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Dichotic Listening CV Lateralization and Developmental Dyslexia*

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ABSTRACT

The present study was carried out on a sample of 125 right-handed boys who are described as follows: 50 boys with dyslexia, 50 controls of a similar age, and 25 controls according to reading level. Using an objective procedure based on regression, we selected three subgroups from among the poor readers: children with difficulties in the lexical pathway (surface dyslexics), children with difficulties in the sublexical pathway (phonological dyslexics), and children with problems in both pathways (mixed dyslexics). When the performances of these children on a dichotic listening task with CV syllables as stimuli were compared, it was found that although the children with dyslexia obtained lower lateralization indices than did the controls, the differences were only clearly significant when the most severe cases of phonological dyslexia were selected.

The assumed sensitivity to dichotic listening used to evaluate hemispheric lateralization for language together with the non-invasive nature of this method have meant that this technique is often used in studies on developmental dyslexia. Since its discovery by Broadbent (Broadbent, 1956), the technique has been implemented with several types of auditory stimuli and in different procedures and attentional conditions. However, the stimuli used most in recent years are numbers and meaningless syllables and the procedures for their administration have usually been circumscribed within what is known as directed attention. Unlike free recall procedures, directed or focused attention is assumed to allow control of the attentional strategies of the subject (Bryden, Munhall, & Allard, 1983).

Since the pioneer works of Kimura with neurologically sound subjects it has been known that verbal stimuli generate an advantage to the right ear (Kimura, 1961). Studies carried out on children point mainly to the existence, as in adults, of a strong right-ear advantage (REA) from the very early years (see review by Hiscock, 1988). By contrast, the results of studies performed on children with dyslexia seem to be less consistent (see reviews by Bryden, 1988; Obrzut, 1988; Obrzut & Boliek, 1988).

The origins of the discrepancies in the results of different studies are also probably diverse: First, there is the lack of a precise definition of the populations studied, which in themselves seem to be quite heterogeneous. The absence of theoretical consensus in issues related to definition (e.g., Fletcher, Francis, Rourke, Shaywitz, & Shaywitz, 1992; Fletcher et al., 1994; Morrison & Siegel, 1991; Pavlidis, 1990; Stanovich, 1991, 1993) has given rise to a plethora of criteria for the selection of populations of children with reading and writing problems. Although most authors require a reading level delay of at least 2 years, other criteria have also been employed. An example is the 1-year delay in reading used by Malatesha and Dougan (1982),

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Dermody, Mackie, and Katsch (1983), and Aylward (1984). In other cases, mathematical performance has also been taken into account (e.g., Kershner & Morton, 1990; Obrzut, Hynd & Obrzut, 1983; Obrzut, Hynd, Obrzut, & Leitgeb, 1980; Obrzut, Hynd, Obrzut, & Pirozzolo, 1981). Other authors have preferred to consider reading comprehension as the selection criterion (e.g., Kershner & Stringer, 1991; Morton & Siegel, 1991).

In regard to this problem, and with a view to facilitating comparison of our results with those of other studies, in the present study we decided to use a poor-reader selection criterion in accordance with traditional views, although we also included certain additional restrictions. Apart from an important delay in reading skills and a suitable IQ, all poor readers in the current study were males, were right-handed, and had no family history of left-handedness.

Some authors, attempting to reduce the heterogeneity of their group of poor readers, have tried to set up some type of classification by subtypes within their poor readers or have chosen only one subtype to study (often dysphonetic or audiolinguistic subjects). When made explicit, subtype classification criteria are in themselves more heterogeneous than poor-reader selection procedures. As examples, the following have been used: A discrepancy of at least 15 points between verbal and manipulative IQ (Obrzut, Obrzut, Bryden, & Bartels, 1985); a pseudoword reading level lower than the 17th percentile (Kershner & Micallef, 1992; Kershner & Stringer, 1991); difficulties in word recognition and/or reading comprehension (Morton, 1994 ; Morton & Siegel, 1991); reading speed and type of error (Masutto, Bravar, & Fabbro, 1994), or a combination of criteria related to reading, writing, and diverse measures of sequential or spatial processing (Lamm & Epstein, 1994). For the time being these problems are unfortunately difficult to solve but because we must live with them we feel that they should at least be taken into account when evaluating the concordance or discrepancy of the results obtained in various studies.

Following the maxim that inspired these and other works, for attempting to reduce within-group variability among our poor readers we opted for a subtype classification procedure. As detailed below, this is based on objective criteria lying within the classification paradigm provided by cognitive neuropsychology for the different types of dyslexia (Castles & Coltheart, 1993; Murphy & Pollatsek, 1994).

Another source of variability hampering comparison of the results of different studies is the actual procedure used for the dichotic listening task and, above all, the type of stimulus employed. Some studies have shown that the use of words or numbers is not equivalent to the use of meaningless words (Bowen & Hynd, 1988; Morton & Siegel, 1991; Obrzut, Boliek, & Obrzut, 1986). Moreover, the reliability of the technique, especially in juvenile populations (Anderson & Hugdahl, 1987; Kershner & Micallef, 1992), and its predictive validity for inferences about hemispherical specialization as regards language should also be taken into consideration.

Regarding these variables, we felt it appropriate to use CV syllables as stimuli and two attentional paradigms: free recall (FR) and attention directed towards one or the other ear (directed-left, LD, and directed-right, RD).

Within the context of interpretations of the auditory advantages observed in dichotic listening, the results obtained in such tests have traditionally been understood on the basis of two initially competitive hypotheses; the structural and the attentional. These classical interpretations, proposed by Kimura and Kinsbourne, respectively (see for example, Kimura, 1961; Kinsbourne, 1970, 1973, 1975), were exclusive hypotheses. More integrative models, however, have also been considered.

Hiscock and Bergström (1982), for example, proposed that three factors would govern auditory advantages in dichotic listening. The first would be structural or attentional or, perhaps, a combination of the effects of both. This factor would account for the basal asymmetry found in most studies. The second factor would be the subject's capacity to *voluntarily* direct attention to one or the other side of space. Depending on the subject's characteristics, the stimuli employed, and the demands of the task, the auditory advantage generated by the first factor could be increased or decreased. The third component would also involve an attentional effect but in this case not under the subject's volition; this would be the priming effect. According to Hiscock and Bergström, if dichotic listening is to be used as a tool to evaluate the lateralization of the receptive components of language, regardless of the theoretical model used to interpret the data, it would be necessary to take into account the bias introduced by all of these factors. The work of Boliek, Obrzut, and Shaw (1988) runs along similar lines.

Aims of Study

In the present study, our aim was to explore two questions:

(1) In a test on dichotic listening with CV syllables as stimuli, do children with dyslexia show patterns of action different from those of other children of the same age or reading level?

(2) In the same dichotic test, is there any pattern of action that differentiates the various subtypes of poor readers or that differentiates these and age-matched or reading-level control groups?

METHOD

Participants

Selection Criteria

Our sample consisted of 125 children divided into three groups: an experimental group comprising 50 children with reading difficulties and two control groups consisting of children of the same age with normal reading skills (age-matched control group, *n* = 50) and of children with the same reading level as the experimental group (reading-level control group, *n* = 25). All children fulfilled the following criteria: (1) all were male; (2) they wrote with their right hands and also used the same hand for at least 7 out of 8 tasks selected from the Edinburgh Inventory (Oldfield, 1971); (3) none of them had any known neurological illness, either at the time of the study or previously (for example, epilepsy and meningitis were criteria for exclusion); (4) on the Spanish version of Wechsler's Intelligence Scale for Children (WISC; Wechsler, 1983) the boys obtained a FS IQ of 85 or above; (5) in a pure-tone test they showed an audiometric threshold in both ears of below 20 dB for 500, 750, 1000, 1500, 2000, 3000, 4000, and 6000 Hz; (6) they attended class regularly; (7) their socio-familial surroundings were not especially unfavourable; (8) left-handedness did not run in the family (both parents had to demonstrate that they performed at least 8 of the 10 tasks comprising the Edinburgh questionnaire with their right hand).

In order to form the sample, we requested the cooperation of the boys' teachers in a first approach to identifying the good and poor readers. Special emphasis was placed on requesting the teachers to indicate not only the poor readers but also to inform us which of them were *slow* readers. Of the total of the 100 poor readers selected initially only 50 satisfied all of the above criteria.

Experimental Group. The experimental group consisted of 50 children who, in addition to fulfilling the criteria mentioned above, were in the 4th or 5th grade of General Basic Education (EGB) at the time of the testing. On the Word Reading subtest of the Test de Análisis de Lectoescritura (TALE) [Reading and Writing Analysis Test] (Toro & Cervera, 1984) the boys were at least 2 years behind in either of their scores (based on the number of errors or on the time taken in reading). Their ages ranged between 9.01 and 12.90 years, (*M* = 10.24, *SD* = 0.84).

Age-Matched Control Group. This group consisted of 50 children who were from the same classes as the children in the experimental group and who in addition to fulfilling the above general criteria also satisfied the specific criteria for this group: (1) were in the 4th or 5th grade of General Basic Education and (2) whose scores in the number of errors and in reading times on the Word Reading subtest of the TALE were close to the average for their age group, that is, 0 years behind in errors and in reading time. The ages in this group ranged between 8.83 and 12.51 years (*M* = 9.93 years, *SD* = 0.72).

Reading-Level Control Group. This group consisted of 25 children who fulfilled the general criteria and who (1) were in second grade of EGB at the time of the test, (2) obtained a score on the Word Reading part of the TALE in precision (errors) *and* reading time close to the average for second graders (0 years behind in correctness and in reading time) and (3) whose reading level was on average similar to that of the children with dyslexia. Their ages ranged between 6.89 and 8.04 years (*M* = 7.41 years, *SD* = 0.36).

Material

Wechsler Intelligence Scale for Children (WISC) [Spanish version]
Assessment of handedness: Edinburgh Inventory-[Spanish version]
Test de Análisis de Lectoescritura [Reading and Writing Analysis Test] (TALE)
This latter measure is a standardised test which was administered in its entirety, although only the performance on the Word Reading subtest was taken into account, in order to determine each child's reading level and to make up the study groups. The test consists of 50 stimuli: 44 words of different frequencies and 6 pseudowords.

Liminal Tonal Audiometry
The test was carried out with an Amplaid Model 151 portable audiometer in a quiet room at the school. All of the children showed a threshold equal to or below 20 dB in both ears in a test with tones of the following frequencies: 500, 750, 1000, 1500, 2000, 3000, 4000 and 6000 Hz.

Dichotic Listening
The dichotic recording used in this study is the result of an earlier research project (Málaga, Martínez, Vera, & Hernando, 1994). This work offers a detailed description of how the instrument is built and how its administration on two occasions to a sample of 52 adults (mean age = 33 years) afforded a test-retest reliability index of 0.70 among right-handed participants. To make the recording, natural language syllables with a CV structure (pronounced by an adult male) were used and then digitalized and processed using a computer program. This program permitted interchannel synchronization with an error of less than 2 ms. The final result was recorded on a conventional chrome-oxide tape and reproduced on a ''Walkman''– type tape player equipped with Dolby system for noise reduction (AIWA, mod. HS-T33) and dynamic earphones (Sony, mod. MDR-CD750) with a frequency response of between 20 and 20,000 Hz.

The test itself comprised 30 assays including all the possible combinations of six pairs of CV syllables, with no repetition of any of the elements in each pair. The syllables were elaborated from a plosive consonant and the vowel ''a'' (''pa'', ''ta'', ''ka'', ''ba'', ''da'', ''ga''). The different combinations were presented randomly, the only restriction being that no syllable should ever appear in more than three consecutive exercises. The attention paradigms (free recall, attention directed left, and attention directed right) were used in blocks of 30 successive assays, thus forming a total of 90 assays. Each attentional condition was preceded by a short pause in which the corresponding instructions were presented (See Appendix 1), and by a group of practice trials. The sequence of administration of the different attentional conditions was the one used by Kershner and Micallef (1991, 1992). All participants started the administration with the free recall test (FR) and then continued with one of the two remaining conditions, attention directed left (DL) and attention directed right (DR). Accordingly, half of the participants in each group received the tests in the following order FR, DL, DR and the other half received it in the order FR, DR, DL. In addition to balancing the order, the test was arranged so that 50% of each of the groups performed it with the earphones in the usual position and the other 50% with the earphones in the opposite position (right earphone in left ear and left earphone in right ear).

The test was given to all the participants in a quiet room with a noise level of around 40 dB. The test was initially conceived for administration on two separate occasions, with an interval of approximately 1 week, in order to obtain replicates of our own data. Each participant kept the same position of earphones and the same order of tests in both sessions. To confirm the absence of bias deriving from a possible effect of the channels, the test was applied on two further occasions. The test was therefore applied four times. In all cases the examiner sat to one side of the child who kept his head and gaze looking forward during the test. If the child turned his head or looked sideways, a gesture was used to indicate that he should look ahead.

Reading Test (L-72)
On elaborating this test, we aimed at creating an instrument that would be independent of the selection criterion (TALE Word Reading Test) and that would facilitate the classification of the children with dyslexia into subtypes according to their difficulties in processing through the lexical or sublexical pathways. Accordingly, we attempted to control variables such as length, frequency, and imageability. In the case of length, the variable was assigned different values. The test consisted of six blocks, each with six stimuli of 4, 5, 6, 7, 8, and 9 letters, respectively. The number of syllables was also controlled so that the first two blocks of 4 and 5 letters were formed by two-syllable words; the two blocks of 6 and 7 letters formed three-syllable words, and those of 8 and 9 letters formed four-syllable words. All stimuli were high-frequency and high imageability words (see Appendix 2). The 36 pseudowords contained in the test were

obtained from these words by altering the order of the syllables (following an original idea of E. Sánchez and developed in a previous study by Yusto, 1993). Thus, for example, the word ‘‘libreta’’ was used to form the pseudoword ‘‘bretali’’. In the selection of stimuli, we endeavored to represent all of the Spanish phonemes, placing special emphasis on consonants.

In the administration of this test, it was particularly important to obtain information relating not only to precision or the number of errors, but also to the latencies of response with respect to each type of stimulus (words and pseudowords) and each value of the variable length. We believe that comparison of the time spent reading the words and pseudowords should allow us to identify children with surface dyslexic profiles. Accordingly, when we administered the test we considered it appropriate to use a computer and a voice-activated device that would allow us to record the child’s reading times. The test was administered with a portable computer (Macintosh Powerbook 170) using a program that enabled us to present the words one by one and record the latency times in milliseconds (Psychlab, v.0.85). The words were presented in the centre of the screen (in bold type, Geneva font, 24 point) at a distance of 50 cm from the child’s face. All efforts were made to make the lighting conditions homogeneous.

For their presentation, we divided the 72 stimuli into two halves so that a pause could be inserted between them. Therefore, we compiled two groups of 36 stimuli, making sure that the stimuli were similar in type (word-pseudoword) and in length. These two halves were preceded by six sample stimuli (three words and three pseudowords) and the corresponding instructions. For the samples, emphasis was placed on the idea that the child should not read the stimuli syllable-by-syllable but rather that he should read correctly and as quickly as possible. This was designed to ensure that the latency in vocalization would reflect the processing time used by the child on each word.

The words remained on the screen until the examiner noted the responses on the spread sheet, after which he proceeded to the next stimulus. In addition to the response times recorded by the computer, the examiner also noted the child’s responses on a spread sheet for later analysis of the number and type of errors. The type of errors counted were the same as those collected in the TALE test (hesitations, repetitions, rectifications, inversions, rotations, substitutions, omissions, additions, and substitutions of words) as well as reading by syllables. We considered it fundamental to include this latter type of error (reading by syllables) in order to facilitate the detection of surface dyslexic participants in our language.

Conditions of Administration of the Tests

All tests were administered individually at the children’s own schools in the quietest room possible. The work described here was part of a more extensive study in which each child was examined for a total of 4 hr, divided into three sessions of approximately 1 hr 20 min each. Each session was carried out on a different day. Between the second and third sessions, in which the test and retest of the dichotic listening task were completed, there was a minimum interval of 7 days and a maximum interval of 20 (M = 12.01, SD = 3.04).

RESULTS

The results are offered in two main sections. In Part I we describe the general characteristics of the sample and the procedure for classification into subtypes and offer data relating to the control variables (position and order of administration of the different attentional conditions). In Part II we address each of the two questions formulated above as the main goals of our study.

Part I

General Characteristics of the Sample

Table 1 shows the most relevant data about the characteristics of the experimental group and the control groups. As expected, the experimental group attained the same level of word and pseudoword reading as the reading-level controls but a lower level than the age-matched controls in the same variables. The only unexpected result was the relative inferiority of the experimental group as regards the intelligence variable, where they obtained scores slightly lower than those of the control groups ($p < .02$ in two tailed Student’s t tests).

Configuration of Subtypes

In a group of children whose primary language was English, Castles and Coltheart (1993) compared the reading of a group of 30 irregular words with that of the same number of pseudowords; the authors assumed that the discrepancy between the effectiveness of reading these two

Table 1. Demographic Data and Test Results.

Measure	Group					
	Age control (n = 50)		Reading level control (n = 25)		Dyslexic (n = 50)	
	M	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Age	9.93	(0.72)	7.41	(0.36)	10.24	(0.84)
WISC Verbal IQ	104.8	(13.6)	109.8	(13.1)	99.5	(10.5)
WISC Performance IQ	111.2	(12.5)	111.4	(12.8)	103.9	(9.6)
WISC Full Scale IQ	110.2	(13.6)	113.2	(12.9)	102.8	(10.1)
L-72 time (words)	8401	(30.9)	1266.5	(417)	1262.9	(360)
L-72 time (pseudowords)	1135.6	(288.3)	1799.6	(775.5)	2049.6	(897.4)

Note. WISC = Wechsler Intelligence Scale for Children; L-72 = Reading Test.

types of stimuli would reveal the existence of selective difficulties in one or the other pathway. The absence of irregular words in Spanish makes it difficult to apply this procedure. Therefore, we were obliged to use reading times in combination with errors (for a more detailed description of this procedure, see Martínez, 1995). Using a procedure based on regression similar to that used by Castles and Coltheart (1993), the children with dyslexia were classified into three groups according to the difficulties they showed in the lexical pathway, the sublexical pathway, or in both. The children were considered to have difficulties in the lexical pathway when the time spent on correctly read words in the L-72 test surpassed the slowest 10% of the age-matched control group with similar reading speeds of pseudowords. In practice, these were children whose word reading times were similar to the times spent by them on reading pseudowords which, it should be recalled, had a similar syllabic complexity. In our case, 18 children out of 50 (36%) fulfilled this criterion.

The above was the procedure used for selecting children with difficulties in lexical processes. However, it was not possible to identify such children as having surface dyslexia because nothing guaranteed that they did not have added problems in the sublexical (phonological) pathway. Therefore, we included a second criterion, that is, we considered the number of serious errors or coding errors. Children with surface dyslexia would fulfil the regression criterion described above and, also, most of their errors (at least 2/3) were minor (such as reading by syllables, hesitations, repetitions, and self-corrections). Ten of the 18 children who fulfilled the first criterion also satisfied the second (20% of the total).

The other 8 children, who fulfilled the regression criterion based on reading times but did not fulfil the criterion based on errors, were considered to have mixed dyslexia. Fulfilment of the first criterion meant that they had difficulties in the lexical pathway, whereas failure to fulfil the second criterion indicated that the children were committing many coding errors and hence had many difficulties in the sublexical pathway.

Selection of children with phonological dyslexia followed the same procedure based on regression. Of the 50 children with dyslexia, 21 fulfilled the criterion that their pseudoword reading times should surpass the slowest 10% of their age-matched controls with similar word reading times. One of these 21 children also fulfilled the regression-based criterion of the times for children with surface dyslexia but not the criterion that errors should essentially be minor. This child was therefore included in the mixed group. Thus, attending only to the regression criterion, overall 20 children (40%) were considered to have phonological dyslexia.

It would be possible to use an even stricter criterion for identifying children with severe phonological dyslexia. This procedure would consist in eliminating from the group of 20 children selected by regression those who had a majority (2/3 or more) of minor errors. Joint application of these two criteria (regression and errors) to the children with phonological dyslexia as well reduced the initial group of 20 children with phonological dyslexia to 12 (24% of the total). We refer to this group as having ''severe phonological dyslexia'', meaning that the children's reading difficulties were more severe than those of the children (8) with a majority of minor errors, even though they fulfilled the regression criterion.

Control variables

In this section we review certain technical aspects mainly related to the effects of the variables of headphone position and order of administration of the different attentional conditions employed.

The mean percent correct, sometimes referred to as precision indices, was 41%. Specifically, these were: an average of 41.1% (*SD* = 13.9%) in the control group of children in second grade; 42.4% (*SD* = 15.8%) in the control group of children in grades 4 and 5, and 41.4% (*SD* = 13.9%) in the group of children with dyslexia. In all cases, the values lay in the 25-75% range, which is a suitable interval for avoiding ceiling or floor effects.

The ''lambda'' laterality indices involve a transformation of direct scores. Developed by Bryden and Sprott (1981) to determine degrees of laterality, these indices have frequently been used by other authors (e.g., Obrzut et al., 1985). One of the advantages of the lambda indices over others commonly used is that they are more sensitive to the overall performance of participants and hence more suitable for comparing the performances of participants with different success levels (Bryden, 1988).

The formulas employed to calculate the lambda indices are:

(1) $\lambda = \ln$ (RE successes/LE successes)

(2) $\lambda = \ln$ [(RE successes x RE intrusions)/(LE successes x LE intrusions)]

The first was used for the free recall condition (FR) and the second for the directed attention conditions (DL–DR).

Headphone position variable

The dichotic listening test was initially administered to all the children in the sample on two different occasions. Approximately half of the children did the test with the earphones in the normal position (right earphone in right ear) and the other half with the earphones in the inverted position. No channel effects were observed either in the group of poor readers or in the reading-level control group. However, in the age-matched controls there was a slight indication of this. This led us to apply the test on a further two occasions (this time with the same recording but from a portable computer). Analysis of the latter administrations revealed that what looked like a channel effect was in fact a sampling bias. New randomization of the participants dispelled the suspicions concerning the problems with the position variable. Accordingly, the test was administered on four occasions with the same dichotic recording. The first two times it was implemented with a tape recorder and the last two times with a computer. Only 2 children were lost from the sample (one from the dyslexic group and the other from the age-matched control group). These boys changed schools between evaluations 2 and 3 and were, therefore, unable to participate in this part of the study.

Order variable

Having analysed the earphone position variable, we then studied the effects of the order of administration variable as referred to the different attentional conditions. It should be recalled that although all the participants began the administration with the free recall condition (FR), 50% continued with the left-ear attention test (DL) and the other 50% with the right-ear attention test (DR). The variable of the order of administration of the attentional conditions remained constant throughout the four administrations of the test. No significant values were obtained in the variance analyses performed with this variable, and we therefore, decided not to use the order variable in ensuing analyses.

Part II

Do children with dyslexia show patterns in dichotic listening with CV stimuli different from those observed in age-matched and reading-level controls?

Because we had available four different administrations of the dichotic listening test, in order to simplify the calculations we averaged the scores from all four administrations. The results are shown in the first rows of Table 2. Analyses were performed considering both the lambda laterality indices and the percent correct achieved in each ear and attentional condition.

Regarding the lambda indices, no significant differences were found either for the free recall condition (FR; $F(2, 122) = 2.124$, $p = .1240$) or for the conditions of directed attention (DL-DR; $F(2, 122) = 1.689$, $p = .1890$).

On performing ANOVA separately for each ear and attentional condition (LE DL, RE DL, LE DR, RE DR, LE FR, RE FR), considering group as the independent variable and the percent correct as the dependent variable, we found significance in the analysis corresponding to the left ear in the condition of attention to that ear (LE DL; $F(2, 122) = 3.331$, $p = .0390$) and in the analysis corresponding to the percent correct with the right ear in the free recall condition (RE FR; $F(2, 122) = 3.259$, $p = .0418$). The contrasts carried out a posteriori with the Fisher test revealed that in the first case (LE DL) the reading-level control group obtained a significantly lower percent correct in that ear and under that condition than either of the other two groups ($p = .0362$ and $p = .0133$ in the comparisons with the age-matched control group and with the dyslexic group, respectively). However, no significant differences were found between the dyslexic group and the age-matched control group ($p = .6303$). In the second case (RE FR), a posteriori contrasts revealed that the children with dyslexia obtained a significantly lower percent correct in that ear and under that condition than the age-matched controls ($p = .0131$).

Is there some differential pattern in the performance of some of the dyslexic subtypes in this same dichotic task with CVs?

In the above analyses, considering the children with reading difficulties as a group, we found no significant differences on comparing the laterality indices of these with those of the controls. However, we did observe a certain trend towards significance as well as some differences in the analyses of the percent correct for each ear and condition. Suspicion that the group of poor readers might show heterogeneous behaviour as a function of the characteristics of their reading difficulties prompted us to perform new analyses, this time fragmenting the group into subtypes: phonological, surface, mixed. To do so, we performed the same analysis of variance with the group variable as factor (phonological, surface, mixed, age-matched control, reading-level control) and with the lambda indices and success percentages in each ear and for each condition as intrasubject variables. In order to facilitate comparison of our results with those from other studies, it should be noted that although the theoretical framework and the specific classification procedures were different, there is a certain conceptual similarity between the auditory-linguistic subtype and the phonological dyslexic subtype of our study.

Regarding the lambda indices, we found no significant differences in either of the contrasts for FR and DL-DR conditions ($F(4, 108) = 1.901$, $p = .1155$ and $F(4, 108) = 1.734$; $p = .1478$, respectively).

Regarding the success percentage in each ear and for each condition, we found significance in the percent correct scores of the right ear in the free recall condition (RE FR; $F(4, 108) = 2.776$, $p = .0306$) and in those of the left ear in the left-directed attention condition (LE DL; $F(4, 108) = 2.631$, $p = .0382$).

A posteriori analyses carried out using the Fisher test revealed that in the first case (RE FR) the contrasts between the age-matched controls and the phonological and surface dyslexic groups were significant. In both cases, the control group obtained a significantly higher percent correct score in the right ear ($p = .0171$ and $p = .0307$, respectively). The differences found in this same analysis between the mixed dyslexic subtype and the phonological and surface dyslexic were also significant ($p = .0325$ and $p = .0330$ respectively). In this case, it was the mixed dyslexic subtype who showed an advantage over the phonological and surface dyslexics subtypes in the percent correct in the RE FR condition.

A posteriori contrasts for the LE DL variable revealed that in this ear and under this condition the younger (reading level) controls scored significantly lower than the older control group ($p = .0351$) and the phonological dyslexic subtype ($p = .0029$). In fact, the phonological dyslexic group obtained the highest scores for this ear in DL. This ease of the phonological dyslexic subtype to attend to the left ear has been reported in earlier studies on auditory-linguistic subtype (e.g., Obrzut, Conrad, & Boliek, 1989; Obrzut et al., 1981, 1983, 1985). Nevertheless, the differences in percent correct scores with the surface and mixed subtypes and the age-matched controls did not reach significance ($p > .05$ in all cases).

Because in the group of poor readers it was the subgroup of children with phonological dyslexia who seemed to have singular performances (they obtained differences in both RE FR and in LE DL), we repeated the analyses, this time including only the children with the most severe phonological dyslexic profile. It should be recalled that this group, selected with the regression criterion alone, comprised 20 children. As well as fulfilling the regression criterion based on times, the new group with more severe phonological problems also fulfilled a second requirement establishing that they could not have a majority (2/3 or more) of minor errors. In other words, they had to show coding errors during their reading as well as spending more time on pseudowords than on words. This new constraint, as discussed above, reduced the group from 20 to 12 children (see Table 2).

When we repeated the same analyses of variance but this time including the children with a more severe phonological profile, we found the same pattern in the results but with more significant differences between this group and the others. Table 3 summarizes the contrast that were significant. As may be seen from Tables 2 and 3, the children with phonological dyslexia obtained the lowest lambda indices, tending to show significant differences with respect to the other groups, with the exception of the children with surface dyslexia (with which, in the case of the lambda index, they only differed for the DL-DR condition). Regarding the analyses based on success percentages, the differences among the groups were significant in each ear and under each condition (LE FR, RE FR, LE DL, RE DL, LE DR, RE DR). Of these six analyses, in the LE DL contrast the severe phonological group obtained a significantly increased number of percent correct than the other groups attending to that ear (left). This was the only analysis in which the children with phonological dyslexia clearly surpassed those with surface dyslexia ($p = .0482$). In a further three analyses (LE DR, LE FR and RE DL) the phonological dyslexic subtype obtained significantly different scores than the control groups and the mixed dyslexic subtype (in all cases, $p < .03$) and their distance from the surface dyslexic subtype was close to significance ($p = .0659$, $p = .0601$ and $p = .0933$, respectively). Similar results pointing to the ease of phonological (or audio-linguistic) dyslexic subtype to attend to the left ear have been reported by other authors (see for example Obrzut et al., 1981, 1983, 1985, 1989). As observed previously in the analyses carried out with the three main groups, the older control group also obtained a significantly higher percent correct score than the younger (reading level) control group ($p = .0378$; see Table 3). These results have also been reported in the literature on the issue (see for example Andersson & Hugdahl, 1987; Bowen & Hynd, 1988; Hugdahl & Andersson, 1986).

This subtype with a more severe profile of phonological dyslexia was the only which committed the fewest mistakes due to intrusion from the right ear when attending to the left one (RE DL). In this case, the differences with the children with surface dyslexia were not significant

Table 2. Percent Correct and Lambda Indices.

	Attentional Condition							
	FR		Lambda FR	DL		DR		Lambda DL-DR
Group	LE	RE		LE	RE	LE	RE	
Main Groups								
Reading level control (n = 25)								
M	29.4	50	.539	29.5	53.3	28.6	55.7	1.278
(*SD*)	(6.4)	(8.4)	(.350)	(6.3)	(7.3)	(5.8)	(8.4)	(.602)
Age control (n = 50)								
M	30.2	53.4	.589	34.5	49.7	26.9	59.7	1.198
(*SD*)	(8)	(9.8)	(.453)	(10.9)	(11.6)	(7.5)	(10.7)	(.808)
Dyslexic (n = 50)								
M	32.6	48.4	.409	35.4	47.7	29.1	55	.957
(*SD*)	(9.1)	(10.7)	(.477)	(9.8)	(11.1)	(8)	(12.6)	(.916)
Dyslexic subtypes								
Phonological dyslexic (n = 20)								
M	34.7	47.1	.330	38.3	45	30.3	54.4	.765
(*SD*)	(11.3)	(10.8)	(.565)	(10.5)	(9.9)	(8.3)	(12.8)	(.896)
Surface dyslexic (n = 10)								
M	32.7	45.9	.337	32.9	49.2	28.4	55.4	1.055
(*SD*)	(7)	(10.6)	(.356)	(6)	(10.4)	(5.4)	(11.6)	(.596)
Mixed dyslexic (n = 8)								
M	28.4	56.6	95	30.7	55.2	25.8	58.9	1.475
(*SD*)	(8.2)	(11.8)	(.502)	(10.4)	(12.1)	(10.7)	(16.5)	(1.182)
Severe phonological dyslexic (n = 12)								
M	39.2	43.3	.102	41.3	41.5	34.1	48.6	.365
(*SD*)	(11)	(10.2)	(.488)	(12.2)	(10.4)	(6.7)	(9.1)	(.784)

Note. The performance of each participant for the four applications of the test was averaged.

($p = .0933$). This tendency of phonological (audio-linguistic) dyslexic subtype to reduce the number of intrusion errors from the right ear when they listen to the left one, as mentioned in the previous section, has been described by other authors (e.g., Obrzut et al., 1981, 1983, 1985, 1989).

The performance of the children with surface dyslexia is almost undistinguishable from those of the controls. The only exception lay in the comparison with the age-matched control groups with respect to the number of successes in the right ear under the free recall condition (RE FR). In this comparison, the surface dyslexic group obtained a significantly lower number of successes ($p = .0285$).

The mixed dyslexic subtype, which was very small in number and showed a broad range of performance, displayed a similar kind of behaviour to that of the control groups of children (see Table 3).

DISCUSSION

In the present study we formulated two aims: first, to study the patterns of hemispheric lateralization (inferred through performance on a dichotic listening test) in a group of right-handed children with dyslexia and no family history of left-handedness; and second, to evaluate whether there are different patterns of performance on the dichotic listening test in the different poor reader subtypes.

Regarding the first of our aims, the results show that although the dyslexic group obtained lower lateralization indices than each of the control groups, both under the free recall and directed attention conditions, the differences were not statistically significant.

Individual analysis of the performance of the different groups for each ear and each attentional condition revealed that with respect to the left ear (LE DL) the performance of the reading-level control group was significantly worse than that of the other two groups (age-matched controls and children with dyslexia). This initially suggests that the capacity to attend to the ''non-dominant'' ear would not be related to the level of reading competence but rather to the children's age. The children with reading difficulties and the older controls obtained a significantly higher percent correct score than the reading-level controls and did not differ significantly between each other.

Regarding the number of percent correct in the right ear in the free recall condition (RE FR), the children with reading difficulties scored significantly lower than their age-matched controls. This suggests that children with dyslexia could have a lateralization pattern other than that of children with normal reading levels, although

Table 3. Significant Contrasts in Percent Correct and Lambda Indices.

LE FR		b**	c**	d**			
RE FR		b**	c**	d*	e*	f*	
Lambda FR		b**	c**	d**			
LE DL	a*	b*	c*	d**			j*
RE DL		b**	c*	d**			
LE DR		b**	c**	d*			
RE DR		b*	c**				
Lambda DL-DR	a*	b**	c**	d**			

1. Severe phonological dyslexic	**a**. 1 vs. 2	**e**. 2 vs. 3	**h**. 3 vs. 4	**j**. 4 vs. 5
2. Surface dyslexic	**b**. 1 vs. 3	**f**. 2 vs. 4	**i**. 3 vs. 5	
3. Mixed dyslexic	**c**. 1 vs. 4	**g**. 2 vs. 5		
4. Age control	**d**. 1 vs. 5			
5. Reading level control				

* $p < .01$; ** $p < .05$.

overall such a difference would not be sufficiently important to be reflected in the lambda laterality indices.

In sum, the lack of differences in the contrasts carried out on the laterality indices together with the only slight differences found with the percent correct score suggest that the children with developmental dyslexia, considered overall as a group, cannot be differentiated from children of the same age with normal reading levels on a CV-syllable dichotic listening task. That the children in the younger control group obtained significantly lower values in the left ear under the DL condition than the older control children suggests that this progression over time could be explained in terms of some maturational factor. This phenomenon, which might be related to some attentional factor, has been described previously (Andersson & Hugdahl, 1987; Bowen & Hynd, 1988; Hugdahl & Andersson, 1986).

It should be mentioned, however, that despite this clear progression in LE DL performance among the control children, no progression at all was seen among the members of these groups regarding laterality, as assessed through the lambda indices. In other words, although we observed an improvement in general performance between those children in 2nd grade and those in 4th and 5th grades together with an improvement in the capacity to attend to the left ear, the laterality indices remained unchanged. Our results are thus consistent with those of many other authors (Geffen & Wale, 1979; Hiscock & Kinsbourne, 1977, 1980; Hynd, Cohen, & Obrzut, 1983; Hynd & Obrzut, 1977; Hynd, Obrzut, Weed, & Hynd, 1979; Obrzut et al., 1980, 1981; Schulman-Galambos, 1977) who refute Lenneberg's (1967) proposal of a progression in laterality with the passage of time.

The second of our aims was to study the pattern of performance in the same dichotic listening test of the different previously established poor reader subtypes. Regarding laterality indices, the analyses carried out after dividing the group of poor readers into subtypes revealed significant differences only when the phonological dyslexic subtype was chosen on the basis of strict criteria; in other words, when from among the children who fulfilled the ''phonological dyslexic'' criterion based on reading times regression we selected only those with an important proportion of coding (or severe) errors.

Concerning the percent correct score, the significance of the differences becomes much more pronounced when only the more severe phonological dyslexic subtype is considered. Regarding the other subgroups, we observed that the performance of the surface and mixed dyslexic subtypes was very similar to that of the age-matched controls (see Table 2).

These results underscore the importance of differentiating different subtypes and we believe that they could help us in our understanding of the inconsistencies reported in the literature in studies comparing the performances of children with and without reading difficulties.

In sum, it may be concluded that only the children with severe phonological dyslexia clearly and significantly differ from the other groups as regards their performance on a dichotic listening task with CV syllables as stimuli.

Although the interpretation of the origin of such differences lies outside the scope of this work, one based on an exclusively attentional advantage in children with phonological dyslexia is questionable. This attentional factor could indeed account for the advantage of these children in attending to the left ear but would be inconsistent with the two findings reported here: first, the fact that this group of poor readers obtained the lowest percent correct score when attending to the right ear (REDR) and, second, this group had the greatest number of intrusion errors from the left ear when attending to the right (LE DR). From the foregoing, we may conclude that underlying this phenomenon there is another factor at play, beyond the capacity to voluntarily direct attention. These results are partly consistent with those reported by Kershner and Micallef (1992). Our proposal is that other intrinsic factor/s, different from voluntary attentional capacities, should be invoked in order to account for this bias in responding to left ear in the phonological dyslexic subtype.

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APPENDIX 1

Instructions For The Different Attentional Conditions Of The Dichotic Listening Test.
After ascertaining that each child could repeat without difficulty each of the syllables comprising the test, articulated one by one by the examiner with his/her lips not in view of the child, he was given the following instructions:

Free Recall Condition (FR)
You are now going to hear two of the previous syllables at the same time, one in each ear. These will always be different. You will think that two people are talking to you at the same time. All you have to do is to repeat what you hear. Please say this clearly so I can understand you. If at any time you are not sure, try to guess what you have heard but don't miss any of them.

Condition Of Attending To The Left Ear (DL)
Now you only have to repeat what you hear in your left ear. Please touch your left ear so that I can see that you have understood. You will tell me only about the syllables you hear in that ear and, if possible, none of what you hear in your right ear O.K.? Please tell me what you hear clearly so I can understand what you are saying.

Condition Of Attending To The Right Ear (DR)
Now you only have to repeat what you hear in your right ear. Please touch your right ear so that I can see that you have understood. You will tell me only about the syllables you hear in that ear and, if possible, none of what you hear in your left ear O.K.? Please tell me what you hear clearly so I can understand what you are saying.

APPENDIX 2

L-72 reading test

Frequency and Imageability table

Stimulus	Nº Syllables	Nº Letters	Frequency	*M*	(*SD*)	Imageab.	*M*	(*SD*)
pato	2	4	230			6.64		
mano	2	4	284			6.42		
niño	2	4	229			6.48		
vaso	2	4	285			6.30		
caja	2	4	243	247.5	(30.1)	6.21	6.40	(0.15)
pino	2	4	214			6.33		
bolsa	2	5	236			6.37		
cerdo	2	5	205			6.61		
radio	2	5	281			6.35		
brazo	2	5	200			6.46		
mujer	2	5	202	245.6	(59.8)	6.16	6.43	(0.17)
perro	2	5	350			6.62		
abrigo	3	6	257			6.22		
águila	3	6	214			6.45		
cabeza	3	6	215			6.15		
muñeca	3	6	241			6.58		
cocina	3	6	257	257.2	(53.5)	6.29	6.36	(0.16)
zapato	3	6	359			6.45		
cartera	3	7	282			6.31		
libreta	3	7	220			6.27		
máquina	3	7	227			6.60		
naranja	3	7	300			6.31		
vestido	3	7	251	252.5	(32.1)	6.26	6.35	(0.13)
plátano	3	7	235			6.35		
camiseta	4	8	256			6.41		
elefante	4	8	247			6.57		
escalera	4	8	203			6.35		
teléfono	4	8	239			6.28		
lavadora	4	8	174	233	(38.1)	6.35	6.37	(0.11)
papelera	4	8	279			6.25		
carretera	4	9	221			6.24		
bicicleta	4	9	268			6.47		
zapatilla	4	9	268			6.34		
bolígrafo	4	9	305			6.41		
margarita	4	9	221	254.3	(32.5)	6.38	6.36	(0.08)
rotulador	4	9	243			6.31		

Imageability and frequency of the 36 words of the L-72 test classified by length.