



Visual and linguistic factors in literacy acquisition: Instructional Implications For Beginning Readers in Low-Income Countries

A literature review prepared for the Global Partnership for Education,
c/o World Bank

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EXECUTIVE SUMMARY

Improving the quality of literacy teaching may require intervening at different levels, for example, encouraging school attendance and optimizing textbook format and teaching methods.

Reading is a complex task involving perceptual, motor, linguistic, phonological, and memory components, each of which has a crucial role in determining reading rate. Taking into consideration variables that affect the acquisition of reading skills may help optimize reading performance. This is particularly important in the case of low-income children in poor countries, such as Africa. In fact, their learning opportunities are generally limited and dropping out from school is quite frequent. High poverty rates continue to have a negative impact on human resource development and education quality in Africa, further complicating the ability of most countries to reach the EFA (Education for All) and Millennium Development Goals. Moreover, Africa and Asia are hosts to most of the world's multilingual countries, in which textbook availability in major indigenous languages is sorely lacking. Therefore, it is important to take all possible steps to maximize the effectiveness of teaching interventions.

In parallel, also the quality of textbooks is a crucial factor for quality education, especially in developing countries. It is important to dispose of well-written and well-designed textbooks, because the quality of textbook can be an important predictor of student learning and can contribute to the effective use of instructional time and classroom teaching. Moreover, good textbook format allows children practicing reading by themselves, with minimal home support; thus it may become an important vehicle for raising reading fluency among children in low-income countries and poor households. It is possible to enhance the quality of education by improving the characteristics and availability of textbooks and instructional materials (Askerud, 1997), as well teaching procedures.

This review examines the evidence regarding variables influencing acquisition of decoding and comprehension reading skills. One important caveat is in order. While the educational, psychological and neuroscience literature on reading is extensive, it largely depends upon studies on English speaking individuals. In this respect, Share (2008) talks of "anglo-centricity" highlighting that English is "an exceptional, indeed, outlier orthography in terms of spelling-sound correspondence". Accordingly, extension of the results based on this language to more consistent orthographies cannot be taken for granted in the absence of direct empirical proofs. This observation has important implications since most poor countries have languages with regular orthographies. Throughout this review, we draw on the existing (predominantly English) literature but we refer to studies on regular orthographies (such as German, Finnish and Italian) whenever possible.

The first part of the review focuses on studies of visual psychophysics and examines the visual limitations affecting reading and its development. This type of information has important implications for determining the optimal visual characteristics of first-grade textbooks for children at the first stage of literacy.

The second part of the review draws on the psychological and neuroscience literature to examine the role of several variables influencing reading acquisition, such as letter knowledge, teaching method, teacher's competence, orthographic

consistency. Moreover, the influence of reading fluency, vocabulary, working memory and more generally linguistic skills on reading comprehension is examined.

Textbook format and visual effects on learning to read in young children

Research in visual psychophysics (and in particular on the development of visual processes) indicates that our ability to read is limited in a bottom-up fashion by text visibility.

In order to draw guidelines to optimize textbook efficacy for reading acquisition it must be noted that there are two sources of visual constraints beside the relational and methodological issues related to teaching to read. Unlike what is usually believed the visual system is far from being mature at age 6 and it continues developing at least up to age 10. Second, this development is not entirely caused by maturation, rather perceptual experience with appropriate material enhances this visual development. In some cases this perceptual learning is a necessary condition for fine-tuning the visual function required by reading. As a consequence in order to optimize textbooks one needs to keep in mind those texts should not provide information using a layout that is not suitable for the young visual system. On the one hand texts should also provide enough visual information to challenge the perceptual learning process. In this vein the guidelines traced in this review must be seen as the resultant of a balance between what is suitable for a 6-7 years old child and what is needed to allow a growth.

Text reading is a particularly challenging visual task, since it requires decoding of small and fine details. In addition, the page of a book contains an enormous amount of information if compared to any other visual task, such as finding a pen on our desk or recognizing the face of a friend. Several variables affect how we process a text. These can be mainly distinguished between variables that affect the spatial layout of text and variables that modulate how much information we can process simultaneously. In the first part of this review we address how reading is modulated by size, spacing, text degradation, script complexity, letters confusion, and word length. The visual constraints to reading seem to hold for different languages and scripts. A recent survey that comprises books written in opaque and transparent orthographies indicates that over the centuries, books have been printed to meet visual demands (Legge & Bigelow, 2011). Main findings of children developmental acquisition through learning and adults learning novel alphabets are also discussed.

Children learning

Visual function development proceeds from elementary features, single oriented lines to more complex objects such as words. Children in school age improve their ability to identify letters with learning. Variables such as size, letter spacing, and letter degradation greatly influence children's performance relative to adults. Recognizing words quickly is a prerequisite of fluent reading, and to recognize a word we need to decode the letters it is composed of. Reading rate will reach maximum speed if all the letters in the words can be decoded simultaneously. Adult fluent readers can process up to 5-8 letters at a time. Learning the alphabet takes about 1000 iterations with the letters. At the beginning of the reading experience, after having learnt the alphabet,

children are able to decode only two characters at any given moment. As a consequence, while reading, children parse words into smaller chunks and again their reading speed cast on the size of the chunk. The span in terms of number of letters increases with learning during the first 3 years of schooling. This enables the use of a whole word reading strategy.

Adult learning

Much of the psychophysical research on learning in adulthood is performed on adult observers learning to read novel alphabets. To our knowledge, no psychophysical study has been reported on illiterate adults learning to read for the first time. However, since perceptual learning is stimulus and task specific a lot can be drawn from what is known. Learning can be quantified in terms of how many trials of the same task are needed to reach maximum performance or what percent of the learned skill generalized to novel stimuli and tasks. Learning a novel alphabet entails laying down new memories about letters; as for children this is a fast process that takes few thousand trials. However, while learning letters, observers are also building up a representation of the relevant dimensions along which letters may vary. Learning a set of new letters partially transfers to a different set of similar shapes. As a consequence, learning an alphabet for the first time will be much harder for illiterates who do not have any previous experience with letters than for adults who are fluent readers in a different alphabet. After having learnt the alphabets adult observers are only able to decode two characters simultaneously. This behavior parallels children learning to read for the first time. It takes a much longer training period to expand this span in order to speed up reading. In addition, results indicate that being fluent readers in a given script does not help the parallel decoding of letters in a novel alphabet enhancing the similarity with illiterate experience of learning to read.

Optimal characteristics of reading textbooks

First- and second-grade textbooks should be printed taking into consideration that the child's visual system is still developing. We have learned that the text size should measure 24 pt double-spaced lines with three letter spaces between words. Sans-serif font-faces separate one character from the next and leave more white space in between, making it easier to read. Furthermore, Courier, that provides contrast letters spacing, is the most effective font type for Latin scripts.

First-grade textbooks should start with single letters, proceed to bigrams and then to words of increasing length. To provide sufficient exposure, words should be repeated in the text and balanced by the addition of new words. Most first grade textbooks can be characterized by incremental densities of words and lines per page, reflecting a steep learning curve of first graders over the course of the school year. Existing studies in industrialized countries report that in general there are approximately 4-8 words per line and about 6-8 lines per page in most first grade reading textbooks. Current evidence does not yet allow directly quantifying the ideal number of words per page and research is urgently needed for this purpose.

Textbooks accompanied by illustrations, in particular by one informative picture per page, may improve comprehension and information retention, especially in young children. They also enable young children to make one-to-one links between visual objects and words and serve as good eye-catching attraction for young readers. However, they may also harm children's attention to word-level features, especially when the number of difficult words being used is high. Thus, informational properties are more important than visual characteristics, such as color or high quality paper. In this vein, if applied ineffectively, illustrations may confuse young children especially when there are changes in scale, also indicating the relevance of the consistency of the position of pictures in the page. Moreover, evidence indicates that several pictures on a page may actually prove detrimental and impair reading. In general, textbook layout should support a situation where the learner's focus of attention often swings back and forth from one place to another. As such, the implication is that textbook illustrations should not be inserted just to fill up empty spaces on a page.

Also colors can impact the learning process if applied functionally and effectively. Consistent use of particular colored texts can help children to quickly memorize a pattern of words and sounds and use of colored overlays and colored paper may increase the readability on textbooks. Therefore, there is some evidence that the costs of colored textbooks are worth the benefit. Notwithstanding a high printing cost, together with pictures, also colors can have some impact on the learning process if employed functionally and effectively. If using one or two extra colors in order to highlight part of the text is necessary to make a point, they need to be used consistently. Colors should be selected on the basis of being readily identifiable, rather than on children's color preference. The use of colors in pictures makes reading more attractive, but it is important to maintain color compatibility with the target (*e.g.*, blue as the sky) to improve comprehension. In order to avoid that colors would distract attention from print in young learners, children must be prompted to pay attention also to the text associated with the pictures. Using colored paper for the background of text may help reducing contrast and luminance, thereby raising student test scores in reading. However, these issues must be considered in light of printing costs and text availability to children since exposure is the primary factor affecting reading acquisition.

The durability of textbooks largely depends on the kinds of papers used. Typically the paper used in textbook printing is low white offset. In order to maintain a textbook for 3 years or more, UNESCO suggests that paper with archival characteristics (rather thick, heavy, and difficult to be torn) is most suitable (*e.g.*, art papers). The size of textbooks is also an important element as it determines the size of the overall visual display. The most common and economically effective size is A4. Existing research emphasizes that various technical matters (such as the choice of paper, type-size and type-face, the kind of printing technology, the number of copies to be printed) affect textbook quality and price. Additionally, the importation of paper can increase costs and represents a major problem in many African countries.

Educational, linguistic and socio-economic factors in reading acquisition

Variables affecting the acquisition of reading skills

Letter knowledge is critical in early reading and spelling because it shapes the acquisition of the alphabetic principle and of grapheme-to-phoneme (and vice versa) correspondences. Acquisition of the link between letter and sound is more effective for reading improvement than letter name knowledge. To this aim, the use of illustrations of objects that start with a given letter (*e.g.*, A as in apple, D as in dog) may be useful. For young children it is easier to recognize and learn the sounds of acrophonic printed letters (*i.e.*, when the initial phoneme of the letter name corresponds to the sound of the letter) than those of non-acrophonic letters; also, it proves easier to acquire the letter sounds related to CV letter names compared to letter sounds related to VC letter names, and especially for letter sounds unrelated to letter names. Then, a more intensive training is requested for learning these letter sounds. Early in reading acquisition, learning letter sounds may require some degree of phonological skills. Specific training in phonological awareness may help children who are at risk for reading acquisition. Adult-child *shared reading* of alphabet books may help improving children's letter knowledge and phoneme awareness. However, this behavior is relatively infrequent, particularly in low SES families.

Overall, in planning teaching procedures for very young children, it is effective to teach letter sounds, starting with acrophonic letters and passing to non-acrophonic letters, which require greater care and effort. Explicit attempts should be made to promote phonological awareness.

There is a large body of evidence concerning the relative effectiveness of various *teaching methods*. Overall, several studies indicate that the phonics method is the most effective one for word decoding and should be considered as a first choice in planning educational programs. This was true especially for regular orthographies in which the acquisition of few grapheme-phoneme conversion rules may allow reading most words correctly. Nevertheless, there is also evidence that whole-word training in opaque orthographies may be useful for improving accuracy in reading (and spelling) irregular words; results on the effectiveness of these methods for improving reading speed are more controversial.

Achievement gains depend also on *teacher effectiveness* and, in particular, on teachers' education and experience. Teachers using highly structured instructions in basic skills and with a drills and practice approach obtain greater learning improvements in children. Also, the teacher's closeness to the child (as well as shared ethnicity and same SES as the child) plays a fundamental role in achievement gains, especially when the child's parents have less parenting attitudes. Teacher effects are much larger in small (as compared to regularly sized) classes and in low than in high SES schools. These influences are particularly important considering that low-income students are those who usually have less effective teachers.

Overall, evidence indicates the importance of teachers having enough education and experience, especially if they are teaching poor children. Particularly if this proves impossible, efforts should be made to keep the number of children per class relatively small. Finally, shared ethnicity and SES among teachers and children promotes learning.

Reinforcement and feedbacks (by teachers as well as peers and parents) play a fundamental role in reading improvement. In general, to avoid demotivating children, failures should not be attributed to poor skills and the efforts of children should receive appreciation. Children should be reinforced also in their attempts to approximate the correct reading (shaping). Also the use of prompts, modelling and direct instruction are effective in improving reading performance. Especially for low-income children, it is important to have teachers who are able to compensate a deprived familiar context. Unfortunately, often in poor countries teachers do not give enough attention, feedback and reinforcements to the less skilled children, increasing the number of illiterate children who drop-out from school. Teachers must learn techniques for keeping all students engaged in learning tasks and must give feedback and reinforcement (and facilitation) especially to the less skilled children.

Orthographic consistency is a powerful factor modulating literacy acquisition. Reading and spelling are acquired faster by readers of regular orthographies than by readers of inconsistent orthographies, such as English, due to the larger number of irregular words to be learned and the difficulty in acquiring the phoneme-grapheme (and vice versa) conversion rules. These cross-linguistic differences persist also later in reading and spelling acquisition. Moreover, in shallow orthographies there is a predominant reliance on grapheme-phoneme conversion, whereas in inconsistent orthographies there is greater reliance on lexical procedure/larger units of conversion.

Learning to read produces detectable morphological changes in the brain area known as visual word form area (VWFA), with an increase in activation early in practice and decreases as reading becomes progressively automatic. The progressive development of the VWFA seems more closely tied to the progression of skills and is not just a matter of maturation. Evidence supporting this point also comes from research examining the effects of training educated adults during reading of unknown alphabetic codes or learning a spelled version of their spoken dialect. Changes in the activity of the VWFA occur also late in development, such as in adults and adolescents.

Preliterate learners, whose language is not written (or has only recently been written, or is being developed), generally progress more slowly in literacy acquisition. In a related context, the literacy acquisition of adult illiterates is different from the reading increase found in children matched to adults for reading achievement level. In fact, adults use contextual cues to improve comprehension more effectively and make a larger use of lexical reading than children at similar reading levels.

Learning a second language (L2) is generally more difficult than learning the native one (L1). Evidence indicates that children are advantaged in L2 literacy if they are proficient in L1 reading and spelling. Difficulties in acquiring L2 are influenced also by the distance between the L1 and L2 orthographies: the more L2 differs from their native language the less easy is L2 reading acquisition.

In view of the large proportion of school dropouts after a few years of instruction in poor countries, one critical question concerns the stability of reading acquisition. There is only limited empirical evidence on such question, except for the findings of the loss of school skills after the summer break. Indeed, after the summer break, regression in reading comprehension, vocabulary, and spelling is reported even beyond the early years of school (*e.g.*, in fifth grade), whereas the seasonal effects of decoding efficiency are restricted to the early grades (especially first grade). This seasonal effect has a greater negative effect on the learning of children who use a different language at school than they do at home. Moreover, the seasonal effect is larger for lower SES children. Without practice, also the orthographic representations (indispensable for automatic word recognition in reading and orthographically correct spelling) of new learned words are lost with time.

Overall, although little information is available on this issue, it appears that stability of learning is limited in the early stages of acquisition, particularly in lower SES children. Also, learning is less stable if it is based on a language different from that spoken at home. Therefore, every effort should be made to encourage continuous and regular school attendance.

Which language should be taught in school?

Identification of which language(s) should to be taught in school is a key issue that involves cultural and political aspects over and above educational and psychological ones. In general, fostering the use of local languages seems to have a number of positive implications. First, in the case of African languages, most have regular orthographies. Therefore, it should be easier for African children to learn reading and spelling in their own languages. Second, it should be kept in mind that these languages are considerably different from western languages, such as English or French and, as stated above, distance between languages has a negative effect on the ease of reading acquisition. Third, the use of the same language at school and home (in oral and written form) favors both the acquisition of literacy skills and the stability of learning. African students have difficulties in following classroom instructions and perform poorly in standardized tests if their understanding of the official language of instruction is poor. This is particularly important in children who attend school for only a few years. Regarding textbooks, the ideal situation is that of schools using bilingual instructional materials where both mother tongue and official languages are printed side by side. However, if only textbooks with the official language are available, the presence in the textbook of a story to sing or some literature source, that students are already familiar with in their local language, may favor their ability of learning to read.

Variables affecting reading comprehension

Text comprehension is closely related to vocabulary, fluency, oral comprehension, and working memory skills; the relative weight of each variable changes as a function of reading acquisition and expertise.

In the first year of reading acquisition, fluency in reading text is critical for reading comprehension. Efficient and fluent word reading releases attentional and cognitive resources to attend to the meaning of the text. Improvement in fluency (due to expertise or as an effect of training) results in improved reading comprehension. By contrast, children who read slowly and with great effort have difficulty understanding what they read, because the cognitive resources necessary for understanding meaning are employed in the reading process. Moreover, slow word reading increases the demands on working memory, which in turn creates difficulty in understanding connected text. This pattern is more often observed in individuals reading English as a second language and language minority students than in native language students.

As decoding expertise is gradually gained, comprehension is less dependent on decoding and more strongly related to general vocabulary skills. Children's rich vocabulary is an important vehicle for reading comprehension and academic achievement. In fact, unknown words create gaps in the meaning of a text; if too many gaps occur, the student may not be able to construct meaning. The depth of vocabulary knowledge is more important than vocabulary size; thus, children who have more complete semantic word representations have an advantage. On the other hand, vocabulary training may improve comprehension, because exposure to print fosters vocabulary growth. In fact, it is possible to acquire, refine and consolidate vocabulary knowledge by reading and deriving inferences from the context.

In turn, vocabulary is also related to fluency, because increased fluency exposes the reader to an expanded vocabulary and a larger vocabulary leads to a faster reading rate. Since vocabulary is influenced by the amount of words children are exposed to, children with low SES typically have a smaller vocabulary and, in particular, a smaller vocabulary growth. Thus, children from low SES backgrounds likely need oriented, effective interventions aimed at vocabulary growth.

Working memory (WM) is critical to the reading process (including word encoding, lexical access, syntactic and semantic analysis, etc.) and also to retrieving, maintaining, and manipulating information related to text comprehension. Readers with lower WM capacity have fewer resources available for the maintenance of information for comprehension. In fact, verbal WM, in addition to lower-level processes (*i.e.*, decoding, word recognition), is involved in the growth of children's reading comprehension abilities. Improvement in fluency could lighten the demands placed on WM resources and allow for greater attention to the comprehension of text. Moreover, working memory capacity influences vocabulary acquisition from context; it allows integrating different information spaced throughout the text to derive the complete meaning of an unknown word. Large distance between the different pieces of information to be integrated increases processing demands, adversely affecting comprehension. Thus, in textbooks sentences should be relatively short particularly when new words are introduced.

Due to the importance of WM in reading comprehension and to predict later academic success, early diagnosis of the WM deficit is crucial as is support to this problem. In particular, for children with poor WM it is important to hear the information at a slow, steady pace. Moreover, because the WM capacity limit is related to the scope of attention, a way to increase performance is to attract the attention of children to the materials to be elaborated. WM capacity is not connected

to parents' level of education, socio-economic status, time spent in pre-school or to the appurtenance to a rural low-income area. This means that, regardless of background or environmental influence, all children can have the same opportunities to fulfil their potential if WM is assessed and problems addressed whenever necessary.

If children have limited WM capacity, it is important to train them in using strategies in order to minimize this functional limitation, such as organization of units into chunks, rehearsal and parsing. If words are assembled in chunks the capacity of the WM increases, it is better organize words into sentences when children were exposed to words to be learnt. Moreover, deeper levels of processing, semantic level, strengthens comprehension. Then, it is important to encourage the learner to engage in a deeper level of processing, in order to increase reading comprehension. Because STM is negatively related to word length, in textbooks it is better to avoid sentences with several long words, and mix long and short words or use long words in highly meaningful contexts.

Overall, in the first years of reading acquisition, every effort should be made to increase reading decoding skills. Fluent reading releases attentional and cognitive resources to attend to the meaning of the text and exposes the reader to an expanded vocabulary. Therefore, acquiring a minimal reading fluency is a critical target particularly in the case of children from poor countries. Teaching should also focus in fostering depth of vocabulary knowledge more than vocabulary size. Exposure to text influences both reading fluency and reading acquisition. Every effort should be made to favor such exposure particularly in children from low SES backgrounds. In this vein, it is important that children will be given the possibility to practice reading at home not only in school. Finally, good oral linguistic competence also favors reading comprehension. This is an additional indication that, other things being equal, teaching local languages be preferred in schools whenever possible.

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INTRODUCTION

“To alleviate poverty and provide basic skills to its largely illiterate population, the government of an African country solicited donor support and made large investments in primary education. Funds were used diligently to train and appoint teachers and administrators and to deliver textbooks to remote areas. As a result, gross enrolment rates in grades 1–5 increased from about 60% in 1992 to about 103% in 2005. However, learning outcomes remained alarmingly low, particularly among the poorer and rural students” (Abatzi, 2008; page 3). Only about 25% of the initial cohort remained by grade 6, and many children dropped out illiterate. Within this context, it seems very important to optimize the quality of teaching and educational materials in order to maximize learning outcomes. Moreover, this situation may indeed extend to nearly all countries. In fact “in times of severe budgetary restraint, additional efforts are being made to identify the most cost-effective ways of improving educational quality” (Crossley and Murby, 1994; page 99). In this respect, the increased provision of high-quality teaching methods, textbooks and learning materials have considerable potential in order to increase learning outcomes.

Reading is a key ability for learning and for individual and social adjustment. It is a complex task involving perceptual, motor, linguistic, phonological, and memory components, each of which has a crucial role in determining reading rate. Understanding these processes is a fundamental prerequisite for intervening when reading acquisition fails, for example, in the presence of developmental learning disabilities, or when teaching procedures are insufficient or ineffective, which results in poor learning outcomes particularly in underdeveloped countries.

In a series of influential papers, Coltheart and colleagues proposed a dual route model to account for adult reading abilities and acquired reading deficits (*e.g.*, Coltheart, Curtis, Atkins and Haller, 1993). This model has been widely accepted and used as a framework for studying the normal acquisition of reading abilities (*e.g.*, Coltheart and Leahy, 1996). Currently, all main models of word recognition explicitly include two mechanisms: cascaded and interactive processing. For example, this is true for Coltheart, Rustle, Perry, Langdon and Ziegler (2001) Dual Route Cascade model (DRC) and for Plaut, McClelland, Seidenberg and Patterson (1996) model. Although the initial visual stage of processing is not extensively described in the DRC model and models differ in terms of how letter position encoding is achieved (*e.g.*, Grainger and Van Heuvel, 2003; Whitney, 2001, SERIOL model or SOLAR model by Davis, 1999), visual factors are presumably quite important in learning to read, particularly in the early stages, which are those of crucial interest for improving learning outcomes in poor countries.

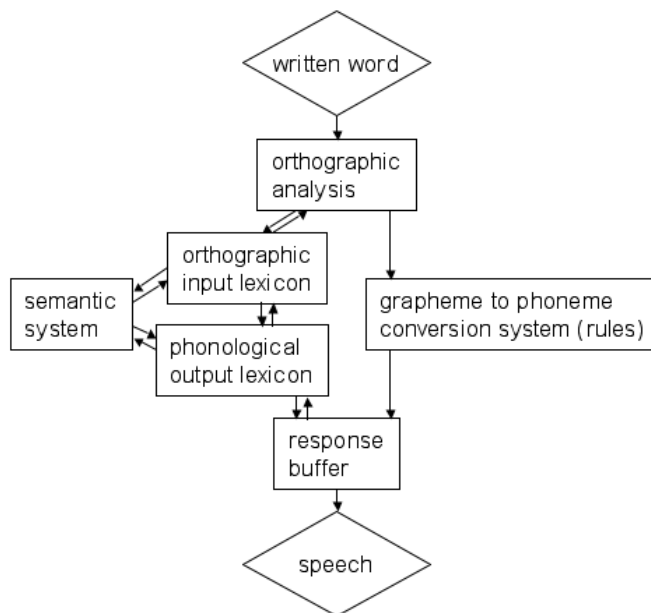
It is widely accepted that a regular word can be read through two independent streams of processing: the sub-lexical phonological route is serial and slow and requires a grapheme-to-phoneme conversion to produce the whole word; the lexical route operates in parallel, but it is fast, it encodes the whole word and matches it to a specific entry in the word lexicon (see box 1 for a brief description). Skilled adult readers use the phonological route only with unknown words and the lexical route with known words and irregular words that cannot be read by the grapheme-to-phoneme route.

Box 1. The Dual Route reading theory

The Dual Route Cascaded model (DRC) is a modular computational model based on the dual-route theory of reading (Coltheart et al., 2001). The model accounts for reading aloud and lexical decision tasks.

The theory has been developed to explain the reading pattern of brain injured patients, and has been extended to the context of normal reading acquisition and developmental dyslexia.

In development most models suggest a reading strategy shift from a slow sequential grapheme to phoneme conversion (right route) to a more efficient direct lexical matching of the whole word form to its sound (left route). Crucial to acquire the fast decoding strategy is the automaticity of the phonological skills.



Basic architecture of the dual-route cascaded model of visual word recognition and reading aloud (Coltheart et al., 2001)

In adult readers the lexicality of the stimulus imposes a different reading mechanism for pseudo words (*i.e.*, legal nonwords) relative to words. Namely, pseudo words are read via a slow grapheme to phoneme conversion strategy, but words are read using direct lexical matching. In opaque orthographies such as English or French the use of the phonological route for reading is limited by the irregularities of the language. As we will see later in part II this has provided a basis for the application of the whole word approach in teaching to read.

Languages differ as to the number of irregular words contained in their vocabularies. Some are characterized by an opaque orthography, such as English and French; other languages have more transparent orthographies, such as Finnish, German, or Italian. The acquisition of reading skills varies considerably across these language types; it also depends on how extensively children rely on the grapheme-to-phoneme conversion route. It is well documented that learning to read in English is characterized by a slow increase in accuracy (*e.g.*, Coltheart and Leahy, 1996). Although this is to be expected for irregular words, many errors in reading regular words are still made after several years of schooling. By contrast, in languages with more transparent orthographies, high levels of reading accuracy are reached quite rapidly (*e.g.*, German: Wimmer and Hummer, 1990; Italian: Zoccolotti, De Luca, Di Filippo, Judica and Martelli, 2009). In these orthographies, it is generally believed that children begin to read by emphasizing alphabetic analysis (Seymour, Aro and Erskine, 2003); in fact, there is no evidence of logographic analysis (Wimmer and Hummer, 1990).

Visual limitations affecting reading and its development are reviewed in the first part of this report to provide a framework for the presentation of the optimal visual characteristics of first-grade textbooks.

In the second part of this report, we present the current knowledge about the acquisition of reading fluency and comprehension and outline the most effective teaching strategies.

FIRST PART

Textbook format and visual effects on learning to read in young children

1.1. Development of pattern formation

Before Piaget's (1937/1955) influential work, perception was considered an immediate process developing *naturally*. In this early view, the ability to recognize object properties, such as color and orientation, depended on maturation of the eyesight. It is now generally accepted that the development of perception (as well as language and thinking) requires high-level concept formation and continues postnatally, with several critical periods during early childhood (Vygotskij, 1962; Chomsky, 1965; Bruner, 1966).

Most developmental studies of object recognition focus on the first two years of life and explore differences across objects and tasks. They investigate the preferences infants show for certain classes of objects, such as faces. Several studies have tracked the learning of object recognition using tests that rely on infants' selective attention to novelty. In fact, researchers use this effect to determine what attracts infants' attention, which tells us something about how they represent a situation and provides evidence about the age at which infants are first able to recognize stimuli (Carey, 1993; Spelke, 1990; Leslie, 1988, 1994; Simion, Macchi Cassia, Turati and Valenza, 2001).

Although reading is a very challenging task, normal adult readers perform with impressive speed. This ability can be greatly hampered by mild visual deficits or strongly limited by low vision. Psychophysics has studied the visual limitations to reading fluency. Although most of the psychophysical studies reported in this review, unless stated otherwise, were performed on English speaking observers. However, it is worth noting that the visual limitation reported in psychophysical studies characterize the brain low level architecture and seem to be invariant across languages and scripts (Legge & Bigelow, 2011). From this perspective, two important questions emerge: how efficiently do children identify objects? When during the course of development does the visual object recognition system reach maturity?

1.2. Features and noise

The complex process of visual word recognition starts with independent detection of elementary features and simple oriented lines and then proceeds to their integration into letters (Robson and Graham, 1981; Pelli, Burns, Farell and Moore-Page, 2006). Each of these steps develops with age.

From a temporal perspective the question focuses on the capacity limits, and measures how much information can be parallelly processed in a unit of time, and how many units are needed to complete all the information processing required by the task. From a spatial standpoint, performance is limited by the resolution ability within the capacity limit, and the word recognition lower bound is determined by letter visibility (Pelli, Farell and Moore, 2003).

With the aim of studying letters and words recognition, a great deal of research has investigated the word superiority effect, which refers to the fact that observers are better at recognizing a letter within the context of a word than in isolation (Reicher,

1969). The word superiority effect has been quantified by measuring percent of correct identification, vocal reaction times, and contrast thresholds, *i.e.*, the minimum amount of ink in the stimuli needed by the observers to reach a performance criterion (Wheeler, 1970; Reicher, 1969; Jordan & deBruijn, 1993; Babkoff, Faust & Lavidor, 1997; Pelli *et al.*, 2003). In all these cases the magnitude of the effect is about a 1.4 advantage for words vs. nonwords or letters in isolation. This effect was taken as evidence of the existence of a special mechanism in the brain tuned to the whole word (McClelland and Rumelhart, 1981). However, it is now clear that the 1.4 word advantage is too small to represent a convincing argument for the existence of visual *templates* for words (*i.e.* a mechanism in the brain that detects the whole word as a single unit). Indeed, the existence of a visual template in human brain that integrates contrast across the entire word would predict that the amount of ink needed by the observers to reach a criterion performance would be distributed over the entire word independently of how much ink is given to each letter (*i.e.*, the ink, that is the contrast difference with the background page distributed over the area of the stimulus, needed would be independent of word length). However this is not the case and the amount of ink at identification threshold for words is equal to the quantity needed for single letters times the number of letters in the words. Rather, the word superiority effect can be predicted by reference to an imperfect confusion probability matrix for letters (*i.e.*, when identification occurs, only the legal letters in the alphabet can appear next; Pelli *et al.*, 2003), which becomes active in development when the regularities operating at the level of sub-lexical orthographic representations are learned (Grainger, 2008). Overall, these studies indicate that the bottleneck of reading is defined by the letter visibility and that this lower bound can be hardly bypassed through text familiarity. As a consequence knowing how the visual abilities involved in letter identification develop seems fundamental in designing textbook for beginner readers.

When exploring a visual scene such as a page of text we do not process all information at the same time. Even compensating for spatial limitations by enhancing letters visibility, at any given moment in time we can only decode the information that does not exceed our capacity limit. If an entire page of text is present in front of our eyes the amount of time it will take to read the page is a function of how much of it we can acquire in parallel, in a single glimpse. Thus, from a temporal standpoint, the ability to identify a word is limited by the number of letters available in a single fixation. This capacity has been called perceptual span, span of apprehension, or visual span. Its size varies considerably depending on the measurement procedure adopted. Here we will refer to the visual span of efficient adult readers, which is about seven letters long and is reduced with increasing eccentricity, when their gaze shifts (Legge, Mansfield and Chung, 2001). We will briefly review how detection of features, identification of letters, and visual span develop with age.

The contrast sensitivity function (CSF) describes our ability to see faint black and white oriented lines or gratings on a grey background as a function of their size, that is, their spatial frequency⁴ (Campbell and Robson, 1968). The temporal counterpart

⁴ Spatial frequency of sinusoidal gratings is measured in cycles per degrees of visual angle (c/deg). A cycle is the contrast distribution that goes from mid grey to the light bar, then dark bar, and back to mid

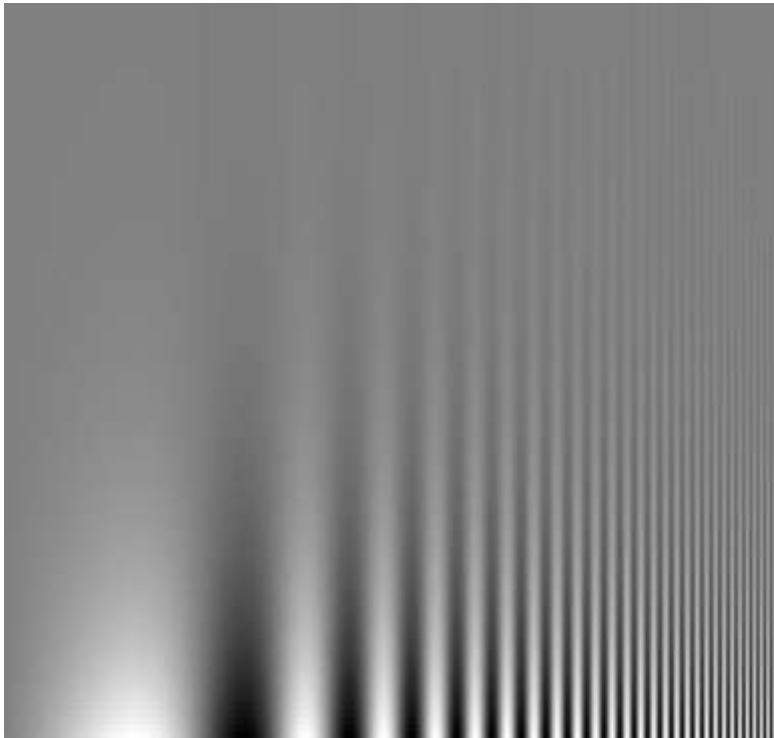
concerns the ability to detect a grating of a given size as a function of its temporal frequency, that is, rate of black and white reversals in Hz. Our visual system detects intermediate sizes (3-4 c/deg) best, with little ink⁵, fine and coarse lines worse; more ink is needed to perform the task at the same accuracy level when size is larger or smaller than optimal. Visual acuity (the smallest shape we can identify) refers to the finest lines we can detect at low contrast (for an overview of the mechanisms responsible for the CSF see box 2).

grey. A degree refers to the angle subtended by the object at the retina. In vision objects are measured in degrees, centimeters are irrelevant, apart from when it comes to the extreme of the scale where for example typographic printing resolution matters. Degrees depend on the distance between the object and the observer. Eventually, even a largely printed book will become unreadable when positioned far enough away from the reader. A degree has roughly the size of a fingernail viewed from an arm distance. Thus, a sinusoidal grating has a spatial frequency of 1 c/deg when its cycle covers roughly 1 cm viewed from 57 cm away.

⁵ With letters contrast refers to the amount of ink used to draw the letters relative to the background page. In the case of sinusoidal gratings contrast refers to the difference between the amount of ink added to the dark bars and the amount of ink subtracted from the light bars relative to a mid grey background (Michelson contrast $(L_{max}-L_{min})/(L_{max}+L_{min})$).

Box 2. The contrast sensitivity function

Fourier, a French mathematician, showed in 1822, that each complex pattern can be described as an appropriate sum of simple sinusoidal waves. In vision this type of object is thought as an elementary feature. Objects are comprised by several elementary features, and we recognize them by first detecting these simple components. In order to detect a feature with at certain accuracy level an observer needs a minimum amount of contrast in the wave (maximum luminance – minimum luminance divided by the background luminance). The amount of contrast needed defines how well we see that particular feature, the less the contrast the better the feature visibility for our visual system. The image below (from Campbell & Robson,



1968) shows these features changing in size (spatial frequency) going from left to right and in contrast from bottom to top. Tracing the faintest feature at the top still visible from left to right, it is possible to note that the sizes around the centre of the demonstration are seen best. The difference in visibility across sizes is not a print artefact, but it is the result of our brain process.

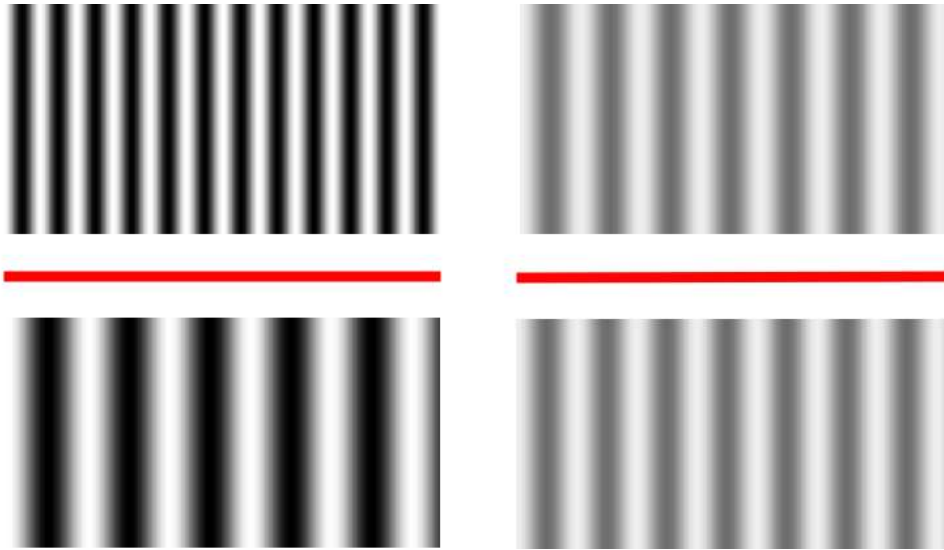
This is the contrast sensitivity function (CSF)

that defines the window of visibility on the world, first measured by Shade (1956). Our sensitivity peaks for intermediate sizes (4-6 cycles/deg), drops at high frequencies (right) because of optical limitations, and at low frequencies (left) due to neural constrains.

In a clever experiment Campbell and Robson (1968) tried to predict the visibility of complex patterns on the basis of the CSF. The Authors showed that observers don't sum contrast across sizes, and suggested that each size (or each small size range) is detected by an independent mechanism. Every independent mechanism, also called channel or feature detector, detects an oriented line of a certain size and can be selectively adapted.

Blakemore and Campbell (1969) have shown that after prolonged viewing of a sinusoidal wave of a certain size, the CSF changes shape showing a small dip at the size previously seen. This effect is based on the adaptation phenomenon by which prolonged exposure to a stimulus fatigues the mechanism most sensitive to that object that will be unlikely to respond for a certain period of time after exposure. The observer's percept reflects the activity of the residual mechanisms that have not been

adapted. The figure below is a demonstration of the adaptation effect on the detection of elementary features (Blakemore and Sutton, 1969). To experience the adaptation effect stare at the left bars, keeping the eyes on the red line for one minute. Then, quickly move the eyes on the right line and look at right bars. Do the bars appear of the same size (top and bottom)? The upper bars look larger than the lower bars.



What happened? During adaptation the upper visual field (above the red line) was stimulated with a relatively higher spatial frequency than that displayed during the test phase (right bars). The opposite happened in the lower visual field. As a consequence, after adaptation, the mechanisms tuned to small sizes were relatively silent on the top and the peak response shifted toward lower frequencies. The opposite happened in the lower visual field.

Feature detectors find their likely neural implementation in the primary visual cortex where cells are selective for size and orientation Hubel and Weisel (1979). In a very influential paper Barlow (1972) proposed that the selectivity is achieved at high level in the perceptual hierarchy by reducing the redundancy of the visual image through the activity of few reliable cells (i.e. the relative number of active cells reduces climbing the steps of the perceptual process).

The shape of the CSF predicts that recognition of more complex patterns and changes in its shape are indicative of visual development, or the presence of peripheral, such as myopia, or central, such as amblyopia,⁶ visual defects (Levi, Song and Pelli, 2007). A visual elementary feature can be thought as an oriented line of a certain size, a sinusoidal grating of a definite spatial frequency, and it is the simplest unit of an object. It is known that at early stages of brain processing, such as in the primary visual cortex V1, we have neurons tuned to these elementary features and that a hierarchical model of the brain can explain how we build objects from these units (Hubel & Wiesel, 1959; 1979). The CSF describes how efficiently we see those elementary features. There is evidence that features are learned early. At few months of age the CSF starts with a tuning to coarser sizes, low spatial frequencies, as a consequence newborns see large objects best. Then, the CSF develops within the first two years of life to the adult-like shape showing peak sensitivity for intermediate frequencies of about 3-4 c/deg (Fiorentini, Pirchio and Spinelli, 1983; Morrone, Fiorentini and Burr, 1996). *This indicates that, at two years of age, we are already able to process the units of objects as efficiently as adult do. However, as mentioned earlier, the visual system builds objects hierarchically and a longer learning period is needed to finely tune this process.*

Traditionally, contrast sensitivity is measured on a blank field. To obtain an exact indication of visual processing selectivity, some authors have emphasized the importance of measuring a contrast threshold also in the presence of external noise added to the stimulus (Barlow, 1962; Pelli and Farell, 1999). External noise is usually a Gaussian contrast distribution of black and white random dots added to the image stimulus; its appearance is much like a television screen when the signal is absent. Measuring contrast threshold to detect or identify an object as a function of the intensity (contrast) of external noise reveals how much the observer sensitivity depends on the visual degradation of the stimuli. These measurements show that the observer's ability to identify an object is independent from the external noise contrast in the low-intensity range, but it progressively worsens with noise contrast at high intensities (*i.e.* when the external noise is weak it is irrelevant for the observer, while it becomes increasingly relevant after a critical intensity is hit). The point of separation between these two regions, the critical contrast at which external noise starts to matter, represents an estimate of the amount of internal noise (*equivalent input noise*); this can be roughly considered as the neural activity uncorrelated with signal intensity (Pelli, 1990; Lu and Doshier, 2008). If we think at noise as the background of old half-erased blackboards⁷, such as those typical of low-income countries or more in general in poorly funded schooling systems, this means that the teacher should press hard on the calc when writing text. Naturally, reading is impaired depending on how much the blackboard is damaged but, as we will see later, also on how large are the

⁶ Amblyopia is a usually monocular defect characterized by poor vision in an eye that is otherwise physically normal. Is the consequence of a sustained period of dysfunction during early childhood due to strabismus or to a differential degree of astigmatism between the two eyes. It is usually corrected during childhood by covering for some hours a day the good eye.

⁷ This is only a rough approximation since the pattern of missing pieces of slate on an old blackboard is probably not perfectly Gaussian. As a consequence it may impair visibility of letters of certain critical sizes more than others determining an even worse performance than Gaussian noise would do.

missing pieces of slate relative to the text size. (for an overview on the effect of noise on reading see box 3).

Box 3. The effect of visual noise on text readability



The image on the left shows a blackboard used in a Mozambique school. As evident from the picture the surface is ruined and the written words are barely visible. How does the visual pattern on an old blackboard affect text readability?

Psychophysical studies uncover the characteristics of the mechanisms used to recognize letters and words by applying visual noise to mask the text

Noise is usually white (Gaussian noise) similar to the one shown in the image below. White noise due to its properties in the spatial frequency domain is able to mask any object independent of kind and size.



Naturally, it is unlikely that the noise on an old blackboard would be white. The size and the distribution of the missing pieces may not be mathematically described in such simple terms as the examples we are

giving here. In any case also noise that is not white but differs in the size of its pattern affects greatly text readability dependent on text size and viewer distance.



The figure below shows how noise affects reading (Majaj, Liang, Martelli, Berger & Pelli, 2003).

The noise in the image is filtered to various bands (0.15-9.7 c/letter). All the rows of text are printed with the same amount of ink. Starting from the top, try to read the text. As you go on row by row reading rate slows down toward the middle and speeds up again toward the end. Although all noise types could potentially be effective in masking the text, the demo is showing that one band of noise is most effective in

impairing reading. If you are viewing the text from a distance of 45 cm, your reading capacity is mostly impaired by noise filtered to 3 c/letter. Moving away the most effective noise would slightly scale to relative lower frequencies (upper rows).

Note that the effect of visual noise is dramatic; the letters disappear making reading impossible. Similarly an old ruined blackboard may not enable reading impairing letters decoding and words recognition.

Thus, when external noise is low (as when words are presented on a uniformly white or grey background), observers' ability is limited by the amount of noise within their visual system, that is neuronal activity uncorrelated with the stimulus intensity. By contrast, in the presence of high external noise observers' ability is independent of internal noise and solely depends on the amount of external noise and the tuning of the perceptual template for objects of the observer. Thus, noise thresholds are measurements of the selectivity of the visual process used by the observer to perform the task (Pelli and Farell, 1999).

Perceptual learning of novel alphabets by adult observer's acts as a combination of external noise exclusion by fine-tuning the visual mechanism used to perform the task, and stimulus enhancement via internal noise reduction. Thus, with learning, neurons finely tune their activity to the signal properties and less uncorrelated neuronal activity affects observers' performance (Doshier and Lu, 1998; Lu and Doshier, 2004). Internal noise reduction is mild, accounting only for a small fraction of the observers' performance, whereas external noise exclusion is large and noise greatly affects performance at the beginning of the learning process. Thresholds in noise are also greatly affected by development (Pelli and Farell, 1999; Pelli *et al.*, 2006). Noticeably, the learning curves (increase in performance as a function of trial number) for identifying letters of a preschool child are as steep as the one measured on adult observers learning a novel alphabet, indicating that similar processes are at work when learning a particular set of stimuli (Pelli *et al.*, 2006). However, contrast threshold in noise for identifying letters improves up to the age of 7-10 and then remains unaltered (Martelli, Baweja, Mishra, Chen, Fox and Majaj *et al.*, 2002). Presumably all the English speaker observers that participated in these studies had prior exposure to letters. By age 6, due to the general tendency of preschool alphabetization in U.S. but also in Europe, children already performed thousands of trials attempting to identify letters in games or books. In this vein, the long improvement period for identifying letters may be partially due to specific perceptual learning with the particular set of objects, and partially to the maturation of the visual system. In developing Countries children from illiterate families may arrive in school with no prior exposure to letters. This, combined with an immature visual system substantially limits the letter learning process. Thus, rather than bypassing this first requirement for reading, in school particular care should be devoted to the early letter decoding phase. In our blackboard example, the combination of these results means that if the slate is moderately intact or new, children at the beginning of learning will be mildly hampered by a physiological limit due to the amount of noise internal in their visual system. However, if the blackboard is deeply damaged they would be greatly impaired until the learning process for letters has not reached a good efficiency. Children able to read will generally have worse performance on old blackboards. However, children who do not know how to read will be disproportionately hampered since their visual templates for letters still need improving in terms of selectivity.

Taken together these results indicate that reading noisy text affects beginner readers more than experienced observers. A parallel question concerns whether it is more difficult learning to read on a damaged blackboard than on a cleaned one; that is, how fast, in terms of number of trials, performance reaches a plateau on a blank field and on a noisy background. Learning proceeds quite similarly; however, maximum performance on a blank field is achieved after about 800 trials, while it takes about

1100 on a noisy background (Li, Levi and Stanley, 2004; Chung, Levi, Tjan, 2005)⁸. This is not a large difference as expected by the above-mentioned perceptual learning results. However, quantifying the effect in terms of text, considering a word length average of five characters and about ten words per page, children would need to read the text 15 times to reach a plateau on a blank field while they would need 6 additional readings on a noisy background.

We may wonder whether writing larger letters on old and noisy blackboards might help letter identification. This is hard to evaluate because we do not know the distribution and size of the slate missing pieces (*i.e.*, we do not know the frequency distribution of the noise; *e.g.* Solomon, 2000). We know that not all the frequency content of letters is relevant for their identification⁹ and that observers only use a frequency band centered on 3 c/deg to identify the object (Solomon & Pelli, 1994). As a consequence, if the noise spectrum on the blackboard hits the preferred letter spatial frequency recognition would be greatly hampered. Counter to intuition, the letter frequency we use for recognition does not perfectly scale with letter size. We use gross strokes (lower frequencies) when letters are small and fine strokes (higher frequencies) with large letters (Majaj *et al.*, 2002). Thus, scaling the blackboard size by moving the child further away may reduce the impact of noise if at closer distances the noise frequency matched the preferred letter frequency.

Two separate systems in the brain, that is, the magnocellular (M) and parvocellular (P) pathways constitute the neural substrates of different parts of the temporal and spatial CSF. Neurons in the M-pathway are tuned to low spatial and high temporal frequencies; by contrast, neurons in the P-pathway are tuned to high spatial and low temporal frequencies (Shapley and Perry, 1986). Thus, the magno system detects large and fast objects best; while parvo cells respond better to stationary small objects. In monkey brains, these pathways segregate early in development dependent on visual experience (Rakic, 1981). The P-pathway cells mature first, reaching adult size at about 12 months. The M-pathway cells reach adult size at 24 months. However, this does not indicate that the pathways are functionally mature by age 2, since neuronal connections may still be developing.

Note that the M- and P-pathways have a broader implication in object perception and action than simple features detection. It is believed that the M/dorsal pathway is implicated in motion perception (Newsome and Paré, 1988; Schiller, 1995) and the P/ventral pathway in color and form perception (Kobatake and Tanaka, 1994; Lennie, Trevarthen, Van Essen and Wassle, 1990). Gordon and McCulloch (1999) used evoked potentials to look at M- and P-pathway maturation in 5-, 8- and 11-year-old children and found no development in the M pathways across these ages; however, the P-pathway was still immature in the 8-year-old children. Similarly, Madrid and Crognale (2000) found that responses to color-defined stimuli (designed to preferentially activate the chromatic M-pathway) are adult-like only after age 12. This does not mean that children are color-blind until age 12 but that they process color less efficiently and are less sensitive to nuances. *Thus, in designing textbooks primary bright colors should be preferred.*

⁸ Note that Pelli et al. (2006) find much longer learning curves of about 2000 trials for novel alphabets.

⁹ Here, we mean that each object in the visual scene has a frequency spectrum, it contains energy at several frequencies (sizes), and that not all of them are used by the observers.

1.3. Letters

Moving from simple features to more complex patterns similar to letters, visual acuity measures have shown improvement up to ages 8-12 and this is also true for stereo-acuity (*i.e.* depth difference perception) and motion-defined letter identification (Giaschi and Regan, 1997; Buckingham and Kelly, 1996; Fox, Patterson and Francis, 1986; Zanker, Mohn, Weber, Zeitler-Driess, and Fahle, 1992). Gibson, Gibson, Pick, and Osser (1962) reported a dramatic improvement in children between the ages of 4 and 8 in the ability to match letter-like shapes. Similarly, measuring efficiency for letter identification, Martelli *et al.* (2002) found a dramatic improvement in performance from age 2 to age 10.

The ability to identify letters has important implications for reading acquisition. Feagans and Merriwether (1990) found that children with learning disabilities who had visual discrimination problems (measured with Gibson's letter-like shapes at 6 years of age) had worse reading performance during the elementary school years than other children with learning disabilities but normal performance on Gibson's task and than normally achieving children. It must be noted that these results do not indicate that the visual system is unable to learn letters until age 8. Pelli *et al.* (2006) found that over the course of hundreds of trials a 3-year-old child is able to learn the alphabet as fast as an adult observer learns a foreign alphabet. Furthermore, after several thousand trials, adult observers perform a letter identification task in a novel alphabet as well as native speakers.

Overall, these results indicate that children's ability to learn is already mature at age 3 and that the brain is still able to learn novel alphabets efficiently in adulthood. Nevertheless, outside the laboratory it takes several years of experience to master an alphabet. Why were Pelli *at al.*'s observers so efficient in learning new alphabets? Unlike the other cited studies, these authors used thousands of repetitions of the same task, with the same stimuli (same identity, font and size), under the same viewing conditions. Thus, they provided the maximal conditions for perceptual learning. By contrast, experience acquired during development is unlikely to occur within such a constrained environment. When controlled stimulation is absent, expertise may be harder to achieve and takes considerably longer.


In fact, reports in the literature on adult perceptual learning indicate that improvements in performance following training are task or stimulus-specific. For instance, the learning effect in simple detection and discrimination tasks is specific to the learned orientation of the stimulus (Fahle and Edelman, 1993; Fiorentini and Berardi, 1980; Poggio, Fahle and Edelman, 1992), the spatial frequency of the stimulus (Fiorentini and Berardi, 1980,1981), and the direction of stimulus motion (Ball and Sekuler, 1982, 1987). Furthermore, the degree of transfer of the learning effect to other tasks, to the same task performed in a different retinal location, or with a different eye is still debated, with estimates of transfer ranging from 0% to 100% (Beard, Levi and Reich, 1995; Fiorentini and Berardi, 1980, 1981; Ball and Sekuler, 1987). Developmental studies indicate that, between age 4 and 8, children learn the features that distinguish the letters in the alphabets and the dimensions (such as size, rotation type face transformation) along which the same letter could vary (Gibson, 1965). Thus part of the long learning period can be explained by the extraction of the

dimension of differences that are critical to discriminate among letters. This learning seems to be particularly relevant because it transfers well to the task of identifying words, while the converse transfer from words to letters is weaker (see Gibson, 1965). These results have two main implications for teaching to read. On the one hand, contrary to the whole word approach, starting from letters can substantially help word decoding. On the other hand, experience with different font types can help acquiring the relevant dimensions that define letters. As a consequence, teaching calligraphy after having taught the alphabet using printed letters may help the process of building a letter prototype.

1.4. Complexity

Usually the visual world (such as a page of text) contains an enormous amount of information that is not immediately available. Interest in measuring the capacity limit of our perceptual process has a long history in the field of psychology (e.g., Miller, 1956; Sperling, 1960; Woodworth, 1938). Although there is a modern tendency in typography to optimize character legibility by reducing the number of features, objects (such as letters) are composed by several elementary features and their visibility is limited by the capacity of our visual system.

The findings of Pelli *et al.*'s (2006) study, which show that it is possible to learn novel alphabets quickly, indicate that observers learn to handle letters as chunks, bypassing the bottleneck of detecting and binding all the features. However, in the same paper, Pelli *et al.* (2006) also manipulated letter complexity by comparing different alphabets in terms of perimetric complexity. This is defined as the (squared)

inside-and-outside perimeter divided by ink area. For example the letter  written in Kunstler is more complex than the letter D written in Times and this in turn is more complex than the same letter (**D**) printed in Times bold. Hartley (1994) pointed out that certain type-faces, such as Gothic and Balloon, are not suitable for instructional texts. Measurements of complexity across different alphabets indicate that Latin Courier characters are three to four times less complex than Arabic or Chinese characters (Attneave and Arnoult, 1956). Pelli et al (2006) investigated whether complexity affects the ability to decode letters by comparing different fonts and different alphabets including Latin, Arabic, and Chinese in native and naïve observers with the tested alphabets. In order to directly compare across different alphabets, the authors computed efficiency, that is, the ratio between the human and the ideal observers' thresholds in noise. The ideal observer is a computer program tested as the human observer; in any given trial, a letter in noise is provided and the ideal observer chooses the likeliest signal. The program is provided with all the samples in the set without noise and chooses the signal on the basis of the closest match between the letter presented in the trial and the ones stored in the set. In other words, it is a template matcher that is only affected by the noise, and that provides a mean to compute the available energy in the stimulus. Thus, efficiency is the fraction of available energy effectively used by the observer to do the task. Efficiency is always less than 100%, typically 20% for detecting a simple feature and 1% for identifying a letter (Dubois, Poeppel & Pelli, 2011). Efficiency for the various identification tasks gives an estimate of the visual cost of binding features together relative to simple detection of a single feature. Results show that although all alphabets were learned at

the same rate, efficiency was inversely proportional to complexity. After learning, Arabic observers identified letters in their native alphabet two to three times less efficiently than Latin letters. Note that, despite years of reading experience, we also recognize words less efficiently than letters, and efficiency is inversely proportional to word length even when tested with the most common words (Pelli, Farell and Moore, 2003). This is the bottleneck of vision, and the results reinforce the idea that letters are the basic unit of reading. Despite the literature on the existence of a word based module in the brain, these results suggest that this module may not be tightly linked with the orthographic input (*i.e.*, it is not a template). As a consequence one may posit that letters should be learned first. We now turn to factors that affect letter identification.

1.5. Type-Face

Typefaces affect readability and entertainment value of learners (Jo and Han, 2006). Figure 1 reports example of sans-serif type-faces and Serif fonts. Faces with serifs are text fonts that have finishing strokes at the ends of letters, such as Times New Roman. Faces without serifs, called sans-serifs, are those that do not have finishing strokes at the ends of letters, such as Helvetica and Arial.

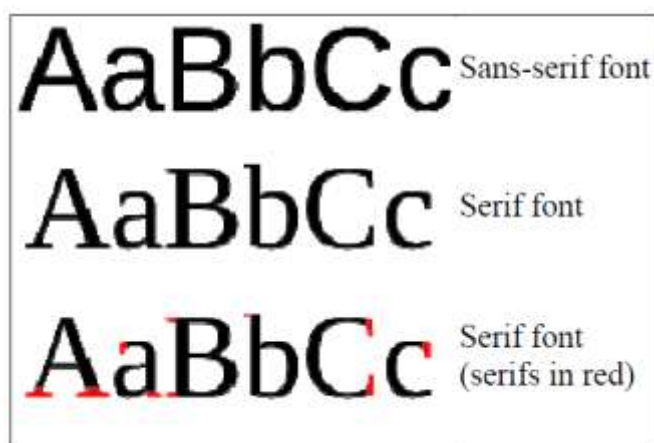


Figure 1. Example of sans-serif type-faces and serif fonts (**Source:** Wikipedia).

Sans-serif type-faces are recommended for headings and texts that are not intended for continuous reading such as tables, reference works, and so forth. Sans-serif type-faces are also more legible than serifs type-faces in the smaller sizes like 6 and 8 points. Since sans-serif type-faces separate one character from the next (and leave more white space in between), some people find it easier to read.¹⁰ Indeed, “the Royal National Institute for the Blind recommends the use of sans-serif type-faces for small blocks of instructional text for visually impaired readers,” (Hartley, 1994, p. 29). For continuous reading where there is ample body of text, faces with serifs, such as

¹⁰ See, Do typefaces really matter? *BBC News magazine*, July 20, 2010, available [online] at <http://www.bbc.co.uk/news/magazine-10689931>.

Times New Roman, are often employed in English. Apparently, this is because serifs reflect handwriting styles, which help the eyes to link the characters.¹¹

In Figure 2, we report two examples of sans-serif type-face (where letters are separated from one another) typically used for first grade reading textbook, such as Cordia New type-face and Levenim MT type-face.

Type-faces	Thai Scripts	Latin Scripts
Sans-Serif	แม่ไก่ สีเทา	Puerto Plata
	Cordia New (40 pt)	Levenim MT (24 pt)

Thai First Grade Reading Textbook Semester 1	Dominican Republic's First Grade Reading Textbook
	

Figure 2: Examples of typefaces used in first grade reading textbooks (Source: Benavot 2010).

In recognizing serif fonts such as Bookman and Courier observers obtain a slightly lower efficiency relative to Helvetica, a sans-serif font. However, the effect on efficiency is too small to recommend Helvetica as a font for children's textbook. Indeed, we will see later that other effects related to letters spacing may suggest the use for Latin scripts of the Courier font, characterized by constant letters spacing.

1.6. Visual span: from letters to words

As stated above, our capacity limit indicates that, at any given moment in time, only part of the visual information can be decoded. Results on complexity measurements indicate that the number of strokes in the characters may be the unit defining this limitation. However, which units should be used to specify the size of this bottleneck, that is, features or letters is being debated (Baddeley, 1986; Nasanen, Kukkonen and Rovamo, 1995; Pelli *et al.*, 2003).

¹¹ Ibid.

At the beginning of the 19th Century, it was calculated that, while reading a text the eyes move across the page (saccadic eye movements) at a nearly constant rate and that adult fluent readers make about four fixations per second (Huey, 1908). In fact, for a long time, reading rate was considered to result from the product of the number of fixations and the number of letters that could be acquired in each fixation. However, since Woodworth (1938), it was clear that there might be a variety of different “spans” under this definition.

O’Regan (1990) proposed distinguishing the visual span measured with random letters from the perceptual span measured with words that might be facilitated by lexical knowledge of the stimulus (see also Rayner, 1986). In a classic paper, Sperling (1960) concluded that our capacity is limited by memory rather than visibility. Pelli *et al.* (2006) used a missing scan paradigm similar to Sperling’s partial report. They briefly presented a string of letters of various lengths (1 to 8) replaced by the same string with a missing item and asked observers to report the missing letter. The assumption was that accuracy would be independent of string length when the span included all the letters. The authors found that the span consisted of 5 characters for English and Armenian speakers with their native alphabets and 3 ideograms for Chinese speakers. This finding suggests that complexity may also reduce the memory span for characters. Table 1 compares the calculation of complexity across fonts and scripts (from Pelli *et al.* 2006). As shown in the table Chinese is characterized by double the complexity than English written in Courier font or Armenian.

Alphabet font/script		Complexity
Courier	a	100
Helvetica	a	67
Arabic	ي	137
Armenian	Ա	106
Chinese	你	199
Devanagari	अ	99
Hebrew	א	90

Table 1. Complexity calculation for several scripts and fonts.

They also found that, although learning improved efficiency for identifying new alphabets, the span remained unaltered in size between 1 and 2 characters. Impairing phonological rehearsal in the native language did not affect the results.

These results suggest that the number of letters available at a glance grows during several years of perceptual experience, possibly explaining the improvement in reading rate during the first years of school. From grade 2 to college English speaking students slowly improve their reading speed at a rate of 14 words per minute each year (Carver, 1990). Legge *et al.* (2001) defined the visual span as the number of letters available in a glimpse and measured letter recognition for triplets (random strings of three letters) as a function of their position in the visual field. In this case, the number of letters to be reported in each trial never exceeded memory limitations and included encoding of

the relative position of letters implied in word recognition. The authors found that the visual span extends to about 6 letters on the right of fixation and 4 on the left. This apparent discrepancy in size with the span measured by Pelli *et al.* (2006) can be explained by differences in the criterion of the task performance adopted by the different authors to estimate the size of the span and by differences in the method used to estimate the span. Indeed, Pelli and colleagues presented long strings that had to be memorized and measured the visual span by multiplying accuracy by the number of letters in the string. Legge and colleagues estimated the size of the visual span at a certain criterion level (such as 80% correct) and defined the number of letter that are correctly identified above the criterion by always presenting only letter triplets at different positions along the string. This led to an underestimation of Pelli's span relative to Legge's.

1.7. Visual span and reading speed

Kwon, Legge and Dubbels (2007) measured the size of the visual span as a function of grade level by comparing 3rd, 5th and 7th English speaking graders. They found consistent improvement with grade level and a difference between 3rd graders and adults of about 2.5 characters. They also found that the improvement in reading rate across grades correlated with the size of the visual span. Thus, they hypothesized that the size of the visual span imposes a fundamental limit on reading speed (Legge *et al.*, 2001).

Chung Mansfield and Legge (1998) found that the visual span also decreases with eccentricity from 10 characters in the fovea to 1.7 characters in the peripheral visual field (at 15 deg of eccentricity¹²). This reduction correlated well with the reduction in reading speed going from the fovea to the periphery. Chung, Legge and Cheung (2004) investigated whether perceptual learning can improve the poor reading abilities and the visual span when measured in the peripheral visual field of adult fluent readers. The authors trained the observers to identify letters in the periphery using the same letter triplets as those used to measure visual span and found that the latter increased in size after training, accompanied by a 40% improvement of reading rate measured at the same retinal location.

These results reinforce the idea that the visual span imposes a limitation on reading speed and suggest that with practice this visual limitation can be reduced. The number of letters we can process in parallel increase during learning starting at a modest 2 letter span. This indicates that, at the beginning of the learning process, children are unable to decode long words quickly, and rather they parse them in two-letter chunks. The span slowly enlarges with learning indicating that five to eight letter words can be decoded in a glimpse by parallel processing. *These results suggest that textbooks should start teaching letters and bigrams that do not exceed the capacity limit and proceed gradually to longer words.*

¹² Eccentricity indicates the distance from where we are looking at (fixation point) and it is measured in degrees of visual angle.

1.8. Effect of size

There is a long tradition of measuring reading rate with the paradigm of rapid visual serial presentation (RSVP): one word at a time is presented at the same retinal location minimizing the role of eye movements (Potter, 1984).

Increasing text size improves reading rate until the rate of increase reaches a plateau and remains unaltered for larger sizes (Legge, Pelli, Rubin and Schleske, 1985). This break point is called critical print size (CPS); it measures approximately 0.2 deg¹³ in fluent adult readers tested in central retinal locations¹⁴ (Mansfield, Legge and Bane, 1996). In fact, this is approximately the size of a letter in a text seen from about 40 cm away, which is the comfortable distance used by adult readers (for a description of the curve see box 4). In children's books, print size is usually larger than that in adult books, ranging from 5 to 10 mm in x-height, equivalent to 0.72–1.43 at a viewing distance of 40 cm (Hughes and Wilkins, 2002).

Hughes and Wilkins (2000) found that the reading speed of 5-7-year-old children decreased as text size decreased below this range, whereas the reading speed of older, 8-11-year-old children was less dependent on letter size. O'Brien, Mansfield and Legge (2005) reported that the critical print size (CPS) decreased from 6 to 8 years of age, indicating that younger children need larger print to reach their maximum reading rate than older children. Kwon *et al.* (2007) measured the effect of increasing print size (0.25 deg and 1 deg) on reading rate as assessed by RSVP, comparing 8, 10 and 12-year-old children. They found no improvement with size across these ages.

Overall, the results indicate that *size affects reading rate in English speaking observers during the first two years of schooling during which children optimize the visual processing involved in word decoding. In addition they indicate that beginner readers require a much larger letter size to achieve optimal reading. The critical print size in this case is roughly 1.2 deg, considering a viewing distance of 40 cm (which is the distance spontaneously used by children); these letters measure around 0.84 cm., which is equal to 24 pt (post script points).*

Hartley (1994) proposed two factors in choosing a type-size for typical textbooks. First, textbook designers must set a maximum permissible line-length that will not hinder the sensible phrasing of the information. Second, they must take into account the relationship between the word-spacing and line-spacing of the information. In regular textbooks and standard texts, the typical type-sizes are 10, 11 and 12 points (*e.g.*, this paper uses 12 points Times New Roman for the whole body of texts). In young children textbooks, however, type-sizes are usually much larger (*e.g.*, 26, 28 and 30 points in English font or 36, 38 points in Thai font for a four-to-six words in one line).¹⁵

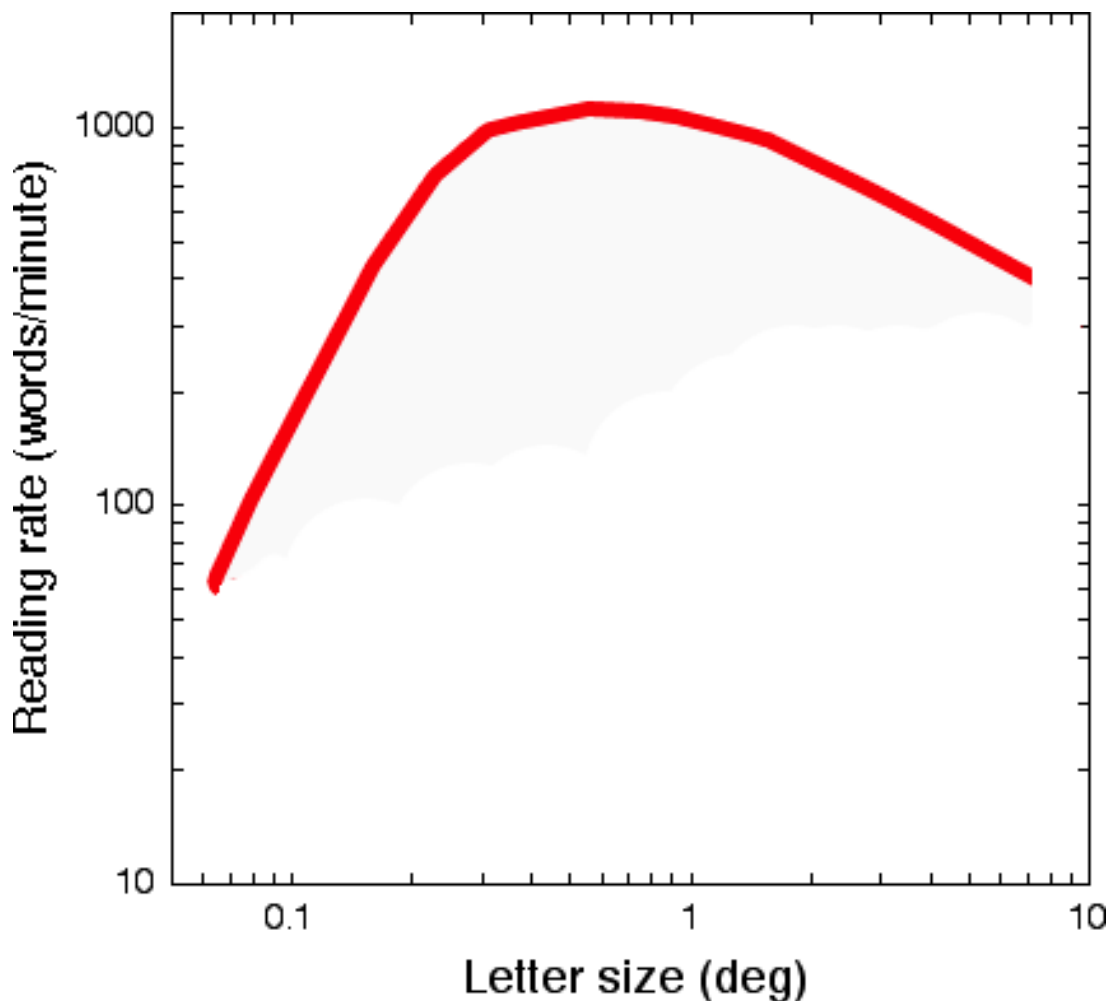
¹³ We have previously seen that 1 degree of visual angle is roughly the measure of 1 cm seen from a distance of 57 cm.

¹⁴ Usually, when words are presented centrally, the fixation point is located in the center of the word. Since the fovea covers about 2 deg around fixation when letters measure 0.2 deg an eight letter word fit within this region.

¹⁵ This example is made from a comparison of available first grade reading textbooks in different countries.

Box 4. The reading rate curve and maximum reading rate

How reading speed varies as a function of the character size is a well described phenomenon (*e.g.* Legge et al 1985). Reading speed increases rapidly for small sizes and then shows a flat plateau for print size from approximately 0.2 deg to 2 deg and then drops again for larger sizes. Thus, there is a 10-fold range of print size for which reading speed is unaffected. This corresponds to x-heights from 1.4 mm (4 points) to 14 mm (40 points) at a reading distance of 40 cm.



The smaller size at which observers reach maximum speed is defined as critical print size (CPS). CPS for adult observers measures about 0.2 deg across opaque and transparent languages (*e.g.* English and Italian), and it is well above acuity for single letters. The general shape of the curve extends to static printed texts and dynamic text presented with a Rapid Visual Serial Presentation (RSVP) procedure. However the maximum speed varies considerably in these procedures. RSVP presents one word at a time in the same retinal location, and minimizes the role of the time-consuming eye movements in reading. Rubin & Turano (1992) report a maximum reading rate of 250 wpm for static text and more than 1000 wpm for text presented one word at a time.

Given the visual constraints, can we establish the desired maximum reading rate attainable for comprehension?

Naturally the desired reading rate to be attained depends on the reading goal one wants to achieve. Reading street signs or product instructions is a much less demanding task than reading a book or a newspaper. Also the visual requirements for reading depend on the reading fluency one might want to attain. As a consequence the visual limitation to achieve let's say 30 WPM would be different from those to achieve 100 WPM (Whittaker & Lovie-Kitchin, 1993). Similarly, the requirements to achieve 100 WPM in reading a difficult text would be different from those needed to obtain the same speed while reading an easy text. The research on visual psychophysics that we have reviewed dealt with maximum reading rate that depends on both text difficulty and the child visual abilities that varies with age.

Back in 1993 Carver noted that students set their reading rate according to the goal they want to achieve with the particular task. This goal also varies with text difficulty (Carver, 1993). Carver defined five reading gears: gear 1 is memorizing; gear 2 is learning; gear 3 is raiding (from reading and auditing); gear 4 is skimming; gear 5 is scanning. The basic process that most readers use most of the time is their raiding gear, it involves looking at each consecutive word in the sentences of textual material and attempting to formulate the complete thoughts that the writer intended to communicate. College students ordinarily operate their raiding process at rates around 300 words per minute. In an historical paper Taylor (1965) surveyed the reading skills of 12,000 US students from first grade to college. The rate of reading with comprehension was determined by measuring the length of an eye movements recording film required to read a known number of words and transposing the length to time. The minimum comprehension was insured by requiring the reader to correctly answer a specified percentage of questions on the content of the text. The author indicates that English speaker second grade students read with adequate comprehension at a rate of 80 WPM.

1.9. Effect of spacing

For adults with normal vision, manipulating print size (Legge, Cheung, Yu, Chung, Lee and Owens, 2007), character spacing (Yu, Cheung, Legge and Chung, 2007), and retinal eccentricity (Legge *et al.*, 2001) produces highly correlated changes in reading speed and size of the visual span. We have seen that reading rate curves are described by a cliff and a plateau as a function of size. The plateau is represented by the maximum reading rate obtained by the observer and correlates with the observer's visual span. The cliff is the drop in reading rate with small sizes; it has been interpreted as an acuity limitation (Legge *et al.*, 2001). However, Levi *et al.* (2007) showed that the drop in reading rate with reduced size occurred well above acuity¹⁶ for single letters. This drop is large across several languages and reading rate slows down 10 to 15 times with small sizes making fluent reading extremely challenging.

In normal text, size and spacing co-vary. Levi *et al.* (2007) disentangled these two variables by measuring reading rate curves as a function of size with normal and doubled letter spacing. They found that doubling the spacing moves the curves by a factor of two toward larger sizes, whereas keeping spacing constant and changing size leaves the curves identical. In other words changing the letter spacing but not the letter size modifies the value of the CPS obtained. This indicates that the cliff-limiting factor is spacing and not size. Letter spacing affects our ability to identify the letter through crowding; separating the letters relieves from crowding and enables identification. On the converse the crowding range is immune to size. Taken together these results suggest that the CPS is equivalent to the critical spacing (crowding range) for crowding.

Crowding is the performance drop in letter recognition in the presence of nearby letters; it is not caused by acuity limitations. It is usually measured in a letter recognition task presenting random letter triplets to the observers and asking the observer to identify the central letter. Typically the central letter is called target while the adjacent two letters are called flankers. Performance is measured as a function of the spacing, center-to-center letter distance, between the target and the flankers. When flankers are close to the target the task is hard, when spacing is large the task is easy. The crowding effect can be described by its range, that is, how far the flanking letters have to be moved apart from the target letter to restore recognition (called critical spacing). Box 5 presents the crowding phenomenon and a brief description of what is known about the mechanisms underlying the effect. A reader not interested in the mechanisms can just glance at the demonstrations to experience crowding.

¹⁶ Visual acuity refers to the resolution ability of the observer tested at high contrast. Acuity can be measured in several ways and depending on the complexity of the task can have different values. In this case we are interested in the smallest letter observers are able to identify. Normal vision is defined as the ability to identify a 4.36 mm letter at a viewing distance of 3 m. At this distance the letter subtends about 0.08 deg well below CPS for reading.

Box 5 The crowding phenomenon

Crowding refers to the impairment in letter recognition due to the presence of adjacent letters. It has first been studied in the context of clinical assessment (Korte, 1923; Ehlers, 1953). In particular it characterizes amblyopic foveal vision (Irvine, 1945). Amblyopia is a developmental disorder caused by strabismus, anisometropia or visual deprivation, which affects the visual system in the critical developmental period. Acuity in amblyopic patients is greatly reduced when measured with rows of letters relative to single letters. The deficit cannot be ascribed to uncorrected refractive errors. Similar to foveal amblyopic vision, in normal periphery object recognition is limited by crowding.

In the following demonstration it is possible to experience crowding. While staring at the square, try to identify the central letter of the right column. It is hard. However, on the left, it is easy (first and second row).



Note that you can move the eyes back and forth on the Ps to the right, and these keep becoming unrecognizable once the eyes are back on the square. Unlike many cognitive demonstrations, here knowing the letter identity and having just seen it with the fovea doesn't help.

The first row shows that the recognition impairment is caused by the presence of the two surrounding letters. The P on the left is well above acuity and recognizable. The second row shows that what counts is the spacing between letters. Once the center-to-center letter spacing is larger than half the target eccentricity recognition is restored (Bouma, 1970). The last row shows that letter similarity may enhance the crowding effect (Nazir, 1992).

The neural structure underpinning crowding is still debated and contrasting evidences have been provided. Stimulus diversity and uncontrolled crowding conditions may be the cause for the discrepancies in the literature that attribute to V1, V2 or V4 the site of crowding (for a recent review see Whitney and Levi, 2011).

Critical spacing scales with eccentricity with a proportionality of 0.5, independent of letter size (Bouma, 1970; Strasburger, Harvey and Rentschler, 1991). Critical spacing describes the portion of the visual field around the target letter that must be isolated to correctly identify it (Bouma, 1973). Although these isolated regions have usually been measured with random letters using a task similar to Legge's visual span, it has been shown that critical spacing limits letter recognition also when words, not random strings, are presented (Martelli, Majaj and Pelli, 2005).

In the fovea, critical spacing measures only a few minutes of arc¹⁷. Along the cliff of the reading rate curves, letter spacing is smaller than critical spacing, exposing the crowding limitation. Pelli, Tillman, Freeman, Su, Berger and Majaj (2007) demonstrated that the plateau of the reading rate curve is also limited by crowding. When words are presented centrally, the letters vary in radial eccentricity. If print size and spacing are large enough the letters around fixation escape crowding; however, letters in positions outside fixation have larger eccentricities and larger critical spacing. In normal print, spacing is kept constant; thus, these letters will be affected by crowding and be less recognizable. Note that the first and last letter in a word are less affected by crowding and thus are more visible because they only have one adjacent letter (Toet and Levi, 1992; Pelli, Palomares and Majaj, 2004). Pelli *et al.* (2007) showed that adding the letter eccentricity computation to the model predicts the drop in maximum reading rate (the plateau) with eccentricity. Pelli *et al.* (2007) also demonstrated that the visual span was equal to the number of uncrowded letters (*uncrowded span*). Thus, both the cliff and the plateau are predicted by the uncrowded span and are dependent on letter spacing.

The maximum reading rate obtained by observers seems to be highly dependent on letter spacing and not size. In agreement with this notion, Spinelli, De Luca, Judica and Zoccolotti (2002) showed that increasing letter spacing improved vocal reaction times of about 50 ms for reading words in disabled readers. Martelli, Di Filippo, Spinelli and Zoccolotti (2009) also demonstrated that disabled readers had larger critical spacing and that critical spacing predicted 40% of their slowness in reading. Enlarged spacing speeded up dyslexic readers, although, as noted by the authors, after curing crowding, dyslexics remained slower than controls. To predict reading rate as a function of eccentricity, Pelli *et al.* (2007) introduced an additional parameter that also scales with eccentricity but is not crowding (see also Kwon *et al.*, 2007; Levi, 2008). The normal peripheral reading rate and dyslexic foveal reading is worse than that predicted by crowding. It is possible that foveal but not peripheral (nor disabled) reading is helped by lexical knowledge of the stimuli. For instance, training sessions on orthographic materials reduce crowding effects (Huckauf and Nazir, 2007). Furthermore, contrary to Pelli and Tillman's (2008) suggestion that the same uncrowded window accounts for the recognition of all object types, Grainger, Tydgate and Isselè (2010) found reduced crowding for letters relative to strings of symbols.

Does the crowding range reduce with development? Critical spacing that defines the crowding range has been variously thought as a rigid limitation that constrains reading and object recognition. However, it is conceivable that years of experience with eccentric letters such as in texts may ameliorate our ability to decode them in the periphery. This observation raises two related and testable predictions. On one side we

¹⁷ 1 minute of arc is equivalent to 0.016 deg.

should expect the range of crowding to reduce during development especially in the first schooling years. On the other hand we should expect a left/right visual field asymmetry in the range of crowding dependent on the characteristic of the script. During reading we preprocess the information with the parafovea to direct eye movements. In languages read left to right, such as English, the relevant information falls in the right parafovea. In languages read right to left, such as Hebrew and Arab, the relevant information falls in the left parafovea (Deutsch, Frost, Peleg, Pollatsek, & Rayner, 2003). As a consequence we should expect critical spacing to be smaller in the right visual field for English readers and in the left for Arab readers. Despite the fact that to our knowledge there are no direct testing of any of these issues, some indirect results speak in favor of flexibility in the crowding range dependent on development and perceptual learning. Although little work has been done in development specifically on crowding using letter triplets or words, and none in the periphery, studies with infants and adolescents from 8 to 11 years of age tested foveally have been reported (Atkinson *et al.* 1988; Jeon *et al.*, 2010). Data show that English speaking children are much more impaired by crowding than adults, even when their acuity is fully developed. Thus, even 11-year-olds are more deeply impaired than adults by surrounding contours despite having single-letter acuity that has been mature for several years. Additionally, as we have seen CPS that represents an estimate of CS reaches adult level at age 8 (O'Brien, Mansfield and Legge, 2005). For what concerns perceptual learning on adult observers it has been shown that training reduces crowding mainly for trained strings of novel symbols presented in the same retinal location (Huckauf & Nazir, 2007). The study demonstrate that part of the crowding limitation results from the absence of higher level representations of the stimulus that can be acquired through learning visual properties of the stimulus.

In summary, it seems that learning the letters, and acquiring experience with reading text that stimulates peripheral visual field locations, may reduce the perceptual limitations for reading.

1.10. Positional noise

The visual span or uncrowded window increases with development and reduces with eccentricity. Visual span measurements take into account the letter position (*e.g.*, a correct identification but in the wrong position relative to the letter triplet is scored as a mistake). Thus, a visual span increase entails a reduction in letter position errors. These error types characterize the initial stages of reading acquisition, when often children exchange similar letters (*e.g.*, Cairns and Setward, 1970). Crowding can predict these mistakes. Chung (2010) found more crowding with visually similar than dissimilar letters. Petrov and Popple (2007) stated that the source of crowding is positional uncertainty due to a perceptual localization shift of the peripheral characters toward the fixation point, so that they are pooled with the inward elements (see also Liu and Arditi, 2001).

Measuring the template used by observers to make their judgments in crowding conditions, Nandy and Tjan (2007) found that observers erroneously attributed parts of the flanking letters to the target. Just as crowding and CPS reduce with development, these mistakes also decrease. Nevertheless, this is a correlational, not a

causal, link. Thus, cognitive factors may also be good candidates to explain these mistakes.

Mason and Katz (1976) found that good and poor readers among 6th-grade children differed in their ability to identify the relative spatial position of letters. Children often correctly identify the letters but mistake the order of the letters in the sequence, which is a skill naturally implied in reading. Farkas and Smothergill (1979) also found that performance on a position-encoding task¹⁸ improved with grade level in children in first, third, and fifth grade. Furthermore, children's reading ability was associated with orientation errors in letter recognition, such as confusing d and b or p and q. This pattern of errors highlights the role of visual-orthographic skills in reading (e.g., Cairns and Setward, 1970; Davidson, 1935; Terepocki, Kruk and Willows, 2002). Kwon *et al.* (2007) found that mislocation errors (e.g., reporting "bqx" instead of "qbx") and orientation errors (e.g., mistaking "b" for "d") decreased with increased grade level and that rate was due to position in the visual field (*i.e.*, it was higher at farther eccentricities). These types of errors could be due to increased crowding.

However, a recent popular idea that spread over the internet suggests that we are insensitive to letter order. Some of the literature on reading and word recognition has focused the attention on the evidences about insensitivity of skilled readers to letter position in European languages such as English, French and Spanish. These studies have shown a surprisingly small cost of letter-transpositions in terms of reading time. They also indicate the presence of a facilitatory effect (priming) exerted by a non-word on a subsequent target word when it shares all the letters arranged in a different order (prime: ASNEWR target: ANSWER) (e.g., Perea & Lupker, 2004; Schoonbaert & Grainger, 2004). Also Japanese Kana shows similar insensitivity (Perea & Perez, 2009).

The theoretical assumption that insensitivity to letter order reflects the special way in which the visual system encodes letter position during decoding has been challenged. Velan & Frost (2007) have shown that the effect may depend on the type of script adopted in each particular language. The Authors used an RSVP procedure in which words with scrambled letters were embedded in sentences, presented one word at a time. Bilingual English and Hebrew observers were asked to report the presence of the scrambled word in the two languages. Observers obtained a d-prime of about 1 in English and 2 in Hebrew, indicating that it is harder to detect scrambled words in the former language. According to Frost the letter position insensitivity rather than exposing the brain computation is a consequence of the reading strategies adopted in different orthographies that are constrained by the language environment (Velan & Frost, 2009).

1.11. Eye movements

The above reviewed studies, which measured reading rate with the RSVP paradigm, minimized the role of eye movements in reading. However, in functional reading eye movements play a substantial role; when reading a line of text part of it falls in the foveal region (*ca.* 2 deg) with good acuity and no crowding, and part falls in the parafoveal or peripheral field (parafoveal up to 5 deg) that is limited by both acuity and

¹⁸ Observers presented with a letter string of variable length are required to identify the to letters in the correct order from left to right.

crowding. Thus, observers make saccadic eye movements in order to progressively fixate the relevant parts of text compensating for the visual limitations.

McConkie and Rayner (1975) developed a technique to measure the amount of information during a fixation that affects eye movements. In the eye-contingent display change paradigm (McConkie, 1997; McConkie and Rayner, 1975), eye movements are monitored and changes are made in the visual display that the reader is looking at, contingent on when the eyes move (or at some other critical point during fixation). Rayner measured the effect on eye movements substituting letters on a page of text with Xs. In this paradigm, the text is perturbed except for the letters that fall in a window whose size is experimentally manipulated. The assumption is that when the window size is as large as the perceptual span, then the eye movement parameters such as fixation duration, saccade length, and frequency of regressions should be the same as in standard texts. With this technique, it has been found that the span extends 4 characters on the left, like Legge's visual span, and 14-15 characters on the right of fixation, that is, three times larger than Legge's span (McConkie and Rayner, 1975; Rayner, Well and Pollatsek, 1980; Underwood and McConkie, 1985). In Hebrew, which is read from right to left, the span is asymmetric to the left of fixation (Pollatsek, Bolozky, Well and Rayner, 1981).



Why is the perceptual span larger than the visual span? Rayner (1998) calls the visual span the word span and distinguishes it from the perceptual span, because the large size of the latter "does not mean that words can be identified that far from fixation; indeed, word length information is acquired further to the right of fixation than is letter information" (Rayner, 1998). Thus, *the perceptual span is a measure of the extent of the pattern layout that can be used to guide saccades during reading rather than a measure of parallel letter information processing*. In fact, deleting the spaces between words deeply hampered the perceptual span by reducing saccade length (Pollatsek and Rayner, 1982). This entails that scripts that do not include spaces between words are harder to read for fluent readers than for beginners. However, it must be noted that orthographic material also affects the size of the perceptual span, which varies with text difficulty (Rayner, 1986). Finally, as in the case of visual span, also the size of the perceptual span is affected by grade level (Rayner 1998) and complexity. Inhoff and Liu (1998) found that with Chinese characters the perceptual span only extends one character on the left and three on the right of fixation.

1.12. Words density in the page

The density of words per page for beginning learners varies from one country to another and without a clear fixed rule. Usually, decisions are made by designers and publishers using what are considered to be 'common practice'. Even so, broad guidelines can be identified. According to Hartley (1994), typical sentences with less than 20 words long are acceptable for adults while those containing over 40 words may be expressed clearer once rewritten. For young children, Hartley recommended that textbooks and reading books contain three or four words per line. This is due to the maximum permissible length of a line that is restricted by the type-size and type-face (Hartley, 1994). Too many words in one line and too many lines in one page may confuse beginning readers in first grade (especially those with limited literacy skills) as they may find the task overwhelming. Furthermore, according to the well-known

Fountas and Pinnell System (Fountas and Pinnell, 1996),¹⁹ first grade reading textbooks can be characterized along 9 levels (from A to I). The beginning levels such as A and B typically have roughly one to four lines of texts per page while the higher levels contain about four to eight or more lines of texts per page, with longer and more sentences. Major U.S. publishers also follow this system for their textbook products. Examples include the Scholastic Guided Reading Programs and Houghton Mifflin Harcourt Leveled Readers.²⁰ Indeed, the recent study from the Center for Research in Educational Policy at the University of Memphis found that Fountas and Pinnell’s Leveled Literacy Intervention System (LLI) was effective in enhancing literacy for children in grades K-2. Especially, Hispanic, African American, English Language Learner and special education students performed significant improvement over non-participants in LLI.²¹

Figures 3 and 4 provide illustrations of elementary reading textbooks containing different word density.

Greek First Grade Textbook of 1950s		North Korea First Grade Textbook	
			
English First Grade Textbook	Palestinian First Grade Textbook	Hindi First Grade Textbook	

¹⁹ Fountas and Pinnell System is a research based program that helps to improve literacy learning in children grades K-8. Via research, practical work with teachers, and classroom teaching, the system focuses on matching books to readers and providing differentiated books through small group reading. See *Fountas and Pinnell*, available [online] at <http://www.heinemann.com/fountasandpinnell/default.aspx>.

²⁰ See, *Guided Reading Programs*, Scholastic, available [online] at <http://teacher.scholastic.com/products/guidedreading/overview.htm>; *Reading*, Houghton Mifflin Harcourt School Publisher, available [online] at <http://www.hmhschool.com/School/index.html>.

²¹ New Study Confirms Effectiveness of Fountas & Pinnell Leveled Literacy Intervention System, in *EarthTimes*, available [online] at <http://www.earthtimes.org/articles/press/leveled-literacy-intervention-system,1522537.html>.



Figure 3: Examples of First Grade Reading Textbooks with Average of Four Words in One Line and Four-to-Eight Lines in One Page in Selected Countries

Source: For Greek textbook, see Abadzi, EFA-FTI, World Bank; for North Korean textbook, see [freerepublic.com](http://www.freerepublic.com/focus/f-news/1690685/posts), available [online] at <http://www.freerepublic.com/focus/f-news/1690685/posts>; for Palestinian textbook, see EU Funding.org, available [online] at <http://www.eufunding.org/Textbooks/NewSchoolbooks.html>; for Hindi textbook, see <http://blogs.wickedlocal.com/abroad/>.

The word density of first grade textbooks in Figure 4 is consistent with what Hartley (1994) and Fountas and Pinnell (1996) suggested. Regardless of page sizes and different language scripts, the prevalence of three to six words per line represents a practical and legible standard to facilitate reading among first graders. In addition, different language textbooks commonly include four to six lines per page. It should be noted that these examples were taken mostly from the *middle* of each textbook. Indeed, a distinctive characteristic of first grade reading textbooks is the changing density of words between the text's initial sections to the latter sections. Word density patterns tend to be very loose at the beginning of the textbooks and get increasingly tighter and denser toward the end of the textbooks. In contrast to other grade levels, the trend toward denser words per page in grade one textbooks reflects significant changes in first grader's symbol recognition and language development over the course of the school year. Fundamentally, it is believed that first graders should be oriented with few words and sounds that are familiar to their daily life at the beginning of the school year and they should increase their acquisition in reading more words by the end of the school year. For example, Johns (2006) found that first graders American children read on average 21 words correct per minute by the winter semester and 48 words correct per minute by the spring. At the end of the school year, first graders usually know some 150 common words²² (see the second part of this review for a detailed analysis of reading speed improvement with age, also as a function of orthographic consistency). By increasing the density of words in the textbooks toward the end of the school year, it is likely that first graders would perform at a sufficient level of reading acquisition and fluency via routine practices from textbooks. This characteristic of incremental densities of words and lines per

²² See *Reading Milestones*, available [online] at http://www.pbs.org/parents/readinglanguage/first/reading_milestone_first.html.

page is clearly seen in first grade textbooks, reflecting a steep learning curve of first graders over the course of the school year. Textbooks for second and third graders show less variation in word densities between the textbook’s beginning and end. To help first graders to know and recognize words, the selected type-face may be applied throughout the entire textbooks (for consistency), while type-size can be decreased once the number of lines per page increases toward the end of the textbook, thereby enabling the presentation of at least 150 new words. Although these basic notions seem straightforward, many producers of reading textbooks in developing countries appear unaware and/or unconcerned about them.

Figure 4 portrays a different scenario from Figure 3. Illustrations in Figure 4 depict a loose density of words per page, dedicating a lot of spaces to pictures and white spaces. For example, the textbook from Mozambique only contains several lines in one page with repetitive texts, while the Cambodian textbook devotes space to illustrations rather than to text. If the word density in the entire textbook is consistent with the examples found in Figure 4, it is likely that children’s reading proficiency would stultify during the school year, as there are insufficient practice texts for them to utilize.


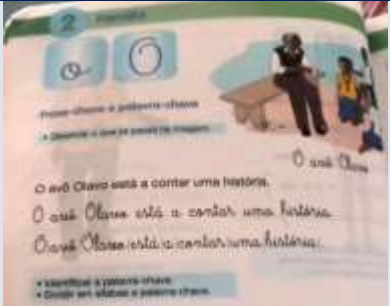
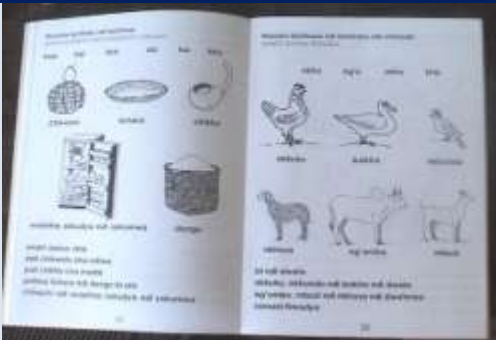

Cambodian Reading Textbook	Mozambique Whole Language Textbook
	
Malawi Whole Language Textbook	Egypt Whole Language Textbook
	



Figure 4: Examples of Elementary Reading Textbooks with Various Word Lengths in Selected Countries

Source: Abadzi, EFA-FTI, World Bank.

Howsam *et al.*'s (2007) analytical essay about textbook publishing in England found several features employed in the 19th century textbooks: illustrations as text

examples, limited color printing, bolded-vs.-unbolded text, and large type-size for main texts while smaller type-size for supplementary texts. Even so, neither how to place illustrations and texts in a page of the textbooks nor what is a proper ratio of graphics and texts was discussed in the paper.

Figure 5 portrays various designs of primary grade reading textbooks. Palestinian and Greek textbooks tend to be simplistic in design, given that illustrations and texts are separated clearly and almost equally in two main parts (top and bottom). There is not much white space left; yet both textbooks do not seem overly dense. The design is partly in line with what Hartley (1994) suggested, “instructional materials should be printed in characters which are firm in line, open and even in spacing...,” (p. 32). It reflects the Malaysian Textbook Division’s guideline that the illustrations in textbooks are not inserted just to fill up the empty spaces (Mahmood, 2009) but rather to depict the meaning of texts. In contrast, Cambodian and Sudani textbooks tend to be quite loose, leaving abundant white space and giving out very few texts and words. In this way, it may lead to students not having much reading and learning experiences. According to Sewall (2005), school textbooks in the U.S. are also geared toward a looser and easier design. If it is true that a picture tells a story and takes the place of a thousand words, it is also true that textbooks across are being transformed into picture instead of clear, simply designed, text-centered primers. They include bright illustrations with seductive colors, which may confuse the page. As the type-size gets larger, textbooks become looser and have fewer words and much more white space per page: “The text itself can get lost...” (Sewall, 2005).

Palestinian First Grade Textbook 2003	Greek Textbook of 1950s
	
Cambodian Auxilary Book	Sudani First Grade English Textbook

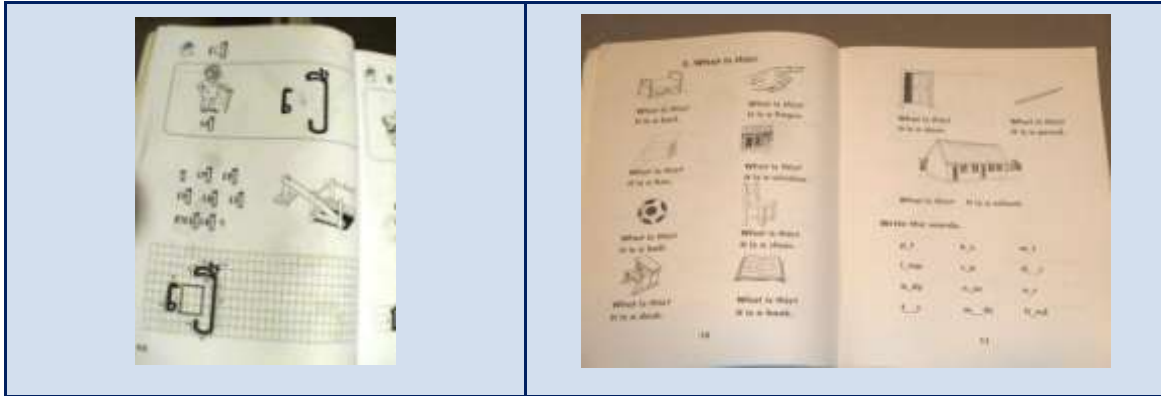


Figure 5: Examples of Spacing and Densities in Reading Textbooks of Primary Grades

Source: For Palestinian textbook, see *EU Funding.org*, available [online] at <http://www.eufunding.org/Textbooks/NewSchoolbooks.html>. For Cambodian and Greek textbooks, see *Abadzi, EFA-FTI, World Bank*. For Sudani textbook, see *Benavot (2010)*

In conclusion, empirical studies suggesting the standard on proportion between illustrations and texts and the guideline on appropriate density each page should have in order to maximize the student's reading outcome were limited. However, to effectively design a reading textbook, one may start with simplicity and consistency of the design that provides substantial learning experiences throughout the book.

1.13. The effect of contextual information

We have seen that reducing size and spacing reduces word visibility by impairing letter recognition. Our ability to identify a word is also modulated by the context of the word. When words are presented in the context of a sentence, the probability of reading a word correctly depends on the words that have already been processed. In their review, Stanovich and Stanovich (1995) estimated that the probability of predicting the next word in a passage across several texts and studies was about 0.3. When reading rate was measured, it was shown that the effect of context improved speed by ca. 50%, *i.e.* a factor of 1.5; adult observers read an ordered text at about 500 words per minute (wpm), and they attained 300 wpm when the sentence was removed by scrambling the word order (Chung *et al.*, 1998; Fine and Peli, 1996; Fine, Peli and Reeves, 1997; Fine, Hazel, Petre and Rubin, 1999). This effect may be larger in young English speaking children, because slower readers with poor decoding skills have been shown to rely more heavily on sentence context than fast readers (West and Stanovich, 1978). All these results have implications on learning to read through a foreign language, which is often the case in low income countries where several different dialects are spoken. These findings suggest the relevance of learning to read in the native children language (see second part of this review for a more in-depth discussion of this point).

The context generated by the presence of a meaningful sentence may influence reading rate by activating/inhibiting certain sets of words in the lexicon. Johnson-Laird (1983) referred to a "mental model" that goes beyond the literal meaning of the text to embody spatial, temporal, causal, motivational, and person- and object-related

information. As the reader progresses through the text, the mental model is continuously updated as new information is read and interpreted (Kintsch, 1998; Zwaan and Madden, 2004). It has been proposed that illustrations are one of the cues used by readers, especially young ones, to facilitate the development of such a mental model (Glenberg and Langston, 1992).

1.14. Pictures in texts

It is a common practice worldwide for illustrations, pictures and graphics to be parts of textbooks at all levels of education (see examples in Figures 3, 4 and 5). Often teachers of beginning readers use pictures in order to build a background for text, to introduce the meaning of new words and to prompt children when they were not able to read words. Yet, inclusion of illustrations in reading textbooks of early grades is controversial among reading researchers. As Levin and Mayer (1993) pointed out, some studies stress that text-accompanying illustrations are harmful to the learners' reading process while others argue that they have beneficial effects (see, *e.g.*, Samuels, 1970, and Houghton and Willows, 1987). The debate partly stems from the unclear distinction among different stages of reading process and textbook effects. This section discusses the relationship between the reading process and textbooks as well as key issues regarding the potential advantages and disadvantages of including illustrations and graphics in early grade reading textbooks (see Figure 6 for a summary).

Different stages of children's reading process are particularly vital for designing textbooks that may include illustrations. Justice and Sofka (2010) summarized three stages of the reading process (see Figure 7). Emergent literacy is the preliminary stage where early childhood learners start to get familiarized with texts and sounds in various forms of print materials and media that surround them. Learning-to-read is the next stage in which beginning learners acquire the initial reading skills of decoding and identifying words. This is followed by the reading-to-learn stage, during which learners acquire reading skills of remembering and comprehending text. According to Levin and Mayer (1993), recurring evidence in the late 1990s suggested that illustrations in instructional texts are appropriate to children in the reading-to-learn stage while earlier studies argued that illustrations could undermine the learning process of children at the learning-to-read stage. In any case, illustrations tend to almost always be part of reading textbooks and picture books at the early grades. Pictures in the text were found to be particularly advantageous among poor readers, especially when pictures were colored (Willows, 1980; cit in Levie and Lentz, 1982). In fact, pictures help poor readers more than good readers (facilitation was 44% and 23% in the two groups, respectively; Levie and Lentz, 1982). Poor readers often moved their eyes from the text to illustrations, in order to check if the features in the pictures were those that they read, while good reader did not show this pattern (Rusted and Coltheart, 1979). However, it is important to remember that often "people living in areas impoverished in pictorial stimuli have difficulty in interpreting some kinds of pictorial cues and in constructing meaning from pictures" (page 224, Levie and Lentz, 1982).²³

²³ Visual illustrations do not constitute a universal language that is interpreted by each individual in the same way. In fact, Boling, Eccarius, Smith and Frick (2004) found that not all individuals interpreted the

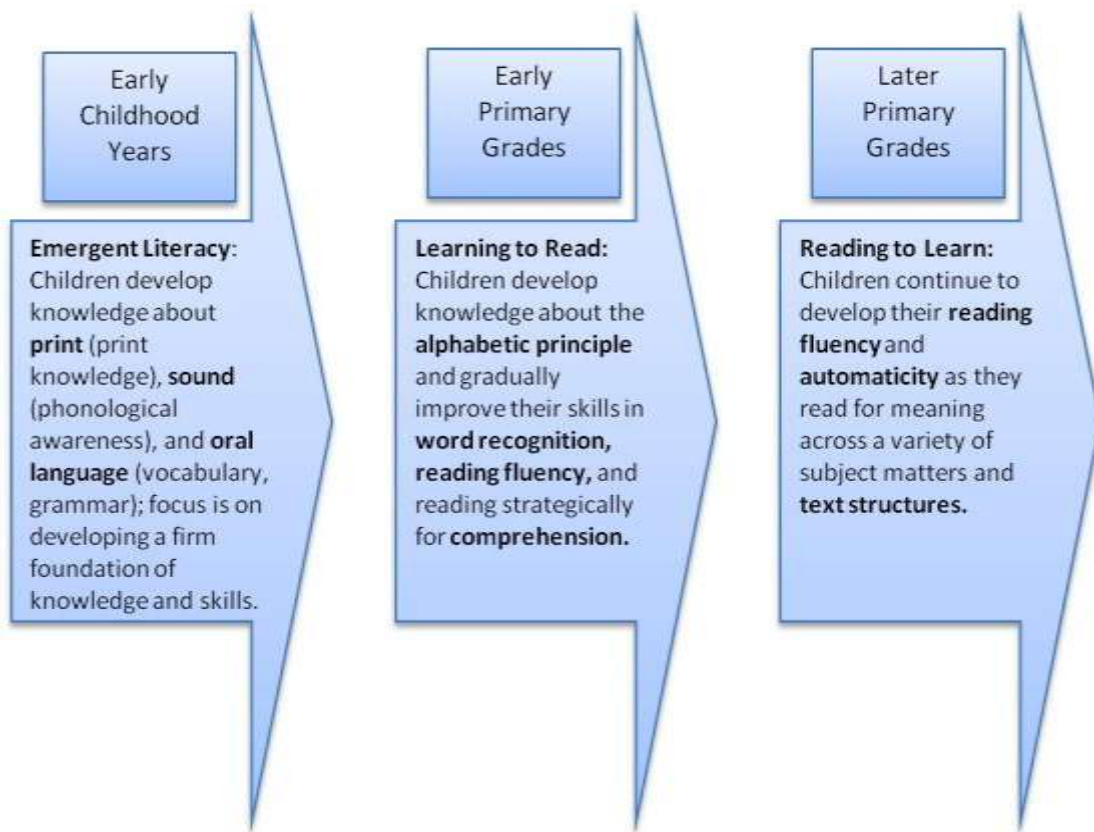


Figure 7: Literacy learning and teaching continuum.

Source: Justice and Sofka (2010).

Texts and illustrations are dependent upon one another and, if designed effectively, can help to improve children’s reading skills (Nicholas, 2007). Many view illustrations or pictorial images as potential positive factors for learning in a broad range of educational research settings, especially in area of reading (see figure 8). Illustrations help beginning readers to remember specific information from the text passage (e.g., Brookshire, Scharff and Moses, 2002; Haring and Fry, 1979; O’Keefe and Solman, 1987; Peeck, 1994). Levie and Lentz’s (1982) comparative analysis of over 40 studies showed that information provided in both text and illustrations have marked

illustrations in the same way. Fewer than one third of the pictures were interpreted correctly by 85% of participants or more; in the rest of cases, lower percentages of correct interpretations were reported. Larger differences in picture illustration were found depending on the language. Culturally-bound conventions may lead to misunderstand when an image is exported from a culture to another (Schiffman, 1996 as cited by Cooper, 2002). Also participant characteristics influence the ability to interpret pictures (Boling *et al.*, 2004): participants who saw surveys with graphical devices interpreted images more consistently with the intention of the designers than did those who saw surveys without the devices (coherently with Sless, 1981). Moreover, “consistent with the theory of Piaget, some scholars have suggested that young children interpret visual information very literally, and that they may not be developmentally ready to understand abstract concepts or representations included in illustrations” (Boling *et al.*, page 189). Finally, readers use actively their experience with similar texts and assumptions about authors of texts to help interpreting the text (Schriver, 1997; Boling *et al.*, 2004).

effects: texts that are illustrated by graphics or pictures aid the recall of instructional texts, although pictures do not help the recall of the non-illustrated texts. Pictures provide a contextual framework in which is easier to understand the text. In fact, when a passage was preceded by an illustration providing a context to understand the text information, this improved learning made easier to recall text information (*e.g.*, Royer and Cable, 1976; Sherman, 1976; Bernard, Petersen and Ally, 1981). Note that graphic contextual information help readers more than the verbal anticipation (*i.e.*, a title for the passage; Sherman, 1976).

Illustrations in the text produce an increase in comprehension skills (*e.g.*, Ackerman, 1988; Barnes, Dennis and Haefele-Kalvaitis, 1996), especially in young (below 6th grade; Levie and Lentz, 1982) as well as older children (Rasco, Tennyson and Boutwell, 1975). In a meta-analysis of 55 studies, Levie and Lentz (1982) found that in 46 studies examining the effect of informative content in the text, in all cases but one (*i.e.*, on 98% of cases; this difference reached significance in 85% of cases) reading comprehension was greater (of about 36%) in texts with pictures than in non-illustrate texts. Note that, according to reviewed studies, pictures help to capture the general idea of the text rather than the recall of details (Haring and Fry, 1979). However, as suggested by Levie and Lentz (1982), illustrations might improve comprehension also “providing a context for interpreting the text information, by increasing the depth of semantic analysis, by providing clarifying examples, and so forth” (page 224).

Pike, Barnes, and Barron (2010) compared the comprehension performance of 7 to 11-year-old English speaking children on texts with informative pictures, no pictures, or pictures describing a context irrelevant to the comprehension questions. Irrelevant pictures greatly impaired performance across all age groups with respect to no-picture texts; instead, they found a clear advantage for informative pictures below third grade. Nicholas (2007) examined the impact of illustrations on first graders’ ability to recall and comprehend a story as well as their indirect vocabulary development. Beginning readers had a better recall when they read aloud and were prompted to pay attention to illustrations accompanying texts. By contrast, those exposed by texts and illustrations without any prompts had lower recall levels. Accordingly, children appear to substantially improve their memories of a text, if it is accompanied by illustrations (Levin and Mayer, 1993). Moreover, illustrations and pictorial images in reading textbooks allow children to make one-to-one links between visual objects and words. In this way, the immediate task of naming objects can be easier than reading through the entire texts (Hiebert and Fisher, 2007). Illustrations are also good eye-catching attractions for young children as opposed to a more ‘abstract’ text. Studies also suggest that children pay more attention to reading texts that are accompanied by meaningful illustrations²⁴ than those only containing a text (Levie and Lentz, 1982; Nicholas, 2007). Moreover, pictures produced an emotional impact that affect attitudes toward text contents (Vernon, 1953) and make learning to read more pleasant. Since illustrations in textbooks can provide powerful positive effects on students’ learning, Levin and Mayer (1993) suggested that one way to enhance the quality of textbooks is to improve the efficacy of textbook illustrations.

²⁴ However, only a small number of words can be presented pictorially. In fact, only concrete nouns and a limited number of adjectives and verbs can be illustrated.

Possible Functions of Text Illustrations

<i>Functions</i>	
Attentional	1. Attracting attention to the material
	2. Directing attention within the material
Affective	3. Enhancing enjoyment
	4. Affecting emotions and attitudes
Cognitive	5. Facilitating learning text content via
	a. improving comprehension
	b. improving retention
6. Providing additional information	
Compensatory	7. Accommodating poor readers

Figure 8. Possible advantages of pictures in the text.

Source: *Levie and Lentz (1982)*

Other scholars have pointed out that the inclusion of illustrations within early grade reading textbooks may have potential negative impact on children's reading proficiency. For example, research in the 1970s discussed the dangers of using illustrations and pictorial images in textbooks (Levin and Mayer, 1993; Nicholas, 2007), particularly during the learning-to-read—or early primary grades—stage (see Figure 7). According to Hartley (1994), several studies claimed that young children may find pictorial images ambiguous, especially if there are changes in scale and if they are unable to interpret action elements from the pictures. For first and second graders, pictures in texts may undermine children's reading comprehension if they appear to contradict the text (Beck, 1984). Moreover, as suggested by Vernon (1953) "perhaps the pictures laid undue emphasis on certain points, and therefore distracted attention for the rest of the text" (page 182). Levie and Lentz (1982) reviewed studies comparing the ability to learn non-illustrated text information from illustrated text vs text alone and did not find a significant difference between the two conditions in 9 out of 10 of them. Then, it seems that illustrations have no effect on learning non-illustrated text information (but also there was no negative impact as originally suggested by Vernon, 1953). In Hiebert and Fisher's (2007) experiment, for instance, the researchers excluded illustrations from the texts but not from the cover of their testing materials. In this way, they were able to assess reading performance of first-graders in a western

U.S. city on a basis of the text, independent of illustrations' influences and clues. They discussed that differences between Critical Word Factor (CWF)²⁵ and guided-reading levels may have increased by partially excluding the effects of illustrations. The researchers recommended that the role of illustrations in texts for young children, particularly when the reading task is challenging, needs further investigation.

Furthermore, Samuels' (1970) influential study pointed out that including pictures, when children are learning words in isolation, does little to benefit their reading development, and that illustrations can actually interfere with the reading development of poor students. Indeed, pictures may distract attention to printed text (*e.g.*, Braun, 1969) more among poor than good readers (*e.g.*, Silverman, Davids and Andrews, 1963; Baker and Maddell, 1965). As reported by Samuels (1970), the influence of picture on learning to read depends on the principle of least effort (Underwood, 1963). In fact, when pictures are present together with their printed name, the correct response was prompted (*i.e.*, elicited) by the picture (because recalling the name of the word represented by the picture is easier than reading the word). Instead of looking at the printed words, children attend only to the illustrations based on the principle of the least effort. In this way, reliance on illustrations can harm children's attention to word-level features and obstacle reading learning, particularly when the number of difficult words is high. Use of certain types of books, such as alphabet books and print-rich storybooks (*i.e.*, storybooks featuring interesting print features, like speech bubbles and font changes; see Smolkin, Conlon and Yaden, 1988) create more authentic and explicit opportunities to highlight print.

Although illustrations have become increasingly salient and elaborate in children's books and often dominate each page of text²⁶, no research has studied the effect of picture context on reading rate (for a discussion of this issue see Brookshire *et al.*, 2002; Willows, 1978). Nonetheless, in research focused on the effect of pictures on comprehension and memory, rather than fluency, some authors underscored the possible confounding role of irrelevant pictures (Willows, 1978).

Despite the benefit of picture on reading and comprehension performance, it must be noted that there is a trade-off between the amount of print and the number of pictures in the textbook. In fact, if there is a limit of textbook dimension and resource, increasing the number of pictures in the textbook implies a reduction in the quantity of printing. Justice *et al.* (2005) reported more than twice as many visual fixations on print for 3-to 5-year-olds in print-rich than typical books. However, the limited text reduced the opportunity of reading practice. Limited print exposure may also affect the extent and quality of lexical knowledge (*e.g.*, see Cunningham and Stanovich, 1993). According to the *self-teaching hypothesis* (Share, 1995), the exposure to print and the opportunity to successfully decode novel letter strings provide opportunities to learn the specific orthographic representation of the words. In fact, print exposure (measured based on the recognition of authors or titles of books) correlated with spelling performance (Stanovich and West, 1989) and with

²⁵ Critical Word Factor (CWF) is "an index of a text's difficulty for learners who are working on a specific set of reading tasks" (Hiebert and Fisher, 2007, page 5). Based on word recognition demands of texts, the CWF index is designed to describe texts at the stage where students, regardless of their age, acquire basic reading proficiency.

²⁶ Note that in elementary text, usually picture occupied the 60-80% of the page space (Evans, Watson and Willows, 1987).

measures of lexical knowledge, such as irregular word reading (Griffin and Snowling, 2002; but see Stanovich, Siegel and Gottardo, 1997 for contradictory results). Also in a connectionist framework, reducing the number of training trials in a connectionist simulation -which can be equated to reduced learning opportunities- produced a reading deficit similar to a 'surface pattern' (Harm and Seidenberg, 1999). According to this reasoning, poor exposure to print, especially in countries in which there is high absenteeism rate, reduced attention at school, lower compliancy with doing homework, will result in impoverished orthographic lexical representations and poor reading and spelling.

Advantages	Disadvantages
<ul style="list-style-type: none"> • Enhance reading process of young children at the reading-to-learn stage. 	<ul style="list-style-type: none"> • Likely hinder reading development of young children at the learning-to-read stage and imply a reduction of the print in the page.
<ul style="list-style-type: none"> • Help beginning readers to recall instructional texts. 	<ul style="list-style-type: none"> • Careless designs of illustrations (<i>e.g.</i>, changes in scale, irrelevant pictures) may cause ambiguity and confusion for young children.
<ul style="list-style-type: none"> • Increase comprehension skills of young children at the reading-to-learn stage. 	<ul style="list-style-type: none"> • Reliance on illustrations likely harms children's attention to words, especially when the number of difficult words is high and reading task becomes challenging.
<ul style="list-style-type: none"> • Provide one-to-one links between pictures and words, making it easier for the immediate task of naming objects and allow to learn the letter names (see second section of this review) 	<ul style="list-style-type: none"> • When learning words in isolation, illustrations do not benefit children's reading development much.

Figure 9: Potential advantages and disadvantages of using illustrations as parts of textbooks.

Consistency in the positioning of illustrations is important in textbook design due to their instructive roles. According to Hartley (1994), text layout must support the situation where the learner's focus of attention may swing back and forth from one place to another. In doing so, textbook designers must seek to provide "a consistent frame of reference within which the learner can move about, leave and return without confusion" (p. 18). Examples of inconsistent positioning of texts and illustrations are usually found in primary school textbooks where the relative position of the texts and illustrations often changes both within a page and from page to page (Hartley, 1994). Young readers may not know what is expected of them when reading through a text in which the position of illustrations changes from page to page. Considering Figure 10, the positions of both illustrations and texts in the Greek textbook are consistent throughout the entire book. One page is divided into two parts where the top is filled

by illustrations and texts in the bottom part. This format is applied throughout. By contrast, in the Lao textbook, different patterns of illustrations and text positioning are found in different parts of the text. For instance, in the above two pages, at least 4 patterns were introduced: phonetics (letters and sounds), new vocabularies, writing, and a short poem or rhyme. Illustrations are in different positions and all over the pages. If students have not already been oriented with such different patterns of designs, they may encounter a slow-down learning process as their learning-to-read is interrupted by technical confusion.



Figure 10: Examples of texts and illustrations positioning in first grade reading textbooks in Greece and Lao.

Source: Abadzi. *EFA-FTI, World Bank.*

1.15. Colors

Effects of Colored Pictures and Texts

Like illustrations, colors are increasingly prevalent in school textbooks and other instructional materials, especially during the primary grades. Colors, if applied functionally, are thought to enrich classroom instruction and aid the learning process. According to Vetter, Ward and Shapiro (1995), colors help to aid classroom instruction in that they can cue actions, facilitate discrimination among objects, stress relationships between objects, and enhance interest in the given topic.²⁷ As such, colors are used to emphasize what is being taught or what young readers should focus on at a particular moment. In Figure 11, for instance, all verbs are colored “red” while other parts of the text are in black. Readers are expected to recognize and differentiate verbs from other word types in each sentence. In this way, as Vetter *et al.* (1995) found, the addition of colors in classroom instruction improves student’s

²⁷ Their study examined the effects of colors used in multimedia projections for classroom instruction.

performance in recall, search-and-locate, decision tasks, and comprehensive of educational materials. Still, young readers would need to be introduced to these conventions of individual words in bold or in color in advance, since they would not automatically know why a standard text color has been altered (Hartley, 1994).

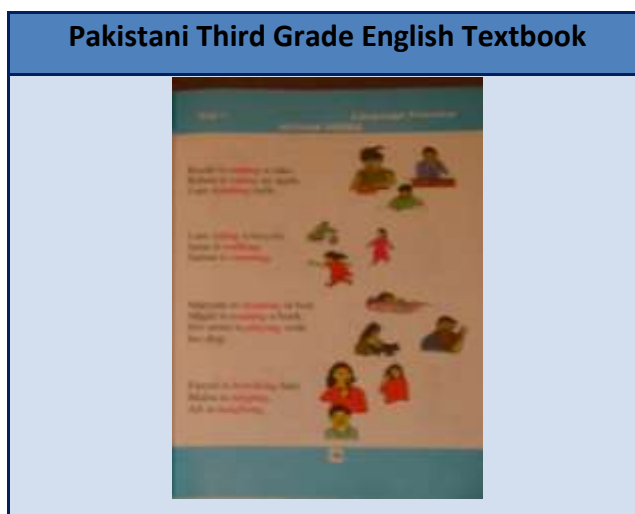


Figure 11: An Example of Colored Texts in Pakistani Third Grade English Textbook.

Source: Benavot (2010)

Despite colors may facilitate the reading task emphasizing some aspect of words or text contents, in other cases they may interfere with the learning to read process. In fact, according to the principle of the least effort (Underwood, 1963), in learning phases colors are a cue facilitating the task, but may distract attention to word print shape and characteristics. When both print shape and color are present, subjects selected the condition minimizing their efforts and concentrated their attention on colors (since the correct response was most easily elicited) and were unable to shift attention to the less salient but more relevant cues, *i.e.*, the word characteristics (Samuels, 1968). Consequently, when the color cue was removed, subjects were unable to respond (and had a worse performance than readers exposed only to black letters).

Effects of Colored Papers and Colored Overlays

Beyond the effects of color in text and illustrations, Duggan's (2009)²⁸ examined whether changes in the color of the paper found in textbooks affected the reading comprehension and vocabulary of fourth graders. Duggan assumed, based on previous

²⁸ Conducted in Georgia, Duggan's research investigated whether there are differences in reading scores among different kinds of fourth graders (regular students, gifted students, special education students, students with speech difficulties, and students with academic difficulty) who took their reading tests on different colored papers (Astrobright blue, goldenrod, and green) as compared to white paper. Her fourth grade student sample was comprised of 51 students in which 76 percent of them participated in the free or reduced breakfast/ lunch programs.

studies, that using colored paper for the background of a text is likely to increase the eye's ability to focus on the print at hand, thereby raising student test scores in reading. The study, however, found no statistically significant effects of colored paper on reading comprehension and vocabulary.

Jeanes *et al.*'s (1997)²⁹ research found that text perception among elementary students improved when using colored overlays continuously. In their study, elementary students who consistently used such overlays improved reading speed by an average of 8 percent. They claimed that colored overlays help reduce contrast and luminance. Indeed, overlays with the preferred color helped to enhance children's reading speed while clear and gray overlays did not.

The evidence suggests that colors are somewhat associated with children's reading performance. Skinner (2004)³⁰ argued that the effects of color on students' test performance vary by individuals. Skinner cited several previous studies that showed the possibility of students having better test scores on tests printed on red, yellow and blue papers. Nevertheless, his study, which examined undergraduate students in higher education, showed superior test results when tests were printed on white paper.

Colors for Aesthetic Purposes

In addition to using colors for utilitarian purposes (in order to convey information that would not be transmitted if colors were removed), colors may also be used for aesthetic purposes. According Buckingham and Harrower's (2007)³¹ only the use of colors for utilitarian reasons affects children's performance, while this does not occur if colors are used for aesthetic purposes. Even so, colors may be regarded as one of the important motivational factors in elementary classroom instructions. To young children, colored textbooks are more attractive than plain black-and-white ones (see Figure 12). In general, colored illustrations tend to attract the attention of younger and less educated children (Hartley, 1994).

Sudani First Grade English Textbook (black-and-white)	Egyptian Whole Language Textbook (colored)
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²⁹ Examining the use of colored overlays in a classroom instruction, these series of consecutive studies provided 10 different colored plastic sheets overlaid on the texts to 93 elementary students and 59 secondary students in the U.K in order to find possible benefits and effects from colored overlays on children's perceptions.

³⁰ Skinner's study examined whether or not printing alternate forms of tests on different colored papers would reduce cheating as well as to find the effects of using different colored papers on students' test performance.

³¹ In particular, the cited studies investigated the effect of color on children map recall.

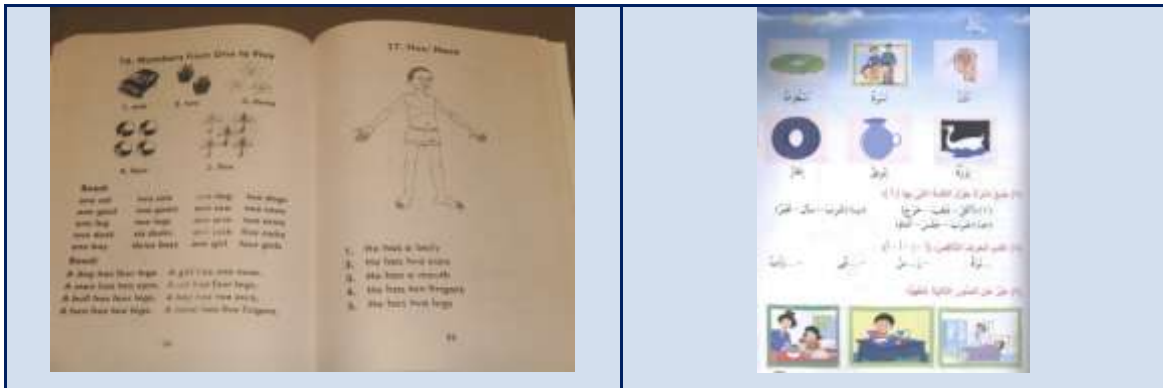


Figure 12: Examples of black-and-white and colored textbooks

Source: From Benavot (2010) for Sudani textbook and from Abadzi (2010) for Egyptian textbook.

Colors should be selected on the basis of being readily identified, while hue preference must be a secondary design concern (Brewer, MacEachren, Pickle and Herrmann, 1997). The preference for colored textbooks varies by age and educational level (Hartley, 1994). According to Sorrell (1978), children dislike dull and unattractive colors, such as brown and tend to reject non-colors (*e.g.*, gray). Moreover, the greater the compatibility of the color with the target word, the greater the comprehension. (*e.g.*, blue for water, yellow for deserts, and green for forests; Sorrell, 1978). Regarding the preference of saturated vs not-fully saturated colors, results were inconsistent. In fact, Sorrell (1978) found that children rejected fully saturated colors and suggested that one to two steps below full saturation should be used. By contrast, Buckingham and Harrower (2007) found that highly saturated colors were strongly favored over low saturated colors. However, it is important to note that saturation had minimal impact on performance and a big impact only on children’s preference (Buckingham and Harrower, 2007).

Costs of Colored Textbooks

Printing textbooks with multiple colors is expensive when compared to black-and-white or single color texts. In the U.S., children’s books printed with multi-colors may cost three times more than those printed with a single color. According to Pramschufer (2007), editing children books can run between 300 USD to 700 USD. Basic editing costs roughly 300 USD; advanced editing (texts and illustrations/ artwork) may run an additional 700 USD. The advanced editing ensures the linkage between words and illustrations. Illustrations for a 32 page colored book can cost between 5,000 and 10,000 USD or more. Although existing studies do not provide conclusive evidence whether publishing textbooks with colors is worth the benefits, many countries do publish colored textbooks for the early grades.

Despite their relatively higher cost, early grade textbooks usually contain colored pictures, illustrations and texts. This is especially the case in most developed countries, but also in many developing countries. In Papua New Guinea in the 1980s, for instance, textbooks were prepared by the National Department of Education’s

Curriculum Development Unit, which included illustrations in two colors and durable multi-colored covers (Crossley and Murby, 1994). Informal results were encouraging and, accordingly, Vanuatu and the Solomon Islands decided to distribute and utilize several of these textbooks. In Uganda, elementary English textbooks are multi-colored in both cover page and content pages; those in Ghana are full-colored only in a cover page; those in Sudan are in plain black-and-white (Benavot, 2010). In Tanzania, today's textbooks are more colorful than old textbooks - covers are always multi-colored (Grahm, Pehrsson and Minzi, 2004). Likewise, existing Indian reading textbooks for learning basic scripts in grade one contain a letter highlighted with bold print or color when used in words to emphasize letter sounds and scripts (Rao, Ratnamala and Smith, 1998). Additionally, in small nation-states such as Anguilla, primary school textbooks include illustrations and drawings printed in colors despite a high cost of production (Crossley and Murby, 1994).

Pro and cons of colors

Notwithstanding a high printing cost, colors can have some impact on the learning process if employed functionally and effectively. Existing studies showed that consistent use of particular colored texts can help children to quickly memorize a pattern of words and sounds and that use of colored overlays and colored papers may increase the children's readability on textbooks. According to Buckingham and Harrower (2007), children's understanding of color has been very little researched and color choice for thematic maps in textbooks "appears to be based on a mix of artistic decision and a belief of what is 'childlike,' not on any formal study" (p. 28). In any case, if colors were to be used in textbooks or learning process, Irlen (2005) suggested that the best paper colors to be used in order to reduce distortions and enhance readability in a classroom instruction include goldenrod, beige, yellow, blue, green, and pink. Colored overlays, colored papers, and colored filters may be applied to only ameliorate the perceptual problem of prints on the page but they will less likely eliminate the reading difficulties with phonetics or weak vocabulary. Furthermore, if using one or two extra colors is necessary to make a point, they need to be used consistently (Hartley, 1994).

1.16. Interim summary: What does evidence from vision science tell us about textbook format

First- and second-grade textbooks should be printed taking into consideration that the child's visual system is still developing. We have learned that the text size should measure 24 pt double-spaced lines with three letter spaces between words. Furthermore, Courier is the most effective font type for Latin script.

First-grade textbooks should start with single letters, proceed to bigrams and then to words of increasing length. Results from visual psychophysics indicate that contrary to the whole word approach, starting from letters can substantially help word decoding. Letters in textbooks should be printed upper case, lower case and using different font types, this helps acquiring the relevant dimensions that define letters. Teaching calligraphy after having taught the alphabet using printed letters may help the process of building a letter prototype. To provide sufficient exposure, words should

be repeated in the text and balanced by the addition of new words. Current evidence does not yet allow directly quantifying the ideal number of words per page and research is urgently needed for this purpose.

Evidence indicates that several pictures on a page may actually prove detrimental and impair reading. By contrast, one informative picture, positioned in a consistent position in the page layout, may improve comprehension and information retention, especially in young children. Thus, informational properties are at least as important as visual characteristics, such as color or high quality paper. However, despite the high cost, colors in the text affect positively reading performance. Using colors for aesthetic purposes may not affect subjects' performance, while using colors for utilitarian purposes (such as conveying information or emphasizing aspects of the text) will likely increase pattern memory in some situations. However, it is important to remember that, for young children, colors make textbooks more attractive than plain black-and-white ones. Colors should be selected on the basis of readily identified, instead of children's color preference. Preference for colored textbooks varies by age and educational level. In general, colored illustrations tend to attract the attention of younger and less educated children. Note that, the greater the compatibility of the color with the target stimuli (*e.g.*, blue as the sky), the greater the comprehension. Using colored paper for the background of a text helps reducing contrast and luminance and is likely to increase the eye's ability to focus on the print at hand, thereby raising student test scores in reading.

1.17. Printing Papers

Durability of Various Papers

There are various types of printing papers. Which kind is most suitable for elementary school textbooks ensuring cost effectiveness is one of the textbook production concerns. Traditionally, printing papers for textbooks are low white and opaque papers so that they are easier to read and that the show through of text from another side of a page would not appear. Textbook papers are also light weight, typically from 60 to 90 grams per square meters (gsm).

According to the APEID's (1986a, 1986b) studies on instructional publishing experiences in Asia and the Pacific, summarized in Figure 13, the most common paper used for textbook printing is white offset paper.³² The report did not specify any particular weight of papers employed in the investigated countries. Even so, durability was indicated in terms of expected replacement time, mostly ranging from 1 semester to 7 years with a one year replacement as a mode.

Country	Paper quality	Paper description	Book sizes	Frequency of home use	Expected replacement	Printing frequency
Australia	White offset	n/a	A4 for	n/a	n/a	n/a

³² Offset paper is a Woodfree uncoated paper (WFU), having ISO brightness of more than 80 percent and a weight of 40 to 300 gsm, available [online] at http://en.wikipedia.org/wiki/Offset_paper.

	(80 – 110 gsm)		senior students; A5 for infants; B5 for teachers' guides			
Bangladesh	Offset; bookprint (special type of offset paper)	21" x 31" normal	9" x 8"	Every day	1 year	Every year
China	Offset (for grades 1 and 2)	Rolls; sheets	185mm x 130mm	Every day	1 term	Every term
Fiji	White offset	n/a	A4 and B5	n/a	n/a	n/a
Malaysia	Bookpaper	Sheets	7 ½" x 10 ½"	Every day	5 years	Annually
Nepal	White printing (dust free)	17" x 27"; 27" x 34"	6 ½" x 8 ¼"	Every day	1 year for primary levels	Annually
New Zealand	White offset (various weights)	Mostly international A size	A4; A5; 240mm x 178mm (mostly)	Occasional	5-7 years	When stock needs replacing (4-5 years)
Pakistan	White; normal; offset	21" x 31"	9" x 7" for primary schools	Every day	1 year for primary levels	Annually
Papua New Guinea	Offset mounting board art paper	Mostly international A & B sizes	A4; A5	Occasional	5 years	5 years
Philippines	Security marked ground wood paper	Rolls	7" x 10"	Alternate days (2 children sharing)	3 years	3 years
Sri Lanka	White printing and offset	Rolls; sheets	Crown quarto&	Every day	3 years	Annually

	letterpress		demy octavo ³³			
Thailand	Mostly newsprint; some glazed/white	Rolls; sheets	A4; A5; 7" x 10"	Every day	½ - 2 years	When stock needs replacing (1-2 times a year)
Tonga	White offset	n/a	A4	n/a	n/a	n/a

Figure 13: Paper quality, book sizes, and replacement periods in selected countries

Source: Information on Australia, Fiji and Tonga are from APEID (1986b); the rest are from APEID (1986a).

Among the selected countries presented in Figure 13, textbooks in New Zealand, Papua New Guinea, and Malaysia have the longest expected replacement of 5-7 years. Regarding textbook durability, the kinds of papers used in these countries matter. For instance, Papua New Guinea uses art papers which are one of the highest quality printing papers for illustrated books and brochures. New Zealand uses white offset with various weights, assuming that the heavier and thicker the paper, the more difficult to be torn. Indeed, these offset book papers generally have a strong surface and archival properties, thereby making it justified for countries which do not implement frequent textbook replacement policy.

On the contrary, some developing countries use low quality of papers for textbook printing partly due to the fact that textbooks and auxiliary materials, such as exercise books, are mostly single used. For example, the Thai textbooks are mostly printed in newsprint, the low-cost newspaper kind of papers which is very thin and non-archival. Such thin paper can be torn too easily when students have to write on and erase on the paper. As a result, they usually last for less than one year and, sometimes, even for only one semester. Tanzania is another example. Grahm, Pehrsson, and Minzi (2004) reported that durability is a critical problem as all of the interviewees complained about binding and paper quality which did not make the textbooks last for more than one or two years (see Figure 14).

³³ Crown quarto is a size of book, about 7 ½" x 10" untrimmed and demy octavo is about 5 ½" x 8 ¾" untrimmed (both are British terms).

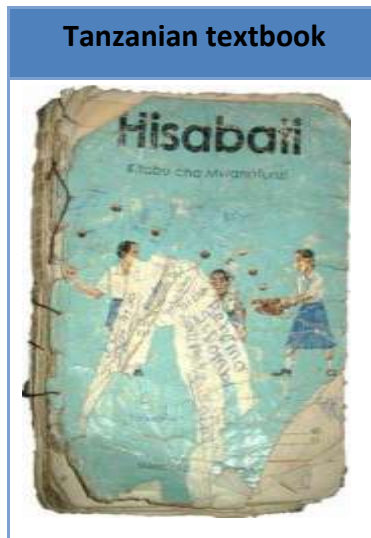


Figure 14: Durability problem in Tanzanian textbook.

Source: Graham, Pehrsson and Minzi (2004).

Textbook Sizes

To maximize cost effectiveness in textbook printing, the size of textbooks matters. Moreover, it is important because it “determines the size of the overall visual display,” (Hartley, 1994, p. 11). Textbooks in many countries are, however, printed in various sizes. Perhaps, the most common size is A4 (8.3” x 11.7” or 210 mm x 297 mm)—ISO 216 paper sizing system used widely in Europe and other regions. In the U.S., this A4 size is almost equally to the standard Letter 8.5” x 11” (215.9 × 279.4 mm) size. According to APEID (1986a, 1986b), many countries such as Australia, Fiji, New Zealand, Papua New Guinea, Thailand and Tonga choose A4 and B5 papers for textbooks and curriculum materials as they are the most cost effective. Still, very limited studies exist to guide textbook designs regarding appropriate page-size. As Hartley (1994) pointed out, page-size is not featured in many empirical studies on legibility and textbook designs.

Textbook Quality and Costs

The production of a high quality textbook is often associated with high cost. Including illustrations into textbooks costs more than having plain texts due to costs of artwork and art editing. While textbook printing with multi-colors nowadays costs much less than in the past, color printing is still more expensive, comparing to black-and-white printing. Along the same line, using good quality paper costs higher than using newsprint. As Altbach (1983) asserted, these technical matters (*e.g.*, the choice of paper, type-size and type-face, the specific kind of printing technology, the number of copies printed, etc.) affect the quality and the prices of textbooks. Such issues are typical trade-offs between textbook quality and costs in education policy formulation and implementation.

According to the APEID (1986a), the tentative publishing cost of a textbook depends on the specifications given by the publishers and production personnel. They include book trimmed size, number of pages and number of colors (both in cover page and body pages or texts), number of copies, types of paper and binding, packaging and distribution, writers fees, typesetting and other art editing requirements. Generally, durability and price are more crucial than innovative artistic design when it comes to textbook publishing (Altbach, 1983). In developing countries with a high poverty rate such as those in Africa, textbook's price can be thought of as relatively expensive. In Rotich's (2000) study on textbook publishing policy in Kenya, for example, the average price of primary school textbooks is approximately Kshs 200 (3.30 USD or 2.00 GBP). The author asserted that the price may seem low but the purchasing power of Kenyan buyers, who are mostly low-income earners, is very low. Indeed, textbook's prices are relatively high when compared to the prices of basic food. Moreover, "the average price of a primary school textbook is approximately 3.8 percent of the average monthly income of the poor Kenyan. This is more than what is typically spent on education," (Rotich, 2000, p. 69).

While the cost of paper is usually high, importing paper makes the cost even higher. According to Krynauw (1994), a number of African countries need to import paper in order to achieve their specifications, resulting in excessive costs and heavy taxes. For instance, in Tanzania, most of the paper for textbook printing was imported which often delayed the printing production (Grahm *et al.*, 2004). In Kenya, Rotich (2000) stressed that paper alone accounts for more than 60 percent of the cost of books. Although Kenya has its own paper mills, which makes the raw materials cheaper than import, others like Mauritius and India still offer better paper prices (Grahm *et al.*, 2004). Likewise, South Africa does not need to import paper as it is locally manufactured. Nevertheless, the shared monopoly paper and pulp producers - Sappi and Mondi - price their paper very high (Krynauw, 1994).

There are various ways to alter the quality standards of textbooks in order to keep the costs low. Designers may use fewer colors, lesser quality of paper (*e.g.*, lighter and thinner paper), fewer illustrations as well as to narrow the range of subject matter (Heyneman, 1990). The ministries of education may adopt, purchase, or revise existing textbooks published elsewhere that meet the curriculum standards and then make them more appropriate for the country's context, as in the case of Papua New Guinea (Crossley and Murby, 1994). However, this has often the effect of producing low durability textbooks and giving up some of the benefices discussed above, such as illustrations and colors.

Existing studies and practices suggest various ways of reducing cost of textbook production while still keeping a certain level of quality. To begin with, Tadjo's (2008) paper discussed textbook production via *partnership* among neighboring countries.³⁴ This allows putting illustrations and colorful pictures in textbooks, that can catch African children's attention "even before they can read and write," (Tadjo, 2008; p.

³⁴ The collaboration among Côte d'Ivoire, Senegal and Togo resulted in the emergence of Les Nouvelles Editions Africaines (NEA) in 1978. While 60 percent of the shares belonged to the three countries (20 each), a group of publishing houses based in France owned the remaining 40 percent. Although such a partnership experienced financial difficulties and failed in 1988, this venture was an encouraging initiative in launching children's books in full color and promoting African literature and reading.

196). Additionally, partnership allows the printing production in high volumes as it likely supplies all participating countries. In this way, partnership helps keeping the textbook cost low due to mass production. Producing textbooks in a *high volume* can keep cost low. Hartley (1994) and Pramschufer (2007) explained about the printing cost of children books³⁵ and instructional materials in the U.S. They stressed that a particular paper size that fits the offset printing press perfectly is necessary because as the quantity increases, such a paper size will fit the offset printing without waste (see Figure 15). Likewise, the higher amount of copies printed, the lower the cost. Meanwhile, Howsam *et al.* (2007) reviewed the English textbooks in the 19th century and found that, in order to reduce costs, publishers preferred *stereotyping and electrotyping*. Also, during that time, the cost of a pocket-size textbook was cheaper than a full-size one.

“As the pages of a book are made by folding the larger basic printing sheet in half—once, twice, three times or more—all the pages made from a standard size basic sheet will be in the ratio of 1: $\sqrt{2}$ [the ISO-recommended principle]. Basic sheets which do not conform to this standard do not exhibit the property of geometric similarity when folded to form pages of a book, and this can create waste”

Figure 15: The Ratio of 1: $\sqrt{2}$ Principle of Paper Sizes

Source: Hartley (1994) (pp. 12-13)

Another way to balance between textbook quality and costs is to *use competitive or international suppliers* as opposed to public monopolies. Heyneman (1990) suggested that while the ministries of education specify contexts to be included in textbooks, the actual design (such as the number of chapters, the inclusion of illustrations and visual aids, number of colors, and so forth) could be outsourced on the basis of competitive bids by private industries. Malaysia, Mexico and Turkey have implemented this competitive bidding, which resulted in lower overall costs and better quality as compared to in-house production.

1.18. Interim summary: What about textbook printing papers?

Textbook durability depends on the kinds of paper used. Art papers are more expensive but can last for 5-7 years while newspapers are cheaper but can only last for less than a year. Ways to balance quality and cost of textbook include 1) textbook production via partnership among neighboring countries; 2) producing textbooks in a high volume; 3) stereotyping and electrotyping; 4) using competitive or international suppliers; 5) adopting existing textbooks published elsewhere. Furthermore, we have previously seen that number and types of figures (and colors) should be carefully evaluated in the planning of children’s textbooks. Avoiding over-representation of

³⁵ It is noted that children’s books that Pramschufer mentioned here are mostly illustrated children books and not necessary referred to as textbooks.

figures and colors may help keeping costs low while maintaining good standards of quality.

1.19. Conclusions

It has been generally held that the visual system is mature by the age 6. Thus, much of the literature has concentrated on lexical and phonological limitations in reading acquisition (*e.g.*, Goswami and Bryant, 1990). It is now clear, however, that visual processing is far from adult-like when children enter school and that visual experience greatly affects the ability to improve the perceptual processing involved in reading. According to the reviewed literature on reading acquisition, visual limitations in word decoding affect fluency in the first three years of school and then their relevance diminishes (Carver, 1990). Therefore, taking into consideration visual factors may be particularly important when the aim is to foster early literacy acquisition and increase learning outcomes in poor beginning readers.

Although features are learned early in development, the ability to exclude visual noise to identify the object develops later and is improved by learning. In poor countries, classrooms often lack adequate furniture and blackboards may be ruined. Consequently, children in first and second grade may find it particularly difficult to read noisy text.

The ability to recognize words is influenced by visual processing limits; increasing character complexity saturates the visual span sooner in terms of number of letters available in a glimpse. For example, when lexical variables are kept constant, a 3-letter word written in Kunstler font will be read as efficiently as a 6-8-letter word written in Courier font. Thus, to improve readability children's textbooks using Latin scripts should be printed in Courier font. This font type also has constant center-to-center letter spacing, which greatly affects readability. San-serif type-faces are recommended for young children's textbooks due to a readability purpose. Children below third grade require larger letter spacing than adults to correctly recognize letters. In first grade, children's reading is impaired if letter size is in the range of 0.7 and 1.2 deg. As outlined in the section on the effect of size, a letter that subtends 1.2 deg at a viewing distance of 40 cm (which is the distance spontaneously used by children) measures around 0.84 cm, which is equal to 24 pt (post script points). Thus, textbooks for first and second graders should not use smaller font sizes. Furthermore, given that the average size of words written on a blackboard is 10 cm, children should not be seated more than 5 meters away (Hughes and Wilkins, 2002).

Beginner readers can only process one or two characters in parallel and the visual span improves with grade level through learning. The reviewed literature indicates that at the beginning of the learning experience, children are unable to decide at a glance whether the word "shirt" is different from the word "skirt". The literature on perceptual learning indicates that training observers with trigrams improves the visual span capacity. Overall, the reviewed literature indicates that children attain reading efficiency by first learning the alphabet, then moving to bigrams, and gradually increasing word length rather than trying to decipher a whole word at a glance.

Long words suffer from crowding. This visual effect is more pronounced in children below third grade. Thus, long words should be introduced last. The first and last letters

in a word are immune to crowding because there is only one adjacent letter. Word spacing has a crucial role in reading fluency (see also Hughes and Wilkins, 2002; Lovie-Kitchin, Bevan and Hein, 2001). In fact, the eye movement literature indicates that reading is greatly compromised if spaces are removed. Thus, words should be separated by at least three characters in first and second grade textbooks.

Word density patterns for first grade textbooks should be loose at the beginning of the books and get tighter and denser toward the end of the books. By increasing the density of words in the textbooks toward the end of the school year, it is likely that first graders would perform at a sufficient level of reading acquisition and fluency via routine practices from textbooks.

The reviewed literature on the visual characteristics of text does not directly address the question of how many different words should be contained in a textbook. We know that learning is highly stimulus selective; thus, although words should be repeated, a fraction of them should be new to maximize the probability of generalizing reading fluency to a different text. How many words to include in children's textbooks to maximize reading fluency also depend on the size of the children's vocabulary and the characteristics of the specific language.

The contribution of visual factors that limit text decoding is particularly relevant in the first two years of schooling and then decreases. By contrast, the contribution of oral vocabulary increases from first to sixth grade (Ouellette and Beers, 2010). The second part of this review analyzes the educational, linguistic and socio-economic status contributions to reading fluency.

To enhance children's reading and learning process in a multilingual setting, publishing textbooks and other educational materials in bilingual (both official and local languages) is necessary. As an alternative, it may prove effective to spell in the official language stories that children know in their native language.

In designing children's textbooks, much space is often given to pictures. Although pictures in children's textbooks may increase clutter and impair exploratory eye movements (Evans and Saint-Aubin, 2005), having one relevant picture may provide a context that can increase the probability of predicting the next word in a passage. If designed effectively, pictures can help to improve children's reading skills. The selection of illustrations and graphics should be highly congruent with the texts they refer to. They should not be intended just to fill up the empty spaces. Notwithstanding a high printing cost, together with pictures, also colors can have certain impact on the learning process if employed functionally and effectively. If using one or two extra colors in order to highlight part of the text is necessary to make a point, they need to be used consistently. Colors should be selected on the basis of being readily identified, instead of children color preference. Regarding the use of color in picture, this makes reading more attractive, but it is necessary to use colors compatibility with the expected stimulus (*e.g.*, blue as the sky) in order to improve comprehension.

SECOND PART

Educational, linguistic and socio-economic factors in reading acquisition

2.1 Variables affecting acquisition of reading skill

2.1.1. Role of letter knowledge

With letter knowledge, we refer to knowledge of letter names, letter shapes, and sounds associated with letters (Adams, 1990). Learning letter knowledge per se does not seem to vary as a function of the regularity and complexity of the orthography (Seymour et al., 2003). However, good letter knowledge has different influences on the effectiveness of reading as a function of the type of orthography. In shallow orthographies, knowing letters may allow kindergarten children reading about half of words (and non-words), even though they do not yet received formal reading instruction (Mann and Wimmer, 2002). By contrast, good letter knowledge by itself may be insufficient to reach accurate identification of words in opaque orthographies, such as English. For example, letter knowledge predicted efficiency in decoding among English first graders more so than among first graders speaking Greek, a shallow orthography (Manolitsis, Georgiou, Stephenson and Parrila, 2009).

To learn the letters of the alphabet children must become acquainted with several identities for each letter, including graphic shapes in upper and lower-case forms, name, and sound (or sounds). Given that letters have basic functions in alphabetic writing systems, all aspects of letter knowledge can affect the course of alphabetic literacy acquisition.

Knowledge of *letter names*, assessed during preschool and kindergarten, has been found to be a significant predictor of children's later reading skills (Schatschneider, Fletcher, Francis, Carlson and Foorman, 2004; Share, Jorm, Maclean and Matthews, 1984; Stage, Sheppard, Davidson and Browning, 2001; Bond and Dykstra, 1967, 1997; Chall, 1967, 1983; National Research Council, 1998; de Jong and van der Leij, 1999; Muter, Hulme, Snowling, and Stevenson, 2004; Tunmer, Herriman, and Nesdale, 1988; Wagner, Torgesen, and Rashotte, 1994), also throughout the elementary school years and even afterwards (Blatchford and Plewis, 1990; Muehl and Di Nello, 1976; Vellutino and Scanlon, 1987).

Such findings are mainly based on sizable positive longitudinal correlations between children's letter naming ability, generally measured with an uppercase naming test in kindergarten and first-grade reading achievement. This line of research has shown that children's knowledge of letter names accounts for 10 up to 80% of the variance in reading ability.

In meta-analyses of prediction studies of learning to read, Scarborough (1998) and Bond and Dykstra (1967) reported that letter name knowledge in kindergarten is the strongest single predictor of first-grade reading achievement when compared with other important variables such as intelligence or phonemic awareness (*e.g.*, Chall, 1967; Cardoso-Martins 1995). For example, Share *et al.* (1984) found that, among 39 variables (*e.g.*, IQ, vocabulary level, home socio-economic status, etc.), letter name knowledge entering kindergarten was the best individual predictor of kindergarten

reading achievement and the second best, after phoneme segmentation, of first-grade reading achievement.

Children's letter-name knowledge also correlates strongly with their ability to spell inventively (Richgels, 1986), suggesting that children use knowledge of letter names to infer the spelling of phonemes. In fact, children more frequently spell letters represented in the letter name (Treiman, Weatherston and Berch, 1994). Moreover, in both consistent and inconsistent orthographies, kindergarten letter name knowledge also predicts initial spelling achievement (Muter, Hulme, Snowling and Taylon, 1997; Pennington and Lefly, 2001; Shatil, Share and Levin, 2000).

Notably, most quoted studies have examined English-speaking children and extension to more regular orthographies would require *ad hoc* investigations (Share, 2008).

Learning the names of letters aids children in early reading and spelling for several reasons. First, letter name knowledge helps young children appreciate that printed letters and words represent spoken language (Justice and Ezell, 2004; Paris, 2005; Whitehurst and Lonigan, 2002; Treiman, Tincoff and Richmond-Welty, 1996) and helps children understanding that spelling is not an arbitrary string of letters (Treiman and Kessler, 2003; Treiman and Rodriguez, 1999). Knowledge of letter names also assists children in learning letter-sound (*i.e.*, grapheme-phoneme) relationships, as reported in both correlational and longitudinal studies (*e.g.*, Burgess and Lonigan, 1998; McBride-Chang, 1999).

In alphabetic languages (*e.g.*, Arabic, English, French, Hebrew, Portuguese, etc.) letter names often include letter sounds (*e.g.*, B begins with the phoneme /b/ and M ends with the phoneme /m/, as well as A is in ape, B is in below). According to the so-called *Alphabetic Theory*, in these cases letter names serve as background knowledge on which children rely to more easily acquire letter-phoneme correspondences (Ehri and Roberts, 2006; Foy and Mann, 2006; Justice, Pence, Bowles and Wiggins, 2006; Share, 2004; Treiman, Sotak and Bowman, 2001).

Much evidence supports this theory. In fact, the properties of letter names affect letter-sound knowledge (Treiman, Tincoff, Rodriguez, Mouzaki and Francis, 1998; but see McBride-Chang, 1999). This is particularly true when letter names follow the acrophonic principle, that is, when the initial phoneme of the letter name corresponds to the sound of the letter. Treiman and colleagues (1998) found that young children were indeed better at identifying the sounds of acrophonic printed letters than those of non-acrophonic letters, such as h and y (see also Share, 2004; Treiman and Rodriguez, 1999). Moreover, the letter-sound knowledge level in kindergartners and first graders was consistently highest for letter sounds related to CV letter names, intermediate for letter sounds related to VC letter names, and lowest for letter sounds unrelated to letter names (McBride-Chang, 1999; Treiman *et al.*, 1998; Treiman *et al.*, 1994). In an experimental study, Treiman *et al.* (1998) trained preschoolers who knew the relevant letter names to learn letter sounds. After three learning sessions, the children had significantly progressed only in letter sounds related to letter names, especially CV letter names. Moreover, regression analyses showed that the type of letter names contributed significantly to differences in letter-sound knowledge, even after controlling for influential factors such as the consistency of letter-sound

correspondences, category of phonemes, and children's age (Treiman *et al.*, 1994, 1998).

A view diametrically opposed to the alphabetic theory proposes that letter name knowledge is an impediment for children learning to read because many letter names deviate from the acrophonic principle (Feitelson, 1988; Venezky, 1975). In this framework, the fact that children learn letter sounds that are more easily related to letter names might be due to the interfering effect of letter names impeding the learning of unrelated letter sounds. A typical case of letter-name interference is the association between the sound /w/ and the letter y, as suggested by the name of the letter (Thomson, Fletcher-Flinn and Cottrell, 1999; Treiman *et al.*, 1994). According to this view, letter names should be avoided during the early stages of reading instruction (Feitelson, 1988; Venezky, 1975).

It is important to keep in mind that many studies in favor of the Alphabetic Theory were performed with students who spoke English, a language that appears particularly suited to this theory. In fact, most English consonant names contain corresponding letter sounds, either as initial phoneme, that is, following the acrophonic principle (CV letter names, *e.g.*, b, d, p...) or as final phonemes (VC letter names: f, l, m, n, r, s). Only a few consonant names are not or are only inconsistently (*e.g.*, c, g, w, y...) related to letter sounds.

In many languages with alphabetic orthography, children are typically introduced to letter names before letter sounds for educational reasons (rather than cognitive or linguistic ones), because letter names, as syllables or rhymes, are presumably easier to acquire than letter sounds. In fact, letter naming is reported to develop before recall of letter sounds (Hecht, Burgess, Torgesen, Wagner and Rashotte, 2000). Studies that made letter-by-letter analyses found that the name of a letter is most often known before the typical sound of the letter (Blatchford and Plewis, 1990; Worden and Boettcher, 1990). In fact, mapping letter names to their symbols is an easy task because children are accustomed to using words to name things. By contrast, across languages, learning the association of symbols with discrete sounds, as in letter-sound knowledge, may be much more challenging because it requires the isolation of a single phoneme. Moreover, extracting letter sounds from letter names requires a certain level of skill in phonemic analysis (*e.g.*, phonemic deletion skills; Burgess and Lonigan, 1998).³⁶

The relationship between preschool letter name knowledge and reading achievement might be mediated by letter-sound knowledge. The particularly transparent links between letter names and letter sounds in English (from which almost all results were obtained) may contribute to this confounding effect. In fact, also letter-sound knowledge is necessary for acquiring the alphabetic principle and learning to read and spell alphabetic texts successfully (Ehri, 1998; Vellutino and Scanlon, 1987).

On the other hand, there is evidence on consistent orthography that letter names can be bypassed without preventing successful learning of letter-sound correspondences (*e.g.*, Caravolas, Volin and Hulme, 2001). Cross-linguistic studies have

³⁶ In fact, letter sounds are easier to learn when included in CV letter names than in VC letter names, because letter names are easier to segment than VC letters (Thomson *et al.*, 1999; Uhry and Ehri, 1999).

shown that deficits in pre-reading letter name knowledge did not necessarily lead to subsequent lateness in reading achievement (Bruck *et al.*, 1997; Mann and Wimmer, 2002).

Another aspect is that both letter name and letter-sound knowledge have specific predictive influences on reading achievement in literacy development (Caravolas, Hulme and Snowling, 2001; Ellis and Large, 1988; McBride-Chang, 1999; Wagner *et al.*, 1994). Torgesen, Wagner and Rashotte (1997) reported that letter-name recall was a more sensitive predictor of literacy among English kindergarten children, whereas letter-sound recall was a better predictor for children in first grade. In fact, up to school entry, letter name knowledge (generally more developed and more variable than letter-sound knowledge) appears as a better predictor of learning to read. But, by the time the letter name knowledge level reaches ceiling in all children, developing letter-sound knowledge takes over as a stronger predictor of reading achievement. In this vein, Duncan and Seymour (2000) reported that letter-sound recall was a better indicator of letter knowledge because it reflected delays in literacy acquisition.

2.1.2. Effect of teaching method on reading improvement

An extensive meta-analysis of research produced by the English National Institute of Child Health and Human Development [NICHD] (The National Reading Panel; NICHD, 2000; see also Ehri, Nunes, Stahl and Willows, 2001) found that systematic phonic instruction, as compared to non-phonics instructions (such as basal reader, whole word, and whole language programs) was the most effective teaching method for reading acquisition. This teaching method was also the most effective one for improving comprehension skills (Connelly, Johnston and Thompson, 2001). The superior reading performance of children being taught with phonics method (compared to other methods) was particularly evident in third grade (Landerl, 2000).

Nevertheless, although most studies showed an advantage for the phonics method, as also reported in the recent review by Wyse and Goswami (2008), a range of different teaching approaches can also be effective. For example, discrete phonic interventions, whole language interventions, whole-word teaching and contextualized methods in which systematic phonics are carefully integrated with whole text work and comprehension activities (Berninger *et al.*, 2003, method c) have also proved effective. In fact, non-phonics teaching produces better performances in reading words with exceptional correspondences (Connelly *et al.*, 2001) and faster reading (Connelly *et al.*, 2001; Lesgold, Resrick and Hammond, 1985) compared with phonic teaching. Moreover, training on whole-word reading does not exclude learning the grapheme-phoneme correspondences (Ehri and Wilce, 1985; Perfetti, 1992; Thompson, Cottrell and Fletcher-Flinn, 1996; Thompson *et al.*, 1999; Van Orden, Pennington and Stone, 1990) and sometimes has been found advantageous compared with explicit instructions of letter decoding (Frith, 1985; Elder, 1971; Lesgold *et al.*, 1985).

All of the reviewed studies compared reading performance in groups that received different teaching approaches. However, several variables (print exposure, work at home, etc.) might not have been controlled and might have modulated the efficacy of the teaching methods. Bishop (1964) and Jeffrey and Samuels (1967) controlled this aspect by comparing the efficiency of phonic and whole-word trainings in improving

the reading of a list of words written with nonsense letters. In a transfer task, subjects were then taught to read a new list of words composed with the same nonsense letters used in the training task. Results showed that only phonic training resulted in appreciable transfer.

Bitan and Karni (2003, 2004) compared the efficacy of three teaching methods in learning to read nonsense words written in an artificial script (in which each phoneme was represented by two discrete symbols) to a group of Israeli adults. They compared alphabetical whole words with letter decoding instruction (Explicit), alphabetical whole words without letter instruction (Implicit), and non-alphabetical whole words with no consistent correspondence of letters to sounds (Arbitrary). Participants were literate adults. Results showed that in the explicit condition training resulted mainly in learning to recognize the individual letters, but also in some word-specific recognition; in the arbitrary condition, training resulted in word-specific recognition that was based on recognition of the internal structure of symbols in the word; in the implicit condition, training resulted in word-specific recognition in all participants and to non-declarative letter decoding knowledge in some participants (note that letter knowledge in the implicit condition was lower than in the explicit condition, and evolved only under specific facilitating conditions). The authors found that the explicit condition yielded a higher, more advanced, level of skilled performance. In fact, performance was more accurate and acquired knowledge was better preserved in the explicit condition than in the arbitrary condition. Nevertheless, reading performance was slower in the explicit condition than in the arbitrary condition, presumably because it involved letter decoding and not lexical reading. By contrast, Spring (1978) found that whole-word instruction did not necessarily result in more automatic word recognition responses than phonics instruction. In this study, the expected speed advantage of whole-word instruction was not obtained and the latencies (time between stimulus onset and beginning of vocal response) decreased as learning was very similar for the two groups.

However, the level of reading accuracy reached by children with phonic and non-phonic methods did not always differ significantly. For example, Thompson, McKay, Fletcher-Flinn, Connelly, Kaa and Ewing (2008) examined children of three different countries all speaking English but that used different teaching method. They found that sample of beginning readers without systematic explicit phonics (teaching centered on story text reading) reached the same level of word reading accuracy as samples with high and moderate explicit phonics. In particular, they tested whether readers employed any compensatory learning to reach that level. First, text comprehension might pay the cost of discrete accuracy in decoding despite the use of a disadvantageous teaching method. According to Stanovich's (1980) *interactive-compensatory model* (but see also Connelly *et al.*, 2001 for experimental evidence on English speaking subjects), without the aid of instruction in explicit phonics, the cognitive attention required by the child to read words would be so great that too few resources would be left to understand the text. Furthermore, beginners without phonics training might be able to acquire accuracy in reading words by trading off reading speed (*i.e.* reading more slowly). Finally, children without explicit phonics might derive a greater advantage from lexical body-rhyme units (*i.e.*, pattern of letters frequently associated in word body or rhyme) than children with explicit phonics instruction based on the grapheme unit, as suggested by Ziegler and Goswami's (2005)

psycholinguistic *Grain Size Theory*.³⁷ Thompson *et al.*'s (2008) results showed that children without phonic training reached the same accuracy as the other experimental groups without trading-off text comprehension and without marked reliance on larger psycholinguistic grain sizes (in the form of rhyme units). The advantage provided by the lexical body units (*i.e.*, the possibility to processing larger orthographic units) for reading pseudo words was small in all four samples and did not significantly vary between them.

In a micro training study (Thompson *et al.*, 2008), no compensation was found in proficiency of initial learning of lexical orthographic representations. Participants did not trade off text reading speed to achieve equal word reading accuracy and equal reading comprehension/recall. On the contrary, across samples children's oral text reading was faster without explicit phonic instructions (for similar findings see Elder, 1970, 1971; Connelly *et al.*, 2001). On average, they read 46% more words per unit of time than the high phonics sample and 20% more than the moderate phonics sample. The greater speed of text reading (words read per unit of time) produced extra exposure and practicing of words. According to the authors, the extra exposure and practice explained this result. In fact, it compensated for their lack of explicit phonics instruction.

2.1.3. Exposure to print at home

In developed countries, children are exposed to written (typically child appropriate) texts since a very early age. As Justice and Sofka (2010) stressed, children's early experiences with print and text (and the quality and frequency of such experiences) matter a great deal in determining how fluent their reading and writing skills will become. Justice and Sofka's (2010) work is grounded by a number of empirical studies in early childhood literacy. The work focuses largely on the U.S. context and teachers and parents³⁸ as stimulating motivators to engage young children with prints and texts in order to increase literacy and reading fluency. However, in other educational systems children were less exposed to books at home. According to

³⁷ The psycholinguistic Grain Size Theory (Goswami and Ziegler, 2006; Ziegler and Goswami, 2005, 2006) aims to explain reading acquisition within a cross-linguistic perspective. According to this theory, cross-linguistic variations reflect differences in the units used for the phonological recoding strategies that are developed in response to the orthography. Children progressively find the most efficient grain size in a given orthography for achieving fluent reading. In reading shallow orthographies, children are expected to rely almost exclusively on phonological recoding at the grapheme-phoneme level, because mapping at this level is simple and direct. However, in deep orthographies, using these small units of phonological recoding would result in mispronunciations. Thus, children are led into converting print to speech by using larger (and less inconsistent) chunks, like patterns of letters, syllables, body rhymes, or even whole words.

Overall, in shallow orthographies, skilled readers are expected to rely almost exclusively on small units of phonological recoding (grapheme-phoneme conversion), whereas, in deep orthographies, readers are expected to use larger grain size units or multiple units varying in size (Ziegler, Perry, Jacobs and Braun, 2001).

³⁸ Philipps and Lonigan (2009) classified parents of five-year old children on the basis of background (income, education, etc.) and type of language and literacy activities in the home. There were three types of families. High-high families had high levels of book-sharing and high levels of code-related activities, such as activities with sounds and letters. Low-low families had low levels of both types of activities. The low-high group did not do much book sharing, but provided some code-related play.

Duggan (2009), the number of books at home is an important indicator of how much young children are exposed to prints, which would help to build vocabulary knowledge (see also, Stanovich and West, 1989; Griffin and Snowling, 2002). While children who arrive in first grade with sufficient understanding of texts and sounds can cope with the formal reading instruction, those who have limited experiences with texts and sounds may experience frustration and set back. Moreover, access to books and written texts represents a critical link to reading fluency. For example, PISA (Program for International Student Achievement) studies have shown that the number of books at home is an important predictor of student outcomes in reading literacy (Ma, 2008).

In low-income countries textbooks serve as an important tool for the acquisition of reading fluency in grades 1-2 and thereby improve learning outcomes: indeed, the availability of textbooks at home is among the most reliable predictors of academic success (Abadzi, 2006; Heyneman, 1990). Having reading textbooks available for young students to practice at home results in improved reading skills and practices and increased reading fluency (*e.g.*, Heyneman, Farrell, and Sepulveda-Stuardo, 1981). For example, in Nicaragua the provision of mathematics textbooks helped to narrow the gap between rural and urban students³⁹ (Jamison *et al.*, 1981).

Many, if not a majority of, children in African countries, who are reared in impoverished settings, suffer from a lack of stimulation in their homes. Since poor households have limited resources to acquire reading and learning materials and adult members are focused on meeting basic family needs, many children are at risk of becoming poor readers and illiterate. Moreover, it is important to remember that poor students often do not have textbooks even at their school and thus spent much of their time copying from the blackboard or taking word-for-word dictation. In this way, they cannot get sufficient practice to automatize reading (also at home) and may remain illiterate for years. Thus, availability of textbooks that allow children practicing reading by themselves or with minimal home support would become important vehicles for raising reading fluency among children in low-income countries and in poor households.

2.1.4. Shared reading

A set of studies examined the importance of adult-child shared reading for reading improvement. Parental involvement in reading may have a positive influence on children's outcomes (*e.g.*, Fawcett, Rasinski and Linek, 1997; Senechal and LeFevre, 2002; Shaver and Walls, 1998; Weinberger, 1996) also longitudinally (Senechal and LeFevre, 2002; Weinberger, 1996). A meta-analysis (Bus, van Ijzendoorn and Pellegrini, 1995) highlighted the importance of parent book reading with preschoolers in supporting reading achievement, emergent literacy and language growth. However, comparing several parent-implemented reading interventions (hearing the child read; paired reading; pause, prompt, and praise; and direct instruction), Leach and Siddall (1990) found that the conditions producing greatest increases in children reading

³⁹ Note that the difference in textbook available between urban and rural areas is very large in low income countries (Crossley and Murby, 1994). For example in Tanzania, in urban areas 2 children out of 3 have a textbook (0.67%), while in rural areas this figure changes to only 1 out of 13 (0.08%).

performance were the parental use of pause, prompt, and praise as well the use of direct instruction.

Stadler and McEvoy (2003) found that shared reading of a storybook (*i.e.*, narrative) prompted parents to talk about the books' illustrations. Print-related comments are rare, that is, usually less than 10% of the dialogue (Bus and van IJzendoorn, 1988; Pellegrini, Perlmutter, Galda and Brody, 1990; Phillips and McNaughton, 1990; Yaden, Smolkin and Conlon, 1989). In a longitudinal study, Senechal (2006) found that shared book reading was related to oral language development, and indirectly to Grade 1 reading comprehension, but also to the reading for pleasure when children were at higher level of literacy (4th grade). By contrast, code-related activities, such as explicit teaching of letters and sounds, influenced more emergent literacy, as well as fluent decoding in later stages of literacy.

However, parents' comments increase with print-salient materials, such as alphabet books (Bus and van IJzendoorn, 1988; Stadler and McEvoy, 2003). In fact, shared reading of alphabet books prompted more discussions of letter-word relationships (Stadler and McEvoy, 2003) and was positively correlated with preschoolers' emerging literacy skills (Bus and van IJzendoorn, 1988). The literature on this topic is relatively small. The few existing studies seem to indicate that adult-child shared reading of alphabet books may lead to gains in children's letter knowledge and phoneme awareness (*e.g.*, Greenewald and Kulig, 1995; Pappas, Hart, Escobar and Barry, 2001; Nodelman, 2001). Moreover, Greenewald and Kulig (1995) found gains in kindergartners' knowledge of upper- and lower-case letters after a 4-week alphabet book-reading program. However, it should be kept in mind that most parents do not often read alphabet books (Baker Fernandez-Fein, Scher and Williams, 1998; Phillips and McNaughton, 1990).

This situation is exacerbated in low-income families and in poor countries. Low family income has consequences for children's achievement, because poverty places constraints on families' investments in material resources (*e.g.*, books) necessary for cognitive development (Becker and Tomes, 1986; Dearing and Taylor, 2007; Votruba-Drzal, 2003; Yeung, Linver and Brooks-Gunn, 2002). Moreover, economic pressures associated with poverty impair parent's psychological well-being, thereby decreasing positive parenting behaviours (*e.g.*, stimulation, support, and responsiveness) and increasing negative parenting behaviours (*e.g.*, insensitive and inconsistent responses; Conger, Rueter and Conger, 2000; Dearing, Taylor and McCartney, 2004; Elder and Caspi, 1988).

2.1.5. Role of teachers' competence

Nye, Konstantopoulos and Hedges (2004) claimed that a substantial proportion of the variance in achievement gains (from 7% to 21%) is due to variations in teacher effectiveness. Although this effect was larger for math, it was also clearly evident for reading (Clotfelter Ladd and Vigdor, 2007).

According to Nye *et al.* (2004), the difference in achievement gains between having a 25th percentile teacher (*i.e.*, a not particularly effective teacher) and a 75th percentile teacher (an effective teacher) is over one third of a standard deviation

(0.35) in reading and 0.48 in mathematics; while the difference between a 50th percentile teacher (an average teacher) and a 90th percentile (a very effective teacher) is 0.33 in reading and 0.46 in mathematics.

The teacher effect has been found to be larger than other effects, such as class size and SES (Clotfelter *et al.*, 2007). Moreover, the teacher effects were much larger in small classes than in regularly sized classes and in low SES than in high SES schools. Notably, low-income students were more likely to be exposed to less effective teachers (Krei, 1998; Lankford, Loeb and Wyckoff, 2002), because schools with high proportions of low income or minority students have often difficulty recruiting and retaining high quality teachers (Darling-Hammond, 1995). Accordingly, teachers of low-SES children tended to be from minority groups and to have lower levels of education and less teaching experience than those of middle-SES children (Saluja, Early and Clifford, 2002; Whitebook, Howes and Philips, 1989; Lee and Ginsburg, 2007).

Students' achievement is predicted by specific characteristics including (Darling-Hammond, 2000): (1) teacher certification; (2) teacher education (*i.e.*, general academic ability and knowledge about teaching and learning as reflected in teacher education courses); and (3) teacher experience.

Credentials, education and experience affect teachers' instructional practices, which in turn predict students' learning. However, although minimal teacher qualifications are important, other factors modulate what teachers actually do in the classroom and how effective they are (Condor, Son, Hindman and Morrison, 2005).

The type and amount of college education teachers receive is related to student achievement for both content area and overall student learning (Darling-Hammond and Youngs, 2002; Greenwald, Hedges and Laine, 1996; Monk, 1994; Wenglinsky, 2000; Condor *et al.*, 2005). Students who had teachers with masters' level degrees demonstrated overall better outcomes than students who had teachers with fewer years of education (Ferguson, 1991). A meta-analysis (Greenwald *et al.*, 1996) revealed that, across studies, teachers' educational levels positively predicted student outcomes (average .20). Also qualitative differences in teaching methods emerged as a function of teacher education. Teachers with extensive education tend to have a child-centered view of valuing children's interests and choices as opposed to teachers' goals and directions (McMullen and Alat, 2002; Snider and Fu, 1990).

However, the effects of teacher education on achievement gains were smaller than those of *teacher experience* (Nye *et al.*, 2004). Teachers with more experience are more effective in raising student achievement than those with less experience (Clotfelter *et al.*, 2007). Nye *et al.* (2004) found that this effect ranged from 0.06 to 0.19 standard deviations (even if significant only in 2nd grade). Greenwald *et al.*'s (1996) meta-analysis suggested that teachers' years of experience positively predicted student outcomes (.17). An additional year of experience produced greater advantages in the early years of teaching (Clotfelter, Ladd and Vigdor, 2006). Nevertheless, more years of experience in teachers who taught ineffectively year after year never led to better student outcomes (Condor *et al.*, 2005).

Note that other variables have also been reported to influence student outcomes: teachers' praise, quantity, and pacing of instruction, and teacher expectations (Brophy and Good, 1986; Fraser, 1987; Stockard and Mayberry, 1992); teachers'

responsiveness, use of decontextualized language and introduction of new vocabulary (Dickinson and Tabors, 2001; Condor *et al.*, 2005); teachers' ability to manage and control their students' learning and behavior in the classroom (Brophy and Good, 1986); teachers' responsiveness to student questions and interests, and the warm and positive emotional climate of the classroom (Connor, Morrison and Katch, 2004a; Connor, Morrison and Petrella, 2004b; Green *et al.*, 1992; Snow, Burns, and Griffin, 1998; Torgesen *et al.*, 1999); teachers investment and acceptance of their role and responsibility for student achievement (Ashton and Webb, 1986; Dunn and Shriener, 1999; Fuchs, Fuchs and Phillips, 1994; NICHD-ECCRN, 2002a, b; Stockard and Mayberry, 1992); teachers' time spent in academic activities (Connor *et al.*, 2004a; Connor *et al.*, 2004b; Taylor, Pearson, Clark and Walpole, 2000; Wharton-McDonald, Pressley and Hampston, 1998); teachers' attention to children's individual needs and pre-existing skill levels (Connor *et al.*, 2004a). These findings call attention to the actual school situation in poor countries, where classes usually start the school year with more than 100 students, and teachers often ignore most of them and mainly interact with those who are particularly intelligent and vivacious (Llambiri 2004) (see paragraph *An overview of teacher feedback and reinforcement in poor countries* for a more detailed description of this phenomenon).

The teacher-child relationship plays a fundamental role in school achievement, also in a longitudinal perspective and even after adjusting for the child's cognitive ability and teacher ratings of classroom misbehavior (Hamre and Pianta, 2000). In fact, young children are more able to learn from adults with whom they have close relationships than from adults with whom they have conflicted relationships (Pianta, 1999). Quality of teacher-child conversations predicted both the level and rate of change in vocabulary and word decoding of children (Dickinson and Sprague, 2002). Teacher closeness to the child was more related to gains in reading scores when the child's parents reported less progressive parenting attitudes (Burchinal, Peisner-Feinberg, Pianta and Howes, 2002).

Teachers' ethnic background also plays a role: teachers from poor and minority family backgrounds tended to stress early academic preparation significantly more than their white and/or higher SES colleagues (Johnson-Beykont, 1999). Moreover, if teachers share ethnicity and SES with their pupils, they tend to understand their needs better (Ehrenberg, Goldhaber and Brewer, 1995). It is important to remember, however, that emotionally and academically supportive instruction was associated with better than expected academic achievement in those students who were at-risk (based on either child functioning or low maternal education) for school failure (Hamre and Pianta, 2005).

2.1.6. Teacher feedback and reinforcement

Classrooms with more frequent drills and practice produced the greatest achievement gains in reading (as well as in math), after controlling for the initial level of achievement (Stallings, 1974; Cooley and Leinhardt, 1980; Soar and Soar, 1979). This patten was present also among poor, minority, and middle-class kindergarten children (DeVries, Reese-Learned and Morgan, 1991; Gersten, Darch and Gleason, 1988; Marcon, 1993; Stipek *et al.*, 1995). However, also the possibility to have positive feedback after the performance plays a fundamental role in reading improvement.

According to Thorndike's 'Law of Effect' (e.g., Thorndike, 1911), if a response to a stimulus is accompanied or closely followed by satisfaction, then that response is likely to occur again in the presence of the same stimulus. If positive reinforcement occurs followed a response, response probability increases (Skinner, 1938, 1953). Reinforcing stimuli act as motivational stimuli towards which behaviour is directed. From a neural standpoint, reinforcement occurs when an appropriate stimulus causes the activation of dopaminergic neurons in the ventral tegmental area (Carlson, 1999). When students receive dopamine pleasure from correct performance in class, they are motivated intrinsically to persevere (Salamone and Correa 2002, Gee 2007). By contrast, in the case of mistakes, the nucleus accumbens releases less dopamine. The network making predictions of success and failure needs timely feedback for the memory storage (Galvan *et al.* 2006), in order to update new information or to have more accurate future predictions (Dragansk and Gaser 2004).

The acquisition of correct reading responses is not only function of practice, but is necessarily related to the reinforcing social feedback. Children need to rely upon the judgment and evaluation of others to guide the direction and appropriateness of their behaviour, including reading. Providing children with reinforcement (*i.e.*, delivering preferred stimuli) on accurate or fluent reading as well as information about their performance (*i.e.*, performance feedback) make it possible improving the reading performance of students in general and special education classrooms (Billingsley, 1977; Holt, 1971; Jenkins, Barksdale and Clinton, 1978; Conte and Hintze, 2000). Social reinforcements have the functions to increase/decrease the incentive value of success and to accentuate/reduce the threat of failure in performance. Then, social reinforcement can serve as an indicator of success, and therefore children's attention and adjustment to teacher feedback could be related to the incentive value they place upon success (Butterfield and Zigler, 1965; Hill, 1967; Stevenson and Hill, 1965). Social reinforcement histories and the subsequent expectancies for success and praise/criticism may mediate the children's responsiveness to reinforcement (feedback on their performance) and then their acquisition of correct reading responses (Cotler and Palmer, 1971). In fact, not only expectancies about failure and success (the histories of academic achievement), but also the success/failure expectancy (generally associated to the anxiety level; Hill, 1967; Stevenson, 1965) affect task performance (Cotler, 1969; Cotler and Palmer, 1970a, 1971; Hill, 1967) through reinforcement responsiveness.⁴⁰ Children performing most effectively in academic situations would receive relatively more positive reinforcements and consequently have a greater likelihood and expectancy for success than children whose academic achievement is relatively low.

Also the attribution of success and failure to an internal or external cause (and henceforth perceived as modifiable or not modifiable) play an important role in children achievement. Children who attribute failures to variables outside their control and not modifiable, such as poor ability, believe that outcome is independent of effort and then are "learned helpless" (Dweck, 1975). No matter how hard they try, they believe, the outcome will be failure. Therefore, in an attempt to avoid or minimize a

⁴⁰ Boys' performances would be significantly more affected by the social reinforcement contingencies than the performances of girls (Cotler and Palmer, 1970a, 1971). Girls have higher incentive values for academic success than boys (Cotler & Palmer, 1970b, 1971; Grossman, 1968; Wright, 1968), and their reading performance is less dependent upon extrinsic motivational factors.

sense of failure, they stop trying, rather than taking the risk of uncovering more evidence that they are stupid by exerting effort and failing anyway (*e.g.*, Covington and Berry, 1976). Clearly, this attribution style produces less motivation in performing the tasks and in perseverating in the case of failure. This in turn yields higher probability of failure and strengthens child's belief of incapacity. If we consider poor readers for which failures are highly probable and that need greater efforts as compared to their friends, but do not reach adequate results anyway, there is a high probability that these children get demotivated in perseverating in performing the task ("if I fail always, there is not reason to perform it"). In this case, it is important that teachers are able to favour a correct attribution of failure. It is better to reinforce the application and effort of poor readers, rather than the attainment of correct performance, in order to avoid demotivating these children. In the case of failure, it is better to give the message that it is due to scarce application (a modifiable cause: "the next time, if you will apply more you will be able to have a good performance") and not to scarce ability (a not modifiable cause producing scarce investment in reading performance).

Note that if children were reinforced every time they performed accurately, it is likely that the reinforcement would lose its power to drive the children's behaviour. In order to avoid this, the token economy can be used (see Kazdin and Bootzin, 1972 for a review). In this technique, children receive a token for each correct performance, but are reinforced only when they reach an already established number of tokens. Progressively, it is possible increasing the number of tokens necessary to obtain the reinforcement in order to progressively ameliorate reading performance. Token economy also allows increasing the children's self-monitoring skills. Tokens may also be auto-provided by children (self-reinforcement) or given not only by teachers but also by parents or other children (peer tutoring).

As suggested by Eckert, Ardoin, Daly and Martens (2002), "attempts to improve children's oral reading fluency [and accuracy] can be divided into two categories: those involving some form of instruction in the form of modelling or practice (*i.e.*, antecedent interventions) and those involving some form of reinforcement contingent on rapid and accurate reading (*i.e.*, consequences)" (page 272). In order to increase oral reading fluency and accuracy of students with reading problems it is possible combine consequence interventions (contingent reinforcement and performance feedback) with antecedent intervention (such as listening passage preview and repeated readings) (Eckert *et al.*, 2002; but see also Daly, Martens, Hamler, Dool, and Eckert, 1999). Moreover, there are other methods to increase the probability that children engage in a correct performance and than in turn increase the probability to be reinforced. These techniques include the use of modelling, direct instruction and prompt (with a progressive fading out of the use of these techniques). Another behavioural technique providing children with the opportunity of being reinforced is shaping (Foxx, 1986). Shaping consists in gradually reinforcing each closer approximation to the target behaviour, in order to promote its occurrence. For example, a child may be initially reinforced in his attempt to read letter by letter (c-a-s-a), then when reads syllable by syllable (ca-sa), progressively when reads the whole word even if incorrectly (cata) and finally only if the whole word is correctly identified (casa; Italian for "house"). In this way, children are not frustrated but motivated to

progress in their reading performance. Naturally, it is important to provide feedback after each performance, in order to promote the emergence of the target behaviour.

Also maternal reinforcement affects reading performance. In fact, a rewarding and nonpunitive mother (and provides support in case of failure) is related not only to better cognitive development, school achievement and higher achievement motivation (*e.g.*, Hermanes, Terlaak and Maes, 1972; Rosen and D'Andrade, 1959), but also to better reading skills (Kagan and Zahn, 1982; Milner, 1951). However, qualifications are in order. For example, extremely positive maternal reinforcement and indulgence may be the expression of an overprotection inhibiting cognitive development, inducing emotional dependence, passivity, lack of security, lower aspiration and need for achievement motivation (Kagan and Moss, 1982; Crandall, Dewey, Katkovsky and Preston, 1964; Crowne, Conn, Marlow and Edwards, 1969). On the other hand, in some cases, maternal restrictiveness associated with mild punishment may lead to increase achievement motivation and cognitive development (Baumrind, 1966; Rosen and D'Andrade, 1959). Parents may be trained in order to give reinforcement correctly and to apply other techniques for improving the reading performance of their sons. The most effective parent tutoring procedures use instruction, reinforcement, modelling, and error correction methods (*e.g.*, Duvall, Delquadri, Elliott and Hall, 1992; Leach and Siddall, 1990; Love and Biervliet, 1984; Thurston and Dasta, 1990). For example Resetar, Noell and Pellegrin (2006) found that if parents were trained to implement a tutoring procedure that included modelling, practice, phonics, fluency building, accuracy building, comprehension, and reinforcement components all but one child exhibited an increase in words correctly read per minute on tutored reading passages. Parent involvement can be a cost-effective and time-efficient method for teaching children, especially in schools with limited resources (Fitton and Gredler, 1996; LFA, 1998, 2000). However, often this is not possible in low-income families with low educational level and low involvement in children's academic achievement.

An overview of teacher feedback and reinforcement in poor countries

Higher quality care from teachers may help compensating for the impoverished home environments of poor children and promoting children's achievement (*e.g.*, Bogard and Takanishi, 2005; Reynolds *et al.*, 2004). Benefits for low-income come through material (*e.g.*, learning materials) and psychosocial (*e.g.*, stimulating and responsive caregivers) investments that compensate for the limited opportunities provided by the home environments (Burchinal, Peisner-Feinberg, Bryant and Clifford, 2000; McCartney, Dearing, Taylor and Bub, 2007; Reynolds, Ou and Topitzes, 2004; Dearing, McCartney and Taylor, 2009). However, improving the quality of teacher's care is not an easy goal to reach in poor countries.

In general, teachers have more and longer academic interactions with the higher performing students (Cooper and Tom, 1984), give more positive feedbacks to those who succeed and punish them less than students who are perceived as not trying hard (Weiner and Kukla 1970). These effects are exacerbated among poor countries where most students have little or no interaction with teachers. Teachers tend to focus on the few pupils who can perform the work and ignore those requiring more help, without giving reinforcement or corrective feedback to them (Lockheed and Harris, 2005; but see also World Bank's Independent Evaluation Group, *e.g.* IEG

2008, 2009a, 2009b, 2009c). For example, Abadzi and Llambiri (2011) found that better students received from teachers 4.7 times more questions than failing students, were 5.4 times more praised and encouraged. Weaker students rarely got feedback regarding their performance; 85% of them reported that the teacher did not talk to them about the need of studying harder and catching up. These usually ignored children may become increasingly absent, attending irregularly and eventually dropping out, thus remaining illiterate. The presence of very large classes contributes to this outcome. This phenomenon, known as *hidden dropout*, is often observed in low-income countries and regards more than a third of the students in lower secondary education (see Abadzi and Llambiri, (2011)for an in depth description of this phenomenon).

“Teachers must learn techniques for keeping all students engaged in learning tasks all the time, ensuring their attention, contemplating the content, reorganizing memorized information items to answer higher-order questions. Observational learning techniques, such as brief targeted video clips shown repeatedly can help teachers automatize these practices (Dowrick 2010, Feldon 2007). They can also help teachers replace the observational models of their own teachers that they often use in class, and which often focus on the more capable students.” (Abadzi and Llambiri, 2011).

2.1.7. Orthographic consistency

Language orthographic consistency is a major factor in how easily a system (whether a neural network or a child) can learn to read and spell (Plaut *et al.*, 1996). Several studies (for a review, see Ziegler and Goswami, 2005) found that orthographic consistency is a crucial factor for determining the rate of reading acquisition across different languages.

There is evidence that during the first years of schooling reading and spelling acquisition proceeds faster in readers of regular orthographies than in readers of English (Caravolas and Bruck, 1993; Seymour *et al.*, 2003; Frith, Wimmer and Landerl, 1998; Naslund, 1999; Oney and Goldman, 1984) . In opaque orthographies, beginning readers need a relatively long period of time to acquire and automatize inconsistent orthography-phonology mappings (Treiman, Mullennix, Bijeljac-Babic and Richmond-Welty, 1995). We would like to emphasize that nearly all studies comparing the effect of orthographic consistency were carried out in developed countries and no direct evidence is yet available for African and Asian languages. While the available studies do offer a number of important indications on the role of orthography in literacy acquisition, studies on languages of undeveloped countries are urgently needed if one would have to base teaching programming on direct empirical evidence.

One of the most striking demonstrations of the influence of orthographic consistency comes from a cross-linguistic investigation in which reading performance on simple words and non-words was measured at the end of Grade 1 in 14 European countries (Seymour *et al.*, 2003). Children varied in age, but were equated for degree of reading instruction across orthographies. Although the method of reading instruction itself could not be equated exactly, schools with phonics teaching (*i.e.*, emphasizing grapheme-phoneme correspondence) were generally chosen. In word

reading, accuracy was near ceiling in most transparent languages (*e.g.*, Italian, German, Greek, Spanish, and Finnish); it was lower (around 80%) in less transparent languages (*e.g.*, Portuguese, French, and Danish), and was only 34% (over three SDs below the 14-nation mean) in English, the least transparent orthography. For English children 2.5 or more years of literacy learning was necessary in order to master the recognition and decoding of familiar words, as compared to ca. one year in consistent orthographies (Seymour *et al.*, 2003). These findings were replicated in a number of small-scale experiments (Bruck, Genesee and Caravolas, 1997; Frith *et al.*, 1998; Goswami, Gombert and de Barrera, 1998; Goswami, Ziegler, Dalton and Schneider, 2001). Seymour *et al.* (2003) found that English children had greater difficulty also in reading non-words (29% of accuracy compared with the cross-national average of 82%), consistently with previous studies in young German (Frith *et al.*, 1998; Wimmer and Goswami, 1994; Wimmer, Landerl, Linortner and Hummer, 1991), Dutch (Wentink, Van Bon and Schreuder, 1997), Spanish (Goswami *et al.*, 1998, Experiment 3; Signorini, 1997), Portuguese (Pinheiro, 1995), Italian (Cossu, Gugliotta and Marshall, 1995), Greek (Goswami, Porpodas and Wheelwright, 1997; Porpodas, Pantelis and Hantziou, 1990) and Turkish (Oney and Durgunoglu, 1997) children.

Almost all these studies examined differences in early phases of reading acquisition. However, one would expect cross-linguistic differences in reading to remain (or emerge even more markedly) later in development. In fact, as readers of English encounter an increasing number of inconsistencies in the mapping between graphemes and phonemes progressing in the acquisition of words, they are presented with obstacles that are not present in readers of a transparent language. Patel, Snowling and de Jong (2004) examined cross-linguistic differences in a developmental prospective and found larger between-language difference in older children (on average 10 years of age).

Overall, lower accuracy in reading an inconsistent language (compared to more consistent ones) can be explained by the larger number of irregular words to be learned, on one hand, and difficulty in acquiring the rules of conversion between phonemes and graphemes (and vice versa) on the other. However, languages not only differ in terms of ease of reading and spelling acquisition as a function of orthography consistency, but also in terms of the strategy used. In fact, learning to read and spell in consistent orthographies may depend on mechanisms qualitatively different than those used in inconsistent orthographies such as English (*e.g.*, Wimmer, 1993; Wimmer and Mayringer, 2002).

In a recent study (Marinelli, Romani, Burani and Zoccolotti, in revision), we examined the acquisition of reading and spelling skills among Italian and English children. To evaluate both lexical and sub-lexical processing, the effect of regularity, frequency, lexicality and length were examined. Apart from quantitative differences, also qualitative differences emerged indicating that children adapted their reading strategies to the characteristics of the language to be learnt. In the early phase of reading acquisition, the reading performance of Italian and English children was modulated by the same variables, indicating reliance to a similar reading strategy in both languages based on the grapheme-to-phoneme conversion. When reading experience improved, also qualitative differences in the performance of the two groups emerged: older Italian children continued to have slower reading and to show marked length effects; English children were less influenced by length in reading RTs,

showed a greater frequency effect, had a high accuracy in reading high frequency words (despite the greater inconsistency of their language), and showed a greater speed improvement with age than Italian children. It seems that, while Italian children continued to rely predominantly to a reading procedure based on grapheme-to-phoneme conversion, older English children also relied on larger units of analysis (also at the level of the whole word). In fact, the inconsistency of English orthography, especially for smaller grapheme units (Treiman *et al.*, 1995), may have induced the English children to rely also on larger grain sizes (more consistent), such as whole word, cluster of consonants, syllables, morphological units, etc. This does not mean that Italian children did not ever use the retrieval of whole words, but they relied to this reading strategy to a smaller extent than English children.

These results were consistent with other experimental evidence. In young readers, a variety of qualitative differences in reading strategies have been reported. Length and regularity effects are significantly greater in shallower orthographies than in English (*e.g.*, Ellis and Hooper, 2001; Seymour *et al.*, 2003; Spencer and Hanley, 2003). Furthermore, compared with children reading in shallow orthographies, English children show a higher number of lexical errors (*i.e.*, real-word substitutions) in reading non-words (Ellis and Hooper, 2001; Frith *et al.*, 1998; Geva and Siegel, 2000; Landerl *et al.*, 1997; Seymour *et al.*, 2003; Spencer and Hanley, 2003; Thorstad, 1991; Wimmer and Goswami, 1994), a reduced lexicality effect (Landerl *et al.*, 1997; Patel *et al.*, 2004; Seymour *et al.*, 2003; Wimmer and Goswami, 1994), and a stronger pseudo-homophone effect (Goswami *et al.*, 2001).

Convergent evidence comes from a study examining event-related brain potentials in a deep orthography, Arabic, and in French, a relatively more consistent orthography (Simon, Bernard, Lalonde and Rebai, 2006). Authors found that adult skilled readers in French displayed a specific component (N320) taken to mark the use of grapheme-phoneme conversion (*e.g.*, Bentin, Mouchetant-Rostaing, Giard, Echallier and Pernier, 1999), whereas Arabic readers did not, indicating smaller reliance on grapheme-phoneme conversion in more inconsistent orthographies. Similar results came from a study comparing English and Italian (a very regular orthography) readers (Paulesu *et al.*, 2000).

Only a few studies tried to investigate cross-linguistic differences in spelling according to properties of orthography. Caravolas and Bruck (1993) found that children who were native speakers of Czech (a shallow orthography) were more accurate than English children in non-word spelling after eight months of schooling, even if they began first grade with less preschool exposure to pre-literacy skills. In an unpublished study by Bruck, Caravolas and Genesee (1996, quoted in Caravolas, 2004), cross-linguistic differences depending on consistency of orthography (France vs English) were found in third grade children for both word and non-word spelling. The lower spelling accuracy in English was independent of the teaching method (Bruck *et al.*, 1998). Wimmer and Landerl (1997) examined German and English children in a task that required inserting ambiguous vowels (*i.e.*, not predictable on the basis of phonology) in the skeleton spelling of words. Words had the same meaning and similar phonemic and orthographic structures in the two languages (*e.g.*, boat-boot, rose-rose, friend-freund). The authors found larger percentages of error and a larger variety of incorrect alternatives produced by English children, indicating that orthographic consistency also influenced reliance on lexical spelling. In an experimental study of

own laboratory, we have examined psycholinguistic variables (such as frequency, length, regularity and lexicality) that influence spelling in English and a more consistent orthographies such as Italian. Consistently with other studies comparing shallow and deep orthographies (Bruck *et al.*, 1996; 1998), English inconsistency produced lower performance than in Italian at all ages considered. Probably, the high consistency of Italian allowed obtaining both high accuracy with phoneme-grapheme conversion rules and rapidly acquiring the lexical representations of the few words with an unpredictable transcription. By contrast, despite also older English children took advantage in spelling words for which both the lexical and sub-lexical procedure might be used, their performance was equally lower than that of Italian children. English children also had difficulty in phoneme-grapheme conversion skills, and this in turn may have contributed to a difficulty in acquiring irregular words (Share, 2008), that represent a large proportion of English words.

Overall, these findings suggest greater reliance on lexical procedure/larger units of conversion in inconsistent orthographies compared to shallow orthographies, in which predominant reliance on grapheme-phoneme conversion is apparent.

Converging evidence comes from cross-linguistic studies focused on the predictors of reading and spelling. Several monolingual studies have found that reading/spelling were influenced by cognitive abilities, such as phonological Short Term Memory (*e.g.*, Hammill, 2004; Swanson *et al.*, 2003), visual attention span⁴¹ (*e.g.*, Bosse, Tainturier and Valdois, 2007), lexical learning ability⁴² (*e.g.*, Hulme *et al.*, 2007), Rapid Automatized Naming⁴³ (*e.g.*, de Jong and van der Leij, 1999; Wolf, Bally and Morris,

⁴¹ Visual attention span (VAS) is the capacity to allocate attention across letter or symbol strings (not an index of perceptual ability). Thus, the VAS is defined as the amount of distinct visual elements that can be processed in parallel in a multi-element array (Valdois *et al.*, 2003). VAS may be estimated asking to report all of the letters of briefly presented multi-letter strings. The task deals with limits on the ability to divide attention between multiple simultaneous targets. Even if this task involves reporting verbal material, it is not considered as a phonological, or phonological short-term memory, task but it is believed to reflect visual attention and visual short-term memory components (Shih and Sperling, 2002). The use of only consonants makes the string unpronounceable and limits the possibility of phonologically recoding the string.

⁴² "Lexical learning" is the ability to set up stable and accurate mental representations of words from a set of previously unrelated units (Di Betta and Romani, 2006). An associative learning process specific for creating links between visual (orthographic) and phonological representations appears to play a key role in learning to read, because this ability is fundamental in the development of orthographic representations (Ehri, 1992) and in acquiring a sight vocabulary. These connections secure the sight word in memory with its spelling, pronunciation, and meaning bonded together as a unit. Such entries in the orthographic lexicon would allow automatic word recognition in reading and orthographically correct spelling. On the other hand, a deficit in the ability to form lexical representations will have negative consequences for fast and proficient reading and accurate spelling (Di Betta and Romani 2006).

⁴³ Rapid Automatized Naming (RAN), also known as naming speed, refers to the speed at which children can name sets of stimuli (Wolf, O'Rourke, Gidney, Lovett, Cirino and Morris, 2002). Following original Denckla and Rudel's (1976) observations, they typically involve presenting a visual array (usually of 50 stimuli), consisting of digits, letters, colours, or objects presented in a random order. Children must name these highly familiar items under speeded conditions. The dependent measure is the time to name the stimuli in the array making as few errors as possible.

The process of rapid naming involves attention to the stimuli, feature detection and visual discrimination, integration of visual information with stored visual or orthographic representations, retrieval of phonological labels, activation of semantic and conceptual information, and activation of articulation (Wolf and Bowers, 1999). Because these processes are analogous to these involved in

1986) and phonological awareness (e.g., Swanson, Trainin, Necochea and Hammill, 2003). In cross linguistic studies, the interest is in investigating if the variables affecting reading and spelling development have a differential impact depending on the degree of orthographic consistency of the language. There are several studies on the predictors of reading (for a German-English comparison: Mann and Wimmer, 2002; for a Dutch-English comparison: Patel, Snowling and de Jong, 2004; for a Czech-English comparison: Caravolas, Volin and Hulme, 2005; for a Greek-English comparison: Georgiou, Parrila and Papadopoulos, 2008; for a Italian-English comparison: Marinelli, Zoccolotti and Romani, 2010; for a comparison across various orthographies varying for the degree of consistency see Ziegler *et al.*, 2010), while only one research has examined predictors of spelling skills (Czech-English comparison: Caravolas *et al.*, 2005). These studies have examined the role of any of these predictors (but not the same and not always in a complete way) in influencing reading/spelling acquisition among consistent and inconsistent orthographies. Overall, results of these studies indicated that predictors of reading and spelling performance are relatively universal, although their precise weight varies systematically as a function of script transparency (e.g., Ziegler *et al.*, 2010). For example, Marinelli *et al.* (2010) found that despite there were similarities between languages, with a influence of phonological awareness and STM, visual attention span and rapid automatic naming (plus lexical learning but only in the case of irregular words) on reading and spelling skills, the orthography consistence play a fundamental role. In inconsistent languages, such as English, the lexical strategy is necessary for both reading and spelling, and then a greater role of lexical learning and visual attention span was found. In shallow orthographies, such as Italian, the regularity of the grapheme-phoneme correspondence allows for a predominant use of the sub-lexical procedure, resulting in a greater influence of phonological STM and phonological awareness. However, even in this language, when the correspondence is not bi-unitary, such as in the case of the irregular words in spelling, require the reliance to the lexical strategy; accordingly a larger involvement of lexical learning was found in the prediction of the performance on irregular words.

2.1.8. Acquiring literacy in L2

An important question concerns the influence of experience in one orthography on becoming literate in other languages. Learners who are literate in some writing systems may have the advantage of experience with deciphering and assigning meaning to print.

For example, in a study of Hmong learners of English at a refugee camp in Thailand, Robson (1982) found that adults with minimal literacy in Hmong acquired English reading skills more rapidly than those who had no Hmong literacy. Similarly, in a study of adult Haitians learning English in New York City, those who received native language literacy instruction while learning English developed stronger literacy skills in L2 than did the English-only group, even though they received the same number of instructional hours (Burtoff, 1985).

reading, naming speed tasks represent a microcosm of reading in their requirement of rapid visual-verbal connexions.

Similar evidence comes from studies on immigrant children.⁴⁴ Among immigrants in Canada, Cummins (1981) found that older learners with more schooling in their L1 acquired cognitive skills more rapidly than younger learners. Similar results were found in trilingual children (Abu-Rabial and Siegel, 2003): although exposure to the three languages was not equal (with smaller exposure to L2 and L3), skilled readers in L1 performed significantly better than less skilled readers in all tests across languages. In fact, preliterate learners (*i.e.*, learners coming from cultures where literacy is uncommon in everyday life because the language is not written, such as the case of Arabic dialects, has only recently been written, or is being developed) generally progress slowly in literacy (Robson, 1982; Davidson and Strucker, 2002).

Note that decoding skills in L1 are transferred to L2 more than oral language competence (Nakamoto, Lindsey and Manis, 2008). However, particular aspects of oral language, such as cognate awareness and reading comprehension strategies, show high transfer across languages (Carlisle and Beeman, 2000; Ordóñez, Carlo, Snow and McLaughlin, 2002). In fact, also L1 comprehension skills may transfer to L2, due to specific comprehension strategies and metalinguistic concepts shared by the two languages (Durgunoğlu, 2002; Bialystok and Hakuta, 1994). In any case, building of background knowledge in their native language before reading an English text can lead to better vocabulary development (Ulanoff and Pucci, 1999). Oral language skills aid in decoding during reading comprehension especially in inconsistent orthographies, such as English (Miller, Heilmann, Nockerts, Iglesias, Fabiano and Francis, 2006).

While L1 ability is a predictor of reading achievement in L2, L1 competence provides limited help in spelling L2 (Rolla San Francisco, Mo, Carlo, August and Snow, 2006) and the influence of L1 can in fact be viewed as an interference, probably because spelling requires specific and precise orthographic representations. This is particularly true when children speaking a language (L1) with regular orthography are trained in a language (L2) with an irregular orthography. For example, Rolla-San Francisco *et al.* (2006) found that bilingual children trained in Spanish (L1) produced the spelling of phonologically plausible but orthographically incorrect spellings in English (L2; *i.e.*, phonologically accurate in Spanish, but orthographically incorrect in English; such as *meid* for *made*). This aspect is particularly relevant for poor countries, since indigenous languages (L1) have often consistent orthographies, but children are trained to literacy in colonial languages (L2) with inconsistent orthographies (such as English, French or Portuguese). A more in-depth discussion of the effect of literacy in native vs colonial languages is presented in paragraph 2.1.8.

The age at which the second language is learnt plays a fundamental role. For example, Cummins (1984) found that children's L2 level was predicted by their L1 level of academic proficiency (but also by age and age of arrival). Similarly, Carlson (1981) found that age of arrival of immigrant children was significantly related to English learning. Skutnabb-Kangas and Toukomaa (1976) found that in ten-year-old immigrant children with a relatively high proficiency in L1 (Finnish), there were no negative consequences in L2 development (Swedish). However, seven-year-old children (whose L1 proficiency was less advanced) showed negative effects in their L2 development. Therefore, degree of L1 development had a significant influence on L2 development.

⁴⁴ Note that immigrant children often attend poor schools and have family with lower SES levels; thus they are at risk for oral and written language development (Kieffer, 2008).

Obviously, the orthographic nature of the original language also influences the acquisition of the second language. For example, in learning English, Japanese (adult) learners, who use both syllabic (kana) and logographic (kanji) writing systems, relied more on word recognition than Russian learners, who use a phonologically based alphabet (Wade-Woolley, 1999). Therefore, in languages with no focus on phoneme-to-sound mapping in reading, learners may try to read the second language by memorizing the whole word.

Moreover, also the distance between the L1 and L2 orthographies has an influence on reading learning. Saiegh-Haddad (2003) found that linguistic distance between Modern Standard Arabic (MSA; a language structurally distinct from the local form of the language) and spoken Arabic interferes with the acquisition of basic reading processes (phonemic awareness and pseudoword decoding) in MSA in young (kindergarten and first grade) Arabic native children.

2.1.9. Acquiring literacy in multilingual countries: indigenous languages vs Colonial languages

Africa (and Asia) is home to some of the most multilingual countries in the world. In Africa, for example, over 2,000 languages are spoken.⁴⁵ In fact, various colonial languages had been imposed throughout the African region due to the colonization of different European imperial powers in the late 19th century, as illustrated in Figure 16. From then on, English or Portuguese have been the main languages of instruction in Eastern and Southern Africa regions while Arabic or French in the West and North African region (Chinapah *et al.*, 2000). In West African region, according to Tadjó (2008),⁴⁶ linguistic situations vary drastically from one country to another; French is used on a daily-life basis in some places while in others it is only spoken by a minority. In other regions, such as Niger and Mauritania, children's literature is published in national languages; yet there are very few bilingual editions (in French and local languages). Similarly, South Africa's reality depicts an "English-only" monolingual practice despite the government's policies proclaiming linguistic pluralism as the national objective (Webb, 1999).

⁴⁵ See, http://www.ethnologue.com/ethno_docs/distribution.asp?by=area. Another continent where multilingualism is widely practiced is Asia (Kosonen, Young, & Malone, 2006).

⁴⁶ The study focused on the production and distribution of children's books written in French in the francophone West African countries, especially at Côte d'Ivoire where the most extensive production in the region took place.

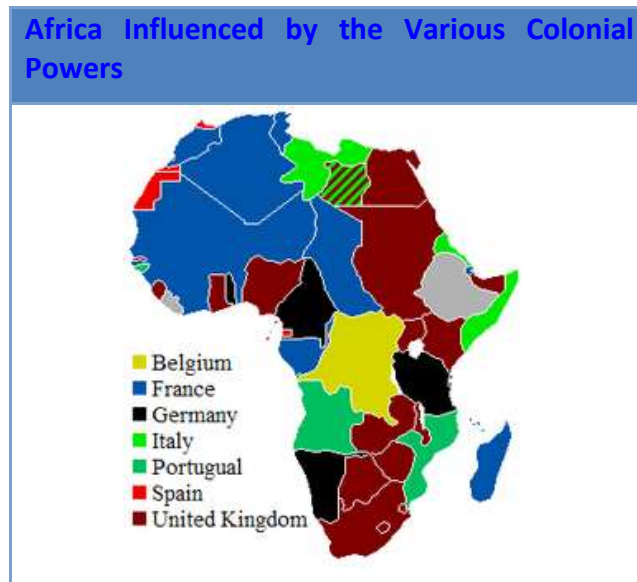


Figure 16: Area of Africa under the Influence of the Colonial Powers

Source: Wikipedia, available [online] at <http://en.wikipedia.org/wiki/Africa>.

Most African countries use colonial languages as the official languages and medium of instruction while Africans usually speak and communicate with indigenous or local languages in their daily lives. Consequently, literacy development of young children may be hindered due partly to the lost connection between a mother-tongue language (spoken at home) and a colonial language (taught at school). At the stage of learning-to-read (early grades), the obligation to learn and be fluent in a colonial language at school (while speaking in a mother tongue at home) may confuse young children and slow down their decoding process, thereby weakening their reading foundation (Tadjo, 2008). Mismatches between the language a child speaks and the language has to write impact on the learning of reading and spelling (*e.g.*, Kohler, Bahr, Silliman, Bryant, Apel and Wilkinson, 2007), even if the language to be learnt has a consistent orthography (*e.g.*, see Nag, Treiman and Snowling, year for Kannada language), with a greater difficulty dealing with the characteristics of written language that are not present in the local dialect. Such a practice causes disadvantages to learners who are not proficient in these languages. Put concisely, non-mother tongue education programs can result in negative outcomes for many learners from ethnic minority communities, which include high repetition and drop-out rates, alienation from their heritage language and culture, and lack of knowledge and skills for employment (Kosonen, Young and Malone, 2006).

The UNESCO report indicated that serious communication problems occur in many African classrooms where students do not have the language competence to understand the foreign (colonial) language the teacher uses, thereby being restricted to only “self-talk” or repetitive mode of learning (Ouane and Glanz, 2005). In Kenya, for instance, Glewwe, Kremer and Moulin’s (2009) study found that textbooks had little effect on regular or weaker students but did appear to raise the scores of the strongest students. There was no indication that textbooks reduced dropping out or grade repetition. Possibly, textbooks were of little use to many students because

English is the medium of instruction in Kenya while being the third language for many students. They cannot effectively read and comprehend the English textbooks. Textbooks are also too difficult for average students.

Despite the fact that local languages are still not being used as media of instruction in many African countries, Tadjó (2008) asserted that it is more advantageous for children to learn to read and write in their mother tongue. Similarly, Abadzi (2008) proposed that children may benefit from learning to read in their native language or one that they know well, even if they rarely read in that language. Also comprehension performance improves if children read in their mother tongue. As reported in Abadzi (2008), the correlation between reading speed and comprehension was greater in local language than in the official one. As suggested by Durgunoglu (year?), “given that families of English Language Learners are likely to have weak English skills themselves (Durgunoglu, Thao and Rojas, 2007; Reese and Goldberg, 2007), book sharing and explicit teaching in L2 may not be feasible options” (page 27). Walter and Trammell (2010) reported the results of an experiment carried out in Cameroun comparing the performance of L2 experimental schools in which the mother tongue (Kom) was used as the primary language of instruction and L2 standard schools in which the colonial language (English) was the primary language of instruction. In the two teaching groups schools were matched by type (private or public), location (remote village, small town), and size (smaller or larger). Results showed larger (about 125%) reading, spelling and math improvement among children in the Kom-program as compared to the English-one. By contrast, children in the English program made little progress because they neither understood the instructions of the teacher nor knew the language in which they were supposed to be learning to read. The advantage for the mother tongue training (compared to the English-program) persisted also after three years of schooling. Moreover, the percentage of children who failed in reading and comprehension was greater among the English- than the Kom-schools.

Bangbose’s (2004) report indicated that there are a number of African countries, once under colonial powers, which prefer the use of African languages as media of instruction. They include Botswana, Gambia, Ghana, Kenya, Lesotho, Malawi, Nigeria, Sudan, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe, all under British influence. Likewise, those under Belgian influence—Burundi, Democratic Republic of Congo and Rwanda—are in favor of using African languages as media of instruction. Furthermore, according to the APEID (1986b), Samoan language policy stressed that all children at the primary level in Samoa must be fluent in speaking and writing Samoan before learning English.

Among thousands of indigenous languages spoken in the Africa region, Swahili is the most commonly used and, indeed, one of the most accessible African languages regarding the difficulty of learning and availability of learning resources. According to the University of Pennsylvania African Studies Center,⁴⁷ Swahili is spoken by over 50 million people in East African countries, including Burundi, Kenya, Tanzania, Uganda and Rwanda as well as in southern Somalia, eastern Democratic Republic of Congo, and several parts of northern Mozambique and the Comoros Islands. Such widespread

⁴⁷ For more information, see *East Africa Living Encyclopedia*, available [online] at <http://www.africa.upenn.edu/NEH/overview.html>.

practice of the common lingua franca—Swahili—unites East African countries all together. In fact, Tanzania uses Swahili as an official language alongside English while Kenya designates Swahili as its national language.⁴⁸

The UNESCO report on literacy in multilingual settings (Kosonen *et al.*, 2006) stressed that it is vital that “the use of the first language continues throughout the education system. Likewise, equally important is that the second language is introduced gradually before it becomes a language of instruction,” (p. 8). Therefore, an effective way to increase education and literacy in multilingual countries, such as those in the African region, is to *use both mother-tongue and official languages* in instruction and learning process. Encouraging examples are shown in many Asian countries including Bangladesh and India (Kosonen *et al.*, 2006).

Since most mother-tongue or local languages are generally spoken (not written) languages, few textbooks are available in most of the major indigenous languages. Given the low literacy rates in many multilingual countries, there is a pressing need to promote reading textbooks in local languages in order to increase access and literacy of marginalized students (Abadzi, 2006). A common practice in developing a textbook in such local languages may be to *apply scripts of official languages* to stories known in local languages. However, a note of caution is necessary if textbook of an official language are simply translated into the local language; in fact. Interpretation of pictures in the text is often culturally related (Boling *et al.*, 2004), and it is possible that children misunderstand when an image is exported from a culture to another one (Schiffman, 1996; cited by Cooper, 2002).

Publishing a bilingual textbook may enhance young children’s reading and learning process. Tadjó (2008) pointed out that the most influential producer of bilingual children’s books in the African region is *L’Harmattan* which is a major Parisian publisher. While the books are targeted for the African market, she stressed that the need for bilingual books in French primary schools is becoming more evident due to the growing population of immigrants. Cambodia is another example that implemented the bilingual literacy programs using both Khmer and local languages as media of instruction; bilingual literacy materials are printed in both local and official languages side by side (Kosonen *et al.*, 2006). Indeed, Altbach (1983) asserted that multinational publishing companies have been influential in publishing in Third World languages, seeing that their branches in developing countries such as India, Malaysia, Nigeria and Zimbabwe are aggressively publishing books in local languages for niche markets. The use of stories or literature that are already familiar in students’ mother tongue may be beneficial as well. In doing so, African children can relate to the stories that are offered to them even though they are written in foreign languages (Tadjó, 2008).

2.1.10. Learning to read in adulthood

One relevant question concerns the effectiveness of reading training late in development (*e.g.*, in the adulthood). Can illiterate adults acquire sufficient automaticity in reading to profit from their late learning?

⁴⁸ Compiled from Languages Spoken in Each Country of the World, *Pearson Education Database*, available [online] at <http://www.infoplease.com/ipa/A0855611.html>.

Several studies (prevalently on English speaking subjects) examined the reading (and spelling) performance of illiterate adults learning to read. These studies found large improvements in reading and spelling after a reading training. However, no studies to date have investigated the improvement in reading speed in these individuals. In any case, it should be noted that the reading improvement of adult illiterates after training has been generally found different from that reported for children matched to the adults for reading achievement level. For example, Thompkins and Binder (2003) found that illiterate adults learning to read outperformed children (at early stages of literacy instruction) in memory ability and use of context and orthographic abilities, whereas children outperformed adults on phonological awareness tasks. Similarly, Greenburg, Ehri and Perin (2002) found that adults outperformed children in tasks that relied on orthographic knowledge (reading irregular words), whereas children performed better on decoding tasks. Error analysis indicated that adults tended to produce real words as errors in nonsense word reading, whereas children made phonologically based errors. Adults were also more likely than children to make errors in rhyme judgment when the spelling of the rhyme differed within the pair, which suggests that the adult learners relied more on orthographic cues. Moreover, they used contextual cues to improve comprehension more effectively than children at similar reading levels (Blalock, 1981; Read and Ruyter, 1985).

In conclusion, the literature comparing adults and children learning to read highlights that visual, word recognition skills are particularly involved in adult learning (see also Binder and Borecki, 2008). This pattern seems to depend on adults' accumulated general world knowledge and linguistic experience.

2.1.11. The loss of orthographic representation of new learned words

Other indirect evidence of the stability of acquisition comes from studies using *lexical learning tasks*. These studies do not deal directly with loss of fluency or reading automaticity, but with loss of the orthographic representation of new learned words (which, in turn, favors fluent reading).

“Lexical learning” is the ability to set up stable and accurate mental representations of words (Di Betta and Romani, 2006). An associative learning process, that is, the ability to create links between orthographic and phonological representations, plays a key role in learning to read, because this ability is fundamental in acquiring a sight word in memory and in the development of orthographic representations (Ehri, 1992). Entries in the orthographic lexicon allow automatic word recognition in reading and orthographically correct spelling. Difficulty in forming lexical representations (and more specifically in these learning tasks) has negative consequences on accurate spelling (Di Betta and Romani, 2006) and, for fast and proficient reading, even in children who can decode accurately (Manis *et al.*, 1999; Wolf and Bowers, 1999).

The ability to store spoken representations has been the subject of several investigations. This ability is strongly correlated with reading ability (*e.g.*, Hulme, Goetz, Gooch, Adams and Snowling, 2007) and is a strong predictor of reading and spelling abilities even after controlling for the effects of other cognitive skills

(Windfuhr and Snowling, 2001; Di Betta and Romani, 2006; Hulme *et al.*, 2007). On the other hand, a lexical learning deficit has been found in dyslexic children on both inconsistent and shallow orthographies (Gascon and Goodglass, 1970; Nelson and Warrington, 1980; Otto, 1961; Vellutino, Scanlon and Spearing, 1995; Vellutino, Steger, Harding and Phillips, 1975; Mayringer and Wimmer, 2000; Wimmer, Mayringer and Landerl, 1998; Messbauer and de Jong, 2003) and in adults with developmental dysgraphia (Baddeley, 1993; Howard and Best, 1997; Romani and Stringer, 1994), despite normal performance on tasks requiring learning associations with non-orthographic stimuli (Goyen and Lyle, 1971; Vellutino *et al.*, 1975; Messbauer and de Jong, 2003; Vellutino *et al.*, 1975). Moreover, also the long-term recall of words learned to criterion was impaired: in spite of many more learning opportunities, after a week the group of adult dyslexics again performed significantly worse than controls (Di Betta and Romani, 2006). In any case, more relevant for this report is the finding that the new orthographic representations stored in this lexical learning task were partially lost after only one week also by adult normal readers.

2.1.12. The effect of time on reading competence: the case of the summer break

In view of the large proportion of school dropouts after a few years of instruction in poor countries, one critical question concerns the stability of reading acquisition. How resilient is reading acquisition after a period devoid of stimulation?

Interesting information comes from the effect of the summer break on children's reading performance. Several studies reported a loss of school skills after the summer break, even after the first years of school (*e.g.* in fifth grade). In fact, the long vacation breaks the rhythm of instruction, leads to forgetting, and necessitates a large amount of time to review the previous acquisitions when students return to school in the fall. As suggested by Cooper, Nye, Charlton, Lindsay and Greathouse (1996), the summer break can have a greater negative effect on the learning of children who use a different language at school from that used at home.

Following is a review of the most relevant papers on this issue. However, note that the literature is not recent and studies usually did not distinguish between different components of reading (comprehension, accuracy in decoding and reading speed). Only Aarnoutse, Van Leeuwe, Vote and Oud (2001) examined the effect of each component separately. They found clear seasonal effects for reading comprehension, vocabulary and spelling, whereas the seasonal effect for decoding efficiency was restricted to the early grades (especially first grade).

Cooper *et al.* (1996) reviewed 13 studies published since 1975. They concluded that summer losses averaged about one month of grade-level (about 0.1 standard deviations below the spring average). Loss did not vary as a function of gender or race, but differed across performance domains (math losses exceeding reading losses), grade level (larger losses at higher grades), and of pupil background (*e.g.*, with middle-class children registering reading gains over summer and lower-class children losses). The results of the meta-analysis support Heyns's (1978) and Entwisle and Alexander's (1992, 1994) finding that SES differences are heightened by the summer break.

In a descriptive study by Entwisle and Alexander (1992, 1994) it appears that summer differentials are larger in the first two years than later on, but this has not

been evaluated analytically. Moreover, whites register greater achievement gains over the summer months than do African in the U.S.; and upper income children register greater summer achievement gains than do lower income children.

One study examined the effect of the long summer break on reading comprehension and math skills also in relation to SES (Alexander, Entwisle and Olson, 2001). Testing was done in the fall and spring each year, covering five school years and four summers, from first to fifth grade. Higher scores in the fall of the new school year (relative to scores of the previous spring) reflected summer gains; higher scores toward year's end (relative to scores from the previous fall) reflected school year gains. Year by year school-year gains were not very different across SES levels. The summer pattern was strikingly different: during the summer, upper SES children's skills continued to advance (albeit at a slower rate than during the school year), but lower SES children's gains were, on average, flat. In the verbal domain, then, among lower SES youth losses predominated and were especially large over the first two summers. This indicates that lower SES children generally started the new school year at about the same level of performance they had had the previous spring or even behind. Upper SES children's scores, on the other hand, improved over the summer months, indicating that they began the new school year ahead of where they had been the previous spring.

2.1.13. Interim summary: Which variables affect the acquisition of reading skills?

Letter knowledge is critical in early reading and spelling because it shapes the acquisition of the alphabetic principle and of grapheme-to-phoneme (and vice versa) correspondences. Acquisition of the link between letter and sound is more effective for reading improvement than letter name knowledge. To this aim, the use of illustrations of objects that start with a given letter (*e.g.*, A as in apple, D as in dog) may be useful. Early in reading acquisition, learning letter sounds may require some phonological skills. Specific training in phonological awareness may help children who are at risk for reading acquisition.

Adult-child *shared reading* of alphabet books may help improving children's letter knowledge and phoneme awareness. However, this behavior is relatively infrequent, particularly in low SES families.

The phonics *teaching method* seems to be the most effective one for word decoding and should be considered as a first choice in planning educational programs. Nevertheless, the literature on this topic is very rich and includes evidence that whole-word training may be useful under specific conditions, *e.g.*, for improving accuracy in reading (and spelling) irregular words.

Achievement gains depend on *teacher effectiveness* and in particular on teachers' education and experience. Also, the teacher's closeness to the child (as well as shared ethnicity and same SES as the child) plays a fundamental role in achievement gains. Teacher effects are much larger in small (as compared to regular sized) classes and in low than in high SES schools. These influences are particularly important considering that low-income students are those who usually have less effective teachers.

Reinforcement and feedback on performance play a fundamental role in reading improvement. They may be provided not only by teacher, but also by peers and parents. It is important to avoid attribution of failure to poor skills in order to avoid demotivating children and to appreciate the efforts of children. Children may be reinforced also in their attempts to approximate the correct reading (shaping). Together with these techniques also the use of prompts, modelling and direct instruction, with the progressive fading-out of these techniques, is effective in improving reading performance. Especially for low-income children, it is important to have teachers who are able to compensate a deprived familiar context. Unfortunately, in poor countries often teachers do not give attention, feedback and reinforcement to the less skilled children, thereby increasing the number of illiterate children that drop out from school. Then, teachers must should techniques for keeping all students engaged in learning tasks across relatively long periods of time; they should give not only feedback and reinforcement but also facilitation especially to the less skilled children.

Orthographic consistency is a powerful factor modulating literacy acquisition. Reading and spelling are acquired faster by readers of regular orthographies than by readers of inconsistent orthographies, such as English, due to the larger number of irregular words to be learned and the difficulty in acquiring the phoneme-grapheme (and vice versa) conversion rules. These cross-linguistic differences persist also later in reading and spelling acquisition. Moreover, in shallow orthographies there is a predominant reliance on grapheme-phoneme conversion, whereas in inconsistent orthographies there is greater reliance on lexical procedure/larger units of conversion.

Learning a second language (L2) is generally more difficult than learning the native one (L1). Evidence indicates that children are advantaged in L2 literacy if they are proficient in L1 reading and spelling. Preliterate learners, whose language is not written (or has only recently been written, or is being developed), generally progress more slowly in literacy acquisition. In a related context, the literacy acquisition of adult illiterates is different from the reading increase found in children matched to adults for reading achievement level. In fact, adults use contextual cues to improve comprehension more effectively and make a larger use of lexical reading than children at similar reading levels.

Establishing the *stability of reading acquisition* is important, particularly when schooling is interrupted after only a few years. However, there is no direct evidence of this, except for the finding of a loss of school skills after the summer break. Indeed, after the summer break, regression in reading comprehension, vocabulary, and spelling is reported even beyond the early years of school (*e.g.*, in fifth grade), whereas the seasonal effects of decoding efficiency are restricted to the early grades (especially first grade). This seasonal effect has a greater negative effect on the learning of children who use a different language at school than that used at home. Without practice, also the orthographic representations (indispensable for automatic word recognition in reading and orthographically correct spelling) of new learned words are lost with time. Further research is needed to establish the long-term stability of reading acquisition as a function of the duration of school attendance.

2.2 Variables affecting reading comprehension

2.2.1. Vocabulary

Vocabulary refers to the knowledge of lexical meanings of words and the concepts connected with these meanings. A rich vocabulary is one of the most important vehicles for reading comprehension and academic achievement (McKeown and Beck, 1999; National Reading Panel, 2000). In fact, differences in vocabulary size have an effect on word recognition skills as well as on reading comprehension (Aarnoutse and Van Leeuwe 1988; Beck and McKeown, 1991).

Vocabulary knowledge and reading comprehension are very closely related to each other (Stahl, 1990): vocabulary knowledge can help reading and reading can contribute to vocabulary growth (Chall, 1987, Seigneuric and Ehrlich, 2005). It is obvious that the best situation for comprehension of a text occurs when virtually all of the words in a given text are highly accessible. In fact, if a text contains too many words of low accessibility (poorly known or unknown words), comprehension of the text may be severely restricted. Unknown words can create gaps in the meaning of a text; if too many gaps occur, the student may not be able to construct meaning.⁴⁹

Multiple studies document the strong positive relationship between knowledge of word meanings and comprehension (Anderson and Freebody, 1981; Baumann and Kamèenui, 1991; Davis, 1944; Nagy, 1988). Stahl and Fairbanks' (1986) meta-analysis of vocabulary studies found that vocabulary knowledge plays a causal role in comprehension. This relationship has been found at all grade levels and in different languages and countries (Anderson and Freebody, 1983). Moreover, the relationship is quantitatively strong. Across a large body of studies, correlation between vocabulary knowledge and comprehension ranged from 0.66 to 0.75 (Just and Carpenter, 1985).

Studies by Dickinson and Tabors (2001), Hart and Rinsley (1995), and White, Graves and Slater (1990) provided further evidence that poor vocabulary development in children's early years negatively affects their reading comprehension in later years. Nation, Snowling and Clarke (2007) found that, although poor comprehenders have difficulty in acquiring and consolidating knowledge of meaning, they have no difficulty in acquiring the phonological representation of new words.

Several studies demonstrated that an improvement in reading comprehension can sometimes be attributed to an increase in vocabulary knowledge (Beck, McKeown and Kucan, 1982; Kameenui, Carnine and Freschi, 1982; Stahl, 1983). Moreover, there is much evidence that vocabulary training improves comprehension (Draper and Moeller, 1971; Kameenui and Gamine, 1982; but see Tuinman and Brady, 1974 for contrasting finding).

Several longitudinal studies support the predictive role of vocabulary on reading comprehension (*e.g.*, Hiebert and Kamil, 2005). Aarnoutse and Van Leeuwe (1988) found that vocabulary (measured in grades 3 and 6) was the most important predictor of reading comprehension, compared to decoding efficiency and spatial intelligence,

⁴⁹ Note that, in some cases, the use of reading comprehension strategies and the availability of a general idea about the text might to some extent compensate for the lack of sufficient knowledge of lexical items in a particular text, but the comprehension would be only partial.

with decoding efficiency making the smallest contribution. Moderate correlations between receptive vocabulary (*i.e.*, the ability to comprehend words) in kindergarten and successive reading comprehension have been reported in several studies (Muter *et al.*, 2004: 2 years later; $r^2 = .52$; Snow *et al.*, 1995: one year later; $r^2 = .44$ and $.53$ for receptive vocabulary and oral definitions, respectively; Roth, Speece and Cooper, 2002: one year later $r^2 = .38$ and $.53$ for receptive vocabulary and oral definitions, respectively; 2 years later $r^2 = .41$ and $.70$ for receptive vocabulary and oral definitions, respectively).

Further, regression analyses for Grade 2 reading comprehension indicated that vocabulary knowledge measured in kindergarten was a more powerful predictor than phoneme awareness. Likewise, Share and Leiken (2004) reported a regression analysis in which a composite of receptive vocabulary and syntax measured in kindergarten accounted for 13.6% of the variance in reading comprehension measured in Grade 1 English children (when entered into the model after age, gender, nonverbal IQ, and SES level). Even when phoneme segmentation was added to the control variables, the composite vocabulary and syntax score was still significant in accounting for 6.6% of variance. Anderson and Freebody (1981) surveyed various studies showing that vocabulary was more predictive of comprehension than grammatical complexity, ability to grasp main ideas and inferential skills. Sénéchal, Basque and Leclaire (2006) found that in French children, receptive vocabulary, measured in kindergarten, predicted 4% of unique variance in reading comprehension in Grade 3 after controlling for parent education and literacy level, child early literacy skills, and phonological awareness. These analyses confirm the relevance of oral vocabulary in the early years of schooling (see also Sénéchal and LeFevre, 2002; Storch and Whitehurst, 2002; Whitehurst and Lonigan, 1998).

In examining the relationship between vocabulary and comprehension, it is important to consider the nature of the vocabulary measures considered. Vocabulary storage involves stored lexical (phonological) representations of the words, as well as semantic representations of word meaning (Levelt, Roelofs and Meyer, 1999). Ouellette (2006) divided vocabulary into *breadth* and *depth*. Vocabulary breadth indicates the number of phonological entries in the lexicon of each subject (how many words one knows), while the depth of vocabulary knowledge refers to the extent of semantic representation (how well words are known). The theoretical construct of vocabulary breadth may be assessed through measures of word vocabulary recognition that estimate the number of known words (or breadth of oral lexicon). Vocabulary depth may be tapped by tasks that assess the extent of semantic representations, such as the ability to provide a complete definition of lexical items. It is important distinguishing between these two aspects of vocabulary knowledge, since “children may store a word form in their lexicon, contributing to their vocabulary breadth, without fully understanding that word’s meaning (see Lahey, 1988). Over time, word meanings are refined, adding to the child’s depth of vocabulary knowledge. Vocabulary growth thus encompasses adding and refining phonological representations to the lexicon as well as storing and elaborating the associated semantic knowledge” (Ouellette, 2006, p. 555).

Different patterns of associations between vocabulary and comprehension were found depending on the vocabulary measure considered. Studies using more demanding semantic tasks measuring depth of vocabulary knowledge reported

stronger associations with reading comprehension (e.g., Roth *et al.*, 2002; Snow *et al.*, 1995) than did studies relying on measures of the size of the lexicon (i.e., reflecting vocabulary breadth more than depth of knowledge). These results suggest an important role for depth of vocabulary knowledge beyond the influence of vocabulary size in Grades 1 and 2.

Nation and Snowling (2004) examined the importance of vocabulary depth in the reading comprehension in a sample of English typical 8-year-olds and Ouellette (2006) in a sample of typically developing Grade 4 English speaking children. Nation and Snowling (2004) found that measures of vocabulary and performance on semantic tasks predicted a substantial portion of variance (25.2% and 15.1%, respectively) of the performance in reading comprehension when entered into separate regression models following age, nonverbal intelligence, and phonological skills. Ouellette (2006) found that depth of vocabulary knowledge played a role in reading comprehension beyond the association explained by conventional measures of vocabulary size or breadth. In fact, expressive vocabulary breadth did not account for statistically significant unique variance in reading comprehension, but depth of vocabulary knowledge did (an additional 8.0%), after controlling for both decoding and visual word recognition scores (these control variables accounted for 42.9% of the total variance).

Likewise, Tannenbaum, Torgesen, and Wagner (2006) found a strong relationship between vocabulary breadth and depth and reading comprehension in third grade children. Semantic weakness has been specifically associated with poor reading comprehension in children (Nation and Snowling, 1998, 1999, 2004; Ricketts, Nation and Bishop, 2007). Neuroimaging studies provide further evidence that semantic weakness affects reading comprehension (e.g., Landi and Perfetti, 2007).

A wealth of research supports the strong relationship between *leisure reading* and vocabulary knowledge (e.g., Cunningham and Stanovich, 1998). Measures of 9-11-year-olds' exposure to print predict significant growth in vocabulary (Echols, West, Stanovich and Zehr, 1996). Practice in reading likely leads to more efficient access to word meanings. Regular reading can also provide the chance to acquire, refine and consolidate vocabulary knowledge through inference from context. However, there is some disagreement about the relative importance of learning from context as a means of vocabulary acquisition (e.g., Biemiller and Slonim, 2001).

Students' vocabulary knowledge is influenced by the amount of words they are exposed to from their very early years. For this reason, it is important to take into account the role of the children's *socio-economic status* on vocabulary growth. In fact, Hart and Rinsley (1995) found qualitative and quantitative differences in the words encountered by children from lower and higher SES families. They reported that children from higher SES families were exposed to approximately three times the number of words as children from low SES families (approximately 30,000 vs 10,000 words, respectively). Further, higher SES children were exposed to a vocabulary that was much more encouraging, supportive, and explaining; by contrast, lower SES children were exposed to a vocabulary that focused more on "negative" words and commands, such as "Don't do that."

Also with regard to reading vocabularies, White, Graves and Slater (1990) found disparities across socioeconomic levels, with children from low socioeconomic backgrounds having reading vocabularies that increased by only one-half to two-thirds

as compared to middle class children. The slower development of vocabulary growth among students from low socio-economic families impedes their ability to understand advanced textbooks (Duggan, 2009). Chall, Jacobs and Baldwin (1990) reported similar findings in their studies of the reading abilities of children from low socioeconomic environments. They reported a deceleration in vocabulary by grade four and beyond; they attributed this decline to an increase in more abstract and technical terms in content area textbooks, as well as an increase in more sophisticated words in literary works. To counter these tendencies, students from low socioeconomic backgrounds need oriented, effective interventions aimed at vocabulary growth.

Note that almost of these studies were carried out on English speaking readers.

2.2.2. Reading fluency

Fluency, commonly operationalized in terms of word reading speed, is a critical factor in reading comprehension (La Berge and Samuels, 1974; Perfetti and Hogaboam, 1975; Perfetti, Marron and Foltz, 1996). According to Perfetti (1985), efficient word reading releases attentional resources to attend to the meaning of text. By contrast, children who read in a dysfluent manner (*i.e.*, slowly and with great effort) have difficulty understanding what they read, because the cognitive resources necessary for creating meaning are employed in the reading process (Samuels, 1979). Slow word reading increases demands placed on other processes, such as working memory, which in turn poses difficulties for comprehending connected text, thus creating a processing obstacle (*e.g.*, Perfetti and Hogaboam, 1975; Perfetti *et al.*, 1996; Wolf and Katzir-Cohen, 2001; Shankweiler, 1999).

Theories of automaticity explain how fluent reading is critical for text comprehension (for reviews see Fuchs, Fuchs, Hosp and Jenkins, 2001; Wolf and Katzir-Cohen, 2001). According to these models, rapid and accurate lower-level processing enables the reader to focus cognitive resources on higher-level processes, *i.e.* on comprehension processes. In turn, when lower-level reading processes are not executed automatically, comprehension breaks down. As word reading becomes more automatized, residual attentional resources can be allocated for the semantic processing of word sequences within text. This process facilitates comprehension; in fact, children who have poor reading fluency may also have difficulty with reading comprehension due to reduced attentional resources (or working memory) available to allocate to semantic processing.

According to Hudson, Lane and Pullen (2005), poor automaticity in word reading might inhibit the reader's capacity to construct an ongoing interpretation of the text and to access the author's intended meaning. Moreover, "poor prosody"⁵⁰ can lead to

⁵⁰ A critical component of reading fluency is the ability to read with prosody, *i.e.* reading with appropriate expression or intonation (Cowie, Douglas-Cowie and Wichmann, 2002; Miller and Schwanenflugel, 2006, 2008; Schwanenflugel, Hamilton, Kuhn, Wisenbaker and Stahl, 2004). When a child is reading prosodically, oral reading sounds much like speech with appropriate phrasing, pause structures, stress, rise and fall patterns, and general expressiveness. Prosodic text reading emerges after children have consolidated automatic decoding skills (Chall, 1996; Kuhn and Stahl, 2003). In fact, prosodic features change as a child develops fluent reading. While young readers sentence's pitch structure was quite unlike that of a skilled adult reader (flat tone), as children become fluent decoders, they read with shorter pauses, steeper sentence-final declines, and with a more adult-like prosodic

confusion through inappropriate or meaningless groupings of words or through inappropriate applications of expression” (Hudson *et al.*, 2005; p. 703). Besides, when reading rate is too slow, also the facilitative effect of context on word recognition suffers (Smith, 1978). However, Connelly *et al.* (2001) provided some evidence against the claim that a slow rate of reading disrupts the child’s use of context for word recognition, at least when dealing with unknown words and in young children.

Several studies reported a strong correlation between fluency and reading comprehension (*e.g.*, Fuchs, Fuchs, and Maxwell, 1988; Shinn, Good, Knutson, Tilly and Collins, 1992; Hosp and Fuchs, 2005; Riedel, 2007; Wiley and Deno, 2005; Fuchs *et al.*, 2001), with correlations sometimes as high as .80 or .90 (*e.g.*, Fuchs *et al.*, 2001), particularly for students in primary grades. For example, correlation coefficients ranged from .73 (Cook, 2003) to .76 (Roberts, Good and Corcoran, 2005) for first graders and from .67 (Good, Simmons and Kameenui, 2001) to .70 (Buck and Torgesen, 2003; Roehrig, Bohn, Turner and Pressley, 2008) for third graders.

Note that text-reading fluency is more strongly related to reading comprehension than is word-reading fluency (Shinn *et al.*, 1992; Fuchs *et al.*, 2001; Thurlow and van den Broek, 1997). Jenkins, Fuchs, Van den Broek, Espin and Deno (2003) investigated a sample of fourth grade students and found that contextual word reading speed predicted reading comprehension, whereas isolated word reading speed did not. Klauda and Guthrie (2008) found that isolated word fluency was associated with bottom-up skills, whereas contextual fluency was related to higher-level skills in reading comprehension.

There are features of text-reading supporting comprehension (that are not available when reading decontextualized words) that allow readers drawing on oral language competence (Jenkins *et al.*, 2003, b; Schwanenflugel, Hamilton, Kuhn, Wisenbaker and Stahl, 2004; Schwanenflugel, Meisinger, Wisenbaker, Kuhn, Strauss and Morris, 2006; Thurlow and van den Broek, 1997). For example, in reading connected text readers took advantage from context-facilitation of word reading; otherwise, they draw on oral language skills in ways that they would not use when reading words out of context (Stanovich, 1980).

contour (Clay and Imlach, 1971; Cowie, Douglas-Cowie and Wichmann, 2002; Miller and Schwanenflugel, 2006, 2008; Schwanenflugel *et al.*, 2004). Prosodic reading improves also after practice, *i.e.* repeated text reading (*e.g.*, Dowhower, 1987; Herman, 1985). Note that improvement in children reading prosody allows predicting later fluency achievement, also controlling for word reading efficiency and text reading rate (Miller and Schwanenflugel, 2008). Some authors have linked reading comprehension with fluency. As a child acquires automatic word decoding skills, there are attention resources that are freed up and can be allocated to higher order functions of reading (LaBerge and Samuels, 1974; Perfetti, 1985), such as reading prosodically. The natural breaks and pitch falls associated with prosodic reading may serve to provide feedback to the child regarding the major syntactic and semantic units of the text, yielding improved comprehension (*e.g.*, Kuhn and Stahl, 2003). Several studies found that prosody is related to children’s reading comprehension (Allington, 1983; Dowhower, 1991; Kuhn and Stahl, 2003; Schreiber, 1991). However, other studies reported inconsistent results (Schwanenflugel *et al.*, 2004; Karlin, 1985) or mixed findings depending on text complexity (Klauda and Guthrie, 2008; Miller and Schwanenflugel, 2006). Moreover, the directionality of the relationship between reading prosody and reading comprehension has yet to be determined.

Reading fluency has also been shown to predict students' later reading comprehension achievement⁵¹, probably because it requires integration of word reading (and lower level skills that contribute to word reading, such as phonological awareness and letter knowledge) and post lexical processing (Jenkins *et al.*, 2003; Wolf and Katzir-Cohen, 2001). For example, fluency at the end of first grade was significantly associated ($r^2 = .54$) with reading comprehension at the end of second grade (Ridel, 2007). Similarly, third-grade children's fluency predicted unique variance in fourth-grade children's reading comprehension (Spear-Swerling, 2006). Schatschneider, Wagner, and Crawford (2008) found that end-of-year fluency in first-grade was positively related to reading comprehension at the end of first and second grade. Kim, Petscher, Schatschneider and Foorman (2010) found that individual differences in fluency growth rate in first grade⁵² were most informative about proximal (*i.e.*, first-grade) and distal (*i.e.*, third-grade) reading comprehension achievement. Therefore, it is important to monitor not only students' absolute reading rate level but also how fast they improve their fluency, particularly in first grade, in order to identify those who may be at risk of future problems in reading comprehension.

On the other hand, children with better reading comprehension read words faster than individuals with poor reading comprehension (Jenkins *et al.*, 2003; Perfetti and Hogaboam, 1975). However, it is important to remember that there is much evidence of specific reading comprehension deficits despite normal word reading speed (*e.g.*, Barnes, Faulkner and Dennis, 2001; Leach, Scarborough and Rescorla, 2003; Stothard and Hulme, 1995).

Several studies have also shown that improvements in fluency often lead to an increase in reading comprehension (*e.g.*, O'Connor, White and Swanson, 2007; see Meyer and Felton, 1999, for review; but see Torgesen *et al.*, 1997 for inconsistent findings). In fact, the use of the repeated reading method (one of the most well-known methods for improving reading fluency) is often successful in improving both reading fluency and reading comprehension.

One important influence on both reading fluency and comprehension involves children's exposure to text (Adams, 1990; Chall, 1996a; LaBerge and Samuels, 1974; Stanovich, 1986; Spear-Swerling, 2006). Furthermore, socioeconomic status probably plays a substantial role (Duke, 2000).

2.2.3. Simple View of Reading

The *Simple View of Reading* (Carver, 1993; Gough and Tunmer 1986; Hoover and Gough 1990) claims that reading comprehension depends on decoding and linguistic comprehension. These two skills are closely related and influence comprehension ability. In fact, fluency exposes the reader to an expanded vocabulary (Stanovich and

⁵¹ Typically, comprehension and decoding skills do not improve in parallel (Aarnoutse *et al.*, 2001): decoding efficiency improved most at first grade and then progressively less, while comprehension improvement was progressively greater across grade levels until third grade (when the improvement was greatest) and then began to decrease.

⁵² Note that students who started with a low reading level rate at the beginning of first grade tended to have a slower growth rate across first grade.

Cunningham, 1992; Stanovich and West, 1989) and a larger vocabulary allows for higher reading speed. The two processes explain a large amount (45-85%) of the variance in reading comprehension (Catts, Hogan and Adlof, 2005; Dreyer and Katz, 1992; Hoover and Gough, 1990). According to Gough and Tunmer (1986), poor reading comprehension is the product of poor decoding and average listening comprehension, poor decoding and poor listening comprehension, or average decoding and poor listening comprehension.⁵³

The relative contributions of these components change over time (Catts *et al.*, 2005; Francis, Fletcher, Catts and Tomblin, 2005; Gough, Hoover, and Peterson, 1996; Adlof, Catts and Little, 2006; Aaron, Joshi and Williams, 1999; Yovanoff, Duesbery, Alonzo and Tindal, 2005). In the early stages of reading competence, reading comprehension is strongly related to word recognition skills, because the ability to read words limits the ability to understand text. During the development of reading skills, as decoding expertise is gradually gained, comprehension is less dependent on decoding and more strongly related to general linguistic comprehension skills (Hoover and Gough, 1990; Valencia, Smith, Reece, Li, Wixson and Newman, 2010) and prosody (Valencia *et al.*, 2010). Beginning readers must allocate a large amount of cognitive resources to the process of word recognition, resulting in lower performance in reading comprehension. However, when word recognition becomes faster and more automatic (*e.g.*, more fluent), resources can be allocated to the process of text comprehension (LaBerge and Samuels, 1974; Perfetti, 1985).⁵⁴ Therefore, although in young readers fluency is a major source of variance in comprehension performance, from middle grades on linguistic comprehension contributes more substantially to reading comprehension than decoding. It has also been reported that, from fourth grade, prosody contributes in influencing reading comprehension (Valencia *et al.*, 2010; see also the model by Chall, 1996b).

Considerable empirical evidence supports the idea that the contribution of fluency and linguistic comprehension vary as a function of reading experience. For example, Yovanoff, Duesbery, Alonzo and Tindal (2005) found that, across grade levels 4 through 8, fluency become less important as student's reading comprehension increased over time, with vocabulary instruction remaining important across grades. Similarly, Ouellette and Beers (2010) found that the contribution of oral vocabulary increased from grade 1 to 6, whereas the contribution of decoding decreased. Grade 1 results indicated that oral vocabulary did not add any unique explanatory power to the model for beginning readers, but word reading skills were the only predictors in the final model explaining reading comprehension. By grade 6, however, children's reading comprehension seemed to rely much more on oral vocabulary than on phonological skills. Therefore, these findings indicate the importance of fostering reading fluency to favor reading comprehension at early stages of reading acquisition.

⁵³ However, poor comprehenders were found also among children with normal performance in decoding and listening comprehension (Georgiou, Das and Hayward, 2009). Moreover, there was also a large proportion of variance that remained unexplained. Then, it seems that other variables were also responsible of reading comprehension performance. For example Johnston and Kirby (2006) found that naming speed and phonological awareness accounted for unique variance in reading comprehension after controlling for the effect of decoding and listening comprehension skills (but see Georgiou *et al.*, 2009 for inconsistent result).

⁵⁴ Note that, according to Stich and James (1984), decoding is well developed by grade 3 whereas vocabulary and comprehension continue developing for many years to come.

The difference in the pattern of results between grades 1 and 6 reflects the increased importance of oral vocabulary and the diminished role of decoding in explaining reading comprehension as children grow and become more proficient readers. These results parallel Sénéchal *et al.*'s (2006) longitudinal results for English and French speaking children from kindergarten to grades 3 and 4, and are consistent with Storch and Whitehurst's (2002) proposal that code related and oral language skills impact reading differently at different phases of literacy acquisition. This highlights the importance of considering the developmental period under study when drawing conclusions about the component processes of reading. However, this pattern of results was less clear-cut in another similar study (Verhoeven and van Leeuwe, 2008).

Daana, Campbell, Grigg, Goodman and Oranje (2005) found a positive relationship between oral reading speed and reading comprehension also in fourth-grade students. Similarly, Joshi and Aaron (2000), using letter naming speed as an indicator of fluency, found that fluency contributed uniquely to reading comprehension in fourth graders after controlling for nonword reading accuracy and listening comprehension. However, Protopapas, Sideridis, Mouzaki and Simos (2007) reported that for high grades in shallow orthography the unique contribution of word reading to comprehension became negligible when vocabulary was partialled out. According to the authors, this finding suggests that all effects of decoding on comprehension are mediated by the lexicon.

Consistent with this line of reasoning, Saiegh-Haddad (2003) found that fluency and reading comprehension did not correlate significantly in a group of Hebrew- and Arabic-speaking adults reading adult-level text in their native languages. However, for both groups, correlations were significant when participants read a second language (English). In L2, readers typically have less well-developed language comprehension skills as well as slower reading than in their native language, rendering individual differences in word identification relatively more important to reading comprehension and increasing the strength of the fluency-reading comprehension relationship.

Similarly, it is possible to suppose that underdeveloped L2 oral language of many language minority (LM) learners⁵⁵ similarly influences the relationship between reading fluency and reading comprehension. Text-reading fluency may be more strongly related to comprehension in LM students than native language students.

Riedel (2007) examined the relationship between text-reading fluency and reading comprehension with 1,518 first graders, including 59 LM first graders. The correlation between text-reading fluency and comprehension was present and in fact stronger for LM students (.69) than for native English speakers (.51) at the end of first grade. In Crosson and Lesaux's (2010) investigation of LM learners reading in English, text-

⁵⁵ Comprehension is an area of academic difficulty for LM learners: these children perform at significantly lower levels than their monolingual peers on measures of reading comprehension (e.g., Aarts and Verhoeven, 1999; Abu-Rabia, 1998; Droop and Verhoeven, 1998, 2003; Garcia, 1991; Hansen et al., 1994; Hutchinson, Whiteley, Smith and Connors, 2003; McEvoy and Johnson, 1989; Reese, Garnier, Gallimore and Goldenberg, 2000; Verhoeven, 1990, 2000). Studies in this area have been conducted with LM learners spanning from primary through middle school grades, and in multiple contexts including Turkish speakers acquiring Dutch in the Netherlands (Aarts and Verhoeven, 1999; Droop and Verhoeven, 1998, 2003; Verhoeven, 1990, 2000), Spanish speakers acquiring English in the United States (Garcia, 1991; Hansen, 1994; Hutchinson et al., 2003; McEvoy and Johnson, 1989; Reese et al., 2000), and Arabic speakers acquiring Hebrew in Israel (Abu-Rabia, 1998).

reading fluency explained unique variance in reading comprehension even when L2 oral language variables (*i.e.*, vocabulary and listening comprehension) were accounted for. Strong text-reading fluency performance was associated with better reading comprehension outcomes, especially for those students who performed well on measures of English listening comprehension skills (a holistic measure of oral language tapping verbal reasoning, memory skills, vocabulary and syntactic knowledge, etc.).

Research suggests that lower comprehension is to be expected in LM speakers given the lower syntactic ability and oral proficiency of these children (*e.g.*, Aarts and Verhoeven, 1999; Verhoeven, 1990). However, Lesaux, Lipka and Siegel (2006) found that limited early exposure to English in the LM group, and lack of proficiency in English upon entering school, did not necessarily result in subsequent low comprehension scores. In this grade 4 cohort, almost 75% of the LM speakers were able to develop age-appropriate comprehension skills after five years of instruction in English.

2.2.4. Working Memory and Short Term Memory

Phonological short-term memory (STM) refers to the ability to use phonological codes to maintain information for short-term storage (Wagner *et al.*, 1994). Working Memory (WM) refers to the capacity of storing information for a short period of time and manipulating and processing it (*e.g.* Baddeley and Hitch, 1974; Gathercole, 2007).

Reading and comprehension ability has been often associated to both STM skill (*e.g.*, Hammill, 2004; Swanson *et al.*, 2003) and WM capacity (*e.g.*, Alloway, Gathercole, Willis and Adams, 2005; Baddeley, 1986; Daneman and Carpenter, 1980; Engle, Cantor and Carullo, 1992; Friedman and Miyake, 2004; Gathercole, Brown and Pickering, 2003; Swanson and Howell, 2001). In the following paragraphs we first examine the characteristics of WM and its relationship with fluency or reading comprehension; then, we focus on STM and the strategies that increase STM and, in turn, reading process.

Characteristics of working memory

WM concerns the capacity of storing information for a short period of time and manipulating and processing it (*e.g.* Baddeley and Hitch, 1974; Gathercole, 2007). According to the well-known proposal by Baddeley and Hitch (1974), WM is not a single store, but a memory system comprised of separable interacting components: a central executive controlling system and two subsidiary storage systems, the speech-based phonological loop and the visual-spatial sketchpad.

The central executive is responsible for allocating resources between processing and storage demands (and assisting these two process) across the two slave systems, retrieving information from long-term memory, and encoding retrieval strategies (Swanson, Cooney, and McNamara, 2004). The phonological loop provides temporary storage of verbal information and comprises a phonological store, which holds information in phonological form, and a rehearsal process, which maintains representations in the phonological store. The visuospatial sketchpad is responsible for the maintenance and manipulation of visual-spatial information (see Baddeley and

Logie, 1999, for a review). A fourth component of this model has recently been added, the episodic buffer, 'responsible for the integration of cognitive events across different representation domains' (Gathercole, 2007, p. 234) and for holding items in the focus of attention (Baddeley, 2000, 2001). This structural organization of memory can be reliably assessed from as young as 4 years of age and remains constant across the childhood years (Alloway, Gathercole and Pickering, 2006).

According to (Alloway et al., 2006), WM increases more in the first 10 years than it does over the lifespan. The average 5 year old can hold 1 item in mind (list of words, instructions, etc); a 7 year old can remember 2 items, a 10 year old can remember 3 items and a 14 year old can remember 4 items. But in some people WM grows faster than others, while others' WM grows more slowly. After the age of 15, there is a constant increase in WM size right up until the twenties. By this age, WM reaches a peak and plateau. When 25 year old, individuals successfully remember about 5 items, while successively WM declines to around 3 to 4 items. While WM does increase with age, its relative capacity remains constant. Then, a student below the 10 percentile compared to their same-aged peers are likely to remain at this level throughout their academic career (without intervention). By the time of 10, the gap in learning between them and their same-aged peers will be widened. That is why early diagnosis and support is so crucial. Moreover, it is important to remember that WM is strongly related to academic success, more than IQ (presumably because it measures a student's potential to learn, not what they have already learned).

Some authors suggest that the control of attention is the skill that distinguishes between people with better or poorer WM spans (*e.g.*, Engle, Kane, and Tuholski, 1999). According to Miyake, Friedman, Emerson, Witzki and Howerter (2000), the relevant executive functions critical to WM include inhibition, "updating (*e.g.*, during a baseball game if one is trying to keep track of how many balls and strikes there are, which is difficult because it keeps changing) and coordination (*e.g.*, at a restaurant when a waiter tries to keep in mind which diner gets which meal while writing them down)" (Cowan, 2005, pp. 3-4), as well as keeping in mind the goal of the task one is doing (*e.g.*, Kane and Engle, 2003). WM measures may be based on any of the attention functions, or at least be related to them (see Cowan, 2005). For example, due to the limited capacity, only some of the activated information within the memory system may be sufficiently active to be the focus of attention and then receives much more complete information processing. Pertinent information in the memory system is used rather automatically to help interpret the incoming information in the focus of attention. Finally, because the WM capacity limit is related to the scope of attention (see Cowan, Morey, Chen and Bunting, 2007), a way to increase the performance is to attract the attention of children to the material to be elaborated.

Note that WM is influenced by the pace at which the information is given (Gathercole and Alloway, 2007). When a teacher speaks too quickly, a student with poor WM is unable to process all the information fast enough. For this reason, students, especially those with poor WM, need to hear the information at a slow, steady pace.

As reported by Gathercole and Alloway (2007) WM is not linked to the parents' level of education or socio-economic status or to the length of time a child spent in pre-school. Moreover, WM capacity was found to be similar in rural low-income kids

and in children from wealthy urban areas. Despite the urban children had more opportunities of learning (at home, their parents have the skills and time to teach them; at school they receive more attention from teachers) and have a rich base of knowledge cultivated over the years, they have the same WM performance than students from deprived backgrounds. It is not an issue of IQ. Quite to the contrary, WM is not linked to the parents' level of education, socio-economic status, or financial background. This means that all children regardless of background or environmental influence can have the same opportunities to fulfil potential if WM is assessed and problems addressed where necessary.

Working memory and fluency

The WM system is a limited resource system. Thus, activities demanding sustained attention or big effort to be carried out leave little or no additional resources for the adequate completion of concurrent tasks. Deficits in WM have implications for performance on a variety of tasks, including reading comprehension. Several studies suggested a substantial association between working memory (WM) and reading comprehension, (for a review, see Daneman and Merikle, 1996), as well as processing speed (*e.g.*, Verhaeghen and Salthouse, 1997). According to Just and Carpenter (1992), memory capacity is limited; consequently, increases in processing speed provide the opportunity to devote more capacity to comprehension.

Also the *automaticity model* of LaBerge and Samuels (1974) suggests that improvement in fluency could lighten the demands placed on WM resources and allow for greater attention to the comprehension of text. Working memory is critical to the reading process because the reader must decode and/or recognize words while remembering what has already been read, and must then retrieve information such as grapheme-phoneme conversion rules (*e.g.*, Baddeley, 1986; Daneman and Carpenter, 1980; Siegel, 1994; Siegel and Ryan, 1988). Moreover, to make inferences (necessary for good comprehension; *e.g.*, Cain and Oakhill, 1998, 2000), individuals must retrieve, maintain, and manipulate information related to the text (Trabasso and Magliano, 1996) and all this activity closely implies WM skills.

Working memory and reading comprehension

WM ability positively influences reading comprehension skills (Swanson and Berninger, 1995) not only because it allows allocating cognitive resources to the execution of word encoding and lexical access, but also to the execution of various fundamental comprehension processes (such as, syntactic and semantic analysis, etc.; *e.g.*, Miyake, Carpenter and Just, 1994). WM skills are involved in reading comprehension because readers must simultaneously decode words, interpret their meaning (also according to contextual information), "integrate the meaning of the text, maintain and remember what has been read, as well as engage in various comprehension strategies, such as making inferences, detecting inconsistencies, self-monitoring, and correcting comprehension errors." (Vukovic and Siegel, 2006, p. 65). Therefore, readers with greater WM capacity should have more resources available for text comprehension. On the other hand, readers with smaller WM capacity might have fewer resources available for the maintenance of information for comprehension. In particular, WM deficits may produce a comprehension failure at any point in the

comprehension process: a child with reading difficulty may not have adequate WM resources left for comprehension. If a child allocates much WM resources to interpret the text, will have fewer resources left to remember what has read.

In fact, several studies have found that WM plays a fundamental role in explaining reading comprehension performance and is highly correlated with comprehension (*e.g.*, Engle, Cantor and Carullo, 1992). A meta-analysis of 77 studies (Daneman and Merikle, 1996), reported an average correlation of .41 (95% confidence interval: .38-.44) between WM and reading comprehension; by contrast, the correlation between comprehension and simple storage tasks, such as the word span task, are typically lower (around .28; 95% confidence interval: .23-.33). For example, Cain, Oakhill and Bryant (2000) found that verbal WM accounted for 11.4% of the variance in children reading comprehension over and above the variance accounted for by age, intelligence scores, vocabulary, and word recognition. This result was replicated even after controlling for age, phonological awareness and general word analysis (*e.g.* Swanson, 2000; Swanson and Alexander, 1997; Swanson and Howell, 2001) or vocabulary and reading fluency (Seigneuric, Ehrlich, Oakhill and Yuill, 2000). This finding was replicated also in longitudinal studies on children: WM explained a significant amount of the variance in reading comprehension over and above the contributions made by vocabulary, verbal abilities, and word recognition (Cain, Oakhill and Bryant, 2004) or even after controlling for phonological awareness and rapid naming (Vukovic and Siegel, 2005). These studies suggest that verbal WM contributes unique variance in reading comprehension also independent of lower-level processes, including word reading skills, phonological processing, and rapid naming. Similar evidence comes from studies on children with word reading difficulties (*e.g.*, Swanson and Alexander, 1997). However, contradictory findings have also been reported. For example, Schatschneider, Harrell and Buck (2007) found that WM did not account for unique variance in reading comprehension once the effects of oral reading fluency and reasoning skills were controlled for. Similarly, McCallum, Bell, Wood, Below, Choate and McCane (2006) demonstrated that WM was not accounting for unique variance in reading comprehension, after controlling for age, phonological awareness, rapid naming speed and orthographic processing. However, WM was found to account for approximately 3% of unique variance in word decoding and 12% of unique variance in silent word reading fluency.

There are two frameworks used to explain individual differences in WM (with consequences on reading): long-term WM theory (Ericsson and Kintsch, 1995) and capacity theories (Daneman and Carpenter, 1980 or Just and Carpenter, 1992; Engle *et al.*, 1992). The long-term WM model (Ericsson and Kintsch, 1995) proposes an additional component to the WM system, namely the long-term WM system, responsive to the retrieval of information (*i.e.*, prior experiences and knowledge) from long-term memory in order to facilitate WM performance on a given task. According to this model, poor performance in comprehension depends on less efficient retrieval and encoding processes in long-term WM. By contrast, the capacity model proposed by Daneman and Carpenter (1980) assumes that the efficiency with which the central executive processes reading-related materials may be responsible of the impaired reading comprehension. Due to an inefficient WM system, many resources would be allocated to the execution of reading, leaving little or no capacity for comprehension. The capacity models proposed by Just and Carpenter (1992), and Engle *et al.* (1992)

assume that some individuals simply have smaller WM capacity than others, and then show deficits in tasks requiring a large number of information to be simultaneously stored and manipulated, as in the case of reading comprehension. In contrast to the Daneman and Carpenter's (1980) model, WM deficits are not conceptualized as specific to reading comprehension but as deficits in a more general WM system.

In order to investigate whether the relationship between reading comprehension and WM reflects a language-based system or a more general WM system, researchers directly investigate the relationship between reading comprehension and various measures of WM, such as verbal, numerical and visual-spatial WM. Swanson and Howell (2001) found that both a general WM system (a composite visual-spatial WM measure) and a language-based WM system may be involved in reading comprehension. Visual-spatial WM alone did not consistently explain the variance in reading comprehension. By contrast, Seigneuric *et al.* (2000) did not find an involvement of a general WM system in reading comprehension: WM measures involving verbal and numerical information accounted for unique variance in reading comprehension, whereas measures of visual-spatial WM did not. In fact, reading comprehension correlated with measures of WM involving numerical information (correlations between .41 and .45) and especially verbal information (correlations between .47 and .56), but not with WM measures involving spatial information. Thus, in contrast to previous studies (*e.g.*, Cain *et al.*, 2004; Swanson and Howell, 2001), these findings indicate that a language-based WM system (involved in both numerical and verbal information), and not a general WM ability, is responsible for the relationship between reading comprehension and WM. Note that Seigneuric *et al.* (2000) found that numerical WM did not explain significant portions of the variance in reading comprehension after verbal WM was controlled, whereas verbal WM contributed uniquely even after controlling for numerical WM. Similarly, Vukovic and Siegel (2005) found that reading comprehension shared stronger correlations with verbal WM than with numerical WM. Furthermore, in regression analyses, verbal WM continued to explain unique variance beyond the influence of word reading skills, phonological awareness, rapid naming, and verbal WM, whereas numerical WM did not account for unique variance after controlling for the effect of these variables. In a meta-analysis of several studies, Daneman and Merikle (1996) found that in typically achieving readers reading comprehension was generally more strongly correlated with WM measures involving verbal information than with numerical WM tasks. Correlations with visual-spatial WM were even smaller. Larger correlations of reading comprehension with measures of verbal WM compared to numerical WM were also found in a longitudinal study (Cain *et al.*, 2004). Together, these studies indicate that reading comprehension is most strongly related to measures of verbal WM. Children with poor reading comprehension were relatively unskilled in encoding linguistic information in WM.

Working memory and high-level processes involved in reading comprehension

According to the *interactive-compensatory model* (Stanovich, 1980), higher level reading processes (*e.g.*, use of context, comprehension) could compensate for weaknesses in lower level processes (*e.g.*, decoding, word recognition). In fact, students who are poor readers and slow decoders might draw on information from

other levels, such as contextual information. On the other hand, children with weak reading comprehension skills were poorer at inferring the meanings of novel vocabulary items from context than their same-age skilled peers (Cain, Oakhill and Lemmon, 2004). Inference from written contexts might be important also for vocabulary development (Swanborn and de Glopper, 1999). On the other hand, children with high vocabulary knowledge had a more sophisticated understanding of the relationship between context and new words and were more likely to use more than one piece of information to constrain the meanings of new words (McKeown, 1985). In this vein, the ability to acquire new information from context also mediates the relationship between reading comprehension and vocabulary knowledge (Jensen, 1980; Nippold, 2002; Sternberg and Powell, 1983).

Also in this case, WM capacity might influence vocabulary acquisition from context and allow integrating different information across a text (Daneman, 1988). In fact, one text variable that affects a student's ability to acquire new word meanings from context is the distance between the target word and its cue (Carnine, Kameenui and Coyle, 1984). In naturalistic texts, readers may have to integrate information from several idea units spaced throughout the passage rather than from a single adjacent idea unit to derive the complete meaning of an unknown word. Increasing the distance between the different pieces of information to be integrated increases the processing demands for the reader, which will adversely affect individuals with smaller memory capacity (Daneman, 1988; Daneman and Green, 1986).

In fact, two types of comprehension deficits may occur: one with a concurrent deficit in word reading, and one in presence of average word reading skills. The former difficulty reflects a deficit in lower level processes (*i.e.*, in word recognition and in the fluency; Perfetti, 1985; Shankweiler, 1989; Swanson and Siegel, 2001; Torgesen, 2000), while the latter is independent of word reading difficulties and due to an impairment in higher-order skills, such as WM and language processing (*e.g.*, Nation *et al.*, 1999; Oakhill, 1993; Swanson and Alexander, 1997).⁵⁶ In fact, there are children (approximately 10-15% of school-aged children) with poor comprehension despite adequate word reading skills. A deficit in verbal WM, and in particular in central executive and phonological store (for a review, see Swanson and Siegel, 2001), or in higher-order cognitive processes, such as integrating information in text, making inferences, and the use of metacognitive strategies (Cain and Oakhill, 1999; Cain *et al.*, 2000; Oakhill, 1993; Oakhill, Yuill and Parkin, 1986; Yuill, Oakhill and Parkin, 1989; Vukovic and Siegel, 2005) may be responsible of the performance of this group of poor comprehenders without deficits in reading and phonological skills. In fact, Cain, Oakhill, and Lemmon (2004) found that 9-10-year old poor comprehenders had difficulty inferring the meaning of novel vocabulary from the context of the story. They were specifically disadvantaged when the useful context was separated from the novel word compared to the condition in which the context necessary to infer the vocabulary meaning was near the pseudo word. Moreover, children did not have a deficit in the ability to answer literal questions from memory, but had an impaired performance in making valid inferences based on information explicitly provided in text (text connecting inference), or in using general knowledge to make an inference

⁵⁶ However, it is possible to find deficits in lower-level processes, such as phonological awareness and rapid naming, among young (kindergarten) poor comprehenders and a deficit restricted to verbal WM at later grades (Vukovic and Siegel, 2005).

(gap-filling inference). When the text was made available again and children were told to look again through the story (to respond to incorrect questions), poor comprehenders were able to use the text information in order to answer the question correctly as well as typical readers, but continued to demonstrate weaker performance in the gap-filling inference questions (Cain and Oakhill, 1999). Thus, these findings indicate more general language processing difficulties in poor comprehenders in addition to the memory difficulties (see also Perfetti and Goldman, 1976).

Short Term Memory

Phonological short-term memory (STM) refers to the ability to use phonological or visual codes to maintain information for short-term storage (Wagner *et al.*, 1994). In this task, small amounts of material are view or held passively and participants are asked to reproduce the sequence of items in the order in which they were presented (for a review see Gathercole, 1998).

STM is related to information processing in reading for several reasons. First of all, reading requires that words and phrases being decoded are temporarily retained in memory to be arranged and encoded into meaningful sentences (Perfetti and Lesgold, 1977). Second, when decoding letters into phonemes, the novice reader needs phonological memory in order to temporarily store the product of decoding before blending the phonemes into a word (Baddeley, 1982; Wagner and Torgesen, 1987). Finally, STM draws on a phonological code (Salame and Baddeley, 1982), which is critical in learning new words (Baddeley *et al.*, 1998), in both reading and spelling (*e.g.*, Gathercole and Baddeley, 1989; 1993; Swanson and Berninger, 1996).

Because younger children have smaller phonological spans than do older children (*e.g.*, Ornstein, Naus and Liberty, 1975), they may be inefficient in the storage of phonological input and then in higher level processing, such as reading (Swanson and Howell, 2001). Therefore, developmental differences in phonological loop might influence other aspects of word recognition, such as learning new words (Baddeley, Gathercole and Papagno, 1998). Moreover, poor readers usually show low performances of span tasks (*e.g.* Bisanz, Das and Mancini 1984; Katz, Healy and Shankweiler 1983; McDougall, Hulme, Ellis and Monk 1994; Olson, Davidson, Kleigl and Davies 1984; Swanson, Ashbake and Lee 1996; for a review see Jorm, 1983). Meta-analyses (Hammill, 2004; Swanson *et al.*, 2003) have reported that STM have in average a correlation with reading ability of 0.31. However, also conflicting results have been reported (*e.g.*, Parrila, Kirby and McQuarrie, 2004; Torgesen *et al.*, 1997).

Short Term Memory (STM) temporarily stores the information being processed, but has a limited capacity (of about seven items plus or minus a couple; Miller, 1956) and rapid decay (Collins and Loftus, 1975), with stimuli retained for no longer than approximately 30 s (Anderson, 1980). Subjects use several strategies to minimize this functional limitation, such as organization units into chunks, using sub-vocal rehearsal and parsing (Miller, 1956; Caplan, 1972; Jarvella, 1971). In fact, as suggested by Miller (1956), this capacity increases if subjects group items together to form higher-level meaningful units or chunks. For example, it is easier to remember the telephone number 980473216453 if one assembles the number in chunks (980-473-216-453) than memorizing one by one the twelve numbers. Similarly, if words are assembled in chunks the capacity of the phonological span increases (Tulving and Patkau, 1962). Moreover, the average chunk grows with increasing level of approximation to English

(*i.e.*, passing from random words at perfect English sentences), indicating a facilitator effect of context on the phonological span. Similarly in reading, 7-10 isolated words cannot be remembered after one presentation, but the same words organised in a sentence could be easily recalled (Luria, 1976). Recall did not diminish even when another sentence was read between the presentation of the first sentence and its recall indicating that the memory trace was stable. This stability is due to semantic organisation. Consistently, brain lesions that usually produce mild mnemonic disorders do not produce mnemonic disorders if the lesion does not encroach the areas responsible for semantic organisation (occipital-parietal and frontal regions). "A deeper level of processing, semantic level strengthens comprehension. Thus, a simple message for improving comprehension is to encourage the learner to engage in a deeper level of processing" (Georgiou, Das and Hayward, 2008; page 314).

Baddeley Thomson and Buchanan (1975) showed that it is not simply the number of meaningful units that mattered in immediate recall, but also word length. Lists of long words were not recalled as well as lists of words that could be pronounced more quickly. In fact, the verbal memories refresh (through rehearsing the words, *i.e.*, saying the words to themselves over and over), is more efficient in the case of short words (with shorter time between one rehearsal and the next), leaving less time for forgetting (Cowan, Morey and Chen, 2007).

Also the reading rate influences the efficiency of STM. In fact, manipulating reading rate, Breznitz and collaborators (Breznitz, 1987a, 1987b, 1988; 1990; Breznitz and Share, 1992) found that accelerated reading rate⁵⁷ increased the level of comprehension and reading accuracy. For example Breznitz and Share (1992), found that the fast-paced manipulation increased reading speed of Hebrew readers by 28%, reading accuracy by 48% and inferential comprehension by 21% compared to self-paced condition (these means refer to experiment 1, but the effect was consistent across the experiments). This may be due to the lower distractibility (Breznitz, 1988), but occurs primarily through STM (Breznitz and Share, 1992). In fact, according to Breznitz and Share (1992), faster reading produces an increase in the number and size of units being held in STM, and in turn the greater efficiency of STM produces a better performance in reading comprehension. In particular, individuals with smaller STM spans benefit more from the accelerated reading rate (Breznitz and Share, 1992). Then, it is possible that, for young children or children with low functioning in STM, the increase of reading rate will lead to substantial gains in reading accuracy and comprehension.

2.2.5 Interim summary: Which variables affect reading comprehension?

Text comprehension is closely related to vocabulary, fluency, oral comprehension, and working memory skills; the relative weight of each variable changes as a function of reading acquisition and expertise.

In the first year of reading acquisition, fluency in reading text is critical for reading comprehension. Efficient and fluent word reading releases attentional and cognitive resources to attend to the meaning of the text. Improvement in fluency (due to

⁵⁷ Note that Breznitz and collaborators presented materials at the maximum rate of demonstrated capacity for a given individual and not at the optimal rate. However, the optimum fast-paced reading rate for each individual was indeed not evaluated.

expertise or as an effect of reading training) results in improved reading comprehension. By contrast, children who read slowly and with great effort have difficulty understanding what they read, because the cognitive resources necessary for understanding meaning are employed in the reading process. Moreover, slow word reading increases the demands on working memory, which in turn creates difficulty in understanding connected text. This pattern is often observed in subjects reading English as a second language and language minority students than in native language students. Thus, whenever possible, textbooks for children of third world countries should be provided in their native language.

As decoding expertise is gradually gained, comprehension is less dependent on decoding and more strongly related to general vocabulary skills. Children's rich vocabulary is an important vehicle for reading comprehension and academic achievement. In fact, unknown words can create gaps in the meaning of a text; if too many gaps occur, the student may not be able to construct meaning. The depth of vocabulary knowledge is more important than vocabulary size; thus, children who have more complete semantic word representations have an advantage. On the other hand, vocabulary training may improve comprehension, because exposure to print fosters vocabulary growth. In fact, it is possible to acquire, refine and consolidate vocabulary knowledge by reading and deriving inferences from the context.

In turn, vocabulary is also related to fluency, because increased fluency exposes the reader to an expanded vocabulary and a larger vocabulary leads to a faster reading rate. Since vocabulary is influenced by the amount of words children are exposed to, children with low SES typically have a smaller vocabulary and, particularly, smaller vocabulary growth. Thus, children from low SES backgrounds likely need oriented, effective interventions aimed at vocabulary growth.

Working memory is critical to the reading process (including word encoding, lexical access, syntactic and semantic analysis, etc.) and also to retrieving, maintaining, and manipulating information related to text comprehension. Readers with lower WM capacity have fewer resources available for the maintenance of information for comprehension. Moreover, working memory capacity influences vocabulary acquisition from context; it allows integrating different information spaced throughout the text to derive the complete meaning of an unknown word. Large distances between the different pieces of information to be integrated increase processing demands, adversely affecting comprehension. Thus, textbooks should be created in which sentences are relatively short when new words are introduced (in order to have made easier the rehearsal of the new words in memory).

Overall, several variables modulate reading comprehension. Considering that these variables are closely related to degree of exposure to text and to efficiency in oral language, they may be particularly important in countries with low SES level, language minority groups, and in children learning reading and spelling in non-native languages.

2.3 Acquisition of reading: evidence from the neuroscience of reading

There is a consensus that no ready-made “module” for visual word recognition is present. However, with reading experience a progressive specialization of pre-existing infero-temporal pathways for visual object recognition is observed. As a consequence, selective responses to orthographic stimuli are recorded in the so-called visual word form area or VWFA (McCandliss, Cohen and Dehaene, 2003).

Functional specialization of the VWFA is thought to emerge during acquisition of reading expertise (McCandliss *et al.* 2003; Pugh *et al.*, 2001). The specialization process of VWFA is thought to be protracted over a long period of experience and proceed in parallel with the rise of cognitive hallmarks of expertise. Specialization in visual processing, with greater use of the most appropriate mechanisms and a decrease in the use of less appropriate mechanisms, is possible through experience, maturation of the underlying neural substrate, and exposure to patterned orthographic information within a specific writing system.

After years of extensive experience with orthographic material, the acquisition of expert word recognition correlates with the amount of activation of the VWFA by letter strings in normal and dyslexic children (McCandliss *et al.*, 2003; Shaywitz *et al.*, 2002; Temple, 2002). Similarly, accuracy of speeded letter recognition correlates with the activation in the VWFA (Garrett *et al.*, 2000).

Shaywitz and colleagues (Shaywitz, Pugh, Mencl, Fulbright, Skudlarski *et al.*, 2002) examined English speaking children’s fMRI responses across a range of ages (7-18 years) and reading abilities (impaired to highly skilled). They found increased activity in a left ventral occipitotemporal region (presumably including the VWFA), which correlated more robustly with reading skills than with age (Sandak *et al.*, 2004). In fact, activation levels of the VWFA and other nearby regions were positively correlated with grapheme-phoneme decoding ability, even when the effect of age was taken into account. By contrast, the VWFA fails to increase its activity in response to word forms in dyslexic adults of both consistent (Italian) and inconsistent (French and English) orthographies (Paulesu *et al.*, 2001). Reading skills are positively correlated with the magnitude of activation in the left occipitotemporal region in dyslexic children (*e.g.*, Shaywitz *et al.*, 2002). Furthermore, reading skill training for dyslexic children produced changes in fMRI activation, including posterior occipito-temporal regions in the vicinity of the VWFA (Shaywitz *et al.*, 2002).

In an fMRI study with English speaking children between six and twenty-two years of age, Turkeltaub, Gareau, Flowers, Zeffiro and Eden (2003) found a shift in brain regions associated with word-processing with experience. As reading began to reflect knowledge of abstract word properties (semantics and phonological properties) and was less supported by logographic strategy, increased activation was revealed in left middle temporal and inferior frontal gyri and decreased activation in the right infero-temporal regions. Moreover, stronger connectivity between the angular gyrus with the inferior frontal and ventral fusiform regions was found as a function of reading skills (Horwitz *et al.*, 1998). By contrast, connectivity in the angular gyrus region was weak among dyslexics for word and pseudoword reading (Pugh *et al.*, 2001).

Maurer, Brandeis and McCandliss (2005) contrasted English children's responses to words and novel characters resembling letters⁵⁸ just before the onset of reading instruction in school. Unlike adults and older children, in preschool children the ERP response revealed no sensitivity to visual words or letters and showed similar activation for stimuli formed by letters or pseudo-characters. Only the group of children most familiar with letters produced some modulation of the N170, but with a right lateralized pattern. After 1.5 years of formal schooling, experiences with visual words brought about changes in the N170 responses that were not observed for the control stimuli (Maurer, Brem, Bucher and Brandeis, 2005). Then, with practice N170 appears to become specific to the writing system in which an individual is trained. In addition, individual differences in reading skills (*i.e.*, fluency) were systematically correlated with the degree of N170 responses.

Specific experience with visual words causes changes even late in development as long as fluency in word recognition is progressively refined (Brem *et al.*, 2006). In fact, as fluency continued to improve between adolescence and adulthood, in parallel the latency of the N170 was shorter for adults than for adolescents (16 years of age) when visual words (but not control stimuli) were presented.⁵⁹

According to the previously reviewed studies, the progressive development of the VWFA seems more closely tied to the progression of skills rather than being merely a matter of maturation. Pugh *et al.* (2008) proposed a learning-curve hypothesis based on skill-acquisition studies (*e.g.*, Poldrack and Gabrieli, 2001). Accordingly, initial skill acquisition was associated with increased activation in task-specific cortical areas, whereas continued practice of an acquired skill was linked to task-specific decreases in activation in the same cortical regions.

In order to examine the role of expertise on reading orthographic characters controlling for the effect of maturation, several studies examined the pattern of cerebral activation of the VWFA in healthy, educated adults during reading of unknown alphabetic codes. In this way, it is possible to simulate the development of reading skills from the pre-school child to the skilled reader independently of cerebral maturation. In fact, brain plasticity in the reading circuit can be observed even in adult subjects as they acquire perceptual expertise for novel items after relatively short periods of training (*e.g.*, Gauthier 2001). For example, in a novel orthography training experiment, Bolger, Schneider and Perfetti (2005) trained subjects to learn to read words written in Korean script. Pilot studies found that increases in cortical activation occurred rapidly: a 0.7% increase in BOLD signal from learning trials one-four to trials thirteen-sixteen (Bolger *et al.*, 2005). After four sessions (with twenty words per session) of training, responses in the VWFA increased significantly, especially in a componential (*i.e.*, learning letter-sound correspondences) as compared to holistic (*i.e.*, learning of the whole word) training approach.

⁵⁸ Note that in skilled readers the VWFA normally responds with greater activation to real versus false fonts or nonletter-strings (Cohen *et al.*, 2000, 2002; Cohen and Dehaene, 2004; Kuriki, Takeuchi and Hirata, 1998; McCandliss *et al.*, 2003; Nobre, Allison and McCarthy, 1994; Petersen, Fox, Posner, Mintun and Raichle, 1988; Petersen, Fox, Snyder and Raichle, 1990; Polk *et al.*, 2002; Puce, Allison, Asgari, Gore and McCarthy, 1996; Walla *et al.*, 1999; Price *et al.*, 1996).

⁵⁹ Note that Brem *et al.* (2006) found a correlation between word-related N170 responses and word-related fMRI responses in the VWFA in adolescent subjects.

Sandak *et al.* (2004) explored the effects of orthographic, phonological, and semantic pseudo words training on overt naming ability. Orthographic training involved making judgments about consonant and vowel patterns in pseudo words; phonological training involved making rhyme judgments in pseudo words; and semantic training involved learning novel semantic associations to pseudo words. Although phonological and semantic training were driven by different neural processes, they resulted in equivalent (but superior when compared to orthographic training) performances in reading ability. After the phonological training, a progressive reduction in activation was found in the VWFA. Also Xue, Chen, Jin and Dong (2006) adopted an artificial language training paradigm to exam the impact of different aspects of language experience (visual familiarity, phonology and semantics) on the neural activation in the visual word form area in a group of Chinese students. They initially trained subjects with visual forms then added in the phonology and semantics. Visual form training decreased the activation in the bilateral fusiform cortex, whereas phonological and semantic training increased activation in these regions as well as in a wide neural network involved in language processing. This result suggests that phonological and semantic training induced sensitivity in the fusiform cortex more than visual form training, suggesting a greater involvement of the former in reading acquisition.

However, training in reading an artificial script is an experimental paradigm devoid of ecological value. Learning to read dialect words more closely matches the processes of children's reading acquisition, which requires the mapping of orthographic representations to an existing system of lexical-semantic representations. In fact, dialects are languages lacking an orthographic representation but, unlike pseudo words or artificial words, they have semantic references and phonological representations. Abutalebi, Keim, Brambati, Tettamanti, Cappa, De Bleser and Perani (2007) examined the effect of training in reading dialect in subjects of an Italian region in which the first spoken language was a local dialect without an orthographic counterpart, while the orthographic "official" language used was German. After the practice in dialect reading, brain activity within the left midfusiform area converged progressively to that activated in German reading. With progressive expertise in reading dialect, dialect words were read lexically and these areas were less active, whereas pseudo words were still processed through grapheme-phoneme conversion.

In conclusion, according to Hill and Schneider (2006), in expert readers words are processed in specialized areas, and learning can produce detectable morphological changes in the VWFA. Learning produces both increases in activation early in practice and decreases as reading becomes more automatic. However, no reviewed study reported evidence regarding the reading speeds corresponding to various patterns of activation in the VWFA. Furthermore, the training studies showed that the nature of the practice (*e.g.*, phonological or semantic encoding) has an impact on these plastic changes.

2.3.1. Interim summary: What does evidence from the neuroscience of reading tells us about the acquisition of reading

Expert readers process words in specialized areas, particularly in the visual word form area or VWFA. Acquisition of expert word recognition correlates with the amount of

activation of the VWFA by letter strings. This also occurs late in development, for example, in adults and adolescents. Moreover, learning to read produces detectable morphological changes in the VWFA, with an increase in activation early in practice and decreases as reading becomes progressively automatic. However, research examining the patterns of activation corresponding to various reading speeds is still lacking.

The progressive development of the VWFA seems more closely tied to the progression of skills and is not just a matter of maturation. Evidence supporting this point also comes from research examining the effects of training educated adults during reading of unknown alphabetic codes or learning a spelled version of their spoken dialect.

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