is a vital component in reading instruction. Therefore, whenever possible, material using the 'Phonics' approach were selected in this study.

Joining these two strands of research, the importance and manner of presenting material in the first year of acquisition becomes clear [42]. Looking at spelling skills by children in Germany and France, there is reason to believe that there is some room for improvement in the presentation of didactic materials in the beginning years. Categories of major spelling problems relate to regularities of the German orthographic system,

¹The explicit and systematic (including clear sequence and scope) instruction of patterns in phoneme-grapheme correspondence)

indicating that a more rigorous approach to teaching regularities might be useful. [43, 44, 45]. Even though German is deemed to have a simple orthography, it is of interest to show how German primers compare to primers in other languages that follow some of those rules.

The rest of the paper is structured as follows. Section 2 introduces the texts that will be studied. Section 3 will explain the theory and implementation of the automatic tools to generate the features that we are studying for each of the texts. Section 4 will discuss the results followed by a conclusion and future work discussion in 5.

2. Corpora

In order to analyze progression in primary primers in various languages, to compare with a number of well-known German primers, a selection for English, French, and Italian were chosen to present a spectrum from rather deep orthography (English, French) to somewhat flat orthography (Italian), with German being in the middle. While item presentation for primers differ (for example choosing texts including high frequency words compared to simple word lists), they are comparable in that they represent the conscious decision of the editors for presenting material to the learners. As motivated in the Introduction, primers that are in use and employ the 'Phonics' approach were chosen whenever possible.

2.1. English

In the US, current teaching of the orthographic system has moved from first grade into the preschools, even into pre-kindergarten. It is therefore not possible to look at a single first grade readers. The current state-of-the-art practice is the reading of easy literature that is chosen by the children themselves from a larger set of stories that is often supplied as leveled readers by the publishers, or books that form part of the reading workshop [46].

In order to study a text that follows the phonics approach [47], a book from the turn of the century was chosen for the analysis. It gives us the opportunity to look at the progression within a single text.

For the purpose of this paper, the 'McGuffey's First Eclectic Reader' [48] was chosen because it was the first widely used textbook in the US, follows a leveled 'Phonics' approach and is still in use today. In stark contrast to today's books, this one is able to describe the methodology in one page.

"This First Reader may be used in teaching reading by any of the methods in common use; but it is especially adapted to the Phonic Method, the Word Method, or a combination of the two.

I Phonic Method. – First teach the elementary sounds and their representative, the letters marked with diacritics, as they occur in the lessons; then, the formation of words by the combination of these sounds. For instance, teach the pupil to identify the characters *a*, *o*, *n*, *d*, *g*, *r*, and *th*, in Lesson I, as the representatives of certain elementary sounds; then teach him to form the words at the head of the lesson, then other words, as *nag*, *on*, *and*, etc. Pursue a similar course in teaching the succeeding lessons. Having read a few lessons in this manner, be-

gin to teach the names of the letters and the spelling of words, and require the groups, "a man," "the man," "a pen," to be read as a good reader would pronounce single words.

- II When one of the letters in the combinations *ou* or *ow*, is marked in the words at the head of the reading exercises, the other is silent. If neither is marked, the two letters represent a diphthong. All other unmarked vowels in the vocabularies, when in combination, are silent letters. In slate or blackboard work, the silent letters may be canceled.
- III Word Method. – Teach the pupil to identify at sight the words placed at the head of the reading exercises, and to read these exercises without hesitation. Having read a few lessons, begin to teach the names of the letters and the spelling of words.
- IV Word Method and Phonic Method Combined. – Teach the pupil to identify words and read sentences, as above. Having read a few lessons in this manner, begin to use the Phonic Method, combining it with the Word Method, by first teaching the words in each lesson as words; then the elementary sounds, the names of the letters, and spelling.
- V Teach the pupil to use script letters in writing, when teaching the names of the letters and the spelling of words."

The preface of the current version gives the following teaching instructions that are relevant to the text analysis:

- 1. "Words of only two or three letters are used in the first lessons. Longer and more difficult ones are gradually introduced as the pupil gains aptness in the mastery of words."
- 2. "A proper gradation has been carefully preserved. All new words are placed at the head of each lesson, to be learned before the lesson is read. Their number in the early lessons is very small, thus making the first steps easy. All words in these vocabularies are used in the text immediately following."

The text is obtained from the online Gutenberg Project as a txt file and is therefore fully digitized for the automated analysis.

2.2. French

Similar to English, the study of learning materials is of great importance in a deep orthography such as French [45]. In a study published only as a technical report [49] several readers in the first grade have been analyzed for their methodology. We chose a book that follows a syllable based approach most closely related to the 'Phonics' approach in English in that it prescribes a leveled approach to reading (and therefore writing). 'Léo et Léa' [50] and 'Kimamila (1&2)' [51, 52] were chosen for this study and digitized.

2.3. German

For German, a selection of readers was taken that represent different methods of teaching. Each of these have been digitized.

Syllabic Method: This method assumes that reading is best taught starting with the syllable. Therefore, the book starts with teaching syllables instead of letters in isolation. Usually, this method also distinguishes stressed from unstressed syllables. An example of such a primer is 'ABC der Tiere' [53].

Analytic-Synthetic Method: This method assumes that there is more or less a 1-1 correspondence between phoneme and grapheme with some more nuances that are postponed to a later stage, without following a Phonics approach. Examples for this approach are 'Jo-Jo' [54] and 'Kunterbunt' [55]. The books are usually complemented with additional materials that also work on the syllable method and most of them have since been updated accordingly.

Phonics Method: The 'Phonics' approach emphasizes regularity over simplification. There are old primers from the turn of the century that exemplify this method, 'Alte Fibel' is used in this study [56]. The description of the method spans the first pages of the primer. It is similar to the 'McGuffey' reader explanation, therefore we choose not to translate it for this paper. A small excerpt is translated below.

The reading material relies on the phonetic method, with few exceptions due to practical reasons ... Most primers start with three phonemes 'nun', 'nein', 'mein' and make the text harder to read for less talented learner for no apparent reason. More interesting and easier to read and write are words like 'Leo', 'Lisa'. Only after mastery of 2-sound syllables should we progress to three-sound syllables. Then it will be much less difficult, especially since they can be introduced with enough mastered grapheme-phoneme material.

2.4. Italian

In Italian, it was difficult to find essays evaluating various readers. The problem of reading and spelling acquisition is much less prominent in a shallow orthography. The chosen text for analysis is a first-grade reader 'A come ...' by a well-known publisher [57]. The first 50 pages were digitized.

2.5. Comparison of Language Corpora

Looking at all the 'Primers' across languages, four main approaches become apparent by inspection; the first two follow the Phonics approach of teaching regularities and word structures along with the introduction of new graphemes:

1. Slow progression with some practice (including grapheme, syllable and word structure)
2. Slow progression with a lot of practice (including grapheme, syllable and word structure)
3. Progression based on introduction of new letters
4. No apparent progression at all (Italian text is simply a number of stories)

From easiest orthography to most difficult one, we see that Phonics comes into play more so for English and French than for Italian. Italian book shows no progression other than practice through texts. There may be books that have a different approach on the market that we are not aware of. The English

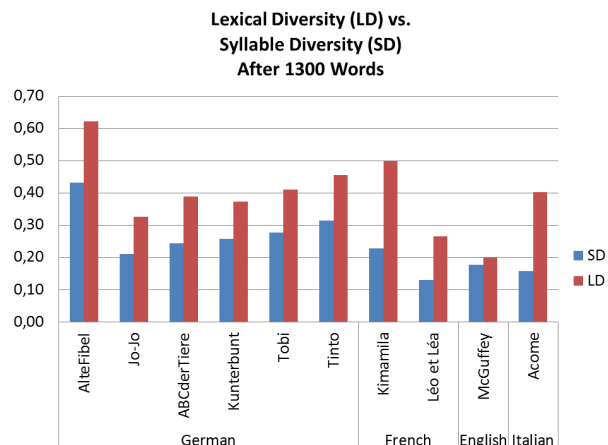


Figure 1: Statistics for each of the analyzed primers after 1300 words. LD=Language Diversity (Types/Tokens). SD=Syllable Diversity, using counts for types and tokens at syllable level.

text shows a slow progression with some practice of new concepts within texts before moving on to the next level. There is a clear difference between the two French texts. While both have a clear and structured progression, with every page introducing new items that are then practiced extensively on that page and used on subsequent pages. 'Léo et Léa' places much more emphasis on practice within the book than 'Kimamila'. The former has a similar concept as the 'McGuffey' primer. Looking at the lexical complexity (language diversity) in Figure 1 we can see that the two primers behave similarly in this respect, a lot of practice for the introduced words (low LD = type-token ratio of words). The latter is more closely comparable to 'ABC der Tiere', a simple syllable approach to German that emphasizes practice and simplicity at the beginning. The other chosen German primers relate more closely to the Italian approach of treating the orthography as having a simple phoneme-grapheme correspondence. They focus mainly on introducing new letters. (Newer versions of these primers incorporate syllable based structure into their progression.) Figure 1 does not show a large difference in lexical diversity at the word level. Looking at the SD measure (type-token ratio of syllables) it can be seen that there is a striking difference between the old primer and the new ones in that both syllable level diversity and word level diversity is significantly larger, giving more practice to different combinations of letters and phonemes over repeating the same combinations.

3. Automated Data Analysis

3.1. Alignment

The alignment of a letter sequence v and a canonic transcription w is derived from their Levenshtein distance, i.e. the minimum edit costs to transform v into w . The edit operations are substitution, deletion and insertion. There is no shared vocabulary between the sequences v and w . As an example, substituting letter 'X' by phoneme /X/ is not a zero-substitution. Therefore, a naive cost function assigning cost 0 to zero-substitutions and 1 to the other operations cannot be applied. Instead we make use of the more flexible PermA approach [58] defining edit costs c in terms of conditional probabilities. The cost of substituting letter v_i by phoneme w_j (i and j refer to their

position in the respective sequence) is thus given as follows: $c(v_i, w_j) = 1 - P(w_j|v_i)$. Insertion and deletion costs are derived by introducing empty letters and phonemes ' '. The letter deletion cost is thus defined as $c(v_i, -) = 1 - P(-|v_i)$, and the phoneme insertion cost as $c(-, w_j) = 1 - P(w_j|-)$. Details on smoothing and permutation techniques to derive the underlying letter-phoneme co-occurrence counts can be found in [58].

In order to gain a better view of the alignment output, there are examples given for each of the languages processed by the system. Some limitations to the computation of the entropy are evident. For example, *They;D...'+eI* will result in the pairs (T,D)(h,)(e,)(y,+eI). A more didactic alignment would have been (Th,D)(ey,+eI). However, the same method is used consistently throughout the texts in all languages and the result is a valid indicator of the entropy. (Future work will include a post-processing to align phonemes with graphemes, such as <th> or <ey> rather than letters. However, an important aspect of difficulty in orthography acquisition relates to multi-letter graphemes, therefore this measure may even be a more accurate reflection of difficulty than the exact alignment between graphemes and phonemes.)

English:

T h e y;D _ _ ' +eI
a r e;' +A: _ _
a l l;' +O: _ l
i n;' +I n
t h e;D _ ' +@
s h a d e;S _ ' +eI d _
n o w;n ' +aU _

French.

l e;l @
c h a t;_ S a _
I l;i l
s ' a f f a l e;s _ a _+. f a l _
s u r;s y R
l e;l @
l i t;l i _
P u i s;p H i _
i l;i l
s e;s @
l a v e;l a v _

German:

H a f e r;h +a:+ f 6 _
H e i d e;h _ +aI+ d @
H e r d e;h +e:6 _+ d @
H a l l e;h +a _ l+ @
D e r;d +e:6 _
D o m;d +o: m
i s t;?+ +I s t
h o c h;h +o: _ x

Italian:

g l i;_ L +i
a l l u c i;a _ ll+. u+. tS i
s i;s +i
t o c c a;t +o _ kk+. a
s o l l e t i c a;s o _ ll+ e+ t i+ k a
p i z z i c a;p +i _ tts+ i+ k a

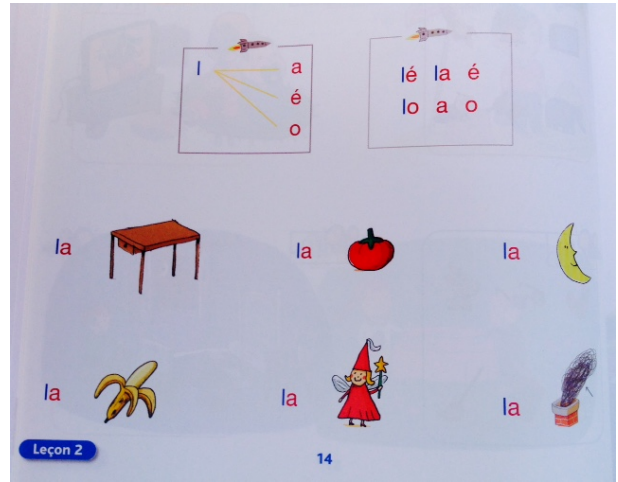


Figure 2: First page in French primer with low entropy.

3.2. Measure of Difficulty

According to Seymour [5, p. 146], European languages have different orthographic depth that can be sorted into levels of difficulty. Using the entropy measure suggested by [59] this ranking can be quantified. While there are other measures of complexity, this paper concentrates only on the phoneme-grapheme correspondence that defines orthographic depth.

We estimate the orthographic depth with the following measures at the phonemic levels. Conditional Entropy, H , can be seen as a measure of complexity for the process of reading (the reader transcribes graphemes into phonemes $H(PHO|GRA)$) and writing (the reader transcribes phonemes into graphemes $H(GRA|PHO)$). PHO stands for the set of phonemes, while GRA stands for the set of graphemes. For beginner readers, this set contains the number of graphemes seen so far in their studies. Therefore, starting with a lower number of graphemes, that have a clear phoneme-grapheme correspondence would result in a low entropy measure. Figure 2 shows a set $GRA = \{<l>, <a>, <e>, <o>\}$ and $PHO = \{/l/, /a/, /e/, /o/\}$, the combination of these exhibiting an entropy of 0, given the reading task and the information that the child has learned up to now. With each additional page in the book, more graphemes and phonemes and more complex interrelationships between the two sets are introduced. The entropy measure reflects how much additional information is needed in order to choose the correct correspondence or the uncertainty given previous knowledge. In languages where phoneme, syllable, and morpheme information is needed for the transcription process, this measure will be higher.

Entropy complexity for reading is given by Equation 1:

$$H(PHO|GRA) = - \sum_{x \in GRA} p(x) \cdot \sum_{y \in PHO} p(y|x) \cdot \log p(y|x) \quad (1)$$

Entropy complexity for spelling is given by Equation 2:

$$H(GRA|PHO) = - \sum_{y \in PHO} p(y) \cdot \sum_{x \in GRA} p(x|y) \cdot \log p(x|y) \quad (2)$$

$H_{read}(n)$ and $H_{write}(n)$ are to be plotted as a function of n , the number of words seen so far and are defined as the respective entropy complexities given up until word n :

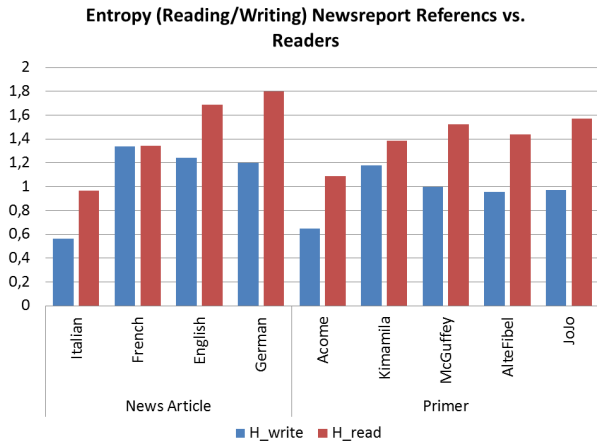


Figure 3: Comparative final H_{read} and H_{write} for selected readers compared to a random newspaper article of around the same length as the primers

$$H_{read}(n) = H(PhO_n | GRAn) \quad (3)$$

and

$$H_{write}(n) = H(GRA_n | PhO_n), \quad (4)$$

where PhO_n and $GRAn$ contain all phonemes and letters seen in the first n words. Figure 3 compares the Entropy measure between selected primers and randomly chosen newspaper articles representing normal language entropy. It can be seen that the languages have different complexity and that the chosen primers are an approximation of the full complexity. The results section will depict H_{read} and H_{write} as a function of n , the number of words seen so far, in increments of 5.

3.3. Measure of Progression

After quantifying complexity of languages according to their orthographic depth with the estimate of entropy measure, the question of progression is to see how the beginning books ramp up to reach this complexity. We look at two measurements that can be examined visually for the curves shown in the results section.

Starting Point: A low start in complexity shows that the material is simplified for both reading and writing complexity.

Steepness/Slope: Slower rise reflects amount of practice that a primer provides for a given level of complexity.

Figure 4 and 5 plot Entropy for a non-didactic random newspaper text for each of the languages from both reading and writing perspective in order to show what the curve would look like without any progression. (This curve looks similar for any chosen text because entropy is based on phoneme-grapheme correspondence and not words. Any non-didactic text covers normal use of graphemes within a short amount of time.)

4. Results

Reading:

Figure 6 depicts German primers in their progression from the point of view of reading. 'Tinto' starts high and remains flat. 'Kunterbunt' starts low and progresses to a high level. 'Jo-Jo'

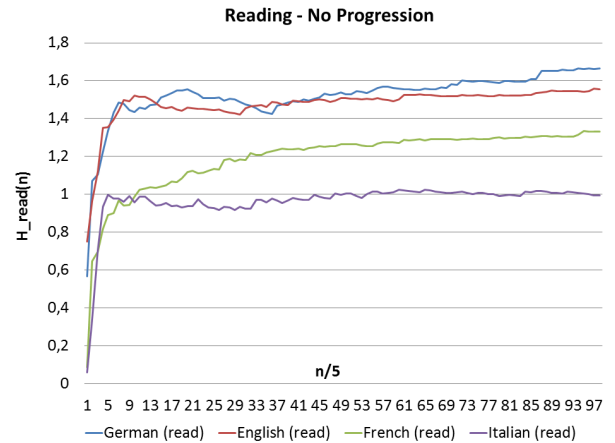


Figure 4: Entropy without progression from reading point of view.

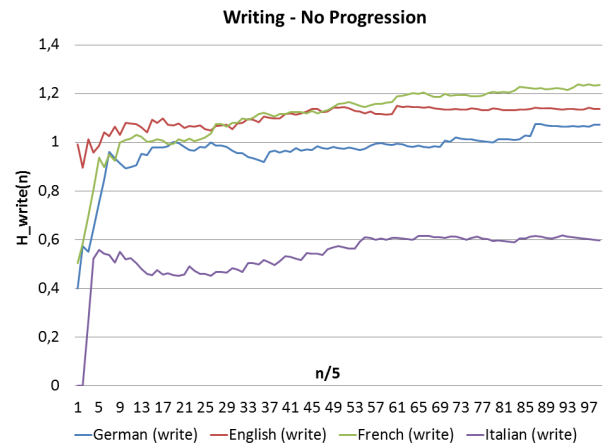


Figure 5: Entropy without progression from writing point of view.

starts high and remains flat. The old primer is similar without going quite as high. 'Tobi' and 'ABC der Tiere' start low and move up slowly. They will be used to compare their slope of learning to primers in other languages.

Figure 7 shows that 'Tobi' has a much faster progression than any of the other primers. The Italian primer is an outlier in that it has no progression but starts at the level of Italian orthographic complexity and remains level. 'Kimamila' and 'McGuffey' choose a rapid ascent, showing little practice at each level, yet more than the German primer. There are some steps visible in the progression. In comparison, 'Léo et Léa' spend a lot more time on the lower level of complexity before moving up slowly.

Writing:

German primers differ in their speed and steepness of progression as shown in Figure 8. The old primer 'Alte Fibel' has a clearly visible staircase that attains the full height of German complexity. 'Tinto' starts high and moves in steps to the full complexity. 'Kunterbunt' starts low and has the steepest ascent. 'Tobi' and 'ABC der Tiere' are primers that have a steady and slow climb in complexity. They are compared to primers in other languages. Figure 9 shows that even though writing has

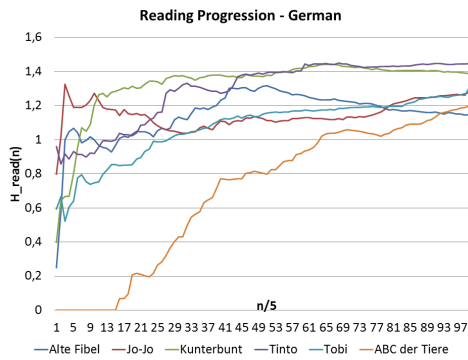


Figure 6: Reading progression for all German primers.

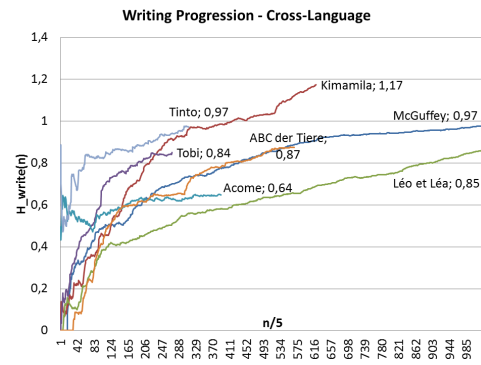


Figure 9: Writing progression for primers across languages, including the German primer with the lowest slope.

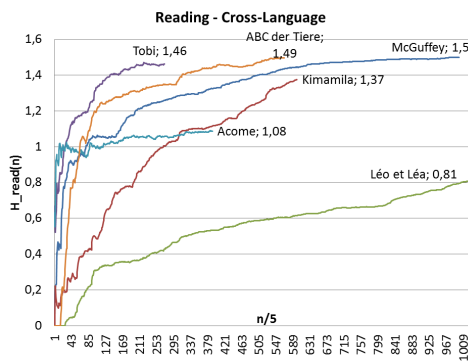


Figure 7: Reading progression for primers across languages, including the German primer with the lowest slope.

a comparative complexity for the elementary texts as French and English, the progression in the text is much more intense even for the primer with the slowest progression. In comparison, 'ABC der Tiere' and 'Tobi' are joined by 'Tinto' as the example for the other German primers that behave similarly. It can also be seen that there are two very different approaches for French. 'Léo et Léa' spends a lot more time practicing at a simpler level than 'Kimamila' that moves forward in complexity steadily. 'McGuffey' primer for English chooses a middle path between the two. 'Acome' is an outlier in that it has no progression but reflects the very low level of orthographic complexity of Italian.

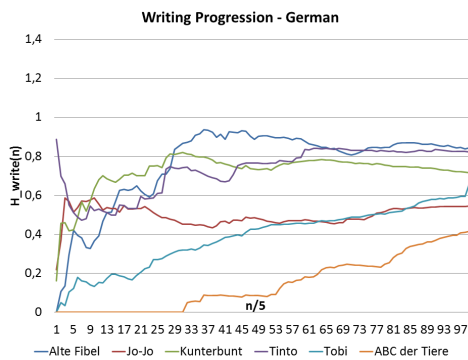


Figure 8: Writing progression for all German primers.

Figure 10 depicts the scatter plots for both reading and writing view of slope vs. intercept, showing the primers that fit into each of the quadrants as marked. Léo et Léa is the only primer that starts slow and adds practice at each stage for both directions (reading and writing). All other primers can be interpreted with respect to that. Most primers have a steep entry for both reading and writing. 'Kimamila' and 'ABC der Tiere' are similar in that they have a leveled start but lack the practice that the green quadrant books offer. 'Tobi' has a slightly more difficult entry and could also benefit from more practice.

5. Discussion

In this paper we have analyzed the beginnings of several primers in their progression with respect to letter and phoneme transcription. These didactic texts were compared across languages and across first-grade primers that are designed as learning materials. We have shown that there are different levels of difficulty in texts for various languages. The assumption is that didactic primers that are designed to teach reading and writing should start with a low level of complexity and rise slowly, with lots of practice. The analysis of the German primers in comparison to primers in other languages has shown that the German primers progress at a much more rapid pace to more complex levels than their counterparts, even taking into account that German orthography may not have the same final complexity as some of the other languages with deeper orthography. In addition, German primers offer a lot less reading practice than any other of their counterparts in other languages. For the German primers we also found a measure of distinguishing an older primer from newer ones by looking at the syllable level repetition. It was shown that the old primer has a much larger variation in both word and syllable presentation. There are lessons to be learned from this work, presenting new ideas on how German primers can be adapted to offer more practice at phoneme, grapheme, syllable and word level to obtain a less steep learning curve for children in first grade. There is also a need for increasing research regarding the presentation of texts in primers and their effect on spelling and reading abilities of children over time.

		Acome	Jo-Jo	Kunterbunt	Alte Fibel	Léo et Léa	Tinto	Tobi	Kimamila	McGuffey	ABCd.T.
Read	slope	0.05	0.08	0.10	0.10	0.12	0.14	0.21	0.22	0.23	0.32
	int.	0.80	0.88	0.92	0.75	-0.23	0.75	0.33	-0.26	-0.01	-0.44
Write	slope	0.03	0.07	0.04	0.08	0.16	0.10	0.22	0.29	0.18	0.23
	int.	0.44	0.29	0.54	0.42	-0.38	0.38	-0.37	-0.78	-0.36	-0.68

Table 1: Intercept and steepness of learning curve as defined by the best fit equation: $y = slope * \ln(x) + int.$ (= *intercept*). Low numbers in both relate to a slow start and a lot of practice at each level of difficulty before moving on. A high intercept with low slope can mean a steep entry at the full level of complexity.

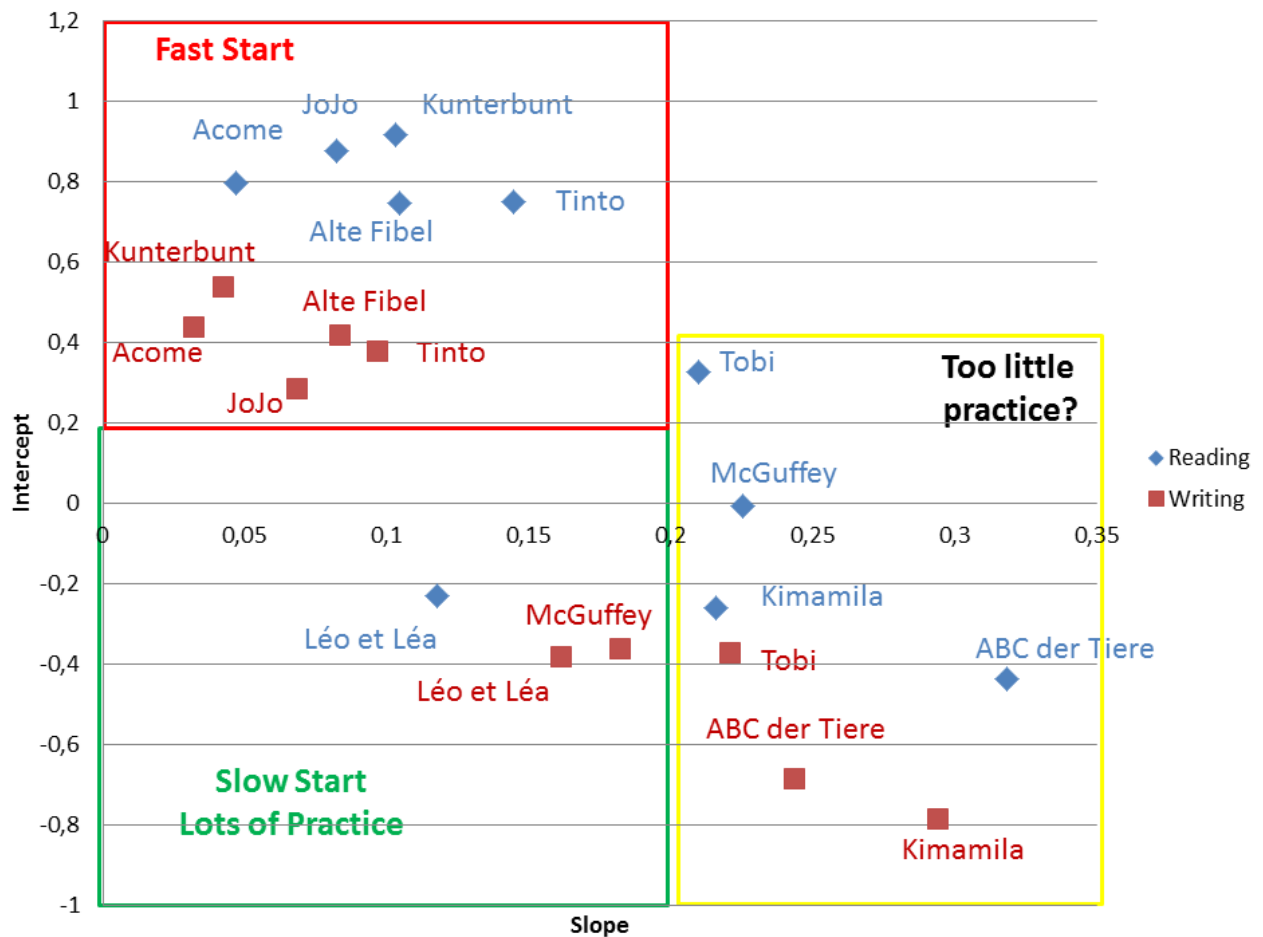


Figure 10: Slope vs. Intercept from Table 1 comparing progression in quantitative manner for primers.

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