Reading Development:
Letter by letter decoding in English and Italian readers

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Abstract

It is well known that vocal reaction time increases with word length for beginning readers of highly regular languages (transparent). However, little is known about the word-length effect in readers of English, a language with highly irregular rules for pronunciation (opaque). The length effect is interpreted as the signature of a reading strategy based on letter by letter decoding, and it is extremely large in dyslexic readers of transparent languages. English is thought to be acquired through holistic word recognition, and the word length effect has not been systematically investigated on normal and dyslexic English readers. Here we test the effect of word length on word naming latency for third and fifth grade English normal readers. The length effect is present in both age groups (75 ms and 26 ms per letter, R^2=0.70 and 0.88 respectively) and surprisingly similar to that found in age-matched Italian readers. Contrary to what is generally thought for English reading acquisition, we conclude that at least up to 5th grade reading is mediated by a letter by letter decoding strategy in both opaque (English) and transparent (Italian) languages. This result is important for understanding normal and dysfunctional reading acquisition.

Introduction

"Do not read, as children do, to amuse yourself, or like the ambitious, for the purpose of instruction. No, read in order to live." Gustave Flaubert (1857)

Reading is crucial for human development. Reading not only increases our life skills and extends our knowledge but goes much deeper. Reading help determines how we think. It has a fundamental effect on the development of the imagination and is a powerful influence on the development of emotional and moral as well as verbal intelligence (Harrison, 2004). To many, reading is like breathing; it does not feel like a cognitive process but rather automatic. Unlike breathing, however, reading must be learned before it can become automatic. In this process many people, about 10% of the population, fail and these people are classified as dyslexic. Dyslexia is still a mystery and understanding normal reading acquisition may be of great help in developing new training programs for young dyslexic readers. Thus it is important to understand the steps of reading acquisition.

All children learn to read letter-by-letter. It has been suggested that adults read words as wholes because they recognize short and long words equally quickly (Stanovich, 2000). Characterizing the transition between childhood and adulthood is relevant in understanding how normal and dysfunctional reading abilities are acquired. The child must first learn to decode letters. Adult observers are thought to match the whole word with one contained in the lexical buffer, independently of the length of the word. Lexical analysis is the first step in text processing: it segments strings into a sequence of words also known as lexical units or lexemes (Fraser, 1999). In previous studies it has been shown that Americans read faster than readers of transparent languages, but this speed is gained at the expense of accuracy. Most mistakes American readers make are errors on words with lower frequencies (D'Angiulli, 2001). Italian readers are much slower than American readers but are more accurate. After second grade, it is very rare that you see an Italian reader make a reading error, whereas American readers make errors throughout their whole lives.

Across languages, one of the key differences between current models of reading aloud is the nonlexical mechanism that translates orthography (writing correctly) into phonology (speaking correctly) (Coltahart, Rastle, Perry Langdon &Ziegler, 2001). Orthography consists of written letters that are combined together to form words, sentences and other forms of written language. It is decomposed into individual letters or letter clusters, and they are assembled into phonology from left to right (Perry & Ziegler, 2002). One significant effect that has been suggested to help decide whether phonology is assembled as a serial process or in parallel is the position-of-irregularity effect. The position-of-irregularity effect was taken as strong evidence of serial processing in reading (Coltahart and Rastle, 1994).

The level of transparency (how reliably a letter maps onto a speech sound) measured on a continuum with 'transparent' or 'shallow' at one end and 'opaque' or 'deep' at the other, has been shown to determine how easily children learn to read. In transparent languages, such as Italian, French, Spanish and Finnish, the grapheme to phoneme method of reading is effective because of the regularity of the language (Ziegler, 2001). In opaque languages, such as English, this grapheme to phoneme conversion is not as effective. English is read through a lexical process. But how does its reading acquisition develop?

Word length can have a dissociable effect on reaction time. The main effects of word frequency and word imageability on reaction time in almost all cases are effects of word length. This interaction is predicted by an interactive account. There have been cases where interaction between a lexical variable and word length has also been demonstrated (Bowers, 1996).

In early reading phases, a critical factor that affects decoding of the visual input in transparent orthographies is the length of the string. The effect of length should be manifest in two ways. First, more time will be needed to pronounce longer than shorter words. Second, a greater latency should be expected for longer words prior to the onset of pronunciation, particularly in younger observers. This latency should reflect the first stages of word decoding. It is commonly examined in terms of vocal reaction times (RT) for naming different length words. Vocal Reaction Time (RT) is the response latency or period of presentation of a stimulus to the beginning of a vocalized response. It is also known as speech reaction time, speech response time, or vocal response time (Corsini, 2002). The reaction time is measured from the onset of a stimulus to the onset of the response. Thus, it is independent of pronunciation time.

It is suggested that normal readers in an orthographically transparent language (Italian) adopt a lexical strategy quite late in their learning. The length effect reduces in size during development, but it is still detectable in adults (Spinelli et al., 2005). The length effect in Italian 5th graders dyslexic readers is of the same magnitude of normal 1st graders (Zoccolotti et al., 2005).

The length effect has been utterly disregarded in opaque orthographies such as English, though it is thought to be a key factor in distinguishing dyslexic readers in transparent orthographies (Wimmer and Hummer, 1990; Seymour et al., 2003). Here we want to directly compare the word length effect in an opaque language, English, and in a transparent language, Italian, in order to evaluate whether the characteristic of the language may enhance different strategies of learning and therefore cause different patterns of disabilities in reading-impaired populations such as dyslexics.

Methods

Observers read aloud words presented one after another on a computer screen, and their vocal reaction time was recorded.

Observers

All observers had normal or corrected to normal acuity and normal contrast sensitivity. The observers did one run as a trial run and one as the experiment. They were not previously exposed to either list of words. The observers were American normal readers from third (n=8) and fifth (n=8) grades, from a middle-class suburban area on Long Island. Aged matched samples of Italian normal readers (n=28, n=30) were tested in Italy.

If an observer was not of normal reading level, as assessed by the *WIAT-II test*, their results from the Vocal Reaction Time Test were not considered. In order to minimize risk and keep all variables consistent the observer was still to participate in the Vocal Reaction Time Test. The students were not informed of the results

WIAT-II Comprehension Test

The Wechsler Individual Achievement Test Second Addition has 9 subsections (word reading, pseudoword decoding, reading comprehension, numerical operations, math reasoning, spelling, written expression, listening comprehension, and oral expression). To assess reading level the reading comprehension and the pseudoword decoding tests were administered to all observers. The reading comprehension required observers to read sentences and short passages and then answer questions about the main idea, specific details, or the order of events. They are also asked to make inferences, draw conclusions or define unfamiliar words by using context clues. The pseudoword decoding test required the observer to use their phonetic knowledge to sound out nonsense or unfamiliar words. The stories and words used are determined by the student's grade level.

Vocal Reaction Time Test

SuperLab Pro was used to run the experiment. Using a standard microphone it measured vocal reaction time with 1 ms accuracy. The program measures vocal reaction time as a function of word length. The stimuli were rendered on an Apple Power Macintosh. Vocal reaction time is independent of pronunciation, and it tests encoding time. The program records the observer the second they start to say the word and then changes to the next word immediately.

Stimuli

We selected 75 simple words varying in length from 4 to 7 letters: 20 four, five, and six letter words, and 15 seven letter words. The four lists were matched for initial phoneme, frequency , and immaginability. For the word lists see Appendix A.

Procedure

The observer was asked to stare at a point of fixation and sat fifty centimeters away from the computer screen in which the words were being presented. The word "PAUSE" appeared in the middle of the screen and the observer was instructed that as soon as they were ready they could click the mouse and a word would appear on the screen. They were to read the word as quickly and as accurately as they could. If they make a mistake they are instructed to not go back and correct the mistake. As soon as the observer recites the word the computer records the vocal reaction time and the next word appears. If an error is made, the error is noted along with what the error was.

The entire process takes about 30 minutes depending on how quickly the reader performs. Only vocal reaction times for correctly read words were included in the analysis.

The observer is talking into a microphone and it is emphasized that there is no stress or pressure involved with participating in this experiment. In order to minimize risk a supervised scientist or a qualified teacher will be present at all times.

Results

Results from the WIAT-II

All observers tested as average readers. The scores ranged from 95 to 105 on a scale that has a spread of 40 to 160. All observers fell in the 40 to 70 percentile ranking which was considered average. The middle 50% are scores 90 to 109.

Grade	Mean reading comprehension score	Mean pseudoword decoding score
3rd (n=8)	99	97
5th (n=8)	101	97

Table 1. The mean reading comprehension and pseudoword decoding scores for third and fifth graders. It shows that the average of each grade was of normal reading level.

English readers

Figure 1 presents the results obtained with English speaking observers. The figure shows vocal reaction times as a function of word length for eight third graders and eight fifth graders. These results show a developmental trend. Increasing school years significantly lowers reaction times of 300 ms independently from word length. For both groups vocal reaction times increased with word length. However, the magnitude of the length effect weakens with increasing school year. A regression analysis indicates that the length effect is 75 ms per letter (R^2=0.70) for third graders, and 26 ms per letter for fifth graders (R^2=0.88).

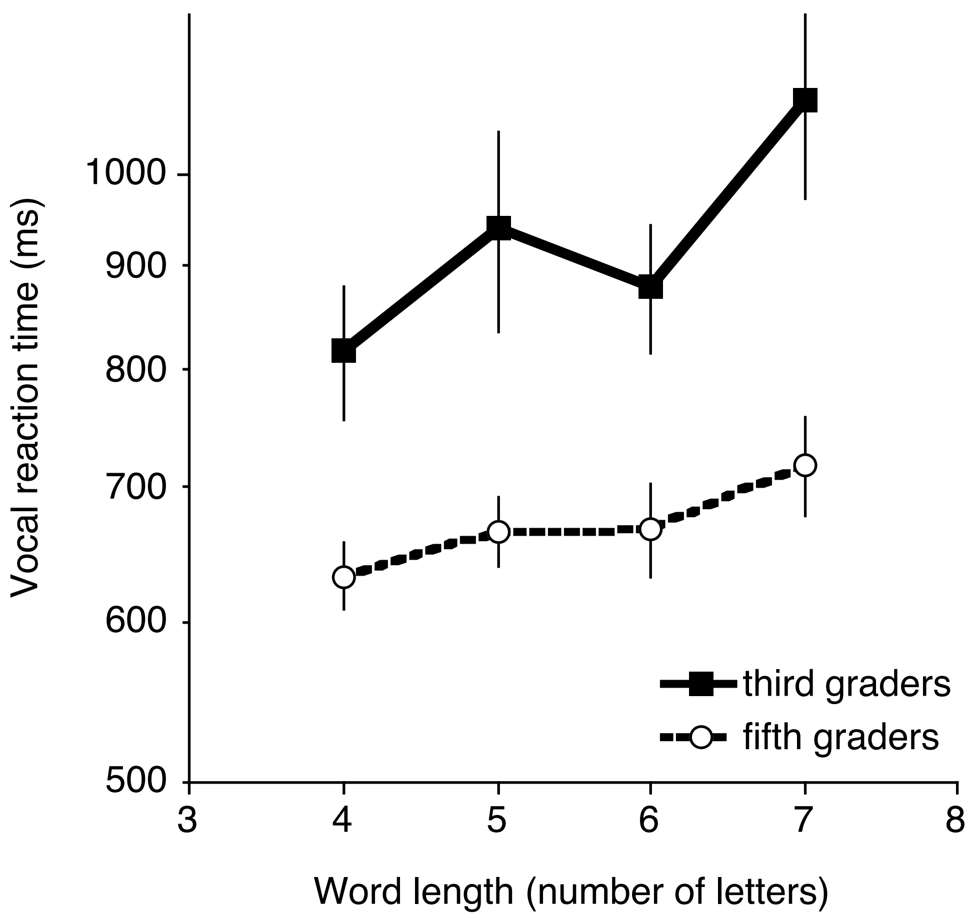

Figure 1. Vocal reaction times as a function of word length for third graders (filled squares) and fifth graders (open circles). Vocal reaction times increase with word length for both age groups.

An ANOVA test of all effects shows a significant interaction between school year and word length ($p<0.05$) and a strong main effect of both word length ($p<0.01$) and school year ($p<0.0001$).

English and Italian readers

Figure 2 presents a comparison between English and Italian readers. English and Italian readers are affected by length in a surprisingly similar way both in third (Fig.2a) and in fifth grade (Fig. 2b).

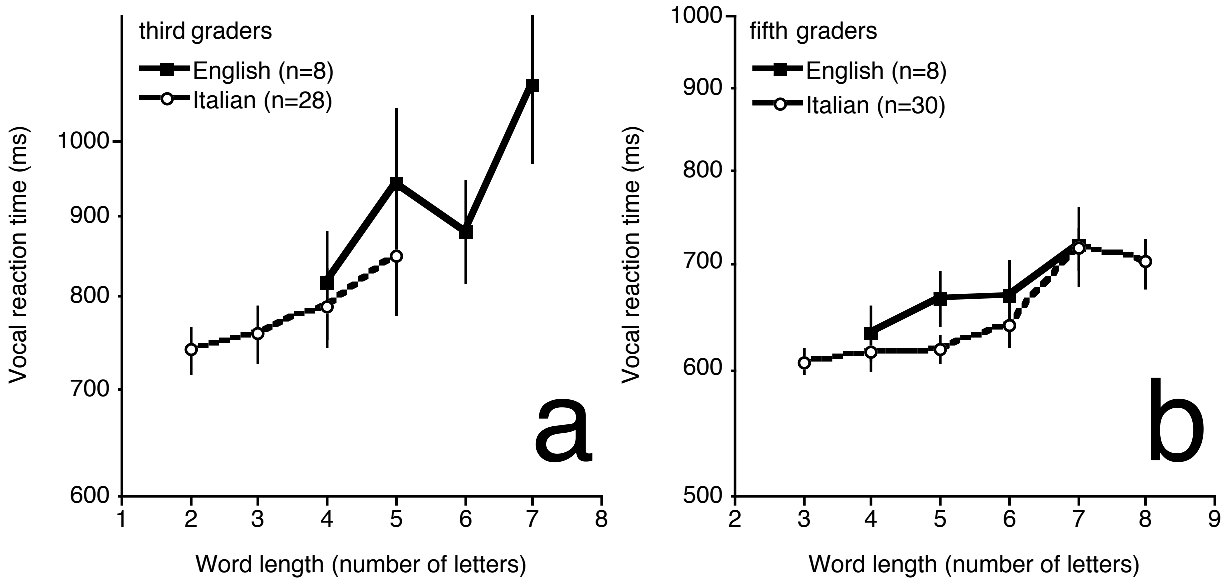

Figure 2. Vocal reaction times as a function of word length for third graders (a), and fifth graders (b). Vocal reaction times increase with word length in a similar way for English (solid squares) and Italian (open circles) readers.

Discussion

The aim of this research was to examine whether there is an effect of word length in early ages of reading development for normal readers. The length effect has been neglected in past studies of English readers. In an opaque language such as English it is hard to evaluate this effect eliminating the influence of other lexical variables. Here we selected regular simple words of various length and measured the length effect as a function of age of exposure. These results show that contrary to the conjecture, the effect of length is as strong in opaque as it is in transparent orthographies, indicating a common ground to understand reading acquisition.

It is generally believed that the length effect arises at the level of perceptual rather than linguistic analysis (e.g., Lee, 1999). Word length effect may be particularly clear in languages, such as Italian or German, characterized by high grapheme-to-phoneme regularity (Ziegler, Perry, Jacobs and Braun, 2001). In opaque orthographies, such as English or French, the presence of high irregularity in the mappings between graphemes and phonemes may introduce complexities in the relationship between number of letters and naming latencies. In English speaking readers, a particularly marked word length effect is present only in a specific sub-group of impaired readers, defined as morphemic dyslexics by Seymour and MacGregor (1984). Here we wonder whether normal reading acquisition displays the same pattern in transparent and opaque languages.

In transparent orthographies, it is generally believed that learning to read initially emphasize the alphabetic analysis (Seymour et al., 2003), while no evidence of global or logographic analysis is detectable (Wimmer and Hummer, 1990). However, in opaque languages, reading acquisition seems to be primarily related to holistic or word form recognition independently of number of letters. Alphabetic decoding is reflected in the influence of stimulus length on reading times. Results showed that length was a powerful factor in modulating performance at early stages of learning and became progressively less critical at later stages. In languages with shallow orthographies, including Italian, the correct decoding of words can be achieved by using the grapheme-to-phoneme routine. Based on this, sometimes it has been proposed that reading is actually achieved only by this procedure (Frost, Katz and Bertin, 1987). The present results show that English acquisition is very similar to other languages requiring letter-by-letter decoding phase. These results may highlight a common ground to understand developmental dyslexia.

Conclusions

The effect of word length decreases with age, from 75 ms to 26 ms per letter for third and fifth graders, but the effect is still present in fifth graders. This supports the hypothesis that older readers read more holistically. The surprisingly similar results for English and Italian readers suggest similar processes in opaque and transparent languages. These finding show that letter-by-letter reading is still an important aspect of reading at fifth grade, and suggest that a better understanding of its development may help in curing dyslexia.

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Appendix A: Words

4 letter	5 letter	6 letter	7 letter
babe	brawl	advice	apricot
earl	claim	appeal	concern
noun	fraud	fiddle	council
riot	rifle	murder	flutter
oven	grief	plunge	mermaid
aunt	issue	damage	attempt
dell	troop	device	purpose
edge	groan	escape	pioneer
grip	porch	marvel	prairie
lift	ankle	bother	triumph
loss	crush	branch	laundry
luck	earth	bubble	neglect
navy	elbow	lumber	evening
plot	greed	nozzle	pasture
plug	linen	number	trouble
raid	lodge	puzzle	
ring	nurse	rattle	
task	ranch	rescue	
tool	tweed	tumble	
trip	manor	willow	