Differences in Eye Movements Control Among Dyslexic, Retarded and Normal Readers in the Spanish Population*

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ABSTRACT: This paper reports a research which examined the relationship between dyslexia and eye movement control in Spanish speaking children. The study compared the eye movements recordings of 30 dyslexic, 30 retarded and 30 normal readers, aged between 7 and 14, in one ocular tracking task and two reading tasks which differed in their degree of reading difficulty. Within each group the subjects were divided into 3 subgroups of 10 in accordance with the following chronological ages: 7—9, 10—11 and 12 years and above. Dependent variables were saccadics (number, size and fixation pause), regressives (number, size and fixation pause), total number of movements and percentage of regressives over the total number of movements. The following results were obtained: (1) In the two reading tasks significant differences were found between dyslexic and normal readers and between retarded and normal readers in most of the parameters, no differences being found between dyslexic and retarded readers except in a few parameters; (2) in the ocular tracking task significant differences both between dyslexic and normal readers and between dyslexic and retarded readers were found in all dependent variables, no differences being found between retarded and normal readers at all, and (3) the age factor produced a significant main effect in the two reading tasks indicating a general improvement of eye movements as age increases but an interaction effect with reading disability in the ocular tracking task — indicating a deterioration in eye movements in the dyslexic group as a function of age — was also found. The results are discussed in the context of alternative theoretical explanations of developmental dyslexia.

KEYWORDS: dyslexia, eye movements, reading disorders.

Many authors claim that developmental dyslexia is a disorder produced by a language alteration or deficiency. Accordingly, verbal processes would be the common denominator for all forms of dyslexia (Vellutino 1980, 1987, Ellis 1984). However, research such as that carried out by Boder (1973) has revealed the existence of at least two types of developmental dyslexia (dyseidetic and dysphonetic dyslexia), showing that the errors manifested among dyseidetic dyslexics seem to be more related to visual or perceptive type factors than to phonetic or linguistic ones. The existence of at least two types of dyslexics, whether with language or with

* This research was supported by grant PR82—1933 from the Spanish Consulting Committee for Scientific and Technological Research (CAYCIT). Requests for reprint should be sent to F. J. Martos, Departamento de Psicologia Experimental y Fisiologia del Comportamiento. Campus de Cartuja, Universidad de Granada. 18071 Granada, Spain.

Reading and Writing: An Interdisciplinary Journal **2**: 175—188, 1990.

visual-spatial problems, has recently been defended by Pirozzolo (1981), Rayner (1987) and Pirozzolo and Rayner (1988). According to Boder (1973), dyseidetic dyslexia affects 9% while dysphonetic dyslexia affects 63% of dyslexics. However, more recent research (Stein and Fowler 1982, 1985, Santini de Souto 1977) questions the generality of the aforementioned distribution. Stein & Fowler (1985) claim that 68% of their dyslexic subjects presented eye dominance problems and made more visual than phonetic type errors. In addition, Santini de Souto (1977) found that 61% of Spanish speaking dyslexics could be included in the dyseidetic or visual category.

In the search for the etiology of the dyslexic disorder within the domain of perceptive problems, a special interest has been awoken by the hypothesis relating dyslexia to an alteration in eye movement control. Nevertheless, the role of eye movements as an etiological factor of dyslexia, has only attained definitive importance with the publication of Pavlidis' studies (1981a, 1981b, 1983). Pavlidis (1981a) compared twelve normal subjects to twelve dyslexics in an ocular tracking task. The subjects were asked to follow with their eyes the successive lighting up of five lights. The lights were emitted by five diodes located four degrees apart from each other on a horizontal continuum. They were lit up one by one and sequentially, both in a right-left direction and in a left-right one. Each light was lit for one second, with the exception of those in the initial and final positions of a sequence, which were lit up for two seconds. The subjects' task consisted of following the light sequences as accurately as possible with their eyes. The results showed that the dyslexic subjects performed poorly on this task. The size and number of saccadics were significantly greater in dyslexics than in normal subjects. The greatest difference between the two groups appeared in the number of regressive movements. This difference was so great that there was no overlap in the data of the two groups. These results led Pavlidis (1981b, 1985, 1987) to propose the recording of eye movements in an ocular tracking task as an objective criterion for the diagnosis of dyslexia. In a later study, which included a group of retarded readers, Pavlidis confirmed his previous findings (1983). He has indicated that whatever the cause of dyslexia might be the presence of an alteration in the pattern of eye movements seems to be unequivocally linked to this disorder (Pavlidis 1987).

Although some researchers have indeed reported data supporting this association (Jones and Stark 1983) others have failed to replicate Pavlidis' results. Browns et al (1983) studied 67 subjects: 34 dyslexics and 33 normal readers. The methodology employed was similar to that of Pavlidis. However, their results revealed no differences between the two groups in any of the eye movement parameters.

Olson, Kliegl and Davidson (1983) also attempted to replicate Pavlidis' data. 70 children divided into a group of normal readers and a group of dyslexics, were tested in an ocular tracking task. The task used was similar to that employed by Pavlidis. It differed in that the presentation of the lights was performed on a computer screen. Once again the results did not confirm the hypothesis of an oculomotor disturbance in dyslexia. The dyslexics and normal readers did not differ with regard to the number of saccadics, the percentage of regressives nor the stability of fixations. Nevertheless a significant correlation was found between eye movement and reading efficiency. This correlation was independent of whether the subject was a normal or a dyslexic reader.

Pavlidis (1983) has argued against the studies that do not confirm his data by indicating that their negative results were probably caused by different demands in the selection of dyslexics. A not very strict selection criterion would lead to overlap among the samples of normal, dyslexic and retarded readers and therefore, contradictory results would be expected to arise. Indeed in the studies carried out by Brown et al (1983) and Olson, Klieg and Davidson (1983) the dyslexic and normal readers were not controlled with regard to IQ. There were differences of 13 and 15 points respectively between the average IQ scores of each group.

The aim of the present study was to examine the relationship between dyslexia and eye movement control in Spanish speaking children taking into account the above mentioned shortcomings. The study compared the electrooculographic recordings of dyslexic subjects with those of retarded and normal readers in three different tasks: one ocular tracking task and two reading tasks which differed in their degree of reading difficulty.

METHOD

Subjects

The subjects were 90 children — 30 dyslexics, 30 retarded readers and 30 normal readers — aged between 7 and 14, selected from a group of 3500 children who were attending 6 primary education schools. The procedure used to select the dyslexic readers was as follows: In the first place, the teachers indicated 209 children out of the 3500 were potentially dyslexic according to their own criterion. These 209 children were then tested for differential diagnosis of dyslexia. 41 out of 209 were diagnosed as dyslexics in accordance with the following criteria: (a) Reading age two years below their chronological age; (b) IQ over 95 in the WISC-R and (c) no hearing or visual disability, brain damage nor any kind of affective, educational or family problems which might influence or explain the reading difficulty. Consequently, only 1.1% of the population studied could be considered dyslexic according to the above-mentioned criteria.

Design

A 3 × 3 factorial design was used, the first factor being Reading Disability at three levels (Dyslexics, Retarded Readers and Normal Readers) and the second factor Age at three levels (7—9, 10—11 and over 12 years old).

The three reading groups of 30 Ss each (21 male and 9 female) were formed according to the following criteria:

— Group of Dyslexics: Reading Age 2 years behind chronological age; IQ > 95,
— Group of Retarded Readers: Reading Age 2 years behind chronological age; IQ between 75 and 90.
— Group of Normal Readers: Reading Age equal to or higher than chronological age; IQ > 95.

Each reading group was divided in turn into 3 subgroups of 10 subjects in accordance with the following chronological ages: 7—9 years, 10—11 years and 12 years upwards.

Experimental tasks

The subjects were administered three different tasks: two reading tasks which consisted of reading a text of different degree of difficulty and an ocular tracking task.

In the two reading tasks the subjects were required to read a text which was presented on a computer screen. The first task involved reading a high level difficulty text and the second a low level difficulty text. The third, the ocular tracking task, consisted in presenting the subjects with a sequential series of five dots which changed place on the monitor screen from left to right and from right to left. The dots were 0.6 degrees of visual angle in diameter and the distance between one and another was 8.2 degrees. The five dots were presented in 5 consecutive double direction cycles, left-right and right-left. Each dot appeared on the screen for one second with the exception of the first and last in each direction sequence, which appeared for two seconds.

Eye movements

The eye movements were recorded using the Electro-oculographic technique (EOG) by means of a Grass DC pre-amplifier (model 7 P1-G) together with a MED's 12-bit Analogue-Digital Converter (Model 701 DG) and a IBM XT computer. The EOG was recorded using Beckman silver/silver chloride electrodes of 1 cm^2 of effective area placed on the corner of both eyes by means of double sided adhesive collars. The earth electrode was placed just about the bridge of the nose. A computer program was used to convert and record the EOG data at a rate of 200 samples per sec. for subsequent analysis.

The following parameter were analysed: Saccadics (number, size and fixation pause); Regressives (number, size and fixation pause); the total number of movements (saccadics plus regressives) and the percentage of regressives over the total number of movements.

RESULTS

The 3 × 3 Anovas, both factors between groups — Reading Disability and Age — applied to each parameter showed significant main effects of the Reading Disability factor in both the two reading tasks and the ocular tracking tasks, and of the Age factor in the two reading tasks. No significant main effect was observed in the ocular tracking task. However in this task a significant interaction Reading Disability X Age effect was observed in the number of saccadics and regressives. Analysis of the significant main effect of Reading Disability was carried out by means of Newman-Keuls tests. These results are shown in Table 1 and 2.

Reading Tasks In the first reading task (high level difficulty) significant differences were found both between dyslexic and normal readers and between retarded and normal readers in all of the parameters. No differences between dyslexic and retarded readers were observed except in the size of saccadics (see Table 1).

In the second reading task (low level difficulty) significant differences between dyslexic and normal readers were also observed in all of the parameters. Differences between retarded and normal readers were also found in most of the parameters except in the number and size of regressives. No differences between retarded and dyslexic readers were observed except in the number of regressives (see Table 1).

Ocular Tracking Task Significant differences between dyslexic and normal readers, and between dyslexic and retarded readers were found in all of the electroculographic parameters. No differences were found between retarded and normal readers, (see Table 2). The above results remained the same irrespective of the movement direction of the dot that appeared on the screen i.e., whether the dot moved from left to right or from right to left.

Age With regard to age, the results showed the existence of significant main effects in both reading tasks. No interaction effects were found in those tasks. In general, eye movements improve as age advances (see Fig. 1). In the case of the ocular tracking task no significant main effect of age was found. However in this task a significant interaction effect between age and reading disability was found in both saccadics and regressives. In

Table 1. Mean and standard deviation of saccadic movements (number, size and fixation pause) and regressive movements (number, size and fixation pause) in the two reading tasks as a function of reading disability. Significant differences between groups (Newman-Keuls Test) are indicated by a segment with an asterisk

	FIRST	READING	TASK	SECOND	READING	TASK
	Dyslexics	*Retardeds*	*Normals*	*Dyslexics*	*Retardeds*	*Normals*
SACCADICS						
NUMBER	74.3 (18.0)	74.9 (14.6)	52.0 (13.6)	96.9 (15.9)	91.0 (18.4)	69.3 (14.4)
		** (Retardeds–Normals)			** (Retardeds–Normals)	
	** (Dyslexics–Normals)			** (Dyslexics–Normals)		
SIZE	3.8 (0.9)	3.3 (0.6)	5.0 (1.1)	4.0 (0.9)	3.6 (0.8)	4.9 (0.9)
	* (Dyslexics–Retardeds)	** (Retardeds–Normals)			** (Retardeds–Normals)	
	** (Dyslexics–Normals)			** (Dyslexics–Normals)		
FIX. PAUSE	300.3 (70.8)	328.4 (155.3)	228.1 (57.9)	288.0 (48.2)	318.7 (139.2)	220.0 (45.3)
		** (Retardeds–Normals)			** (Retardeds–Normals)	
	* (Dyslexics–Normals)			** (Dyslexics–Normals)		

Table 1. (continued)

	FIRST	READING	TASK	SECOND	READING	TASK
	Dyslexics	*Retardeds*	*Normals*	*Dyslexics*	*Retardeds*	*Normals*
REGRESSIVES NUMBER	32.6 (8.8)	30.4 (14.6)	22.7 (11.3)	42.2 (12.7)	35.6 (13.5)	31.9 (12.4)
		*		*		
		*			**	
SIZE	8.6 (2.1)	9.3 (3.4)	11.9 (3.1)	8.9 (2.2)	10.1 (2.8)	11.2 (2.6)
		**				
		**			**	
FIX. PAUSE	283.3 (84.3)	281.4 (89.1)	219.2 (52.0)	270.0 (53.1)	279.2 (76.5)	219.0 (50.13)
		**				**
	**				**	

* $p < 0.05$; ** $p < 0.01$.

Table 2. Mean and standard deviation of saccadics' regressives, total number of movements and percentage of regressives in the ocular tracking task as a function of reading disability. Significant differences between groups (Newman-Keuls Test) are indicated by a segment with an asterisk

	OCULAR *Dyslexics*	TRACKING *Retardeds*	TASK *Normals*
SACCADICS			
NUMBER	57.6 (10.3)	49.8 (10.7)	49.8 (12.3)
	*		
		*	
FIX. PAUSE	513.9 (125.4)	620.3 (172.9)	628.0 (173.1)
	*		
		*	
REGRESSIVES			
NUMBER	18.2 (10.8)	12.5 (8.8)	10.9 (9.7)
	*		
		*	
FIX. PAUSE	421.6 (157.1)	538.6 (210.0)	599.8 (213.0)
	*		
		**	
TOTAL MOV.	75.6 (19.1)	62.3 (17.3)	60.8 (20.7)
	*		
		*	
% REGRESSIV.	22.1 (8.4)	18.5 (9.0)	15.9 (9.3)
	*		
		*	

* $p < 0.05$; ** $p < 0.01$.

general, the eye movements of the dyslexic group decreased with increasing age. This was apparent in both saccadics and regressives (see Fig. 2).

Discussion

Our results indicate that in general there are no significant differences

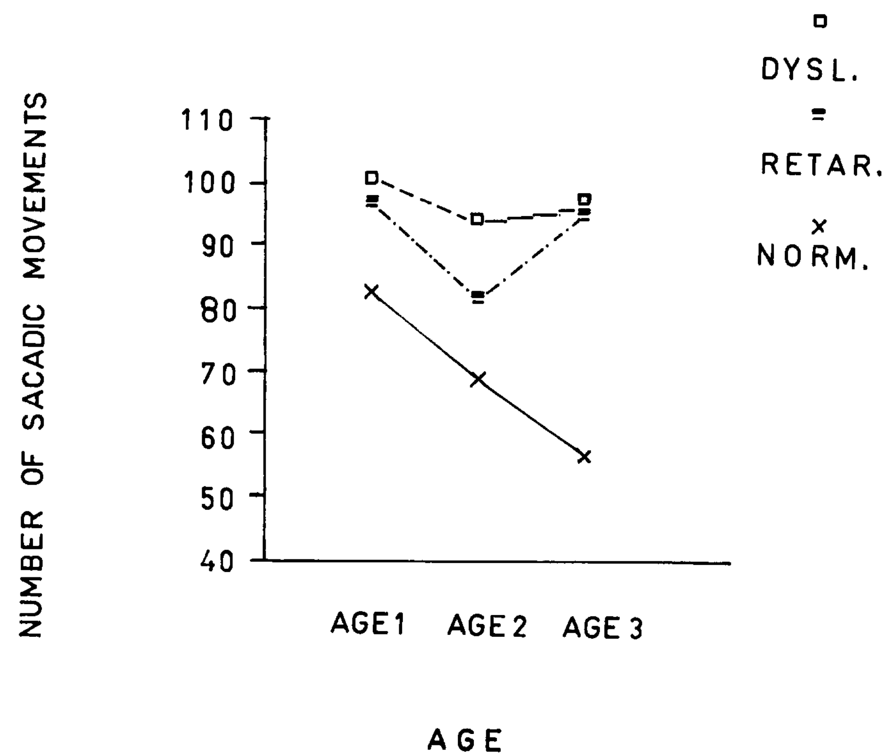

Fig. 1. Mean number of saccadic movements during the second reading task in the dyslexic, retarded and normal groups as a function of age (The graphic representation in the rest of parameters are similar to this).

between dyslexic and retarded readers in their eye movements if we consider the reading tasks only. Differences were apparent, however, in the reading tasks between each of the above-mentioned groups and the group of normal readers. On the contrary, with regard to the ocular tracking task, no significant differences were observed between retarded and normal readers but they were found to exist between each of these two groups and the group of dyslexics. The lack of significant differences between dyslexic and retarded readers in the reading tasks could be interpreted as evidence that the presence of erratic eye movements in these two groups is a consequence and not a cause of their reading disability. Pollatseck (1983) argues against interpreting the existence of altered patterns of eye movements in dyslexics as the causal explanation for their reading difficulties. The presence of such patterns is more likely to be the consequence and not the cause of the problem. The dyslexic subjects as compared to the normal readers would perform such a greater number of saccadic and regressive movements, the size of their move-

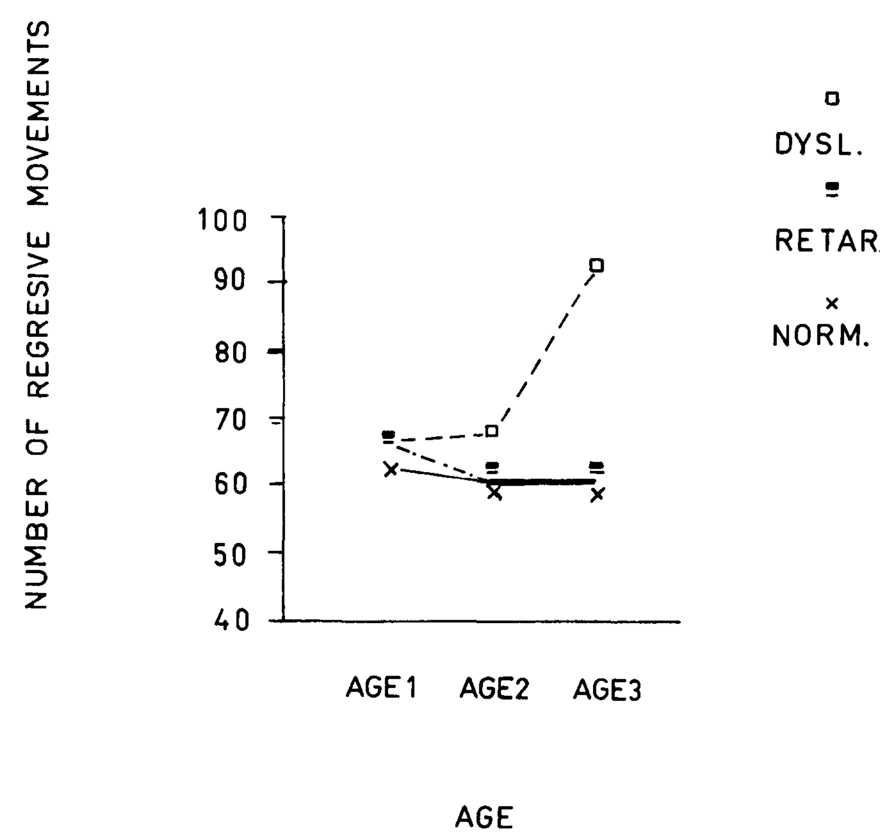

Fig. 2. Mean number of regressive movements during the ocular tracking task in the dyslexic, retarded and normal groups as a function of age (The graphic representation in the rest of parameters are similar to this).

ments would be so small and the fixation pauses just so long, simply because they have difficulty in reading the text. This would make them commit more eye movement errors: the number of regressives would increase and, therefore, the number of movements in general. In addition, the subjects would spend more time in processing the text.

Such reasoning seems logical. But if the eye movement alteration is caused by the reading disability and not the other way round, then the eye movement alterations should vary as a function of the level of difficulty of the text. Our data, however does not reflect this. Differences in eye movements between dyslexics and normal readers were found irrespective of the difficulty level of the text. Furthermore, such differences were also maintained when eye movements are recorded in a non-reading task: the ocular tracking task. This task is similar to the reading task in the sequencing of eye movements and that it also requires adequate oculomotor control.

It does not seem possible, therefore, to conclude that the eye movements alteration of dyslexics is caused by their reading disability. The eye movement patterns of dyslexics which differ significantly from those of normal subjects in all parameters, seems to be independent of the reading process.

In general, these results confirm those obtained by Jones and Stark (1983) and Pavlidis (1981a, 1983, 1985) comparing dyslexic and normal readers. Nonetheless, our results give further support to the theory relating eye movements to dyslexia. Our research compared dyslexic to retarded readers and both dyslexic and retarded readers to normal ones. In the case of retarded readers our results suggest that their eye movements alteration is a result of their reading disability. The significant differences between retarded and normal readers as regards the two reading tasks dissapeared in the ocular tracking tasks. On the contrary when comparing retarded and dyslexic readers no differences were observed with regard to the reading tasks, but significant differences were found in the ocular tracking task.

It is obvious, therefore, that the reason for erratic eye movements in retarded readers is their reading disability. The same is not the case with dyslexic readers as mentioned above. The eye movement alteration of dyslexics was independent of both the reading difficulty of the text and the reading task. This effect was apparent when comparing dyslexic subjects with both normal and retarded readers. As Rayner (1987) points out, a possible explanation for discrepant results might be found in the existence of at least two subtypes of dyslexics: dyslexics with deficits fundamentally related to language problems — dysphonetics — and dyslexics with deficit fundamentally related to visual-spatial problems — dyseidetics —. The erratic eye movement patterns are expected to be present only in the second category. Therefore, the methodology applied when selecting the sample of subjects would determine the subtype of dyslexics that fundamentally form the experimental group. Such differences in the selection procedure could explain the discrepancies found in the literature. On the other hand, Rayner (1987), Pirozzolo and Rayner (1988) and Boder (1973) have pointed out that the distribution of both types of dyslexia is not the same, the proportion of dyslexics with linguistic problems being far greater in English speaking populations.

For a number of reasons we are led to suppose that differences in syntactic structure or in phonetic regularity and even in the spatial disposition of the text that some of other languages present can generate major differences with regard to prevalence, type and distribution of reading disorders. As stated earlier, Santini de Souto (1977) found a greater proportion of dyslexics with visual problems than with linguistic problems among Spanish speaking population.

In our own research, we found it difficult to select the sample of dyslexics, given the low number of subjects complying with the diagnostic criteria (1.1% of the population). This lower incidence of dyslexia in the Spanish speaking population as compared to the English speaking one is likely to be related to differences in syntactic structure and, above all, in phonetic regularity between Spanish and English. Such differences may also explain the existence of a higher proportion of Spanish speaking dyslexics with visual-spatial problems — and therefore with difficulties in eye movement control — than with linguistic problems as compared to English speaking dyslexics.

Nonetheless, the fact that eye movement and dyslexia might be strongly related does not tell us much about the cause of the disorder. We cannot conclude from such an association that the former is the cause of the latter. On the contrary, some of our results concerning the age factor suggest that this is not the case. The significant main effect of age in the two reading tasks indicates that eye movements generally improve as age increases. It is likely, therefore, that the effect of age in the reading tasks was due to the corresponding increase in the reading age of the subjects. Notwithstanding, in the ocular tracking task, the significant interaction found between age and reading disability indicates that a deterioration in eye movements occurs in the dyslexic group as a function of age. This effect is such that as dyslexics get older their eye movement pattern gets worse. It seems logical to think that the increase in the number of saccadics and regressives produced by dyslexics, as they get older, is due to some kind of learnt strategy that they apply in order to avoid or reduce any other kind of deficit.

With reference to this later possibility, Breitmeyer (1983) and Rayner (1987), have suggested that the presence of erratic eye movements in dyslexics should be considered not the cause of dyslexia but a symptom associated with the cause of dyslexia. Further, Breitmeyer (1983) has suggested that reading can be considered a specific variant of a general kind of visual exploratory behavior, characterised by the directionality of the sequences of saccadic fixations. He suggests that this directionality would be controlled by plans or anticipatory schemes with a triple function: (a) to guide the width and direction of the saccadics in order to locate the potential information of the visual field; (b) to anticipate cognitive-sensory information to be processed in the next fixation pause; and (c) to integrate the information of the previous saccadics with that of the following ones.

From this perspective the control of saccadics would be affected as much by central cognitive processes as by peripheral motor or sensory processes. In this way, the existence of altered patterns in the oculomotor control of dyslexics could be caused by the existence of some kind of disorder in the initial stages of the visual information processing. It would be convenient, therefore, to carry out specific research in order to track the initial stages of the visual information processing in dyslexics. Such research would clarify the role played by alterations at this level, given the relationship between eye movement and dyslexic disorder found in the present study.

REFERENCES

Boder, E. 1973. Developmental dyslexia: a diagnostic approach based on three atypical reading spelling paterns. *Developmental Medicine and Child Neurology, 15*, 663—687.

Breitmeyer, B. G. 1983. Sensory masking, persistence, and enhancement in visual exploration and reading. *In* Rayner, K. (ed.). *Eye movements in Reading.* New York: Academic Press.

Brown, B., Haegerstrom-Portnoy, G., Adams, A. J., Yingling, CH. D., Galin, D., Herron, J. and Marcus, M. 1983. Predictive eye movements do not discriminate between dyslexic and control children. *Neuropsychologia,21*, 121—128.

Dossertor, D. R. and Papaiannov, J. 1975. Dyslexia and eye movements. *Language and Speech, 18*, 312—317.

Ellis, A. W. 1984. *Reading, writing and Dyslexia: A cognitive analysis.* Hillsdale, N.J.: Erlbaum.

Jones, A. and Stark, L. 1983. Abnormal patterns of normal eye movements in specific dyslexia. *In* Rayner (ed.). *Eye movements in Reading.* New York: Academic Press.

Olson, R. K., Kliegl, R. and Davidson, B. J. 1983. Dyslexic and normal reader's eye movements. *Journal of Experimental Psychology: Human Perception and Performance, 9*, 816—825.

Pavlidis, G. Th. 1981(a.) Do eye movements hold the key to dyslexia? *Neuropsychologia, 19*, 57—64.

Pavlidis, G. Th. 1981(b.) Sequencing, eye movements and the early objective diagnosis of dyslexia. *In* Pavlidis G. Th. and Miles, T. R. (eds). *Dyslexia research and its applications to education.* Chichester: John Wiley.

Pavlidis, G. Th. 1983. The 'dyslexia syndrome" and its objective diagnosis by erratic eye movements. *In* Rayner, K. (ed.). *Eye movements in reading.* New York: Academic Press.

Pavlidis, G. Th. 1985. Eye movements differences between dyslexics, normals and retarded readers while sequentially fixating digits. *American Journal of Optometry and Physiological Optics, 62*, 820—832.

Pavlidis, G. Th. 1987. The role of eye movements in the diagnosis of dyslexia. *In* Pavlidis, G. Th. and Fisher, D. F. (eds). *Dyslexia: Its Neuropsychology and Treatment.* Chichester.: John Wiley.

Pirozzolo, F. J. 1981. Language and brain: Neuropsychological aspects of developmental reading disability. *School Psychology Review, 10*, 350—355.

Pirozzolo, F. J. and Rayner, K. 1988. Dyslexia: The role of eye movements in developmental reading disabilities. *In* Johnston, C. W. and Pirozzolo, F. J. (eds). *Neuropsychology of Eye Movements.* Hillsdale, N.J.: Erlbaum.

Pollatsek, A. 1983. What can eye movements tell us about dyslexia?. *In* Rayner, K. (ed.) *Eye movements in reading.* New York: Academic Press.

Rayner, K.: 1987. Eye movements and the perceptual span: Evidence for dyslexic typology.

In Pavlidis, G. Th. and Fisher, D. F. (eds). *Dyslexia. Its Neuropsychology and Treatment.* Chichester: John Wiley.

Santini de Souto, A. 1977. Tipos de dislexia. *Neuropediatría Latinoamericana, II,* 41—48.

Stanley, G., Smith, G. A. and Howell, E. A. 1983. Eye movements and sequential tracking in dyslexic and control children. *British Journal of Psychology, 74,* 181—187.

Stein, J. F. and Fowler, S. 1982. Diagnosis of dyslexia by means of a new indicator of eye dominance. *British Journal of Oftalmology, 66,* 332—336.

Stein, J. F. and Fowler, S. 1985. Effect of monocular occlusion on visuomotor perception and reading in dyslexic children. *The Lancet, 13,* 69—73.

Vellutino, F. R. 1980. *Dyslexia: Theory and Research.* Cambridge: MIT Press.

Vellutino, F. R. 1987. Dislexia. *Investigación y Ciencia, 128,* 12—20.

Zangwell, O. and Blakemore, C. 1972. Dyslexia: Reversal of eye movements during reading. *Neuropsychologia, 10,* 371—373.