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IQ vs phonological recoding skill in explaining differences between poor readers and normal readers in word recognition: Evidence from a naming task

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Abstract. The aim of this study was to investigate whether differences in reading performance between poor readers and normal readers could be better explained by phonological recoding deficiences than IQ. A sample of 132 Spanish children was classified into four groups according to IQ (<80; 81–90; 91–109; 110–140) and into two groups based on reading skills (poor readers vs normal readers). A word naming task was also administered. We manipulated the word parameters (length, positional syllable frequency, and word frequency) and nonword parameters (length and positional syllable frequency) to find out whether students with reading disabilities would have more difficulties than normal readers in naming words under conditions that require extensive phonological computation. The results demonstrated that there were differences between Spanish children who were normal readers and those who were poor readers, independent of their IQs.

Keywords: Reading disabilities, Phonological recoding, Word recognition, Intelligence quotient, Linguistic parameters

Introduction

Among school children diagnosed as having poor reading ability, usually two groups are identified: those who demonstrate general learning backwardness (i.e. garden-variety poor readers) and those who are one or two years behind in reading in spite of having average or above-average IQ (i.e. dyslexics). Children with dyslexia are also described as having learning disabilities (LD) or specific reading disabilities.

The most common criterion in differentiating children with LD in reading from those who have general backwardness is the 'discrepancy' between intellectual potential, expressed as IQ, and reading performance. If IQ is in normal range and in addition if there is a large discrepancy between these two measures, then the child is diagnosed as having specific reading disability. Based on this diagnosis, educational programmes are designed.

However, using the concept of 'discrepancy' to classify reading disabilities leads to many problems. In the first place, the term intelligence implies ability to solve problems, logical reasoning and adaptation to the environment. As Stanovich (1989) notes, the concept of intelligence is controversial and there is no agreement about what constitutes intelligence. Many authors claim that IQ scores are not valid measures of intellectual potential (Siegel 1989; Stanovich 1989). This lack of agreement among researchers calls for caution in using intelligence as a criterion in determining LD. Secondly, implicit in the use of the discrepancy quotient is the assumption that intelligence can be measured independently of performance. IQs obtained from a standardized test measure the abilities of expressive language, short-term memory, processing speed, and specific knowledge. However, many studies show that these functions are also deficient in subjects who have learning difficulties (for a review, see Siegel 1990). There is evidence that children who have difficulty in learning to read have less experience of the printed word, and have low motivation and low self-esteem. Therefore, a low IQ could be the consequence of these difficulties and may not correspond to the level of intelligence that the subject really has (Stanovich 1986).

As a consequence of these and other factors, there has been growing criticism of the use of IQ as a predictor of reading potential. The inadequacy of IQ as a measure of intelligence has also been made evident by studies in which no differences in reading performance were found among children with different levels of IQ, all of whom had learning difficulties (Jiménez & Rodrigo 1994; Share, Jorm, Matthews & Maclean 1988; Share, Jorm, McGee, Silva, McLean, Matthews & Williams 1987). Also relevant to this question is the work of Siegel (1989) in which the performance of poor readers with different IQ scores was compared in a series of tasks including spelling, reading words and nonwords, language and arithmetic skills. The author found that there were no differences between poor readers although they had different IQ levels. It may be that tasks which measure the cognitive processes which are important for reading are more useful. In her later work, Siegel (1989, 1992) using a different experimental design, further verified the problems of using IQ in the identification of pupils with learning difficulties. These and other similar results have caused researchers to turn their attention to other factors that are more immediately related to the reading process. Possibly, then, a better way to identify a child with learning disability would be to evaluate the different cognitive processes (e.g. word recognition) that are involved in reading.

Contemporary research on word recognition by individuals with acquired dyslexia has led to the formulation of detailed reading models of isolated words. Word recognition is an important requirement in reading development and weakness in word recognition is a main source of LD in children (Perfetti 1986, 1989; Siegel 1986).

It is well documented that good readers have good skills in word recognition, and pupils with reading difficulties show deficits in lexical and sub-lexical processes (Beech & Awaida 1992; Ehri & Wilce 1983; Manis 1985; Perfetti 1985). Other studies using the paradigm of lexical decision have also demonstrated that pupils with reading difficulty are slower in accessing the lexicon than good readers (Cirrin 1984; Ellis 1981; Jiménez & Rodrigo 1994; Rayner 1988; Seymour 1987; Seymour & Porpodas 1980). What these studies consistently show is that the major cause of reading difficulty seems to be deficiency in phonological skills (Stanovich 1988a). The study by Siegel (1993) supports this claim and shows that in readers of the English language, the phonological process constitutes a modular function that operates automatically and is independent of general cognitive ability.

The aim of this study was to investigate whether differences in reading performance between poor readers and normal readers could be better explained by phonological recording deficiences than by IQ. We selected the naming task because many authors consider it to be the task which best detects reading problems (Olson, Wise, Conners, Rack & Fulker 1989; Perfetti 1986; Siegel 1986).

In this investigation the word parameters length, positional syllable frequency (PSF) and word frequency, and non-word parameters length and PSF were manipulated. The differences in reaction time (RT) were expected to be a function of variables such as lexicality (words as opposed to nonwords), word frequency, PSF and word length. In addition, RT would also be greater in individuals with reading disabilities, independent of their IQ. Therefore, this paper tries to answer the following question: Can IQ explain the differences between normal readers and children with reading disability better than word naming skill?

Methods and participants

The subjects in this study were 132 Spanish children, 45 of whom were normal readers and 87 of whom were poor readers. The sample was obtained as follows: From a local population of 1,000 children, teachers were asked to identify which children they considered to be normal readers and which they considered poor readers. The children came from urban areas, from average socio-economic backgrounds and from grades 4 and 5 of several different state schools. Two hundred and seventy-six children were chosen, 108 'normal' readers and 168 'poor' readers. Each child was then individually tested using a reading test, Test de Análisis de Lectoescritura (TALE) (Toro & Cervera 1980). A group of 132 children was formed, with 45 normal readers and 87 poor readers. These children were then classified into four groups

Table 1. Distribution of the sample according to IQ and reading level

	IQ			
	<80	81–90	91–109	110–140
Reading level				
Normal readers	8	10	14	13
Poor readers	20	19	31	17

according to their IQ, as measured by the Wechsler Intelligence Scale for Children – Revised (WISC-R) (Wechsler 1974) (<80; 81–90; 91–109; 110–140).The normal readers (28 males, 17 females) (average age 118 months, sd = 8.6) consisted of above-average readers who scored at or above the 75th percentile on the sub-tests (i.e. letter, syllables, word decoding and reading comprehension) of the TALE. The poor readers (58 males, 29 females) (average age 115 months, sd = 12.2) scored at or below the 25th percentile on all subtests of the TALE. Children with sensory deficits, neurological deficits, or mental handicaps were excluded. There were no significant statistical differences in chronological ages between normal readers and poor readers ($t = -0.88$, $p \leqslant 0.38$).

These children had learned to read by phonic instruction, and grapheme-phoneme correspondences were explicity taught in first grade. This method moves children gradually from simple to complex correspondences and is the most common approach to reading instruction in Spanish schools. The distribution of the subjects according to IQ and reading level is shown in Table 1.

Materials

Reading measures. The Letter, Syllable, Word, and Comprehension subtests of the TALE (Toro & Cervera 1980) were administered. In the Letter subtest the subjects read all the letters in the Spanish alphabet, presented as lower and upper-case letters; the Syllable subtest included a list of syllables with different structures (e.g. CV, VC, CVC); the Word subtest requires correct reading aloud of ordinary words; the Comprehension subtest included questions which were to be answered after reading a short passage.

Psycholinguistic parameters. A normative study was carried out on a sample of 10,000 words obtained from different texts of juvenile literature to select a sample of words for this research, taking into account the different psycholinguistic parameters of word length, word frequency, and words with different PSF. A list of nonwords was selected from a study by de Vega, Carreiras, Gutiérrez-Calvo & Alonso-Quecuty (1990).

Lexicality (i.e. the difference between words and nonwords) is considered to be a good predictor of voice onset time, because the reader knows only words and does not know nonwords. Word length was measured in term of letters, which is a better predictor of Reaction Time than the number of syllables in the word (Just & Carpenter 1984). This variable could have an effect on voice onset time and probably reflects the use of the phonological route, as reading time increases as word length increases (Just & Carpenter 1980). The cut-off point of seven or more letters was used to categorize words as long words and short words. Word frequency was measured using Juilland and Chang-Rodriguez's Spanish frequency dictionary (1964). Word frequency was assumed to influence voice onset time, as it is assumed that common words are read at a faster rate than uncommon words because common words are more familiar and thus more readily accessed than uncommon words. Words with a score of thirty one or over were considered to be frequently appearing words and those with a score lower than thirteen were considered to be infrequent. The positional syllable frequency (PSF) is the number of times that a syllable appears in a particular position in a word (first, second, final, etc.) Syllables were selected by frequency according to the Spanish Syllable-Frequency Dictionary (de Vega et al. 1990), which was constructed from a sample of 10,000 Spanish words from small paragraphs selected from a variety of texts (modern books, newspapers and magazines). PSFs were calculated for each word used in the experiment by computing the average positional frequency of syllables. Syllables were considered to be of high frequency only when they had a minimum mean frequency of occurrence of 125 per 10,000 words. Syllables that had a mean frequency of 60 per 10,000 words were considered low frequency. PSFs were measured because they influence word processing. In English orthography, bigram frequencies are usually studied (Solso & Juel 1980), but this approach is not appropriate in Spanish (Alvarez, Carreiras & de Vega 1992). Syllablic frequency is used because Spanish syllables are well-defined and this parameter has a significant influence on lexical decision tasks (Jiménez & Rodrigo 1994; de Vega & Carreiras 1989). Positional frequency effects have, in fact, been found in nonword naming (Carreiras, Alvarez & de Vega 1993), as well as in word naming (Domínguez, Cuetos & de Vega 1993). Thus, it seems that the syllable is an important sublexical access unit for Spanish readers.

In total, 96 words were used, arranged in eight sets. Each set was made up of four verbs, four nouns and four adjectives. Words in Set 1 were short and of low lexical frequency and low PSF. In Set 2, there were short words of low lexical frequency but high PSF. Set 3 contained short words of high lexical frequency but low PSF. Set 4 had short words of high lexical frequency and high PSF. Set 5 was made up of long words of low lexical frequency and low PSF. Set 6 was made up of long words of low lexical frequency and high PSF. In Set 7 there were long words of high lexical frequency and low PSF. Finally Set 8 contained long words of high lexical frequency and high PSF.

The linguistic variables of length and PSF were used to construct 96 nonwords. PSF was rigourously applied in the construction of the nonwords to ensure that these could be pronounced according to Spanish pronunciation rules. Nonwords that included context- dependent pronunciation rules were not included in the list. For instance, the letter g has a context-dependent pronunciation in Spanish because this depends on the graphemes which follow it (i.e. ‘g’ is pronounced as /g/ when it is followed by the vowels ‘a’, ‘o’ and ‘u’ and /x/ when it is followed by the vowels ‘e’, ‘i’). The 96 nonword stimuli were divided into four sets, with 24 items in each. Set 1 contained short nonwords of high PSF and Set 2 short nonwords of low PSF. Set 3 was made up of long nonwords of high PSF and Set 4 of long nonwords of low PSF.

Procedure

The naming task required the reading aloud of the stimuli which appeared one after another on the computer screen. The subject was asked to read the item as quickly as possible. The timer started as soon as the stimulus appeared on the screen and stopped when the subject uttered the first reading sound (stimulus onset time). The sound was recorded by the voice key which stopped the computer’s chronometer. The stimuli were presented in blocks of words and nonwords. It is known that when words and nonwords are presented in the same block, the most efficient strategy for carrying out the task is to use only the phonological route, as Alvarez et al. (1992), Domínguez et al. (1993) and Tabossi (1989) have suggested. Half of the subjects were presented with the block of real words first and then the nonwords. The other half received the words in the reverse order.

For this experiment the programme UNICEN was designed (Escribano 1991), together with a device which detected the sounds within the broad band of the human voice. At the beginning of the experiment, a few test items were administered to train the subjects in the type of task they had to perform. Then the first test stimulus appeared, setting in motion the chronometer, which was stopped when the subject emitted any vocal sound; after registering the RT the second item appeared on the screen. The sequencing in the administration of the stimuli was as follows: blank screen on the computer

(200 msec.), fixed point in the center of the screen (*) indicating to the subject where the stimulus would appear (400 msec.), and stimulus word or nonword. An Olivetti M211 portable computer was used, to which the sound key and the naming program were attached. The experiment was conducted in a single session. The stimuli were presented randomly within each block. In total, 96 words and 96 nonwords were presented.

Design. A mixed factorial design was used in this study. This includes two between-subjects factors (IQ and Reading Level) and the following within-subjects factors: Word Length (short and long), Word Frequency (high and low) and Word with different Positional Syllable Frequency (PSF) (high and low). For the analysis of nonwords it also includes two between-subject factors (IQ and Reading Level) and the following within-subject factors: Nonword Length (short and long), and Nonwords with different PSF (high and low).

Results

Words. A (4 × 2 × 2 × 2 × 2) IQ (<80; 81–90; 91–109; 110–140) × Reading Level (poor readers, normal readers) × Length (short, long) × Frequency (high, low) × PSF (high, low) mixed analysis of variance (ANOVA) was performed on the reaction times for correct responses for words and was calculated separately across subjects and items. The main effect of Reading Level was significant [F1 (1,124) = 9.60; $p < 0.002$, F2 (1,88) = 969.05; $p < 0.001$], which means that the naming times of the PR were longer than for NR. Nevertheless, the influence of IQ was not significant. An interaction between Word Length and IQ was significant [F1 (3,124) = 3.49; $p < 0.17$, F2 (3,264) = 14.69; $p < 0.001$]. Subsequent tests of simple main effects confirmed that Word Length had a greater effect on subjects with a low IQ, increasing latency [F (3,130) = 1.99; $p < 0.02$].

With regard to the psycholinguistic parameters, Word Length produced a main effect on voice onset time [F1 (1,124) = 34.86; $p < 0.0001$, F2 (1,88) = 1.64; $p < 0.001$]; onset time for long words was slower than short ones. Similarly, Word frequency also produced a main effect [F1 (1,124) = 23.71; $p < 0.0001$, F2 (1,88) = 5.11; $p < 0.02$], words with high frequency read more quickly than words of low frequency. PSF also produced a main effect, but only when subject were treated as a random factor [F1 (1,24) = 3.72; $p < 0.05$, F2 > 1]. The onset naming times for words with syllables of high PSF were greater than for words with low PSF.

Furthermore, an interaction between Length and PSF was found [F1 (1,124) = 28.02; $p < 0.0001$, F2 (1,88) = 8.74; $p < 0.004$]. Tests of simple

Table 2. Mean reaction time (in msecs) in word naming tasks

	IQ							
	<80		81–90		91–109		110–140	
	NR	PR	NR	PR	NR	PR	NR	PR
Word Length								
shorter								
Mean	950	1255	863	1028	841	1143	775	988
sd	246	354	127	183	239	743	141	277
longer								
Mean	1086	1483	930	1100	846	1261	783	1049
sd	373	617	191	246	247	840	160	294
Word Frequency								
high								
Mean	989	1314	895	785	842	1200	768	993
sd	286	457	166	214	227	823	144	254
low								
Mean	1047	1424	899	1092	876	1204	815	1043
sd	333	514	152	262	258	761	157	317
PSF								
high								
Mean	1010	1400	898	1077	877	1223	773	1027
sd	309	508	181	250	267	606	146	302
low								
Mean	1027	1338	909	1051	840	1182	786	1010
sd	619	463	137	223	218	727	155	269

PSF = Positional Syllable Frequency.
NR = Normal readers; PR = Poor readers.

main effect confirmed that there were differences between shorter and longer words when they were made up of syllables of low PSF [F (1,133) = 10.1; $p < 0.001$]. Table 2 shows the mean RTs and standard deviations in the word naming task as a function of IQ and psycholinguistic parameters.

Nonwords. A (4 × 2 × 2 × 2) IQ (<80; 81–90; 91–109; 110–140) × Reading Level (poor readers, normal readers) × Length (short, long) × PSF (high, low) mixed analysis of variance (ANOVA) was performed on the reaction times for correct responses for nonwords and was calculated separately across subjects and items. Again, the main effect of Reading Level was significant [F1 (1,125) = 10.78; $p < 0.001$, F2 (1,92) = 953.84; $p < 0.001$]. This means that reading onset times of PR were greater than for NR. IQ did not explain the differences between PR and NR in nonwords, although IQ produced a significant effect [F1 (3,125) = 3.59; $p < 0.01$, F2 (3,276) = 436.40; $p < 0.001$], which indicates that RT decreases as IQ increases. An IQ word length interaction was also apparent but it did not reach conventional levels of statistical significance [F1 (3,125) = 2.60; $p < 0.055$, F2 (3,276) = 13.49; $p < 0.001$].

With regard to the psycholinguistic parameters, length of nonwords had an effect [F1 (1,125) = 65.41; $p < 0.0001$, F2 (1,92) = 36.38; $p < 0.001$]. In general, latencies of naming were greater for long nonwords. Another significant effect found was that of the PSF [F1 (1,125) = 92.65; $p < 0.0001$, F2 (1,92) = 3.81; $p < 0.054$]. Similarly the Length and PSF interaction was significant [F1 (1,125) = 35.54; $p < 0.0001$, F2 (1,92) = 38.08; $p < 0.001$]. Subsequent tests of simple main effects confirmed that long nonwords formed by high frequency syllables were read significantly more slowly [F1 (1,133) = 119.2; $p < 0.001$]. Table 3 shows the mean RTs and standard deviations in the nonword naming task as a function of IQ and psycholinguistic parameters.

Lexicality. A ($4 \times 2 \times 2$) IQ (<80; 81–90; 91–109; 110–140) $\times$ Reading Level (poor readers, normal readers) $\times$ Lexicality (words, nonwords) mixed ANOVA yielded a main effect of lexicality [F1 (1,123) = 125.10; $p < 0.001$, F2 (1,184) = 307.55; $p < 0.001$]. Similarly, IQ had a significant effect [F1 (3,123) = 2.87; $p < 0.039$, F2 (3,552) = 56.62; $p < 0.001$]. Tests of simple main effect confirmed that latencies of naming increased for nonwords when the subjects have an IQ of less than 80 [F (3,130) = 5.46; $p < 0.001$].

Discussion

This study was designed to test whether there would be differences in a word naming task between good and poor readers independently of their IQs. Overall, we found that the PR group showed a longer naming latency than the NR group, for both words and nonwords. This pattern of data has also been demonstrated in other studies of languages with opaque orthography (e.g. Cirrin 1984; Ellis 1981; Laxon, Coltheart & Keating 1988; Rayner 1988; Seymour 1987; Seymour & Porpodas 1980; Share et al. 1988).

We also found that IQ did not explain the differences between NR and PR in this task. It is apparent, then, from this study, that the group of poor readers, independently of their IQ, was slower in the naming task probably

Table 3. Mean reaction time (in msecs) in naming nonwords

	IQ							
	<80		81–90		91–109		110–140	
	NR	PR	NR	PR	NR	PR	NR	PR
Nonword length								
shorter								
Mean	1257	1733	1095	1285	1024	1335	958	1224
sd	430	818	288	277	315	579	248	255
longer								
Mean	1503	2051	1270	1399	1086	1535	1066	1361
sd	558	1056	361	300	334	758	291	344
Nonword PSF								
high								
Mean	1490	2042	1276	1406	1112	1525	1087	1357
sd	556	1054	360	249	331	740	322	314
low								
Mean	1271	1742	1090	1277	1002	1345	938	1227
sd	433	820	289	278	319	597	217	286

PSF = Positional Syllable Frequency.
NR = Normal readers; PR = Poor readers.

due to difficulty with phonological processing. This result is consistent with the results of Jiménez & Rodrigo (1994) and Siegel (1989). However, this does not mean that IQ is totally independent of reading. This is shown by the interaction between length and IQ for words and nonwords and is corroborated by the fact that subjects with an IQ of less than 80 were more affected by the length of both words and nonwords. There was the same effect of IQ on the joint analysis of words and nonwords, in which subjects with an IQ of less than 80 are seen to be more affected. This effect is more pronounced in the reading of nonwords, as the interaction IQ $\times$ Lexicality shows. Thus, IQ is not completely independent of reading, although it does not explain the differences between those with and without reading disabilities.

One particularly relevant result of this study is seen in the differences found between the groups in reading nonwords. Many authors have suggested that probably the most significant measure of phonological processing is the reading of nonwords. This requires a knowledge of the sound-spelling relations, and although some researchers point out that while in a transparent orthographical system like Spanish, nonwords can be read by analogy (Sebastián-Gallés 1991), in fact, it is impossible to read them correctly without doing some kind of segmentation and without knowing the rules of letter-sound correspondence. For this reason, many researchers consider this task to be the most discriminatory in detecting reading ability (Perfetti 1986; Siegel 1986). There is also evidence that the PR have greater difficulty reading nonwords (Ehri 1975; Ehri & Wilce 1983; Siegel & Faux 1989; Siegel & Ryan 1988; Snowling 1980; Venezky & Johnson 1973; Waters, Bruck & Seidenberg 1985). What seems to be clear is the problem of PR students in phonological recoding (Perfetti 1985). Stanovich (1988a, b) has proposed that a deficit in phonological recoding is at the root of the problem of reading difficulty and in the same way, Gough & Tunmer (1986) have highlighted the importance of phonological recoding difficulties as the basis of reading problems.

In the present study, only RTs were analyzed and the results demonstrated that there were differences between poor readers and normal readers in the naming task, for both words and nonwords. In our hypothesis we predicted that the PR, independently of their IQ, would have more difficulties than normal readers in naming words under conditions that require extensive phonological computation. However, no interaction was found between reading level and psycholinguistic parameters. Nevertheless, in another study (Rodrigo & Jiménez, submitted for publication), error performance was also analyzed for the same groups in the naming task. As we expected, the poor readers committed more errors than the normal readers in word and nonword naming tasks. Also, poor readers were more affected than the normal readers by the length of nonwords. In addition, the poor readers committed more errors when they named words of low frequency. Finally, poor readers were more affected by lexicality than the normal readers, since they made more 'omission errors' for nonwords. Consequently, we concluded that error analysis is a more reliable measure than RT for analyzing phenotypic performance pattern in individuals with reading disabilities.

In summary, taking into account the data obtained in this research, we could conclude that IQ does not explain the differences between NR and PR in word recognition and that phonological processing is a more significant component of word reading ability.

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