Locus and Nature of Perceptual Phonological Deficit in Spanish Children With Reading Disabilities

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Abstract

The aims of this study were (a) to determine whether Spanish children with reading disabilities (RD) show a speech perception deficit and (b) to explore the locus and nature of this perceptive deficit. A group of 29 children with RD, 41 chronological age–matched controls, and 27 reading ability–matched younger controls were tested on tasks of speech perception. The effect of linguistic unit (word vs. syllable) and type of phonetic contrast (voicing, place and manner of articulation) were analyzed in terms of the number of errors and the response time. The results revealed a speech perception deficit in Spanish children with RD that was independent of the type of phonetic contrast and of linguistic unit.

In the last 2 decades, numerous studies have revealed that phonological processing is critically involved in reading acquisition difficulties (Fletcher et al., 1994; Foorman, Francis, Fletcher, & Lynn, 1996; I. Y. Liberman, Shankweiler, & Liberman, 1989; Stanovich & Siegel, 1994; Wagner, Torgesen, & Rashotte, 1994). Research has yet to determine why most children with reading disabilities (RD) show a phonological processing deficit. More basic perceptual subskills may provide an explanation for the difficulties in phonological processing experienced by children with dyslexia.

There is a history of controversy regarding the nature of speech perception deficits in children with RD—more specifically, whether this deficit is general auditory or speech specific. The *general auditory processing deficit hypothesis* originated in the work of Tallal and her colleagues (Tallal, 1980; Tallal & Piercy, 1973, 1974, 1975), who showed that children with language impairment and children with dyslexia showed deficits in their ability to discriminate between and to reproduce the order of rapidly presented nonspeech auditory stimuli. This hypothesis holds that the deficit in RD is a rapid temporal processing deficit. That is, children with dyslexia have trouble perceiving the rapid, unstable acoustic characteristics of speech and in particular of short events such as formant transitions (Rey, De Martino, Espesser, & Habib, 2002). Several studies have supported this first hypothesis (e.g., Farmer & Klein, 1995; Habib et al., 2002; Hari & Kiesila, 1996; Kinsbourne, Rufo, Gamzu, Palmer, & Berliner, 1991; Reed, 1989; Rey et al., 2002; Stein & McAnally, 1995).

The second hypothesis—the *speech perception specific deficit hypothesis*—suggests that phonological processing deficits are due to a difficulty with deriving phonological segments from the acoustic stream of speech (Brady, Shankweiler, & Mann, 1983; A. M. Liberman & Mattingly, 1989; Lieberman, Meskill, Chatillon, & Schupack, 1985; Mody, 2003; Mody, Studdert-Kennedy, & Brady, 1997; Studdert-Kennedy & Mody, 1995). This view is supported by studies that have shown that individuals with RD present specific problems in the perception of words and phonemes that are not problems of general auditory discrimination (Adlard & Hazan, 1998; Blomert & Mitterer, 2004; de Weirdt, 1988; Schulte-Koerne, Deimel, Bartling, & Remschmidt, 1999; Tobey & Cullen, 1984; Werker & Tees, 1987). Furthermore, there are studies that have failed to find evidence for a general auditory temporal processing deficit in children with RD (e.g., Best & Avery, 1999; Bishop, Carlyon, Deeks, & Bishop, 1999; Bradlow et al., 1999; Breier, Gray, Fletcher, Foorman, & Klaas, 2002; McAnally, Hansen, Cornelissen, & Stein, 1997; Serniclaes, Sprenger-Charolles, Carré, & Demonet, 2001; Share, Jorm, Maclean, & Matthews, 2002).

In contrast to studies of general auditory problems, several studies have shown the relevance of speech-specific perception to reading performance and reading-related skills such as phonological awareness. Numerous findings have suggested that speech perception contributes to reading skill (e.g., Csépe, Gyurkócza, & Osman-Sági, 1998; Chiappe, Chiappe, & Siegel, 2001; Godfrey, Syrdal-Lasky, Millay, & Knox, 1981; Metsala, 1997; Reed, 1989; Werker & Tees, 1987). However, there are conflicting findings about whether the contribution of speech perception to variance in reading ability is direct or indirect. On the one hand, it has been proposed that speech perception can be a precursor of phonological awareness, and some studies have shown that speech perception may influence reading indirectly, through its association with phonological awareness (McBride-Chang, 1996; McBride-Chang, Wagner, & Chang, 1997). On the other hand, it has been found that speech perception contributes directly to reading performance in young readers (Metsala, 1997) and in Spanish poor readers (Ortiz & Guzmán, 2003). Although the results of research in this area are far from conclusive, a plausible explanation may be that speech perception in children with RD is more holistic, resembling speech perception in younger, typically achieving children (Metsala & Walley, 1998). Thus, the speech perception problems of children with RD may have a negative impact on their reading.

Nevertheless, it is not entirely clear whether *all* students with dyslexia show a deficit of speech perception or whether those showing such a deficit merely represent a subgroup, given that some studies have reported the absence of differences in speech perception between reading groups (e.g., Adlard & Hazan, 1998; Elliot, Scholl, Grant, & Hammer, 1990; Manis et al., 1997; Nittrouer, 1999; Snowling, Goulandris, Bowlby, & Howell, 1986). In the majority of these studies, a subgroup of children with specific RD showed poor performance on speech discrimination tests, whereas the rest of the group performed within the average range (e.g., Adlard & Hazan, 1998; Manis et al., 1997). Whether and under which circumstances children with RD show a speech perception deficit would therefore appear to be a problem-specific issue.

Given that most but not all children with RD show a phonological processing deficit, a possible explanation for these conflicting results might be that speech perception problems are more common among children with phonological dyslexia. In Manis et al's (1997) study, the proportion of children with dyslexia who had speech perception problems was greater in the group of children with low phoneme awareness than in the children with typical phoneme awareness. However, Nittrouer (1999) did not find a speech perception deficit in poor readers with severe phonological problems. What is clear is that there are inconsistent findings about speech perception deficits in children with RD and phonological problems.

Walley, Metsala, and Garlock (2003) pointed out that more studies are needed to establish cross-linguistic validity regarding the association of speech perception, phonological processing, and reading. In Spanish-language speakers, this issue has received little attention. Because Spanish is a language with a high degree of orthographic consistency, a facilitation of the further development of both phonemic awareness and grapheme–phoneme decoding skills is to be expected. In spite of this orthographic transparency, there is some empirical evidence that children with dyslexia who are learning to read Spanish exhibit the same difficulties in phonemic segmentation that are exhibited by older English-speaking children with dyslexia (Jiménez, 1997). Some researchers have studied which of the two reading procedures (i.e., phonological vs. lexical processes) is responsible for the differences between good and poor Spanish readers and found that the cause of difficulties experienced by the poor readers seems to reside in the grapheme–phoneme decomposition procedure (Domínguez & Cuetos, 1992; Jiménez & Hernández-Valle, 2000; Rodrigo & Jiménez, 1999).

Jiménez and Ramírez (2002) replicated the finding of a dyslexic deficit in a reading-level match study analyzing subtypes. They found that both Spanish dyslexia subtype samples (i.e., phonological and surface dyslexia) showed impairment as a group relative to the chronological age–matched group on phonological awareness tasks. Furthermore, both dyslexia subtypes performed significantly worse than the reading level–matched group on the measures of phonological awareness. All these findings in native Spanish readers reinforce the hypothesis that the basis of reading problems is a difficulty in phonological processing. Nevertheless, the reasons why Spanish children with RD show a phonological processing deficit are yet to be determined. It would therefore seem necessary to examine perceptive processes such as speech perception in Spanish-language speakers with RD.

Another explanation for the divergent findings is related to the linguistic features of stimuli used to evaluate speech perception. All studies cited earlier in which no reading group differences were found obtained their results from the perception of high-frequency, monosyllabic words (e.g., Adlard & Hazan, 1998; Elliot et al., 1990; Manis et al., 1997; Snowling et al., 1986). In contrast, when the stimuli were pseudowords and low-frequency words, perception problems did occur (Snowling et al. 1986). It would therefore seem that the linguistic features of stimuli provide a possible explanation of these differing patterns of results. In word speech perception, both the lexicon and contextual information may allow compensation for inaccurate sublexical phonological representations (Ramus, 2001)—a process that may also occur in children with RD when they listen to frequent words in perception tasks. Chiappe et al. (2001) examined the relationship between speech perception and lexical information and found that lexical information was used by both good and poor readers to resolve ambiguities in word perception. Therefore, deficits in speech perception in children with RD may not be shown in word perception, but could become apparent in sublexical segment perception. According to the major models of speech perception, auditory word recognition requires finding a lexical representation that matches the sublexical sequence of phonemes (McClelland & Elman, 1986; Norris, McQueen, & Cutler, 2000). That is, the acoustic information is organized into sublexical units before the lexicon is accessed.

Furthermore, several lines of evidence from speech perception and production suggest a distinction between lexical and sublexical phonological representations. For example, long before infants learn their first words, they show categorical perception of phonemes (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). This finding can only be understood if one assumes that infants show sublexical phonological representations, which are distinct from representations of words. Traditionally, it has been assumed that the core deficit of students with dyslexia is at the level of lexical phonological representation. Nevertheless, the idea of a deficit in the sublexical phonological representation that is critically implicated in the phonological route would also seem plausible. This hypothesis of a sublexical phonological deficit could account for the phonological awareness deficit in students with dyslexia, because these tasks require them to pay attention to and operate with sublexical representations (syllables, rimes, or phonemes), and it would also explain the poor results of children with RD in categorical perception tasks (e.g., Godfrey et al., 1981; Werker & Tees, 1987).

Cross-linguistic research has indicated that properties of the sublexical units seem to be dependent on the phonological properties of the language and has revealed the existence of language-specific mechanisms in speech segmentation (Sebastián-Gallés, 1996). English speakers seem to segment the speech signal at the onset of every strong syllable before accessing the lexicon (Cutler, 1990; Cutler & Norris, 1988), whereas French, Catalan, and Spanish speakers appear to use a syllabic segmentation strategy (Bradley, Sánchez-Casas, & García-Albea, 1993; Mehler, Dommergues, Frauenfelder, & Seguí, 1981; Sebastián, Dopoux, Seguí, & Mehler, 1992). In Mehler et al.'s (1981) study, French speakers had to monitor for either consonant-vowel (CV) or CVC sequences in bisyllabic words that started with CV or CVC. When they had to detect CV in CV words they reacted faster than when they had to detect CV in words starting with CVC, and the reverse occurred when participants had to detect CVC sequences. The results therefore show an interaction of target type and syllable structure, indicating that monitoring in the task was faster when there was a match between target and syllable than when there was no match. This result provides support for the hypothesis that the syllable is a unit of segmentation in French—a language with clearly marked syllabic structures and fixed accent.

Cutler, Mehler, Norris, and Seguí (1983, 1986) tried to replicate the experiments of Mehler et al. (1981) in English, but found no evidence for any syllabic effect. Bradley et al. (1993) found a strong interaction of target type and syllabic structure in Spanish, whereas their results for English showed an overall advantage for CVC targets, but no interaction. Sebastián et al. (1992) found a syllable match effect for Catalan with second-syllable stress words, and syllabic effects in both stressed and unstressed syllables in Spanish when participants' response times were slowed by a secondary task. The results of Pallier, Sebastián-Gallés, Felguera, Christophe, and Mehler (1993), who used a different technique, also support the hypothesis that the syllable is a unit of segmentation for French and Spanish. Spanish is a language with clear syllables and a small inventory of syllables (19 structures). The clear syllabification of French and Spanish might encourage syllabic strategies in speech segmentation. These findings should therefore be taken into account in the explanation of phonological problems in Spanish speakers with RD. As the locus of the speech perception deficit in Spanish speakers with RD has yet to be determined, we must ask whether Spanish speakers with RD show a syllable perception deficit.

In syllable perception, a limited number of distinctive features serve to contrast phonemes along a number of dimensions. Phonemes can be described by their phonetic features: voicing and place and manner of articulation. Distinctive features are not, however, absolute, but relational and contrastive. Certain phonological features could be misrepresented or underspecified at the sublexical level in children with RD. Mody (2003) concluded that poorly defined phonological categories may interfere with the development of grapheme–phoneme correspondences that are essential to learning to read.

Several studies on speech perception in students with dyslexia have focused on the perception of sublexical contrasts (e.g., /ba/ versus /da/ and /da/ versus /ga/). For example, Godfrey et al. (1981) showed significant differences between children with dyslexia and matched controls in the identification and discrimination of voiced stop consonants that differed in place of articulation. Csépe et al. (1998) compared children with dyslexia and age-matched controls and also found that the most consistent deficit was in the processing of the place of articulation. Similar findings have been obtained by Werker and Tees (1987), Reed (1989), and de Gelder and Vroomen (1998). Maassen, Groenen, Crul, Assman-Hulsmans, and Gabreels (2001) compared children with developmental dyslexia to two control groups (age matched and reading level matched) on identification and discrimination functions of the features of voicing and place of articulation. With respect to discrimination tasks, children with dyslexia showed poorer performances in both voicing and place of articulation contrasts than both age-matched controls and reading level–matched controls. In Breier et al.'s (2001) study, children with RD also showed a deficit in voicing perception that was evident in inconsistent labeling of tokens in a voice-onset-time (VOT) (/ga/–/ka/) series. Nevertheless, Post, Foorman, and Hiscock (1997) did not find differences between reading groups in the perception of consonants that differed in voicing. These findings suggest an inconsistency in the phonetic classification of auditory cues for the students with dyslexia, but it is not clear which phonetic contrast is more difficult for children with RD.

Serniclaes et al. (2001) compared syllable discrimination within and across phonemic boundaries, and found that individuals with dyslexia did poorly on between-category discrimination but did better on discriminating within-category differences than typically reading controls. These results suggest that speech perception in dyslexia is less categorical and based more on purely acoustic cues. There is also the view that it is not so much a question of the *kind* of phonetic contrast, but of the *amount* of acoustic information present for the contrast, such as the number of formant frequencies that differ between stimuli (e.g., Godfrey et al., 1981; Kraus et al., 1996). Nevertheless, languages vary in the size and shape of their phonemic inventories, which has effects on the number of meaningful phonemic contrasts in each language. Thus, the phonetic contrasts implicated in phonological deficits could be dependent on language. To date, there have been no studies in relation to Spanish in which researchers have examined whether some of the distinctive features that serve to contrast phonemes might indeed be critically involved in the phonological deficits of Spanish speakers with RD.

The current study, therefore, extends previous knowledge by exploring the speech perception specific deficit hypothesis in Spanish speakers with RD. There are three principal aims:

1. to determine whether Spanish children with RD show a speech perception deficit;
2. to examine the locus of the deficit—that is, whether the deficit is present at the sublexical level or at the lexical level, or both. Our hypothesis is that the Spanish children with RD show a sublexical perception deficit that emerges in syllable perception;
3. to examine the performance of these children in discriminating phonological contrasts.

To this end, we compared the performance of Spanish children with RD to two control groups, one matched for reading level (RL group) and one for chronological age (CA group). This design allows not only for a comparison within chronological age across reading levels, as in the two-group approach, but also for the comparison of children of different chronological ages with the same reading level. When only two groups with different reading levels are compared, any differences found between them could be interpreted as a product rather than as a cause of such differences (Bryant & Goswami, 1986). Goswami (2003) argued that studies of dyslexia require both chronological age (CA) and reading level (RL) controls:

> Dyslexic children will typically have had 2–3 years more tuition in reading than RL controls and will also have higher mental ages. If differences are found in a cognitive task compared with both CA and RL controls, dyslexic children's development is significantly slower than it should be given their developmental level and given the level of reading attained. This suggests a causal link with dyslexia (a training study is then required to test the causal hypothesis). (p. 535)

In the present study, this design allows us to examine whether Spanish children with RD show a deficit in speech perception that could be causally linked with RD. We hypothesized that if the performance of children with RD on the speech perception test was inferior compared to that of reading-age–matched, nondisabled younger controls and chronological-age–matched controls, then the existence of a speech perception deficit causally linked with RD could be accepted. In contrast, if the performance of children with RD on the speech perception test was inferior compared to chronological-age–matched controls, but similar compared to reading-age–matched, nondisabled younger controls, this result would tell us nothing about the causes of RD. In this case, the results would tell us only that the speech perception development in Spanish children with RD is significantly slower than it should be given their developmental level.

With respect to the second aim—that is to say, the locus of deficit—our prediction was that the children with RD would show greater difficulties in syllable discrimination than the two control groups, but that their performance, although lower than that of the CA group, would be similar to that of the RL group in word perception, because the lexicon may operate as a compensatory mechanism for resolving ambiguities in this task. The CA group might be seen to have better word perception because of their greater experience in reading. That is, we expected a sublexical perception deficit and a developmental lag in word perception for the RD group. To explore the nature of the speech perception deficit, we compared the performance of the three groups in discriminating phonological contrasts on place of articulation (e.g., /ta/ vs. /pa/), on voicing (e.g., /pa/ vs. /ba/), and on manner of articulation (e.g.,

/ma/ vs. /ba/). A hypothesis based on the notion that Spanish children with RD have poorly defined phonological categories would predict that there would be differences in performance on some phonological contrasts between RD and control groups.

Method

Participants

A group of 97 children, all native speakers of Spanish, was selected (52 boys, 45 girls) with an age range of 7 to 10 years ($M = 109.9$, $SD = 12.5$). All children were Spanish and had no communicative competence in English or other languages. The children came from urban areas and from average socioeconomic backgrounds and attended second ($n = 27$) and fourth ($n = 70$) grades of state primary schools. These children were recruited from six elementary schools in two small cities. They had learned to read by phonics instruction, and grapheme–phoneme correspondences had been explicitly 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. According to school records, all children had typical hearing ability. The children's IQ scores were above 90 on the nonverbal *g* factor of Cattell and Cattell (1950/1995, 1950/2001). Children who had sensory deficits, acquired neurological deficits, and other problems that are traditionally used as exclusionary criteria for learning disabilities were excluded.

The children were classified into three groups according to reading level on the Pseudoword Reading test and the Word Reading test of the *Standardized Reading Skills Test* (PROLEC; Cuetos, Rodríguez, & Ruano, 1996) as follows:

1. An experimental group of 29 children (19 boys, 10 girls) with reading disabilities (RD), who had a percentile score of < 25 on the Pseudoword Reading test and read at the same grade-equivalent level of second grade on the Word Reading test (age $M = 117.6$, $SD = 6.5$);
2. A control group of 41 nondisabled readers (20 boys, 21 girls) matched in chronological age (CA) with the RD group (age $M = 117.6$, $SD = 5.6$); and
3. A control group of 27 younger children (13 boys, 14 girls) at the same reading level (RL) as the RD group (age $M = 91.6$, $SD = 4.2$).

There were no significant differences among groups in the distribution of the participants as a function of gender, $\chi^2(2, N = 97) = 3.54$, $p = .17$. Moreover, the results showed that there were no significant differences among groups in IQ, $F(2, 94) = 1.79$, $p = .17$, but there were differences in verbal working memory (VWM), $F(2, 94) = 5.44$; $p < .01$. Post hoc comparisons of these means showed that children with RD had significantly lower scores in VWM than nondisabled readers matched on age, $F(1, 95) = 10.9$; $p < .001$, and younger nondisabled readers at the same reading level, $F(1, 94) = 8.99$; $p < .01$. The means and standard deviations for IQ, age, VWM, and reading measures by groups are presented in Table 1.

Design

A three-group design was used in this study. In a three-group design, there are two control groups in addition to the target group—one matched for reading level (RL group) and one matched for chronological age (CA group). For the analysis of speech perception achievement, we compared the three groups on accuracy and response time of correct responses (measured from stimulus onset until button press response). For the analysis of locus of speech perception deficit, we included group (RD, CA, RL) as a between-participants factor and unit (syllable, word) as a within-participants factor. Accuracy and response time for words and syllables were the dependent variables. Finally, to analyze the distinctive features of phonemes that are critical for speech perception in children with RD, the design included group as the between-participants factor and phonetic feature (manner of articulation, place of articulation, voicing) as a within-participants factor. The dependent variables were accuracy and response time of correct responses for each contrast.

Materials

Speech Perception Test. The perceptive processing of speech was evaluated by a computerized Speech Perception test (SPT) that is included in the SICOLE test battery (Jiménez et al., 2002). This is a computerized system for the diagnosis of RD in the Spanish language that assesses the various linguistic and cognitive processes involved in reading. The aim of the SPT is to evaluate the listeners' ability to discriminate consonant contrasts in the context of syllable and word pairs. The stimulus pairs were recorded by a phonetically trained female Spanish speaker. The test includes 21 identical pairs; 22 pairs are alike in all respects except in the place of articulation of the initial consonant; 8 pairs differ only in the manner of articulation of the initial consonant; 6 pairs are alike in all respects but voicing; and 16 pairs differ in two phonetic features. The interstimulus interval (ISI) was 1 second, and the maximum intertrial interval was 5 seconds.

In the SPT, children are required to listen through headphones to stimuli presented on a computer, decide whether the two stimuli are the same or different, and then to left- or right-click the mouse, respectively. Correct and incorrect responses and the response time in ms were registered. The SPT includes three tasks:

1. *Phonological word discrimination*. In this task, the children listened to two words with high sound proximity but different meaning (e.g., /toro/–/loro/, *bull–parrot*). There were 29 pairs of words presented.

TABLE 1
Means and Standard Deviations on IQ, Age, Working Memory, and Reading Measures by Group

Measure	RD *M*	RD *SD*	RL *M*	RL *SD*	CA *M*	CA *SD*
IQ	112.0	16.0	111.0	9.8	117.6	18.3
Age	117.6	6.5	91.6	4.2	117.6	5.6
Working Memory	2.6	0.8	2.9	0.7	3.3	0.8
Word Reading						
Raw scores	28.6	1.26	29.6	0.62	29.8	0.52
Percentile	40		40		99	
Pseudoword Reading						
Raw scores	25.1	2.70	29.2	0.65	29.7	0.46
Percentile	10		70		99	

Note. RD = children with reading disabilities; RL = controls matched on reading level; CA = controls matched on chronological age.

2. *Syllabic phonological discrimination, consonant-vowel (CV)*. A total of 26 pairs of syllables were presented (e.g., /pa/–/ba/).

Syllabic phonological discrimination, consonant-consonant-vowel (CCV). This task consists of 18 items (e.g., /pra/–/tra/).

The SPT displayed strong reliability for accuracy (Cronbach's alpha = .91) and for response time of correct responses (Cronbach's alpha = .88). To control for guessing rates, a derived score was calculated by subtracting the proportion of incorrect responses from the proportion of correct responses. This derived score was used in all accuracy analyses (range = 0–1).

Standardized Reading Skills Test. The *Standardized Reading Skills Test* (PROLEC; Cuetos et al., 1996) includes various reading subtests. We administered the Word Reading and Pseudoword Reading subtests. These subtests require the correct identification of 30 ordinary words and 30 pseudowords with different linguistic structures (CCV, CVV, CVC, CCVC, CVVC, VC). Correct responses were assigned a score of 1; incorrect responses were assigned a score of 0. Both subtests measure the accuracy of the responses (i.e., number of correct responses). For each subtest, the raw score is the number of items that can be read correctly. Percentile scores on the Word Reading subtest were used to match RD and RL groups. There are ceiling effects on the PROLEC Word Reading measure in fourth grade. Cuetos et al. reported an alpha coefficient of .92, and they used the teacher's ratings of reading ability as validity criteria. Teachers were asked to rate reading ability on a 10-point scale, ranging from *low ability* = 1 to *high ability* = 10. All correlations were significant statistically between reading measures and teachers' ratings, $r = .32$; $p < .001$.

Culture Fair Intelligence Test. The *Culture Fair* (or *Culture Free*) *Intelligence Test*, also known as a measure of *g* (Scale 1 and 2, Form A; Cattell & Cattell, 1950/1995, 1950/2001), allows a measurement of general mental capacity without interference from cultural bias. We administered Scale 1 to the RL group. This form includes the following subtests: Substitutions, Classifications, Mazes, and Similarities. Form A of Scale 2 was administered to the RD and CA groups. It includes four subtests: Series, Classifications, Matrixes, and Conditions. Cattell and Cattell used the split-half method to calculate reliability and reported a correlation coefficient of .86. Scores on the *School Aptitude Test* (TEA-1; Seisdedos, De la Cruz, Cordero, & González, 1991) were used as validity criteria. The TEA-1 has three factors: Verbal, Reasoning, and Calculation. A correlation coefficient of .68 was found between the *g* factor measure and the TEA-1 test.

Verbal Working Memory. To assess the children's verbal working memory (VWM), we administered the task used by Siegel and Ryan (1989). This task was modeled on the procedure developed by Daneman and Carpenter (1980). The children heard sentences that had the final word missing. The task was to supply the missing word and then to repeat all the missing words from the set. There were three trials at each level or set size (2, 3, 4, and 5 words). Task administration was stopped when the child failed all the trials at one level.

Procedure

Six experienced psychologists carried out the administration of the reading test, VWM tests, IQ test, and speech perception tests using the SICOLE computer software. They were blind regarding the group status of the children. The assessments were carried out individually during four sessions per participant in quiet, well-lit rooms provided by the schools that the children attended. The tasks were presented randomly, each being preceded by two examples to ensure that the children understood the instructions.

Results

Computerized Speech Perception Test

The comparison between children with RD, nondisabled readers matched for age, and younger nondisabled readers matched for reading level was compromised somewhat by the fact that the RD group had a lower VWM mean than the control groups. To control for this difference, two one-way analyses of covariance (ANCOVAs) in which VWM served as the covariate should have been conducted across the groups for accuracy differences. Prior to conducting each ANCOVA, however, it was necessary to test the goodness assumption of using ANCOVA. This assumption was not met, and thus ANCOVA was not used.

An ANOVA was performed on speech perception accuracy as a dependent variable, calculated separately across participants and items. This analysis yielded a main effect of group, $F_1(2, 79) = 10,80$, $p < .001$; $F_2(2, 68) = 72.67$, $p < .001$. Subsequent analysis revealed that the CA group and the RL group scored significantly higher than the RD group, $F(1, 79) = 21.52$, $p < .001$, and $F(1, 79) = 5.83$, $p < .01$, respectively. However, there were no differences between RL and CA groups, $F(1, 79) = 2.85$, $p = .095$.

An ANOVA was performed on the response time for correct responses as a dependent variable, calculated separately across participants and items. Response time analysis showed a main effect of group, $F_1(2, 79) = 5.62$, $p < .01$, $ES = 0.125$; $F_2(2, 68) = 16.2$, $p < .001$. As with the accuracy analysis, there were significant differences between the CA group and the other two groups: RL group, $F(1, 79) = 5.58$, $p < .05$, and RD group, $F(1, 79) = 15.6$, $p < .001$. The differences between the RL and RD groups were not significant, $F(1, 79) = 0.21$; $p = .651$. Table 2 presents means and standard deviations for the three groups on measures of accuracy and response time for correct responses in the SPT, syllable discrimination tasks, and word tasks.

Lexical and Sublexical Units

A second analysis was conducted to examine the locus of the perceptual phonological deficit found in the RD group. To this end, 26 pairs of words and 26 pairs of syllables (CV) were selected. The group with RD had a lower VWM mean than the control groups. To control for this difference, two one-way ANCOVAs in which VWM served as the covariate were conducted across the groups only for accuracy differences by linguistic unit (syllable, word). Prior to conducting each ANCOVA, we had to test the goodness assumption of using ANCOVA. If this assumption was not met, then ANCOVA was not used.

A 3 × 2 Group (RD vs. CA vs. RL) × Unit (syllable vs. word) ANOVA was performed with accuracy as a dependent variable, calculated separately across participants and items. Also, a mixed ANOVA was used with the response time for correct responses as a dependent variable.

The ANOVA yielded a main effect of group, $F_1(2, 79) = 10.60$, $p < .001$, $ES = 0.212$; $F_2(1, 52) = 73.17$; $p < .001$, although no main effect of lexical unit was found, $F_1(1, 79) = .90$, $p = .346$, $ES = 0.011$. A subsequent test of simple main effects revealed that the RL group scored significantly higher than the group with RD, $F(1, 79) = 5.59$, $p < .05$. Also, the CA group scored higher than the RD group, $F(1, 79) = 21.14$, $p < .001$. We did not find differences between the CA and RL groups, $F(1, 79) = 2.90$, $p = .092$.

The analysis of the response times yielded a main effect of group, $F_1(2, 79) = 5.62$, $p < .01$, $ES = 0.125$; $F_2(1, 52) = 19.23$, $p < .001$. A subsequent test of simple main effects revealed that the CA group was faster than the RD group, $F(1, 79) = 9.92$, $p < .01$, and than the RL group, $F(1, 79) = 5.58$, $p < .05$. There was no difference between RL and CA groups, $F(1, 79) = 0.21$, $p = .651$. We did, however, find a main effect of unit, revealing that word perception was faster than syllable perception, independently of group, $F_1(1, 79) = 25.96$, $p < .001$, $ES = 2.47$; $F_2(1, 52) = 66.14$, $p < .001$.

Phonetic Features

A third analysis was directed at examining whether phonetic features affected the performance of children with RD on speech perception tasks. With this objective, items were selected and grouped in three blocks. The items in the first block were pairs of syllables and words whose initial phonemes were identical in manner of articulation and voicing but differed in place of articulation (*place of articulation contrast*). In the second block, the initial phonemes of the pairs were alike in all respects except their manner of articulation (*manner of articulation contrast*). In the last block, phonemes were alike in all respects but voicing (*voicing contrast*). Table 3 presents means and standard deviations for each phonetic contrast in the three groups.

TABLE 2
Means and Standard Deviations of Speech Perception Accuracy and Response Time Measures by Group

	RD		RL		CA	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*
Speech Perception						
Accuracy	0.51	0.34	0.68	0.22	0.79	0.12
Response time	826.10	524.92	776.97	371.44	528.10	134.01
Syllable Perception						
Accuracy	0.49	0.38	0.67	0.37	0.80	0.20
Response time	1021.08	798.82	901.93	546.30	633.97	205.29
Word Perception						
Accuracy	0.56	0.30	0.70	0.13	0.78	0.11
Response time	631.11	347.36	652.00	355.43	422.25	155.35

Note. RD = children with reading disabilities; RL = controls matched on reading level; CA = controls matched on chronological age.

TABLE 3
Means and Standard Deviations of Phonetic Contrast Discrimination Measures by Group

	RD		RL		CA	
Measure	*M*	*SD*	*M*	*SD*	*M*	*SD*
Manner of articulation						
Accuracy	0.43	0.34	0.58	0.26	0.70	0.13
Response time	761.48	594.92	571.27	347.36	476.05	200.01
Place of articulation						
Accuracy	0.50	0.32	0.65	0.27	0.80	0.19
Response time	853.89	665.61	760.06	447.20	488.19	239.51
Voicing						
Accuracy	0.33	0.28	0.45	0.22	0.44	0.21
Response time	807.21	634.2	585.5	383.72	454.50	276.97

Note. RD = children with reading disabilities; RL = controls matched on reading level; CA = controls matched on chronological age.

A 3 × 3 Group (RD vs. CA vs. RL) × Phonetic Feature (manner of articulation, place of articulation, voicing) MANOVA was performed with accuracy and response time for correct responses as dependent variables, calculated separately across participants and items. The analysis of accuracy yielded a main effect of group, $F_1(2, 79) = 10.49$, $p < .001$, $ES = 0.210$; $F_2(2, 12) = 15.53$, $p < .01$. Subsequent analysis revealed that the RL group scored significantly higher than the group with RD, $F(1, 79) = 6.52$, $p < .05$. The same difference was found between the CA group and the RD group, $F(1, 78) = 15.87$, $p < .001$. There were no differences between the RL and CA groups, $F(1, 79) = 2.05$; $p = .156$. The analysis of the accuracy also yielded a main effect of phonetic feature, $F_1(2, 78) = 22.76$, $p < .001$, $ES = 0.369$; $F_2(2, 12) = 13.2$, $p < .001$. All groups scored lower on voicing contrasts than on both manner of articulation contrasts, $F(1, 79) = 21.77$, $p < .001$, and place of articulation contrasts, $F(1, 79) = 31.02$, $p < .001$. There were also differences between manner of articulation and place of articulation contrasts, $F(1, 79) = 8.56$; $p < .01$.

The analysis of response times yielded a main effect of group, $F_1(2, 79) = 3.52$, $p < .05$, $ES = 0.82$; $F_2(2, 12) = 14.27$, $p < .01$. Tests of simple main effect confirmed that there were differences between the CA and RD groups, $F(1, 79) = 7.04$, $p < .01$. We did not find differences between RL and RD groups, $F(1, 79) = 1.67$, $p = .2$, or RL and CA groups, $F(1, 79) = 1.12$, $p = .293$. A main effect of phonetic feature was found, $F_1(2, 78) = 5.97$, $p < .01$, $ES = 0.058$; $F_2(2, 12) = 9.07$, $p < .05$. All groups were slower on place of articulation contrasts than on voicing contrasts, $F(1, 79) = 8.59$, $p < .01$, and manner of articulation contrasts, $F(1, 79) = 7.55$, $p < .01$. There were no differences between voicing contrasts and manner of articulation contrasts, $F(1, 79) = .07$, $p = .796$.

Discussion

The current study was designed to address the speech perception specific deficit hypothesis in Spanish speakers with RD. It has addressed three main issues. First, we sought to determine whether Spanish students with RD presented a speech perception deficit. Second, we examined the locus of the deficit—that is, whether the Spanish children with RD showed greater difficulties in syllable discrimination than the two control groups. Third, we examined the phonetic features that affected the performance of children with RD on the speech perception tasks. The results were different for performance on accuracy and response time measures. Because the response time measures showed a strong maturational trend, contaminating any reading-level comparison, we first discuss the results for accuracy and then the results for response times.

With regard to the first issue, the results of the present study revealed that Spanish children with RD performed significantly worse than their chronological-age and reading-age controls on the accuracy of speech perception tasks. As expected, our results support the existence of a speech perception deficit in Spanish children with RD. They are consistent with the results of studies in other languages that have shown that children with RD and phonological impairment present a speech perception deficit (e.g., Adlard & Hazan, 1998; de Gelder & Vroomen, 1998; Manis et al., 1997). This deficit in Spanish speakers with RD might be causally linked with RD because the RD group performed less well than both control groups. There has in fact been a training study in speech perception in Spanish speakers with RD showing that speech perception is an effective component in phonological training (Ortiz, García, & Guzmán, 2002). Based on the results from this previous study, the current findings may be interpreted in terms of the idea that the Spanish children with RD show a speech perception deficit that is causally linked to reading difficulty.

With regard to the second issue, syllable and word perception were examined to determine whether the speech perception deficit is at the level of sublexical phonological representations or at the lexical level. The Spanish children with RD performed more poorly than age-matched nondisabled readers and younger readers matched for reading level independently of whether the stimuli were words or syllables. Thus, the present results fail to support our prediction of a syllable perception deficit and a developmental lag in word perception for the RD group. Furthermore, syllable perception was not more difficult than word perception for Spanish children independently of age and reading level. These findings are congruent with those reported in a study by Jiménez and Ortiz (1994) that revealed that Spanish children who had not yet started learning the alphabetic code could analyze or divide words into syllables (the percentage of success achieved was 91.2%). Furthermore, in a second experiment in their study, Jiménez and Ortiz did not find differences between groups on this task when comparing three groups of Spanish children who had had reading instruction for 2 years but showed different levels of acquisition of the alphabetic code (typical readers, readers with disabilities, and nonreaders). The failure to find support for our prediction of a syllable perception deficit can be explained by the fact that in Spanish, syllables are well defined, and syllable boundaries are always clear. Even though the current study does not address the perception of isolated phonemes, it is possible to speculate that the speech perception deficit in Spanish children with RD may be sublexical but located at the subsyllabic level, as the present results revealed that they are not able to discriminate between syllable and word pairs that differ in terms of a single phoneme. In fact, in Jiménez and Ortiz's study, the pre-readers were unable to divide syllables into their phonemes, and the good readers differed from the RD and nonreader groups on tasks that required them to segment the syllable into smaller units. If their ability to discriminate particular phonemes is unreliable at a perceptual level, this may cause difficulty in both phonemic awareness tasks and the automation of the one-to-one grapheme–phoneme correspondences required to decode Spanish.

The third goal of this study was to analyze the distinctive features of phonemes that are critical for speech perception in children with RD. Our clearest finding is that children with RD showed a deficit in discriminating phonemes independently of phonetic contrast (place of articulation, manner of articulation, or voicing). The performance of Spanish children with RD was lower than that of age-matched nondisabled readers and reading level–matched younger readers in discriminating items whose initial phonemes are identical in all respects but one phonetic feature. This finding supports the hypothesis that Spanish children with RD have poorly defined phonological categories. Our results are consistent with the findings of earlier studies showing that children with RD performed less well than age-matched controls on the identification or discrimination of phonetic contrasts (e.g., Breier et al., 2001; Csépe et al., 1998; de Gelder & Vroomen, 1998; Godfrey et al., 1981; Maassen et al., 2001; Reed, 1989; Werker & Tees, 1987). The stimuli in the current study were syllable pairs and word pairs that were alike in all respects except in a phonetic feature of the initial consonant. If establishing correspondences between acoustic signals and phonetic segments requires contrasting the phonetic features that differentiate phonemes, we speculate that the cause of the speech perception deficit of the RD group might be at the phoneme level. Overall, our results suggest that a deficit in the phonetic classification of phonemes might be causally linked with RD, but they do *not* tell us which phonetic contrast is more difficult for children with RD. For all groups of Spanish speakers, the voicing contrasts represented a greater challenge than the manner of articulation and place of articulation contrasts, and the manner of articulation contrasts were more difficult than were those of place of articulation. It is important to note that if a rapid temporal processing deficit were present in Spanish children with RD, a deficit only in the place of articulation contrast should be observed in this group. It has been suggested that place contrasts are especially difficult because of the transience of the acoustic cues signaling this phonetic dimension, and their perception requires the integration of acoustic events over a relatively short period of time. Instead, in the present study, the place of articulation contrast in stop consonants was the easiest for all groups, and the deficit of the RD group was independent of contrast type. It follows, therefore, that the present results are more compatible with a *phonological coding deficit* than with a *temporal processing deficit*.

Consistent with the developmental findings on speech perception, we did not find differences between typical reader groups on speech perception accuracy. There is evidence that children's phonological representations shift from larger structures to more segmental, phonemic components throughout childhood (Chiappe et al., 2001; Fowler, 1991; Metsala & Walley, 1998). It has been proposed that this gradual segmental restructuring of lexical representation begins in the second year of life and continues up until at least 7 years of age (Nittrouer, Studdert-Kennedy, & McGowan, 1989; Studdert-Kennedy, 1987). This implies that both typical reader groups with an age range of 7 to 10 years had completed the segmental restructuring process of lexical representation.

When response times were analyzed, we found that the RD group children were slower than their chronological-age controls and were as slow as the younger readers matched for reading level. This was a consistent result throughout all analyses. The speech perception deficit hypothesis as a cause of RD could not be explored with response time measures because the effects of neurological maturation on speed of responses contaminated any reading-level comparison. In such comparisons; older children are strongly advantaged, because the baseline components of RT (response preparation, execution, etc.) are faster in older participants (Kail, 1991). However, the current results showed that older children with RD were as slow as the younger good readers and slower than their chronological-age peers. This finding is supported by studies suggesting that that individuals with dyslexia are slower than typical readers when processing auditory information (Breznitz, 2003; Breznitz & Meyler, 2003; Farmer & Klein, 1993; Tallal, Miller & Fitch, 1993; Waber et al., 2001). The results further indicate that children with RD require more time for discrimination of the acoustic recoding elements in the brain than typical readers. In the present study, the speech perception differences between typical readers and children with RD appeared both in accuracy and processing time. This finding suggests that a primary source of phonological deficits to be found among children with RD may be implicit phonological representation. This interpretation is in line with the wealth of data indicating that impaired phonological processing is the most salient word reading deficit among individuals with dyslexia (Fletcher et al., 1994; Foorman et al., 1996; I. Y. Liberman et al., 1989; Stanovich & Siegel, 1994; Wagner et al., 1994).

The findings in this study must be viewed cautiously, in that only variables of speech processing were examined, namely, linguistic unit (syllable vs. word) and phonetic features. The possibility that individuals with RD will perform more poorly than nondisabled participants on variables of speech processing not examined in this study cannot be overlooked. Current research on speech perception has focused exclusively on data obtained from behavioral measures, namely, response time and response accuracy. These measures provide information about the perception process at the conclusion of the processing sequence. Therefore, they cannot specify *all* of the covert component operations that contribute to the speech perception process. Another limitation of this study involves the number of items in each phonetic contrast task. In future research, the number of items for each phonetic contrast will have to be increased. Nevertheless, from a practical point of view, the SPT not only helps us to reach a functional diagnosis of the ability to perceive speech, but may also provide guidelines for phonological intervention in children with RD.

In conclusion, the findings of this study have provided some evidence for the following conditions:

1. the existence of a speech perception deficit in Spanish children with RD that is independent of the type of phonetic contrast and of linguistic unit;
2. the misrepresentation or underspecification of phonetic features in Spanish children with RD;
3. a slower speech processing rate in Spanish children with RD than in their chronological-age controls.

These findings have implications for remedial practice. Our results have suggested that phonological programs that include training in speech perception are needed for children with RD. Possible tasks that could be used to train children in speech perception are phoneme discrimination in words or syllables (e.g., the trainer presents a set of five words orally, of which only one is different, e.g., pala, pala, pala, *tala*, pala; and the children put their hands up when they hear the different word); word pair categorization (e.g., the children hear a pair of words and give a response of *same* or *different*); word phonological identification (e.g., the children listen to a word , e.g., /pala/, and have to match it with one of two different pictures, e.g., pala–bala). Syllable and word pairs should differ in terms of a single phoneme. This phoneme would be identical in all respects but one phonetic feature. If place of articulation contrasts are easier than other types of contrasts for all children, then it would make sense to begin speech perception training with the discrimination of syllable or word pairs that differ in place of articulation, then progressing to manner of articulation contrasts, and finally working with voicing contrasts. We believe that this type of training would help children with RD in the phonetic classification of phonemes and that it would allow them to finalize the segmental restructuring process of phonological representation of words. The automation of grapheme–phoneme correspondences and word reading would thus be facilitated. Ortiz et al. (2002) showed that a training program that integrates speech perception, phoneme awareness, and instruction in sound–symbol connections improved word reading in Spanish children with RD. Future research in other languages should explore the values of training in speech perception abilities to improve reading in children with dyslexia.

The issue of locus and nature of the speech perception deficit in dyslexia should be further investigated. The phonological level of representation also embodies patterns of phoneme assimilation and alternation, stress, intonation and rhythm. Some of these areas could be relevant in children with RD, and they should be included in the research agenda on locus of speech perception deficit in dyslexia.

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