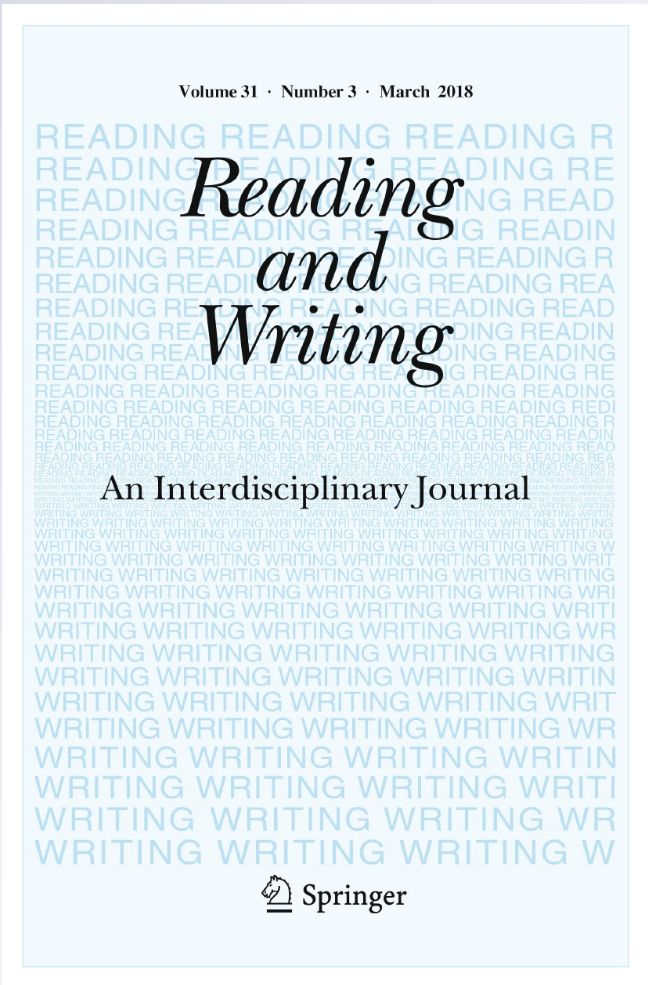
Completely illiterate adults can learn to decode in 3 months

Régine Kolinsky, Isabel Leite, Cristina Carvalho, Ana Franco & José Morais

Reading and Writing
An Interdisciplinary Journal

ISSN 0922-4777
Volume 31
Number 3

Read Writ (2018) 31:649-677
DOI 10.1007/s11145-017-9804-7



Springer

Read Writ (2018) 31:649–677
https://doi.org/10.1007/s11145-017-9804-7

Completely illiterate adults can learn to decode in 3 months

Régine Kolinsky[1,2] · Isabel Leite[3] · Cristina Carvalho[4] · Ana Franco[5] · José Morais[6]

Published online: 1 December 2017

Abstract The purpose of this case series was to explore whether adults who did not have the opportunity to acquire reading skills during childhood are able to do so rapidly if trained with an adequate literacy program. After 14 weeks of training with a new, optimized, literacy course based on cognitive research, six out of eight participants became able to read words they had never encountered, hence demonstrating that they were definitely engaged in decoding processes that allow autonomous reading. Moreover, they showed enhanced phonemic sensitivity and phonological memory. The latter finding implies that functional changes can take place rapidly outside the reading domain even when reading is acquired in adulthood. Thus, there is no major plasticity impediment preventing rapid eradication of illiteracy in adults.

Keywords Adult illiteracy · Adult literacy · Decoding · Reading instruction · Phonics

✉ Régine Kolinsky
rkolins@ulb.ac.be

[1] Fonds de la Recherche Scientifique – FNRS, Brussels, Belgium

[2] Unité de Recherche en Neurosciences Cognitives (UNESCOG), Center for Research in Cognition & Neurosciences (CRCN), Université Libre de Bruxelles (ULB), CP 191, 50 Ave. F. Roosevelt, 1050 Brussels, Belgium

[3] Department of Psychology, University of Évora, Évora, Portugal

[4] Lisbon, Portugal

[5] CRCN, ULB, Brussels, Belgium

[6] UNESCOG, CRCN, ULB, Brussels, Belgium

Introduction

According to the most recent worldwide data (United Nations Educational, Scientific and Cultural Organization, UNESCO, 2016), over 2005–2014, 15% of the people aged at least 15 years ($\sim$ 758 million individuals) lacked any reading and writing skills, and adult illiteracy rates remained substantial even in some emerging and European countries (e.g., Brazil: 9%; Portugal: 6%).[1] Discounting people with cognitive and/or emotional impairments, these high rates are mainly explained by the lack of adequate learning opportunities. Due to socioeconomic or cultural reasons, many persons do not go to school in childhood, or only go for some months or years on an irregular basis.

Adult illiteracy has long been recognized as a serious problem for the sustainable development of contemporary societies (United Nations, UN, 1961) and recently literacy and schooling became considered as human rights (UNESCO, 1990; for a review: Oxenham, 2008), thanks to the growing recognition that adult illiteracy often condemns to poverty, poor health and social exclusion not only the illiterate adults themselves but also their children (e.g., Oxenham, 2008; Post, 2016). Various literacy campaigns have been launched since the UN Development Decade of the 1960s, some quite successfully. For example, in China the illiterate population decreased by 100 million between 1990 and 2000–2004 (Lind, 2008). Yet, although worldwide adult literacy rates slowly but steadily improve over time, in most countries these gains have been achieved exclusively through schooling for the young (Barakat, 2016; Lind, 2008; De Grauwe et al., 2015). Furthermore, the studies that attempted at evaluating adult literacy programs report modest, disappointing, gains (e.g., Abadzi, 2003, 2004; Royer, Abadzi, & Kinda, 2004). For instance, a review of the World Bank (Abadzi, 2003) reported that of the 32 literacy programs for which statistics were available, the median completion rate was 78%, median attendance was 62%, and pass rate of a final test was 56%. Consistently, scientific studies that either compared illiterate adults with both literates who learned to read in childhood and *ex-illiterates* who did not attend school in childhood but learned to read later on (e.g., Dehaene et al., 2010) or tracked adult reading acquisition longitudinally (Braga et al., 2017) showed modest levels of decoding after adult instruction. In short, although reading can be clearly taught to adults, only but a few learners become fluent readers at the end of a literacy course.

What are the reasons for the modest efficiency of adult literacy programs? As reading acquisition requires the reorganization of various brain systems (Dehaene et al., 2010), it is theoretically possible that adults do not develop the neuronal reading circuits as easily as children do and hence have more difficulty in achieving fluent reading (e.g., Abdazi, 2012). Unfortunately, to our knowledge no study has compared reading acquisition in children and adults to see to what extent gains are similar when instruction time and method are identical. Yet, although the influence of instruction age has been studied within a restricted age range, typically by comparing reading progress in children starting the acquisition at age 5 versus 7, an

[1] As acknowledged by UNESCO (2016), these data may overestimate actual literacy levels, as they are not based on any test but rather on either self- and third-party declarations or educational attainment proxies.

earlier onset of reading instruction by 1–2 years leads to no advantage in long-term reading achievement (e.g., Suggate, Schaughency, & Reese, 2013). In addition, reading relies on the same neuronal circuits and leads to similar brain reorganization when its acquisition occurs in adulthood as when it occurs in childhood (e.g., Braga et al., 2017; Dehaene et al., 2010). Thus, the available evidence does not support the assumption that there is a sensitive period for reading development during childhood or even until at least middle adulthood.

The modest efficiency of reading interventions in adulthood probably reflects other limitations, among which States' lack of involvement and support to the small-scale and underfunded initiatives of NGOs, which in some cases go beyond their areas of expertise and therefore are insufficiently prepared (e.g., Abadzi, 2004). This in turn may lead to the use of inadequate instruction methods and/or reading materials (which may also be the case in other contexts, see e.g., Braga et al., 2017). Nonetheless, the scarcity of information, in the majority of adult literacy studies, about the instruction methods and time devoted to instruction as well as about the level of ability before and after instruction makes it difficult to rigorously assess the effects of literacy programs. Without such knowledge it is not possible to infer how adult literacy programs can be improved and scaled up (Robinson, 2005).

The present study

Given that evidence on reading acquisition in adult illiterates is scarce, it is important to show that adults who did not have the opportunity to acquire reading skills during childhood are able to do so rapidly if trained with an adequate literacy program. To this aim we elaborated and applied to a small group of completely illiterate women a new literacy course aimed at optimizing reading acquisition, while fully controlling the instruction provided and repeatedly measuring its effects. The set of behavioral measures was defined in order to explore how the processes involved in reading acquisition develop and to investigate the skill level up to which these students can learn to read in a very short period of time, namely 3 months.

The literacy course

The course, that we called *literacy for illiterate adults* (LIA), is based on the phonics approach, with four overarching principles: (1) to develop first the comprehension of the alphabetic principle, namely that letters, alone or in combination (graphemes), stand for phonemes; (2) to teach the orthographic code, namely the correspondences between graphemes and phonemes (GPCs, here of European Portuguese) in a progressive way, from the simplest to the most complex, capitalizing on current knowledge about the possible stumbling blocks in reading acquisition (e.g., Dehaene, 2009); (3) to teach lower- and upper-case letters in parallel; and (4) to combine systematically reading and handwriting activities.

The phonics approach is reported to elicit the best results in both children (e.g., Ehri, Nunes, Nunes, Stahl, & Willows, 2001) and adults (see discussion in Kolinsky, Carvalho, Leite, Franco, & Morais, in revision). Accordingly, we considered crucial to develop explicit representations of speech, particularly of phonemes. Indeed, reading in an alphabetic script is contingent on the understanding of the alphabetic principle, and phonemic awareness develops hand in hand with the acquisition of this principle (e.g., Morais, Alegria, & Content, 1987b) as illustrated by the fact that it is virtually absent in illiterate adults (Morais, Bertelson, Cary, & Alegria, 1986; Morais, Cary, Alegria, & Bertelson, 1979), especially for phonemes that are not pronounceable in isolation (e.g., plosives, cf. Morais et al., 1986). Therefore, LIA combines opportunities for insight and learning of GPCs of increasing level of difficulty, which is the best way to teach word decoding (Byrne & Fielding-Barnsley, 1989).

Initially, the students' attention is directed to the phonological length of word pairs displaying an incongruent relation with size of the referents (e.g., Kolinsky, Cary, & Morais, 1987) as well as to the number of syllables included in these words and their associated articulatory gestures. This illustrates that one needs, for instance, to close and open the mouth three times to pronounce the word "butterfly", whereas one mouth movement is enough to produce the word "cat". Next, LIA relates that notion to the length of written words, illustrating that phonologically longer words need in principle more letters to be written than phonologically shorter words. After exercising this rough correspondence, each syllable is isolated in turn, illustrating the left–right directionality of reading/writing, a notion that illiterate adults also lack (e.g., Kolinsky, 2015). Still in the first lesson, phonemic awareness and the understanding of the alphabetic principle are then promoted by insisting, simultaneously, on sounds, articulatory gestures, and letters, illustrating for instance that the /f/ sound of the written syllables <fi> and <fu> corresponds to the same articulatory gesture and hence is written with the same letter, whereas /i/ and /u/ correspond to different articulatory gestures and are, therefore, written with different letters. The understanding of the alphabetic principle is then tested using new consonant–vowel (CV) combinations. For instance, after learning to decode <fi> and <fu>, <vi> and <vu> and the sound of <lu>, the students are asked to guess how to pronounce <li>.

To decode implies obviously to master the language's orthographic code. The European Portuguese code is not fully transparent, hence learning difficulty increases from consistent and regular GPCs to inconsistent and irregular ones (e.g., Seymour, Aro, & Erskine, 2003; Waters, Seidenberg, & Bruck, 1984). We also took into account the specific visual difficulty that mirrored letters (e.g., <b> <d>) represent for illiterate adults, who, like preliterate children, struggle at discriminating mirror images (e.g., Kolinsky et al., 2011). Based on these notions, the order of GPCs teaching in LIA obeys five principles. (1) *Phoneme accessibility*: From the easiest to the most difficult GPCs in terms of access to the phonological value of the corresponding segments, with phonemes pronounceable in isolation (vowels, fricatives and liquids) worked out before plosives. (2) *Degree of consistency*: From higher to lower degree of consistency, with for instance, the letter <i> introduced before <o> because in European Portuguese, almost always, <i> is pronounced /i/ and /i/ is written <i>, whereas the pronunciation of <o> depends on its position in the word. (3) *Grapheme complexity*: From simpler to more complex graphemes, with single letters introduced before digraphs and letters with a diacritic. (4) *Visual difficulty of letter recognition*: From letter pairs of higher to lower visual discriminability, with for instance <d> and <b> introduced quite late in the course. (5) *Phonological structure*: From simpler to more complex syllabic environment, initially only CV sequences, then CVCV ones, then rapidly other simple short structures (VCV and CVV), then sequences ending with a C as well as tri-syllables, and, much later, items with an initial or medial CC cluster.

Accordingly, the course is subdivided in 17 *modules* of increasing complexity. Each module is taught in two or three lessons, for a total of 41 lessons, and corresponds to the introduction of one (or more) GPCs, concepts or orthographic rules. For instance, the first two modules (5 lessons) aim exclusively at the acquisition of the alphabetic principle and hence present only simple letters (no digraphs), specifically vowels and non-plosive consonantal phonemes (fricatives and liquids), and use grapheme-phoneme pairs in a consistent way, first in short items with simple syllabic structure (CV; e.g., <vi>—meaning *saw*), next in longer items with the same structure (CVCV; e.g., <vivi>—meaning *lived*). Inconsistent GPCs are introduced at module 3, together with unstressed vowels and a new structure (VCV; e.g., <uva>—meaning *grape*). Some simple contextual and positional rules are introduced in modules 4–6, together with simple digraphs. For instance, in module 4, the phonemes /R/ and /s/, which had already been introduced in module 2 but only in word initial position, in which case they are always written <r> and <s>, respectively, are now also introduced in intervocalic position, in which case they are written <rr> and <ss>. In module 5, the students learn the GPCs <r>-/ɾ/ and <s>-/z/, namely the pronunciation of the simple graphemes when they occur in intervocalic position. New graphemes and syllabic structures (e.g., CVC) are added progressively, but plosives (<t>, <d>) and mirrored letters (<b>) do not appear before modules 11 (lesson 24) and 12, respectively. Later, other contextual rules and new graphemes are presented, including nasal diphthongs (e.g., <ãe>-/ɐ̃j/). Complex onsets illustrating the CCV syllabic structure (e.g., <pr> as in <praça>— meaning *square*) do not appear before module 16. The 17th and last module is devoted to the highly inconsistent letter <x>. Note that the number of lexical items is very limited with the GPCs of the first two modules. In order to guarantee a sufficient number of items for teaching and practicing, we therefore used mainly pseudowords in those modules. On the contrary, in further modules we mainly used words and sentences: First very short noun phrases at the beginning of module 3 (e.g., "a luva", meaning *the glove*; "o ralo", meaning *the drain*), then three to four-words sentences later on in module 3 (e.g., "vi a lua", meaning *I saw the moon*; "ela leva a sua fivela", meaning *she takes her buckle*), and then longer and longer sentences, with a maximum (from module 10 on) of eight to nine words (e.g., "o jovem José leva as melhores laranjas à avó", meaning *The young José takes the best oranges to grandma*).

The third overarching principle of LIA, that lower- and upper-case letters are taught in parallel, was motivated by the fact that mastering the alphabet requires to acquire abstract letter units, namely to consider as identical symbols that may be physically quite different, as <A> and <a>. According to current neural proposals, letter representations are activated regardless of their visual characteristics (e.g., Dehaene, Cohen, Sigman, & Vinckier, 2005; Grainger, Rey, & Dufau, 2008). Yet in children the acquisition of abstract letter units proceeds slowly (Perea, Jiménez, & Gomez, 2015; Thompson, 2009). Teaching lower- and upper-case letters in parallel may accelerate this process. The last overarching principle, namely that reading and handwriting are taught and exercised jointly throughout the course, was not meant to allow written production to develop substantially in the very short instruction period we used. Yet training handwriting may benefit reading acquisition, including in adults: In literate adults, the recognition of novel characters is better when these are copied manually rather than typed on a keyboard (e.g., Longcamp et al., 2008).

Assessing the effectiveness of LIA

LIA was applied to eight illiterate women during 14 weeks (Table 1); 1 and 2 weeks before (T1 and T2), they were pretested to obtain a baseline controlling for familiarity with the tasks and materials. LIA effectiveness was examined twice

Table 1 Illustration of the design: Testing sessions before (T1 and T2), during (T3 and T4) and immediately after (T5) the literacy course, and tests at each session

	Testing session							
	T1	T2		T3		T4		T5
Weeks	1	3		*5*		*10*		16–17
Literacy course			*Modules 1–2* (*Pseudowords*)		*Modules 3–8* (*Words*)		*Modules 9–17* (*Words*)	
Tests								
Anamnesis	X							
Edinburgh inventory	X							
MMSE	X							
Snellen numerical chart	X							
Audiometry	X							
Letter knowledge	X	X		*X*		*X*		X
Complex grapheme knowledge	X	X				*X*		X
Letter-identity matching	X	X		*X*		*X*		X
Reading items with GPCs of modules	X 1–8	X 1–8		*X 1–8*		*X 1–10*		X 3–17
Reading pseudowords with GPCs of modules								X 3–17
Metaphonological abilities	X	X		*X*		*X*		X
Phonological memory	X	X		*X*		*X*		X

X test was presented, *italics* period of application of the course during the course (T3 and T4) and once (T5) shortly after its end. We screened students' letter and complex grapheme knowledge, checked for their ability to match letters across case, and examined their reading and metaphonological abilities, namely the degree to which they were sensitive to and able to explicitly manipulate phonological units such as syllables and phonemes. Phonological memory was also examined, because children data support the idea that reading acquisition modulates verbal memory (e.g., Nation & Hulme, 2011). Here, we checked whether the same holds true when literacy is acquired in adulthood.

Method

Participants

We recruited all but one (constantly agitated and not motivated) of the women coming from a small community of Romani people located in Lisbon and attending a non-governmental community center, and matching three criteria: Being Portuguese native, completely illiterate, and suffering from no mental disease or sensory deficit. The eight participants had either received no schooling at all during childhood (4 participants) or attended school in a very irregular way for one (3 participants) to two (1 participant) years. They were aged 40 years on average, from 22 years 7 months to 64 years. They were volunteers, gave their informed consent, and received 400 € for course attendance and participation to the tests. They were fully functional in their daily lives, socially integrated and in good health at the time of the study. None suffered from cognitive impairment, as attested by their Mini-Mental State Examination scores (Guerreiro et al., 1994): on average, 24.75; minimum: 21, which is in the range of the scores usually observed on unschooled adults (Crum, Anthony, Bassett, & Folstein, 1993). All were right-handed (Edinburgh inventory), had normal or corrected-to-normal visual acuity (Snellen numerical chart), normal audition (as estimated through audiometry), and reported no neurological disease.

Intervention: literacy course

LIA was applied through group instruction at the community center by two of the co-authors, who gave, for approximately 14 weeks, three lessons (of 2 h each) per week. One taught the content of the lessons while the other monitored the students' individual performance and provided additional support to those in greatest need. LIA is based on the principles outlined in the Introduction (detailed description of the course will be published elsewhere). Except for the first, each lesson began with a revision, either of the material of the last lesson when it was a module including several lessons (which was the case of most modules), or of the whole preceding module if it was the first lesson of a new module. The final lesson was a general revision. Students also received homework, which observance was checked, and which was corrected most of the time individually after the class, providing an opportunity to give individual feedback.

Literacy tests

Testing was applied at the community center by three of the co-authors. Several tests were adapted from those developed for a study commissioned by the National Reading Plan of the Portuguese Ministry of Education (Morais et al., 2010). All literacy tests but one (pseudoword reading) were presented either four or five times (Table 1).

Letter and complex grapheme knowledge

Participants had to identify the written strings orally. The letter identification tests presented the 26 letters of the alphabet in lower-case in one test and in upper-case in the other. The complex grapheme identification test used 30 lower-case digraphs (e.g., <lh>) and eight lower-case letters with diacritics (e.g., <ã>).

Letter-identity matching

Each one of the 64 trials began with a 500 ms fixation cross in the middle of a computer screen and then presented two letters simultaneously, one on the left, the other on the right (Arial 120 white font, black background) until participant decided whether the two letters were identical or different independently of case variation by pressing either the s or the l key, respectively, of a computer Azerty keyboard. Eight different letter identities were used: <a>, <e>, <o>, <u>, <n>, <r>, <s>, and <v>. There were 5 types of trials: 16 *fully different*, where letters differed in both identity and case; 16 presenting different letters in the same case; 16 *identical*; and 16 with the same letter presented in different cases. The latter were further characterized as a function of cross-case similarity, distinguishing between letters visually similar across case (<V v>, <S s>, <O o>, <U u>; 8 *same letter, different case, similar trials*) and letters visually different across case (<R r>, <N n>, <A a>, <E e>; 8 *same letter, different case, dissimilar trials*). Stimuli presentation and data recording were controlled by *PsyScope X B57* (Cohen, MacWhinney, Flatt, & Provost, 1993) running on a MacBookPro.

Word and pseudoword reading

Items were presented in ascending order of difficulty, starting from those with GPCs studied in module 1, next those with GPCs of module 2, and so on. Due to the very long testing time, not all items were presented at each testing session (except for those with GPCs of modules 3–8; Table 1), and not all participants were presented with all items. For T1 to T4, there were 10 items per module. If a participant was unable to read six items correctly, the experimenter proceeded to the items of the next module. At T5, the same principle was adopted but using a criterion of four out of eight items. The total allocated time was 45 min per test; if there was time left, participants were then presented with the remaining items. For each GPC, two lists of items were created and presented in alternation across the various testing sessions. Half of the items of each list had been presented in the classroom (*old* items), whereas the others had never been presented in the course (*new* items). In addition, at T3 and T4, items included either studied or unstudied GPCs (Table 1).

Items with GPCs of modules 1 and 2 were all pseudowords, whereas items with GPCs of further modules were all words. To allow comparison, pseudoword reading was evaluated at T5 using GPCs of modules 3–17, as in the corresponding T5 word reading test. The pseudoword reading test included 30 new items (half in upper- and half in lower-case; 2 per module, presented in ascending order of difficulty), with 20 min allocated for the task.

Metaphonological abilities

Three tasks of varying difficulty were presented, each using two lists of items presented in alternation across the testing sessions. In the *phonemic sensitivity test*, participants were presented with six panels, each with six drawings of common objects. On each panel, they were asked to point to the drawings corresponding to names of objects that started with a target phoneme. In the demo trial, for the phoneme /f/, they heard six words uttered by the experimenter: “fita”, “fada”, “ferro”, “fumo”, “fato”. Their attention was directed to the fact that all words started with the /f/ “sound”. They were next presented with six drawings and asked to point to those corresponding to a name starting with /f/. On each panel there were from two to four images to be pointed to (total: 18), half with a name starting with a simple (C) onset (e.g., “faca”), the others with a name starting with a complex (CC) onset (e.g., “flor”).

Phoneme deletion requires more than conscious recognition of phoneme identity, as it involves intentional manipulations of segments, hence leading to lower performance than phonemic sensitivity, at least in children (e.g., Stanovich, Cunningham, & Cramer, 1984; Morais et al., 2010). *Syllable deletion* is far easier, including for illiterate adults (Morais et al., 1986). The syllable and phoneme deletion tests included 18 disyllabic items each (15 with a C onset and 3 with a CC onset), plus two training trials with corrective feedback. In both tests, participants had to repeat part of a spoken pseudoword uttered by the experimenter after having deleted its initial part, either the first syllable (e.g.,/lilu/-/lu/) or the first phoneme (e.g., /lilu/-/ilu/). All expected responses were also pseudowords.

Phonological memory

In the *nonword repetition test*, participants had to repeat immediately a single nonword uttered by the experimenter. The stimuli were presented in ascending order of difficulty, with increasing syllable complexity (first all CVs, then CCVs) and length (from 1 to 6 syllables). The test included 24 items except at T1, where only 12 items were used; 2 training trials with corrective feedback were presented for each structure.

Data analysis

Except if mentioned otherwise, computations and analyses were performed using the open-source graphical statistical package *JASP* (JASP Team, 2016, Version 0.7.5.5, https://jasp-stats.org/). To evaluate progress, we used *regression coefficient analyses* (RCA), first calculating individual regression slopes for each participant and each score. RCA circumvents methodological problems of standard regression methods, which assume that observations are independent (Lorch & Myers, 1990); yet it assumes a linear relation between the predictor and dependent variable. We thus also calculated *relative gains* (RG), which take into account what could be improved given the pre-intervention performance level, according to the formula: [100 * (post-intervention score—pre-intervention score)/(maximum possible score—pre-intervention score)]. Given that, for practical reasons, we only collected two pre-intervention measures, we could not estimate a baseline trend. We thus decided to calculate individual regression slopes and RGs from T2 (the second pre-intervention measurement) to T5. This allows checking whether there is further progress once improvement due to familiarity with the test and/or material has been controlled for.

The slopes and RGs were then tested as reliably different from zero or not via one-sample t tests. Rather than estimating effect sizes (which for one-sample repeated measures tests and small samples remain biased even after correction, see e.g., Lakens, 2013), we also tested the same hypothesis using Bayesian one-sample t tests (see e.g., Rouder, Speckman, Sun, Morey, & Iverson, 2009, for a discussion on the advantages of this approach). More specifically, we used the Bayes Factor BF_{10}, which quantifies evidence for the alternative (H_1) relative to the null (H_0) hypothesis, using a Cauchy prior width of 0.707, looking at $BF{+}0$, which quantifies evidence for the one-sided alternative hypothesis that the population mean is larger than the test value (zero in the present case). The Bayes factor is directly interpretable as an odds ratio: A value of 1 means that data are equally likely to occur under H_0 (here, that either slope or RG equals zero) and under H_1 (here, that either slope or RG is greater than zero), and a value of 3 indicates that the data are three times more likely under H_1 than under H_0, which is considered as substantial evidence; odds greater than 10 are considered as strong evidence, those greater than 30 as very strong evidence, and those greater than 100 as extreme evidence for one hypothesis over another (Jeffreys, 1961). In addition, when necessary the Bayesian t test can also be interpreted as supporting H_0 by computing BF_{01}, the Bayes factor that quantifies evidence for H_0 relative to H_1. Although the Bayesian t test is more conservative than classic p values, multiple testing would inflate the risk for type I errors (false positives). To reduce as much as possible the number of one-sample tests, preliminary analyses of the various tests checked whether performance progress was affected by material manipulations and/or correlated between various measures.

Results

Letter and complex grapheme knowledge

In letter identification, we excluded responses on <w> and <y>, which are extremely rare in Portuguese and are not included in LIA. On the remaining 24 letters, both letter names and phonological values were accepted as correct responses. Although average performance was slightly better for upper- than lower-case letters (Appendix), case did not affect slopes significantly, as shown by a paired samples two-way t test, $t(7) = -0.108$, $p = .917$, 95% CI [− 4.777, 4.360], and confirmed by a Bayesian paired samples two-way t test, $BF_{01} = 2.959$ (i.e., there is some evidence favoring H_0). We thus pooled performance across case. As shown in Table 2, progress estimated on these averaged scores was highly significant on both slope and RG, reflecting the fact that all participants learned to recognize single letters (Fig. 1a). Performance was lower on complex graphemes, with two participants still struggling at T5 (Fig. 1b), although progress was significant (Table 2). Progress on letter and on complex grapheme knowledge was correlated, at least on RGs, $r(6) = .72$, $p < .025$ (slopes: $r(6) = .54$, $p < .10$).

Letter-identity matching

A repeated measure analysis of variance (ANOVA) on the individual slopes showed a significant effect of condition (5 levels), $F(4, 28) = 28.84$, $p < .001$, $\eta_p^2 = .805$, a result confirmed by a Bayesian repeated measures ANOVA, $BF_{\text{Inclusion}} = 1.401\text{e}+8$. Performance improved mainly for "same" trials including letters that are visually dissimilar across case, such as <A a> (Fig. 1c).

As we were mainly interested in examining the acquisition of abstract letter units, namely in the performance evolution on trials presenting identical letters in different case, we estimated a *cross-case similarity effect* by subtracting, on "same" trials, the performance on letters visually dissimilar across case (e.g., <A a>) from the performance on letters visually similar across case (e.g., <V v>). The average slope and RG of this effect were significantly negative (Table 2): Matching physically different letters was initially easier for letters that are similar across case than for dissimilar ones, but this difference decreased over time. All participants but one (S8, who did not learn to read; see next subsection) displayed such a decreasing effect (Fig. 1d).

Word and pseudoword reading

Response was considered as correct only when the item was fully correctly decoded (all GPCs correct). In line with the selection criterion for participating in the study (no reading at all), virtually all participants scored 0 at baseline (T1 and T2, Table 3). Post-intervention (T5), the progress in reading was robust, except for one participant who did not learn to read at all. Among the others, there were strong individual differences, with overall reading scores at T5 ranging from 43% (S3) to

Table 2 Average overall performance at each testing session (T) on each test, in % correct except for phonemic sensitivity (d'), average slopes and relative gains from T2 to T5 (in bold; standard deviations in brackets), and associated 95% one-sided confidence bounds (CB in brackets), unilateral t tests and Bayes BF_{10} Factors (BF+0)

	Testing session					Slope				Relative gain			
	T1	T2	T3	T4	T5	Average	95% CB	*t*	*BF*+0	Average	95% CB	*t*	*BF* +0
Letter knowledge	36.72	38.28	58.59	63.28	82.55	**13.75**	[10.19]	7.312****	369	**78.17**	[61.09]	8.671****	910.7
	[25.22]	[24.14]	[21.64]	[19.41]	[22.85]	[5.32]				[25.5]			
Complex grapheme knowledge	3.62	4.28	–	17.11	34.54	**9.56**	[5.67]	4.658****	41.65	**31.78**	[18.45]	4.517****	36.37
	[4.65]	[5.06]		[8.44]	[20.21]	[5.81]				[19.9]			
Cross-case similarity effect[a]	43.75	60.94	54.69	32.81	12.5	− **16.72**	[-11.28]	−5.819****	116.87	− **48.44**	[-32.03]	−5.594****	96.65
	[29.12]	[23.56]	[32]	[38.35]	[37.2]	[8.13]				[24.49]			
Reading words with GPCs of modules 3-8	0	0	4.41	54.02	56.51	**21.91**	[14.68]	5.74****	109.4	**56.51**	[37.55]	5.646****	101.1
	[0]	[0]	[9.41]	[29.16]	[28.31]	[10.8]				[28.73]			
Reading all presented GPCs, corrected score	0.24	0	15.84	29.94	41.55	**13.88**	[7.95]	4.436***	36.37	**41.55**	[23.12]	4.27****	28.6
	[0.67]	[0]	[10.6]	[15.41]	[27.52]	[8.85]				[27.52]			
Syllable deletion	43.75	65.56	70.69	84.72	79.17	**5.49**	[2.76]	3.807***	17.875	**54.54**	[22.8]	3.256**	9.95
	[29.76]	[18.95]	[21.6]	[17.76]	[26.18]	[4.08]				[47.38]			
Phoneme deletion	4.17	2.78	14.31	11.11	13.19	**2.81**	[-2]	1.107	0.899	**9.62**	[-9.43]	0.957	0.77
	[9.74]	[7.86]	[30.23]	[20.57]	[24.48]	[7.17]				[28.44]			
Phonemic sensitivity	1.4	1.82	2.32	2.52	2.68	**0.28**	[0.1]	2.959**	7.166	**32.63**	[9.2]	2.638*	4.997
	[0.86]	[1]	[0.79]	[0.72]	[0.52]	[0.27]				[34.98]			
Phonological memory	21.43	28.57	31.25	35.71	38.39	**3.39**	[1.29]	3.138**	7.717	**14.83**	[5.65]	3.136**	7.701
(7 participants)	[15.67]	[10.11]	[13.5]	[16.02]	[15.49]	[2.86]				[12.51]			

*$p \leq .025$, ** $p \leq .01$, *** $p \leq .005$, **** $p \leq .001$, ***** $p < .0005$

[a] For this effect, the absolute gain and BF-0 are reported

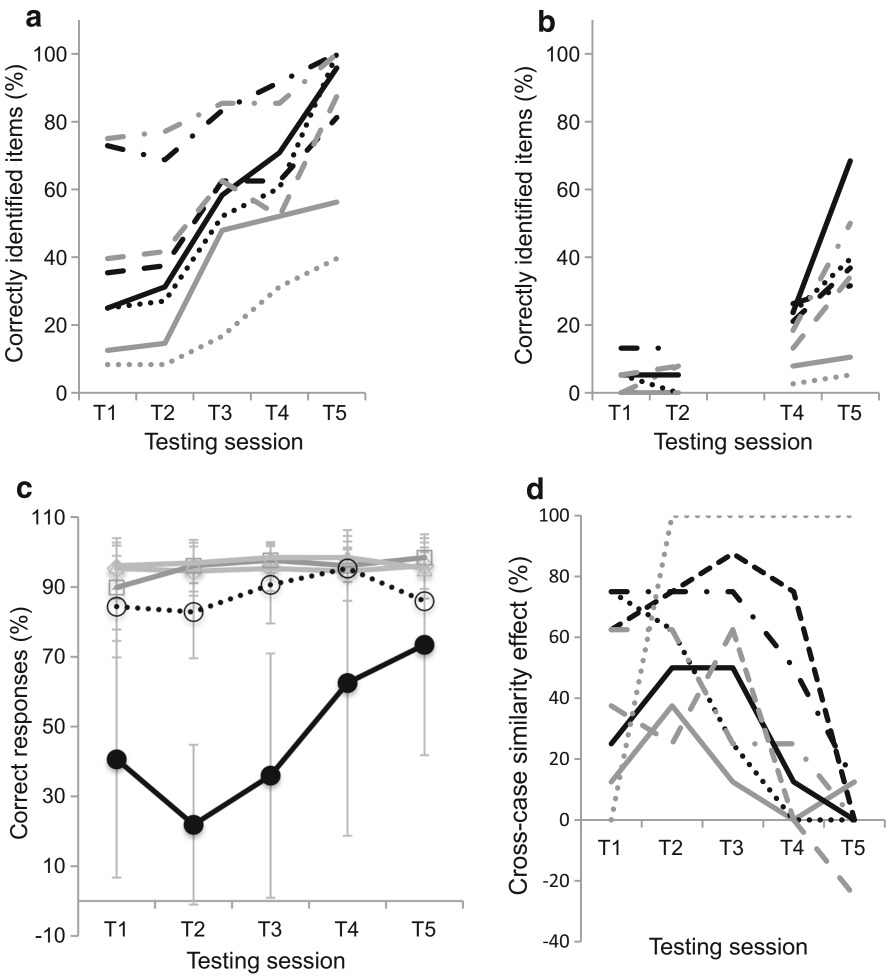


Fig. 1 Individual scores (in percentages of correct identification responses) at each testing session (T) on **a** letter knowledge **b** complex grapheme knowledge and **d** cross-case similarity effects: dashed line S1; dotted dashed line S2; grey solid line S3; dotted line S4; grey dotted dashed line S5; solid line S6; grey dashed line S7; grey dotted line S8. **c** Average percentages of correct responses on the letter-identity matching task, at each testing session (T), separately for each condition: diamond fully different; square different letter, same case; triangle identical. Circle same letter, different case, similar; filled circle same letter, different case, dissimilar (errors bars represent standard deviations)

88% (S6) for words that had been presented in the classroom (*old words*), and from 21% (S3) to 85% (S6) for new words. For all participants progress was mostly limited to the studied GPCs: At T3, performance was far better on items with the studied GPCs of modules 1 and 2 than on those with unstudied GPCs of modules 3–8. Similarly, at T4, performance on items with the studied GPCs of modules 3–8 was better than on items with unstudied GPCs of modules 9 and 10.

Table 3 Individual and average (in bold; standard deviations in brackets) reading scores at each testing session (T), as a function of GPCs and item type

Items with GPCs of		**T1**	**T2**	**T3**		**T4**		**T5**		
		U GPCs	U GPCs	S GPCs Old PW	S GPCs New PW	S GPCs Old PW	S GPCs New PW			
Modules 1 & 2	**S1**	0	0	100	100	100	100	—*	—	—
	S2	12.5	0	100	100	100	100	—	—	—
	S3	0	0	0	0	50	40	—	—	—
	S4	0	0	100	100	100	100	—	—	—
	S5	0	0	100	100	100	100	—	—	—
	S6	0	0	100	100	100	100	—	—	—
	S7	0	0	100	100	100	100	—	—	—
	S8	0	0	0	0	0	0	—	—	—
	Average	**1.56**	**0**	**75**	**75**	**81.25**	**80**	—*	—	—
		[4.42]	**[0]**	[46.29]	[46.29]	[37.2]	[38.55]	—	—	—
Modules 3 to 8		U GPCs	U GPCs	U GPCs		S GPCs Old W	S GPCs New W	S GPCs Old W	S GPCs New W	S GPCs New PW
	S1	0	0	0		86.67	78.57	91.67	41.67	33.33
	S2	0	0	31.25		71.43	67.86	83.33	66.67	58.33
	S3	0	0	0		28.57	7.14	50	25	16.67
	S4	0	0	5.56		84.62	53.85	83.33	66.67	66.67
	S5	0	0	2.78		85.71	60.71	66.67	41.67	41.67
	S6	0	0	20		80	66.67	91.67	100	66.67
	S7	0	0	0		72.22	50	58.33	41.67	41.67
	S8	0	0	0		0	0	0	0	20
	Average	**0**	**0**	**7.45**		**63.65**	**48.1**	**65.63**	**47.92**	**43.13**
		[0]	**[0]**	**[11.78]**		[31.94]	[28.91]	[30.68]	[30.13]	[19.55]

Table 3 continued

Modules 9 & 10						U GPCs		S GPCs	S GPCs	S GPCs
								Old W	New W	New PW
	S1	__	__	__	__	NR		25	25	0
	S2	__	__	__	__	25		25	25	25
	S3	__	__	__	__	NR		0	0	NR
	S4	__	__	__	__	16.67		75	50	50
	S5	__	__	__	__	0		100	75	50
	S6	__	__	__	__	NR		75	100	50
	S7	__	__	__	__	0		25	25	0
	S8	__	__	__	__	0		NR	NR	NR
	Average	__	__	__	__	**8.33**		**46.43**	**42.86**	**29.17**
		__	__	__	__	**[11.79]**		[36.6]	[34.5]	[24.58]
Modules 11 to 17								S GPCs	S GPCs	S GPCs
								Old W	New W	New PW
	S1	__	__	__	__	__	__	25	25	25
	S2	__	__	__	__	__	__	50	25	75
	S3	__	__	__	__	__	__	NR	NR	NR
	S4	__	__	__	__	__	__	71.43	57.14	35.71
	S5	__	__	__	__	__	__	60	50	10
	S6	__	__	__	__	__	__	92.86	64.29	42.86
	S7	__	__	__	__	__	__	42.86	14.29	10
	S8	__	__	__	__	__	__	NR	NR	NR
	Average	__	__	__	__	__	__	**57.02**	**39.29**	**33.1**
		__	__	__	__	__	__	[23.56]	[20.45]	[24.46]

* __ : not presented in the test

Shaded: unstudied GPCs (U); Unshaded: studied GPCs (S), used in either old (O) or new (N) words (W) or pseudowords (PW).

Among the studied GPCs, progress varied as a function of the complexity of the material, which increased throughout the course. GPCs of modules 1 and 2 were acquired quite rapidly, with a strong performance jump at T3 ($\sim$75% on average); the further slight improvement at T4 indicates that even if there were any interference from the newly studied GPCs (of modules 3 and 8), it did not prevent consolidation of the previously acquired knowledge. Similarly, once GPCs of modules 3–8 were taught, the performance jump on these GPCs was rapid, being observed already at T4. Yet on those GPCs there was no further improvement at T5. In addition, at T5 the performance jump on GPCs of modules 9 and 10 was quite weaker, and, similarly, performance on GPCs of modules 11–17 remained relatively low. This probably reflects both the intrinsic complexity of the GPCs introduced in the second half of the course and the higher demands of the last modules. Indeed, the 30 GPCs of modules 9–17 had to be studied in only 7 weeks, whereas the 10 GPCs of modules 1 and 2 were studied in 2 weeks and the 24 GPCs of modules 3–8 in 5 weeks. Time was probably insufficient to consolidate the GPCs studied at the end of the course. In addition, the GPCs that were introduced first were presented more often, as they were also used in words including GPCs of further modules.

As the complexity of the items increased between the first three versus last two testing sessions (Tables 1, 3), the raw average reading score at each testing session would overlook this varying difficulty and thus can hardly be used to estimate overall progress. In addition, items were presented in increasing order of difficulty at each session, and participants stopped the test at varying levels, when the total time allocated for the task was over. Two solutions were adopted to allow comparison of average reading scores between testing sessions and individuals.

First, we restricted analysis to items with GPCs of modules 3–8, which were evaluated at all sessions and on all students. We first calculated slopes separately for upper- and lower-case items, as well as separately for old words versus new words with the same GPCs. Individual progress was sounder for upper- compared to lower-case items, and for old compared to new words (Fig. 2), as confirmed by an ANOVA ran on the individual slopes, showing significant effects of item type, $F(1, 7) = 8.372$, $p < .025$, $\eta_p^2 = 0.545$, and case, $F(1, 7) = 17.624$, $p < .005$, $\eta_p^2 = 0.716$, without interaction between these factors, $F < 1$; Bayesian repeated measures ANOVA: $BF_{\text{Inclusion}} = 12.43$, 19.478 and 1.537 for item type, case, and their interaction, respectively. The four slopes were strongly correlated, $r(6)$ from .79 to .93, all ps ≤ .01, which allows pooling performance across materials at each session. Yet, it is important to check whether progress was significant not only on these average scores (which was the case, see Table 2), but also when only new words are considered. Being able to read words that had never been presented in the classroom (and hence that the participants probably had never read before) is indeed the signature of autonomous decoding. This was the case: On new words the slope was significantly larger than zero (on average: 19.14, $SD = 10.75$, $t(7) = 5.036$, $p <$ 001; $BF_{10} = 59.13$), as was the relative gain (on average: 50%, $SD = 29.88$, $t(7) = 4.733$, $p = .001$; $BF_{10} = 44.68$). Still, performance on both new and old words was far from being perfect at T5, as most students still struggled with items including a nasal digraph, which had been introduced in module 8 (average at T5: 17.86%; only S6 reached 75% correct on these items).

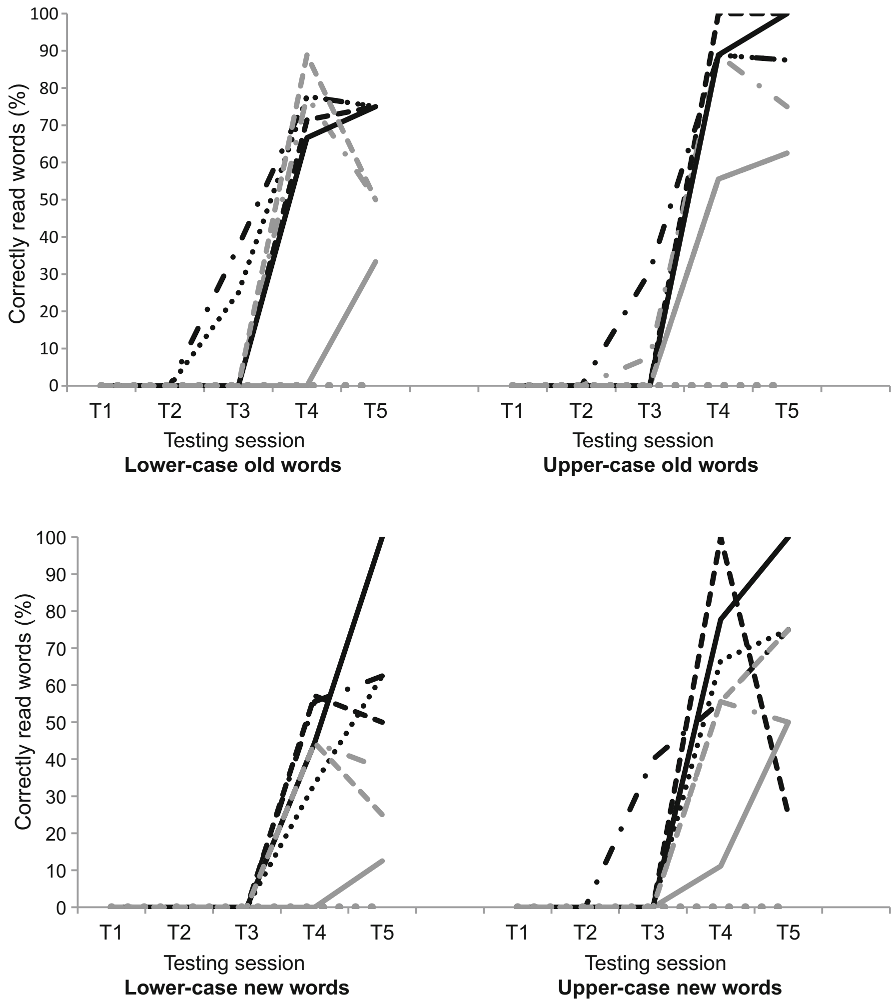


Fig. 2 Individual scores (in percentages of correct responses) in reading words with GPCs studied in modules 3–8 at each testing session (T), separately for upper- and lower-case items, as well as for words to which participants had been exposed during classes (old) versus other words with the same GPCs (new): dashed line S1; dotted dashed line S2; grey solid line S3; dotted line S4; grey dotted dashed line S5; solid line S6; grey dashed line S7; grey dotted line S8

Second, we estimated overall progress by taking into account the level of difficulty of the items, applying the formula [(% correct responses X number of last presented module)/17] to the average raw reading scores.[2] As was the case for items

[2] With this formula, performance at T5 would remain unchanged if a participant succeeded to proceed until module 17, but would be lowered if the participant stopped the test before the end (being thus presented with easier items than one who succeeded in completing the test). The corrected score thus underestimates performance for students who did not reach the end of the test because of time limit. Yet, corrected and uncorrected (calculated on GPCs of modules 3–8) slopes and RGs were strongly correlated, $r(6) = .87$ and $= .89$, respectively, both ps $< .01$, suggesting that our estimation is valid.

with GPCs of modules 3–8, reading improvement was observed not only overall (Table 2) but also, critically, on new items (Fig. 3a; average slope: 11.84, $SD = 8.90$, $t(7) = 3.764$, $p < .005$, $BF_{10} = 17.10$; average RG: 35.73%, $SD = 27.32$, $t(7) = 3.70$, $p < .005$; $BF_{10} = 15.99$), although performance was significantly better on old items (average slope: 16.19, $SD = 9.35$; average RG: 47.39%, $SD = 28.23$) than on new ones ($t(7) = 4.49$, $p < .001$; $BF_{10} = 35.46$). As was the case with uncorrected scores, there were strong individual differences, with corrected scores at T5 ranging from 0 (S8) to 86% (S6).

Those individual differences were further analyzed with the help of linear mixed-effects models (ggplot2 and lme4 packages, *R*-version 3.0.2). We started by creating a third-order orthogonal polynomial model for performance on both old and new items and then extracted the random effects that describe each participant's deviation from the overall group pattern either across item types (i.e., individual variability at the subject level) or for the participant-by-item type combination. These values confirmed visual analysis (Fig. 3a) by showing that two participants (S3 and S8) presented an overall weaker performance and a gentler linear slope, whereas two others (S4 and S6) presented a better overall performance and a steeper slope. In addition, four participants (S1, S4, S5 and S7) presented a particularly gentler linear slope only for new items, whereas one participant (S6) tended to present a steeper linear slope only on new items.

Progress on the corrected overall reading score[3] correlated significantly with progress on both letter knowledge (RGs: $r(6) = .84$, $p < .01$; slopes: $r(6) = .59$, $p < .10$) and complex grapheme knowledge (slopes: $r(6) = .92$; RGs: $r(6) = .93$, both ps $< .001$), as well as with the evolution of the cross-case similarity effect (slopes: $r(6) = -.67$; RGs: $r(6) = -.64$, both ps $< .05$).

On new pseudowords, average performance at T5 was 34.23% ($SD = 15.93$). To examine individual scores and estimate the lexicality effect, we corrected raw scores in a similar way as for word reading, with performance remaining unchanged if the participant was presented with the 30 items of the test, but lowered otherwise. The corrected average score was 27.92% ($SD = 17.75$), being thus somewhat lower than on new words. Yet the difference only tended toward significance, $t(7) = 1.77$, $p = .06$; $BF_{10} = 1.86$, as variability was rather pronounced (Fig. 3b), with individual performance ranging from $\sim$ 8 to 53% correct (S6).

Metaphonological tasks

Average performance on each test is presented in Table 2, and individual scores in Fig. 4a–c. In both phonemic sensitivity and phoneme deletion, although performance was slightly better for items with simple compared to complex onset (Appendix), this factor did not influence the slopes, $t \leq 1$ for both tests; Bayesian paired samples two-way *t* test: $BF_{01} = 2.914$ for phonemic sensitivity and $= 1.782$

[3] We considered this score in correlation computation because the slopes on old and new items were strongly correlated, $r(6) = .96$.

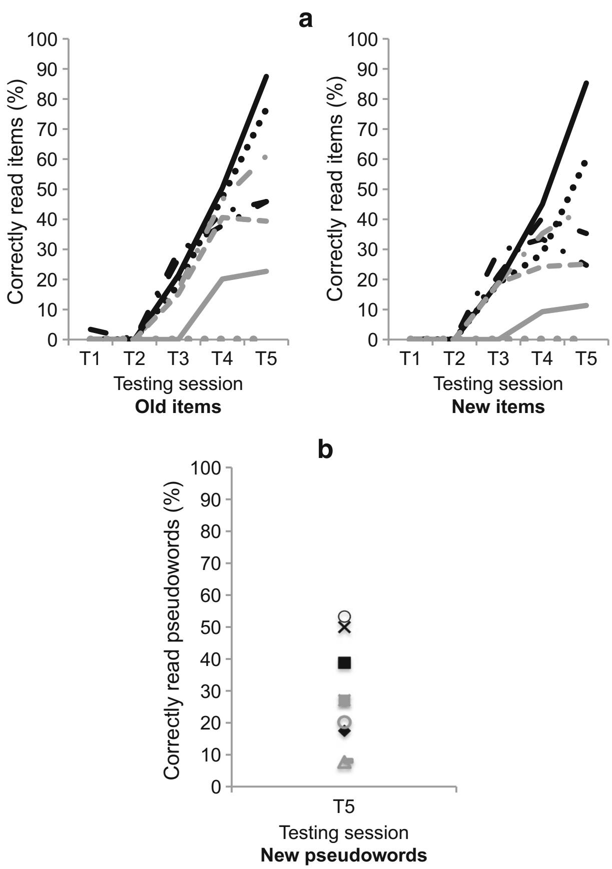


Fig. 3 Individual corrected scores (in percentages of correct responses) in reading **a** old or new items at each testing session (T): dashed line S1; dotted dashed line S2; grey solid line S3; dotted line S4; grey dotted dashed line S5; solid line S6; grey dashed line S7; grey dotted line S8 and **b** pseudowords at T5: filled diamond S1; filled square S2; triangle S3; X S4; grey filled square S5; circle; S6; grey circle S7; grey dash S8

for phoneme deletion. We thus pooled the data on simple and complex onsets in both tests. On phonemic sensitivity, as participants frequently pointed to the foils (e.g., for /f/, to a picture which name is "osso"), we computed the signal detection theory *d'* parameter, taking correct responses as hits and responses to foils as false alarms (Table 2; Fig. 4c).

Performance significantly improved in two out of the three metaphonological tests, namely phonemic sensitivity and syllable deletion (Table 2; Fig. 4a, c), but not in the much more difficult phoneme deletion test, except for one participant (S6, Fig. 4b). Most participants presented relatively good syllable deletion performance already at baseline (Fig. 4a).

Progress on syllable deletion was not (or poorly) correlated with progress on either phonemic deletion or phonemic sensitivity (slopes: $r(6) = -.05$ and $= .30$;

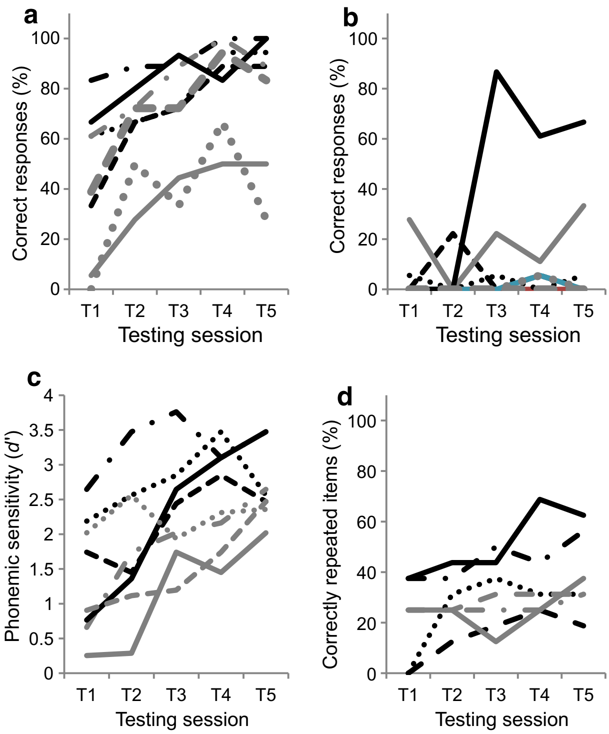


Fig. 4 Individual scores at each testing session (T) on **a** syllable deletion, **b** phoneme deletion (both in percentages of correct responses), **c** phonemic sensitivity (*d*′), and **d** phonological memory (in percentages of correct responses, on the 8 item types without ceiling effect): dashed line S1; dotted dashed line S2; grey solid line S3; dotted line S4; grey dotted dashed line S5; solid line S6; grey dashed line S7; grey dotted line S8

RGs: $r(6) = .22$ and $= .39$, all ps $> .10$). Progress on phonemic sensitivity and deletion tended to be more strongly associated, although no correlation reached significance (slopes: $r(6) = .60$; RGs: $r(6) = .54$, both ps $< .10$). RGs on both syllable deletion and phonemic sensitivity were correlated with RGs on grapheme knowledge, $r(6) = .71$, $p = .025$ and $= .64$, $p < .05$, respectively, and RGs on syllable deletion was also correlated with RGs on letter knowledge, $r(6) = .88$, $p < .005$. No other correlation with letter or grapheme knowledge was significant. Progress on syllable deletion tended to be correlated with overall (corrected) reading progress (slopes: $r(6) = .56$, ps $< .10$; RGs: $r(6) = .83$, $p < .005$), which was not the case with either phonemic sensitivity (slopes: $r(6) = .34$; RGs: $r(6) = .47$) or phoneme deletion (slopes: $r(6) = .44$; RGs: $r(6) = .46$). It is, however, worth noting that the only participant who reached good performance on phoneme deletion (S6) was also the best reader, particularly of new words (Figs. 2, 3a).

Phonological memory

Response was considered as correct only when the nonword was reproduced exactly in its entirety. Every participant was able to correctly repeat a single CV and made only a few errors in repeating 2–4 CV nonwords even prior to attending the course. In contrast, participants performed poorly on 5 and 6 CV nonwords. For CCVs, they made only a few errors in repeating one syllable, many more in repeating two, and performed below 20% correct when repeating three or more syllables (Appendix). Both sequence length and phonological complexity thus seem to modulate performance. In the repeated measures ANOVA on slopes,[4] neither structure (2 levels: CV vs. CCV) nor length (6 levels: from 1 to 6 syllables) main effects were significant, $F < 1$ and $F(5, 306) = 2.296$, $p = .07$, $\eta_p^2 = .277$, but these factors interacted, $F(5, 30) = 3.128$, $p < .025$, $\eta_p^2 = .343$; Bayesian ANOVA: $BF_{\text{Inclusion}} = 1.161$, 1.644 and 4.762 for structure, length, and their interaction, respectively.

As performance was at ceiling already at baseline for the shortest items, we discarded the materials for which there was a ceiling effect (one-way t tests of significance, theoretical value: 100%); this was the case for CCVs monosyllables and for CVs of 1, 3 and 4 syllables (all ts ≤ 1 and $BF_{10} < 1$). Once these items discarded, a small but significant overall improvement was observed on the eight remaining item types (average values in Table 2; individual scores in Fig. 4d).

Improvement in nonword repetition was correlated neither with (corrected) reading progress (both rs $< .22$), nor with progress on letter or complex grapheme knowledge (all rs $< .15$). Yet, it did correlate positively with phoneme deletion (slopes: $r(5) = .74$, $p < .05$; RGs: $r(5) = .62$, $p = .10$), and was strongly negatively correlated with progress on syllable deletion, at least when estimated on slopes, $r(5) = -.86$, $p < .01$ (RGs: $r(5) = -.33$). Correlations with progress in phonemic sensitivity were not significant (both rs $< .16$).

Discussion

The main objective of the present study was to show that adults who did not have the opportunity to acquire reading skills during childhood are able to do so rapidly if trained with an adequate literacy program. To this aim we designed an adult literacy course, LIA, optimized for reading acquisition on the basis of the most consistent and recent findings on the processes and knowledge involved in reading acquisition, and assessed its effectiveness during and after 3 months of instruction. The LIA course yielded, overall, a rather significant improvement in almost all of the evaluated abilities. We will first summarize the average results, then the individual profiles.

[4] This analysis took only into account the seven participants who had learned to read to some extent.

Overall findings

Knowledge of letters and complex graphemes, and of their abstract identity

Throughout the learning period, there was a steady increase in the knowledge of simple letters and, to a lesser but still significant extent, of complex graphemes. Students developed abstract letter representations: The cross-case similarity effect, which reflects better categorization of visually similar forms of the same letter (e.g., <V v>) than of dissimilar ones (e.g., <A a>), almost disappeared post-intervention.

Word and pseudoword reading

At any test session, performance improved only for the studied GPCs. On these, progress was rapid and was maintained at further testing sessions, suggesting that performance on GPCs studied at the beginning (in modules 1 and 2) or middle (in modules 3–8) of the course was not compromised by the introduction of new GPCs.

The results further show that the students, entirely illiterate at the beginning (except for knowledge of a few letters), clearly learned to decode, a *sine qua non* condition towards becoming autonomous readers (Share, 1995). Indeed, many new words were perfectly read post-intervention, which shows that students were developing a genuine decoding ability rather than resorting to whole-word pattern recognition. Neither did the students merely resort to simple letters: Reading progress not only tended to be related to progress in letter knowledge (which is consistent with children data, e.g., Leppänen, Aunola, Niemi, & Nurmi, 2008), but was strongly related to progress in complex grapheme knowledge (digraphs and letters with diacritics), namely to different uses of the initially learned function of the letter.

Nevertheless, as expected, words that had been presented in the classroom were slightly better read than new words, although the difference post-intervention was not huge, reaching $\sim$ 13% on GPCs from modules 3–8, and $\sim$ 12% on all modules (corrected score). Reading new pseudowords remained slightly more difficult than reading new words, and clearly more difficult than reading words that had been presented in the classroom. On the basis of these results we may thus formulate the hypothesis that, in the initial stages of learning to read, adults are both able to use their lexical knowledge available from spoken language to assist in the process of decoding new (previously unseen) words, and to capitalize on recent exposure to and explicit training with written words.

Metaphonological abilities

Scores in metaphonological tasks increased through the successive test sessions, but progress on these scores did not (or poorly) correlate with each other. Performance on syllable deletion and phonemic sensitivity began to improve even before learning to read, which is consistent with the idea that those abilities may benefit from learning to read, but do not depend crucially on it (e.g., Morais et al., 1986; Morais, Alegria, & Content, 1987a). Yet, only progress in syllable deletion was significantly correlated with reading progress. This can be explained by the fact that by calling attention from the beginning to word length based on number of syllables, and by using almost from the beginning multisyllabic items, the LIA course required syllable segmentation. Finally, it is worth noting that only one student, the best reader, was quite good in phoneme deletion. This corroborates the claim that the conscious manipulation of phonemes is not a precursor of reading (see discussion in e.g., Morais et al., 1987a) and allows the stronger claim that, in addition, it is not entailed automatically by basic reading skills. Phonemic awareness would be brought by higher reading abilities, as displayed by the best reader.

Phonological memory

Before they began learning to read, students were very poor at correctly repeating nonwords made out either of 5 or 6 CVs, or of 3 or more CCVs. These effects of sequence length and phonological complexity, which interacted, are probably partly due to the fact that the sequences were meaningless. Indeed, due to vocalic reduction there are, phonetically, many CCVs in European Portuguese, but word knowledge and context probably compensate for length and complexity in daily communication. Similar effects had already been observed in a very similar test applied to Portuguese children (Morais et al., 2010). For sake of comparison, the average uncorrected score at T1 was in the present study of ~ 64% correct for CVs and ~ 26% correct for CCVs. This performance falls in-between the one observed at the beginning of Grade 1 in children from medium to high social classes (on average, ~ 67% for CVs and 33% for CCVs) and low social class (58.1% for CVs and 25.8% for CCVs). At the end of Grade 1, the latter reached ~ 54 and 19% for CVs and CCVs, respectively, whereas those from medium to high social classes reached ~ 78 and 46%, respectively. Here, after only 14 weeks of literacy course, we observed (uncorrected) average scores of 77% for CVs and 39% for CCVs. Thus, literacy has a modest but quite rapid impact on phonological memory, even when acquired in adulthood.

In the present study, phonological memory improvement (most apparent for 5 syllables CVs and 4 syllables CCVs) was not correlated with reading progress, but correlated significantly with progress in phoneme deletion and was strongly negatively correlated with syllable deletion. This may reflect one of the various mechanisms by which literacy modulates phonological memory (see discussion in Demoulin & Kolinsky, 2016): In nonword repetition, literate people can use an attentional strategy based on the explicit awareness of phonemes that illiterate people cannot develop because they lack phonemic awareness.

Individual profiles

Our study included eight illiterate adults, all socially integrated women, in good health, but differing largely in age, civil status, number of children attending or having attended school, and probably in their motivation to learn. Large individual differences in learning curves were therefore expected. A fan-shaped pattern was indeed observed to open largely from ~ 0 at baseline until T5, with individual performance remaining near 0 or increasing up to 60% or even more than 90%, in particular for knowledge of complex graphemes and word reading. Only one student (S8) did not learn to read at all. She was also the only one to display a large cross-case similarity effect for letters even post-intervention, showing that she had been unable to develop abstract representations of letters. Although the very small sample size does not allow generalization, it is worth noting that she was the oldest (64 years old) and less motivated of the sample. It would be worth examining in a larger sample whether instruction age may have indirect effects on reading achievement, due to motivation and/or other possibly age-related factors such as fatigability, distractibility, etc. Examining differences in acquisition across the life span for reading is particularly important, as it is clear, from the present results, that phonics instruction *can* lead completely illiterate adults to rapidly acquire decoding abilities.

Another student (S3) remained quite poor post-intervention in the identification of complex graphemes, being also the poorest reader among those who did learn to read to some extent, struggling in particular with lower-case strings and in decoding new items. Unexpectedly, she was, exception made of the best reader, the only other to obtain a non-negligible score in phoneme deletion. It is difficult to explain this incongruence. Post-intervention, all the other students reached a level indicating that they were in the process of becoming autonomous decoders, even if there were still large differences between them: three became able to read between 30 and 40% of all the words tested (on corrected scores), one reached 50%, one almost reached 70%, and the best reader succeeded at almost 90%. These large differences also impacted reading speed: Three participants spent too much time when item difficulty increased and had to stop before the end because the time allocated for the test was over. Consequently, the accuracy level of those participants may have been somewhat underestimated.

Concluding remarks

Although our study was restricted to a specific language and the sample was very small, the results clearly show that six out of eight students learned to decode to a variable degree. This rate of success might seem modest, and would even be considered as unacceptable in the context of children education. Yet, the differences between literacy classes at school and the LIA course regarding tuition length and frequency of the lessons per week do not allow direct comparison between the present results and the rates of successful reading acquisition in children. If instead we consider the dropout rates and the very modest achievements of current adult literacy programs (Abadzi, 2003, 2004; Royer et al., 2004), the results of the present study sound much more promising. In any case, the present results suggest that there is no major plasticity impediment preventing the eradication of full illiteracy in adults. In addition, the students showed enhanced phonemic sensitivity and phonological memory. This implies that functional changes can take place rapidly outside the reading domain even when reading is acquired in adulthood, a result that is consistent with brain-imaging data (for a review see Dehaene, Cohen, Morais, & Kolinsky, 2015).

We believe that these rapid advances were possible for most of the students because the course was based on a phonics approach, with four main principles: (1) to develop first the comprehension of the alphabetic principle; (2) to teach the orthographic code systematically, in a progressive way, from the simplest to the most complex correspondences; (3) to favor the acquisition of abstract letter units by teaching lower- and upper-case letters in parallel and (4) to combine systematically reading and handwriting activities.

In future studies, it will be of great scientific interest to evaluate the potential contribution of each of these principles. To this aim, larger groups of participants should be tested using a randomized control trial design. Indeed, there was no control group in the present study, which, as any case series, can thus be threatened by intervening effects such as placebo, practice, and the Hawthorne and Rosenthal effects. Yet, whatever the level of motivation, expectation, awareness of being observed, or repeated exposure to written materials, it is hardly probable that non-reading lessons offered to a control group would lead to literacy. Indeed, reading is not acquired by mere exposition to written materials (otherwise, there would be no illiteracy in literate societies); it requires explicit tuition and effortful learning. In addition, our sample came from a small community in which all people know each other. Therefore, it was ethically unacceptable, in that context, to propose non-reading lessons. In future studies, the alternative would be to include a waiting list control group, although that option is quite time consuming and increases the difficulty of recruiting a large number of completely illiterate adults willing to participate in the program and to be tested individually several times.

Future studies will also have to check whether it is possible to go beyond decoding and reach automatic processing in reading as well as good spelling skills. The present results clearly show that a total of 82 h training delivered in 3 months is insufficient to go beyond slow and effortful decoding. This is particularly relevant in the light of the fact that adult literacy courses are often quite limited in instruction time; this is the case for instance in Portugal, with a maximum of 150 h training. A longer and more intensive training is most probably required to become a fluent reader. Examining learners with some simple texts (and not only with isolated words or pseudowords, as in the present study) would also be useful to have an indication as to whether they are able to transfer their reading skills to connected text. The persistence of the literacy gains long after instruction must also be checked, as well as generalization across different degrees of orthographic transparency. These most welcomed controlled studies, in addition to draw the attention of the society to the possibility to make the right to literacy for all a reality, will help identifying the most effective literacy programs, which is crucial to establish a rational strategy and advocate commitment to an adult literacy policy.

It is also necessary to examine how to implement those programs. Indeed, we acknowledge that, except for the training period limit, the conditions under which the program was carried out in the present study were ideally suited to research purposes: The instruction was given by two experts in reading research, the teacher/student ratio was optimal (1/4) and participants received financial reward. It is very unlikely that the organizations that are offering adult literacy courses can offer such perfect conditions. Nevertheless, we believe that a crucial condition of success is to train the teachers themselves to apply correctly the literacy programs that have been identified as being the most effective ones. This idea will also need to be tested through appropriately controlled studies.

Acknowledgements Régine Kolinsky is Research Director of the Fonds de la Recherche Scientifique (FRS)–FNRS, Belgium. This work was supported by the FRS-FNRS under grant FRFC 2.4515.12 and by an Interuniversity Attraction Poles (IAP) Grant 7/33, Belspo. We warmly thank the non-governmental community center that lent its facilities for the literacy course and testing, and are very grateful to the participants for agreeing to be enrolled in the course. We also sincerely thank the Editor and the two anonymous Reviewers for their very constructive comments and suggestions, which we believe have led to a significant improvement of the original manuscript.

Appendix

See Table 4.

Table 4 Detailed average correct performance (%) at each testing session (T) on each test. Standard deviations in brackets

	Testing session				
	T1	T2	T3	T4	T5
Letter knowledge					
Lower-case	37.5	34.9	57.81	59.9	79.69
	[28.95]	[24.99]	[22.21]	[23.14]	[27.13]
Upper-case	35.94	41.67	59.38	66.67	85.42
	[22.92]	[25.1]	[21.33]	[16.21]	[18.9]
Phoneme deletion					
C onsets	4.17	3.33	14.17	12.5	15
	[11.79]	[9.43]	[30.12]	[22.38]	[27.31]
CC onsets	4.17	0	15	4.17	4.17
	[11.79]	[0]	[31.22]	[11.79]	[11.79]
Phonemic sensitivity					
C onsets	61.11	63.89	76.39	73.61	83.33
	[23]	[41.47]	[21.77]	[22.95]	[10.29]
CC onsets	38.89	50	73.61	66.67	73.61
	[32.53]	[33.6]	[17.76]	[25.2]	[18.72]
Phonological memory					
CV 1 syllable	100	100	100	100	100
	[0]	[0]	[0]	[0]	[0]
CV 2 syllables	75	81.25	75	100	93.75
	[43.3]	[24.21]	[25]	[0]	[16.54]
CV 3 syllables	100	87.5	75	81.25	87.5
	[0]	[21.65]	[25]	[24.21]	[21.65]
CV 4 syllables	87.5	100	81.25	93.75	93.75
	[33.07]	[0]	[24.21]	[16.54]	[16.54]
CV 5 syllables	12.5	18.75	37.5	25	62.5
	[33.07]	[24.21]	[33.07]	[25]	[33.07]

Table 4 continued

	Testing session				
	T1	T2	T3	T4	T5
CV 6 syllables	12.5	25	6.25	6.25	12.5
	[33.07]	[25]	[16.54]	[16.54]	[21.65]
CCV 1 syllable	87.5	93.75	81.25	81.25	100
	[33.07]	[16.54]	[24.21]	[24.21]	[0]
CCV 2 syllables	50	68.75	87.5	93.75	56.25
	[50]	[24.21]	[21.65]	[16.54]	[29.97]
CCV 3 syllables	0	18.75	18.75	18.75	25
	[0]	[24.21]	[34.8]	[34.8]	[35.36]
CCV 4 syllables	12.5	0	12.5	12.5	37.5
	[33.07]	[0]	[21.65]	[21.65]	[33.07]
CCV 5 syllables	0	0	0	0	0
	[0]	[0]	[0]	[0]	[0]
CCV 6 syllables	0	0	0	12.5	0
	[0]	[0]	[0]	[33.07]	[0]

References

Abadzi, H. (2003). Adult literacy: A review of implementation experience. Operations Evaluation Department (OED) working paper series. Washington DC: World Bank. Retrieved from http://documents.worldbank.org/curated/en/111821468330039348/Adult-literacy-a-review-of-implementation-experience.

Abadzi, H. (2004). Background paper for the UNESCO education for all global monitoring report 2006. Retrieved from https://uta-ir.tdl.org/uta-ir/handle/10106/24328.

Abadzi, H. (2012). Can adults become fluent readers in newly learned scripts? *Education Research International, 2012,* 1–8.

Barakat, B. (2016). Improving adult literacy without improving the literacy of adults? A cross-national cohort analysis. *World Development, 87,* 242–257.

Braga, L. W., Amemiya, E., Tauil, A., Suguieda, D., Lacerda, C., Klein, E., et al. (2017). Tracking adult literacy acquisition with functional MRI: A single-case study. *Mind, Brain and Education, 11,* 121–132.

Byrne, B., & Fielding-Barnsley, R. (1989). Phonemic awareness and letter knowledge in the child's acquisitions of the alphabetic principle. *Journal of Educational Psychology, 80,* 313–321.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavior Methods, Research, Instruments, and Computers, 25,* 257–271.

Crum, R. M., Anthony, J. C., Bassett, S. S., & Folstein, M. F. (1993). Population-based norms for the mini-mental-state-examination by age and educational-level. *Journal of the American Medical Association, 269,* 2386–2391.

De Grauwe, A., Bitoun, C., Chauvet, A., Gay, D., Hite, S., Suso, E., & Valderrama, A. (2015). The impact of the EFA agenda: Comparing national education plans before and after Dakar. Paper commissioned for the EFA global monitoring report 2015, education for all 2000–2015: Achievements and challenges. Retrieved from http://unesdoc.unesco.org/images/0023/002324/232462e.pdf.

Dehaene, S. (2009). *Reading in the brain*. New York, NY: Penguin.

Dehaene, S., Cohen, L., Morais, J., & Kolinsky, R. (2015). Illiterate to literate: Behavioural and cerebral changes induced by reading acquisition. *Nature Reviews Neuroscience, 16*(4), 234–244.

Dehaene, S., Cohen, L., Sigman, M., & Vinckier, F. (2005). The neural code for written words: A proposal. *Trends in Cognitive Sciences, 9,* 335–341.

Dehaene, S., Pegado, F. Braga, L. W. Ventura, P., Nunes, G., Jobert, A., Dehaene-Lambertz, G., Kolinsky, R., Morais, J., & Cohen, L. (2010). How learning to read changes the cortical networks for vision and language. *Science, 330*(6009), 1359-1364.

Demoulin, C., & Kolinsky, R. (2016). Does learning to read shape verbal working memory? *Psychonomic Bulletin & Review, 23*(3), 703-722.

Ehri, L. C., Nunes, S. R., Stahl, S. A., & Willows, D. M. (2001). Systematic phonics instruction helps students learn to read: Evidence from the National Reading Panel's meta-analysis. *Review of Educational Research, 71,* 393–447.

Grainger, J., Rey, A., & Dufau, S. (2008). Letter perception: From pixels to pandemonium. *Trends in Cognitive Sciences, 12,* 381–387.

Guerreiro, M., Silva, A. P., Botelho, M., Leitão, O., Castro-Caldas, A., & Garcia, C. (1994). Adaptação portuguesa da tradução do Mini mental State Examination (MMSE) [Adaptation to the Portuguese population of the translation of the Mini Mental State Examination (MMSE)]. *Revista Portuguesa de Neurologia, 1,* 9–10.

Jeffreys, H. (1961). *Theory of probability* (3rd ed.). Oxford: Oxford University Press.

Kolinsky, R. (2015). How learning to read influences language and cognition. In A. Pollatsek & R. Treiman (Eds.), *The Oxford Handbook of Reading* (pp. 377–393). New York, NY: Oxford University Press.

Kolinsky, R., Carvalho, C., Leite, I., Franco, A., & Morais, J. (in revision). How to teach fully illiterate adults to read. In D. Perin (Ed.), *The Wiley Adult Literacy Handbook*. Hoboken, NJ: John Wiley & Sons.

Kolinsky, R., Cary, L., & Morais, J. (1987). Awareness of words as phonological entities: The role of literacy. *Applied Psycholinguistics, 8*(03), 223–232.

Kolinsky, R., Verhaeghe, A., Fernandes, T., Mengarda, E. J. Grimm-Cabral, L., & Morais, J. (2011). Enantiomorphy through the looking-glass: Literacy effects on mirror-image discrimination. *Journal of Experimental Psychology: General, 140*(2), 210–238.

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for *t* tests and ANOVAs. *Frontiers in Psychology, 4,* 863.

Leppänen, U., Aunola, K., Niemi, P., & Nurmi, J.-E. (2008). Letter knowledge predicts grade 4 reading fluency and reading comprehension. *Learning and Instruction, 18,* 548–564.

Lind, A. (2008). *Literacy for all. Making a difference*. Paris: UNESCO Publishing.

Longcamp, M., Boucard, C., Gilhodes, J.-C., Anton, J.-L., Roth, M., Nazarian, B., et al. (2008). Learning through hand- or typewriting influences visual recognition of new graphic shapes: Behavioral and functional imaging evidence. *Journal of Cognitive Neuroscience, 20,* 802–815.

Lorch, R. F., & Myers, J. L. (1990). Regression analyses of repeated measures data in cognitive research. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 16,* 149–157.

Morais, J., Alegria, J., & Content, A. (1987a). The relationships between segmental analysis and alphabetic literacy: An interactive view. *Cahiers de Psychologie Cognitive/ European Bulletin of Cognitive Psychology, 7*(5), 415–438.

Morais, J., Alegria, J., & Content, A. (1987b). Segmental awareness: Respectable, useful, and almost always necessary. *Cahiers de Psychologie Cognitive/European Bulletin of Cognitive Psychology, 7,* 630–556.

Morais, J., Araújo, L., Leite, I., Carvalho, C., Fernandes, S., & Querido, L. (2010). *Relatório final, Jan 2008 – Out 2010. Estudo Psicolinguístico. Estabelecimento de Níveis de Referência do Desenvolvimento da Leitura e da Escrita do 1o ao 6o ano de Escolaridade*, Plano Nacional de Leitura do Ministério da Educação, Portugal [Final report Jan 2008 - Oct 2010 study Psycholinguistic. Establishment of Reading and writing Development Reference Levels from the first to the 6th year of Education, National Reading Plan of the Ministry of Education, Portugal]. http://www.planonacionaldeleitura.gov.pt/PNLEstudos/uploads/ficheiros/psico_15fev.pdf. Accessed 12 April 2017.

Morais, J., Bertelson, P., Cary, L, & Alegria, J. (1986). Literacy training and speech segmentation. *Cognition, 24*(1-2), 45–64.

Morais, J., Cary, L., Alegria, J., & Bertelson, P. (1979). Does awareness of speech as a sequence of phones arise spontaneously? *Cognition, 7*(4), 323-331.

Nation, K., & Hulme, C. (2011). Learning to read changes children's phonological skills: Evidence from a latent variable longitudinal study of reading and nonword repetition. *Developmental Science, 14,* 649–659.

Oxenham, J. (2008). *Effective literacy programmes: Options for policy makers. Fundamentals of educational planning series* (Vol. 91). Paris: UNESCO-IIEP.

Perea, M., Jiménez, M., & Gomez, P. (2015). Do young readers have fast access to abstract lexical representations? Evidence from masked priming. *Journal of Experimental Child Psychology, 129,* 140–147.

Post, D. (2016). Adult literacy benefits? New opportunities for research into sustainable development. *International Review of Education, 62,* 751–760.

Robinson, C. (2005). Promoting literacy: What is the record of education for all? *International Journal of Educational Development, 25,* 436–444.

Rouder, J. N., Speckman, P. L., Sun, D., Morey, R. D., & Iverson, G. (2009). Bayesian *t* tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin & Review, 16,* 225–237.

Royer, J. M., Abadzi, H., & Kinda, J. (2004). The impact of phonological-awareness and rapid-reading training on the reading skills of adolescent and adult neoliterate. *International Review of Education, 50,* 53–71.

Seymour, P. H. K., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology, 94,* 143–174.

Share, D. (1995). Phonological recoding and self-teaching: Sine qua non of reading acquisition. *Cognition, 55,* 151–218.

Stanovich, K. E., Cunningham, A. E., & Cramer, B. B. (1984). Assessing phonological awareness in kindergarten children: Issues of task comparability. *Journal of Experimental Child Psychology, 38,* 175–190.

Suggate, S., Schaughency, E., & Reese, E. (2013). Children learning to read later catch up to children reading earlier. *Early Childhood Research Quarterly, 28,* 33–48.

Thompson, G. B. (2009). The long learning route to abstract letter units. *Cognitive Neuropsychology, 26,* 50–69.

United Nations. (1961). Resolution 1710 (XVI): United Nations development decade. A programme for international economic cooperation (I). In *United Nations General Assembly—16th session*. Resolutions adopted on the reports of the Second Committee (pp. 17–18). New York, NY: United Nations.

UNESCO. (1990). *World declaration on education for all and framework for action to meet basic learning needs*. Paris: UNESCO Publishing.

UNESCO. (2016). *Global education monitoring report 2016. Education for people and planet: Creating sustainable futures for all*. Paris: UNESCO Publishing.

Waters, G. S., Seidenberg, G. M. S., & Bruck, M. (1984). Children's and adults' use of spelling sound information in three reading task. *Memory & Cognition, 12,* 293–305.