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Facets of Dyslexia and its Remediation
S.F. Wright and R. Groner (Editors)

THE OPTIMAL VIEWING POSITION FOR CHILDREN WITH NORMAL AND WITH POOR READING ABILITIES

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INTRODUCTION

Eye movements during reading are characterized by a succession of saccades and fixations. Saccades bring new information into the centre of the visual field; fixations serve to take up the information. Erdmann & Dodge (1898) already noted that fixations are not uniformly distributed over a text line, but fall almost exclusively on the words rather than on the gaps between the words, and "probably almost always on the middle of the word". These findings have recently received considerable attention (McConkie, Kerr, Reddix, & Zola, 1988; Rayner, 1978; Vitu, O'Regan, & Mittau, 1990) and it is now well established that there is a preferred landing position between the beginning and the middle of a word.

Part of the reason why the eye prefers to land between the beginning and the middle of a word probably is because this is the best place to recognize a word (Brysbaert & d'Ydewalle, 1988, 1991; Nazir, 1991b; Nazir, O'Regan, & Jacobs, 1991; O'Regan & Lévy-Schoen, 1987; O'Regan, Lévy-Schoen, Pynte, & Brugaillère, 1984). Nazir, O'Regan, & Jacobs (1991), for instance, found that the probability of recognizing a tachistoscopically presented nine-letter word amounted to 77% if the subjects were forced to look at the first letter, 90% for fixations on the third and the fifth letter, 77% for fixations on the seventh letter, and only 47% for fixations on the last letter. The same result is obtained when response latencies are used as the dependent variable, as can be seen in Fig. 1 (see also Brysbaert, 1991c). This figure displays response latencies for tachistoscopically presented five-letter words as a function of the letter fixated. The left part shows data of a word naming experiment; the right part shows data of a lexical decision experiment. Subjects were asked to fixate a gap between two vertically aligned lines and to process a verbal stimulus displayed between those lines. The stimulus was presented horizontally for 160 msec in such a way that a different letter fell between the fixation lines (for more information on the method, see below). In the first part of the experiment subjects had to read words aloud; in the second part they had to decide whether the presented stimulus was a word or a non-word. If we confine the discussion to the subjects with left cerebral hemisphere dominance (the most frequent case; see solid lines), we find that the optimal viewing position (OVP) for both tasks was situated on the second letter.

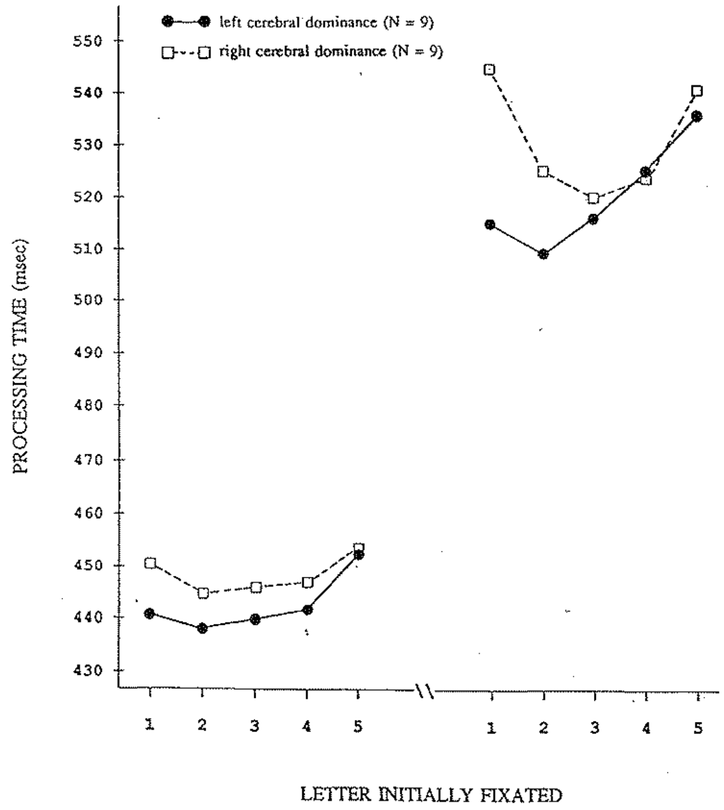

FIG. 1. Processing time (msec) of isolated five-letter words as a function of cerebral dominance of the subjects, and of the initially fixated letter. Left part: data of a naming task; right part: data of a lexical decision task.

The pattern of data displayed in Fig. 1 is explained by the joint contribution of four factors. The first factor has to do with the drop of visual acuity outside the centre of fixation. It has been shown (Alpern, 1962; Anstis, 1974; Jacobs, 1979; Wertheim, 1894) that the resolution of the visual system decreases rapidly for stimuli presented outside the fixation location, and certainly when these stimuli are flanked by other stimuli (i.e. the phenomenon of lateral masking or inhibition; Bouma, 1970). This is even true for distances of less than one degree, that is, for stimuli well within the foveal area. If the drop in visual acuity were the only significant factor, the OVP would lie in the middle of a

word and processing time would be a perfect U-shaped curve of the letter initially fixated (McConkie, Kerr, Reddix, Zola, & Jacobs, 1989).

Two additional factors have been invoked to explain why the OVP lies between the beginning and the middle of a word, and why processing time usually looks more like a J-shaped than a U-shaped curve. The first of these additional factors involves the fact that there is more information in the beginning of a word than at the end, and that in most languages studied processing happens in a left-to-right order (O'Regan & Lévy-Schoen, 1987). This favours fixations towards the beginning. The second additional factor has to do with cerebral asymmetry and interhemispheric transfer, as is shown in Fig. 1 (see also Brysbaert & d'Ydewalle, 1988, 1991). Because most people have better language capacities in the left cerebral hemisphere (Bradshaw & Nettleton, 1983), fixations towards the beginning of a word demand less interhemispheric transfer than fixations towards the end of a word. This is because fixations at the beginning make the whole word fall into the right visual half field which has direct communication to the left hemisphere. On the other hand, persons with language capacities mainly situated in the right cerebral hemisphere (about 5% of the population) need less interhemispheric transfer after fixations at the end of a word. A final factor determining the OVP has to do with task requirements (Brysbaert & d'Ydewalle, 1991; Nazir, 1991a, 1991b), as can also be seen in Fig. 1. The curves are flatter for naming tasks than for lexical decision tasks. Similarly, the OVP lies more to the middle when refixation probability is taken as dependent variable than when response accuracy or latency are considered (Nazir, 1991a).

The above analysis suggests that the OVP paradigm may be used to investigate the importance of low-order processes (such as visual acuity and interhemispheric transfer) in reading. The experiment below presents the first of a series of studies in which the OVP effect for different subject samples is examined. More specifically, data of children with poor reading abilities are compared with data of age-controls and adult readers. Because the study is the first of a series, it was decided to use a free-vision task (see below) similar to normal reading.

Three outcomes were plausible on different grounds. First, it could be expected that the OVP pattern of primary school children would be very similar to that of adults, certainly for the children with normal reading capacities. This is because the basic visual functions of 8- to 12 year old children are equivalent to those of adults (Gwiazda, Bauer, & Held, 1989). Second, it could be expected that the OVP effect would be smaller for children. Children need more time to read a word (see below), so that more than one fixation is needed to process the word. This might weaken the effect of the first fixation location. Finally, it could be hypothesized that the OVP effect would be stronger for children, because they need more visual input before they are able to recognize a word.

With respect to the children with reading difficulties, an additional hypothesis of large interindividual differences might be stated. Agreement is rising that reading difficulties can be due to deficiencies in different stages of the reading process, either in the visual or in the linguistic system; and even if the same stage of the process is affected, the inadequacy need not be the same. For example, with respect to the decrease of visual acuity outside the centre of fixation, two different bases of reading difficulties have been proposed: Bouma & Legein (1977) argued that for their sample reading problems were caused by too sharp a decrease of acuity, so that the subjects experienced a kind of tunnel vision. Geiger & Lettvin (1987; see also Perry, Dember, Warm, & Sacks, 1989; Rayner, Murphy, Henderson, & Pollatsek, 1989; but see Klein, Berry, Briand, d'Entremont, & Farmer, 1990), on the other hand, maintained that for their subjects reading difficulties were due to an excessively shallow decrease of acuity, so that information over an overly large region of the visual field was sampled and peripheral stimuli interfered with the processing of the foveal stimulus.

METHOD

Subjects

There were three samples of subjects. The first sample consisted of 15 children with reading difficulties, between 8 and 12 years old (mean age 9.9 years). They were of normal intelligence and, at the time of the experiment, received treatment for their reading problems. The centre with which we collaborated had the tendency to give us their children with the mildest difficulties in order to make a good impression. This means that the subject sample was more in line with a group of poor readers than with true dyslexics. All subjects were boys. The second sample of subjects consisted of 21 male age-matched controls (mean age 10.1) who were considered to be normal readers by their school teachers. Twenty-one male undergraduate students constituted the third group of subjects.

Stimuli

The stimuli consisted of 700 five-letter words randomly divided over seven groups. Care was taken to incorporate words with which young children were likely to be familiar. Subjects were distributed over seven latin-square groups with each group seeing the words at a different fixation location (see below). All subjects processed the whole sample of stimuli, but in a different order (for the randomization procedure used, see Brysbaert, 1991a). Stimulus presentation was controlled by an IBM XT microcomputer and displayed on a Philips monochrome CRT screen.

Procedure

Subjects were placed in front of the CRT display, so that they were sitting at a norma[l] viewing distance between 50 and 70 cm (there were no head restraints). Subjects were told to fixate a gap between two vertically aligned lines. In order to ensure adequate fixation, at a random time interval a small figure (ASCII codes 1 or 15) was presented between the fixation lines for 50 msec. Subjects had to indicate whether the figure was a laughing face or a star. They were warned by a tone if they made a mistake on these fixation control stimuli. The same procedure using digits had been applied successfully before (Brysbaert & d'Ydewalle, 1988, 1991) and is explained in greater detail in Brysbaert (1991a). As soon as the stimulus word appeared, subjects had to name it. Voice onset time was detected by a voice trigger. Unlike in the experiments leading to Figure 1, the stimuli were not presented tachistoscopically but remained on the screen until a reaction was made. This was done to assess the importance of the OVP effect in a normal reading task (see above). Incorrect responses or reaction times smaller than 200 msec and larger than 3500 msec led to a second presentation of the stimulus at a random time later in the series. A mistake on the second occasion was considered as a failure.

Words were presented in such a way that subjects initially fixated at one of seven different locations. They either looked at the blank space in front of the word, the first letter of the word, the second, the third, the fourth, the fifth letter, or the blank space behind the word. The place where the subject fixated varied randomly from trial to trial. After the response, the experimenter typed in whether the subject was correct or incorrect. The subjects did not get immediate feedback about the correctness of their answers to the words. A new trial started automatically half a second after the experimenter typed in the response. The series could be interrupted any time, in order to give the subjects a rest. Especially for the children with reading difficulties this was necessary. The experiment was divided in two sessions. After each session, the subjects were given a short rest and an overall appreciation of their performance. This consisted of feedback about the number of incorrect responses, the mean reaction time, and the number of fixation stimuli (see above) missed. The duration of the experiment varied between 40 minutes for the adult subjects to three hours for one of the poor readers (who had to be studied in two separate periods with one week in between).

RESULTS

Group Analyses

ANOVAs. Percentages of incorrect responses amounted to 0.1%, 1.1%, and 3.5% for the undergraduate students, the normal children and the children with reading difficulties respectively, which confirms the easiness of the stimuli the poor readers. There were no differences between the fixation locations or the sessions, except for the poor readers who made significantly less errors in the second session (2.8%) than in the first session (4.1%).

Percentages of stimuli that had to be administered twice before they were correctly responded amounted to 2.6%, 9.5%, and 8.4% for the undergraduate students, the normal children and the children with reading difficulties, respectively. There were again no differences between fixation locations and sessions.

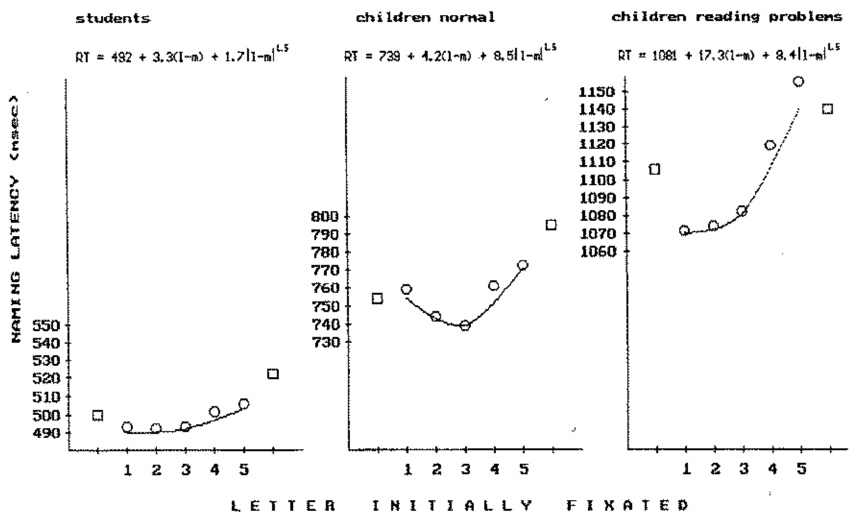

FIG. 2. Naming latency (msec) of isolated five-letter words as a function of the letter initially fixated, and the reading level of the subjects. Left part: graduate students; Middle part: normally reading children; right part: children with reading difficulties.

Reaction times of the three groups as a function of the letter location first fixated are shown in Fig. 2. These data are corrected for outliers. That is, data which after logarithmic transformation were larger or smaller than the mean plus or minus three times the standard deviation, were omitted. Percentage of outliers amounted to 1.6%, 1.7%, and 1.1% for the students, the normal children and the children with reading difficulties respectively. Visual inspection of Fig. 2 reveals that the U/J- shaped function of Fig. 1 is present for all three samples. To some extent this is surprising as naming latencies exceed 730 msec for the normal children and 1060 msec for the poor readers, which makes it quite unlikely that the words were processed within a single fixation. Still the effects remain and as we will see below become even stronger.

Separate analyses of variance for each subject sample with one between-subjects variable (latin-square Group) and two repeated measures (Session and Letter location fixated) yielded a significant main effect of Letter location for all three groups [students: $F(6,84) = 26.23$, $p < .001$; normal children: $F(6,84) = 5.48$, $p < .001$; poor readers: $F(6,48) = 4.57$, $p < .01$], and a significant Session effect for the students [session 1: RT = 518, session 2: RT = 481; $F(1,14) = 10.22$, $p < .01$]. No other effects were significant.

Analysis with a Mathematical Model.

Brysbaert and d'Ydewalle (1991) argued that ANOVAs of raw data are not well suited to investigate the effects of the different factors underlying an OVP pattern. Instead, they proposed the following model:

$$RT = a + b(l - m) + c\,|l - m|^{1.5}$$

in which
- RT = reaction time
- l = letter location fixated
- m = middle position of the word (i.e. the 3rd letter for 5-letter words)
- |l-m| = the absolute value of l-m,
- a,b,c = weights to be estimated via regression analysis.

In this model, the last component with the c-weight represents the importance of visual acuity. It starts from a minimum in the centre of the word, where acuity constraints are smallest, and raises symmetrically towards the beginning and the end of the word. The exponent 1.5 was preferred to the more familiar exponent 2 (i.e., the square value), because empirical data showed that an exponent of 1.5 resulted in c weights of relatively constant size for words ranging from 3 to 9 letters while an exponent of 2 would have resulted in unequal c weights decreasing with word length The second component of the model, with the b value, stands for the effect due to left-to-right processing and cerebral asymmetry (see above). If this component equals zero, the OVP pattern is perfectly U-shaped; a negative b-value results in a mirrored J-shaped curve with a minimum at the right side of the word; a positive b-value leads to a normal J-shaped curve with minimum between beginning and centre of the word. As indicated in Figure 1, the b-value usually is positive for adults. Finally, the constant a roughly coincides with reaction times after initial fixation in the middle of the word; that is, reaction times independent of the OVP manipulation.

Figure 2 contains the results of the analysis with the mathematical model for the three groups of subjects. In the analysis the two extreme positions, namely the blank space before and after the word, were omitted. Analyses of variance with two between-subject variables (reading level and latin-square group) gave a significant main effect of reading level for the constant a [students a= 492, normal children a= 739, poor readers a= 1080; $F(2,36) = 20.59$, $p < .001$], the linear component b [students b = 3.27, normal children b= 4.15, poor readers b= 17.34; $F(2,36) = 3.61$, $p < .05$], but not for the quadratic component c [students c= 1.73, normal children c= 8.50, poor readers c= 8.41; $F(2,36) = 1.68$, $p > .10$]. A posteriori tests (due to Spjøtvoll & Stoline, see Kirk, 1982, pp. 118-119) indicated that all groups differed from one another at the .05 level for the constant, but that the students and the normal children did not differ significantly from each other on the linear component. Mean percentages of variance explained by the model for individual subjects amounted to 65% for the students, 56% for the normal children, and 72% for the children with reading difficulties. The difference between fixations towards the blank space behind the words and fixations towards the blank space in front of the words amounted to 22 msec for the students, 41 msec for the normal children, and 31 msec for the children with reading problems. The differences between the three groups were not significant [$F(2,54) = 0.534$, $p > .50$].

Individual Analyses

Group analyses like the ones just described are claimed to be of limited value in neuropsychology because they are likely to obscure the large individual differences that are present in the samples (Caramazza, 1986; Caramazza & McCloskey, 1988; Shallice, 1988). Therefore Figs. 3-6 present histograms of individual data.

The constant: Fig. 3 shows the distribution of reaction times when subjects fixated in the middle of the words (i.e., the constant a). The distribution of the undergraduate students is one that should be expected from a homogeneous group: unimodal and with a reasonable scatter. The distribution of the normal children gives rise to more heterogeneity, which can be expected from the fact that children of different ages (8 till 12) participated in the experiment. Fifty percent of the variance is explained by age differences (correlation between school grade and reaction time equals -.69, n = 21, $p < .01$). Finally, the distribution of the children with reading difficulties shows a very large scatter. Although as a group these children are worse than the normal children (see group analyses), some of them are well within the range of children without reading problems. Two children are even in the range of the students. The fact that some children with reading problems do have difficulties with the processing of isolated words, and others do not, strengthens the argument that it is unwarranted to treat reading disability as a uniform syndrome. Only a non-significant 9% of the variance was explained by age differences between the poor readers (correlation between school grade and reaction time is -.29, n = 15, $p > .10$).

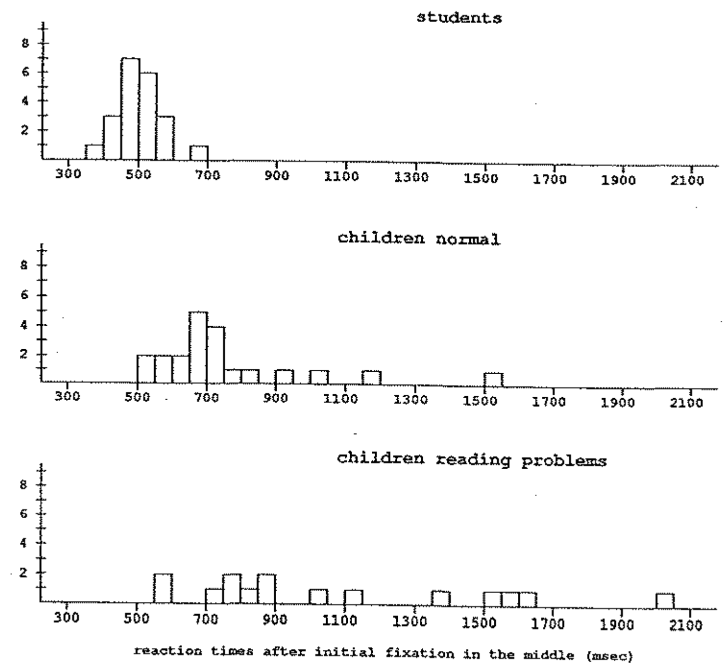

FIG 3. Distribution of the constant a for the different samples of subjects.

The linear component: Fig. 4 shows the distribution of linear components, the b values. The distribution of the students is again unimodal and with a reasonable standard deviation. The average value 3.3 is in line with the values obtained in comparable experiments (Brysbaert & d'Ydewalle, 1991). The linear component has a significant positive correlation with the constant ($r = 0.65$, n = 21, $p < .01$), so that the difference found between the linear components of the groups is also present within the sample of the students: The more time it takes for a person to name a word the larger the difference becomes between fixations at the beginning and fixations at the end of a word.

In contrast with the students, the distribution of linear components for the normal children appears to be bimodal, with one peak around -7.5 msec and another around +7.5 msec. That is, some children name words faster after initial fixations on the beginning of a word, whereas other children show better performance after initial fixations on the end of a word. We have indicated above that the linear component is due to left-to-right processing and/or to cerebral asymmetry. The linear component is not correlated with school grade ($r = -.23$, $n = 21$, $p > .10$), but just like for the student sample, is related to the constant a ($r = 0.48$, $n = 21$, $p < .05$). The latter correlation is higher when the absolute value of the linear component is taken into account rather than the raw value ($r = 0.73$, $n = 21$, $p < .01$).

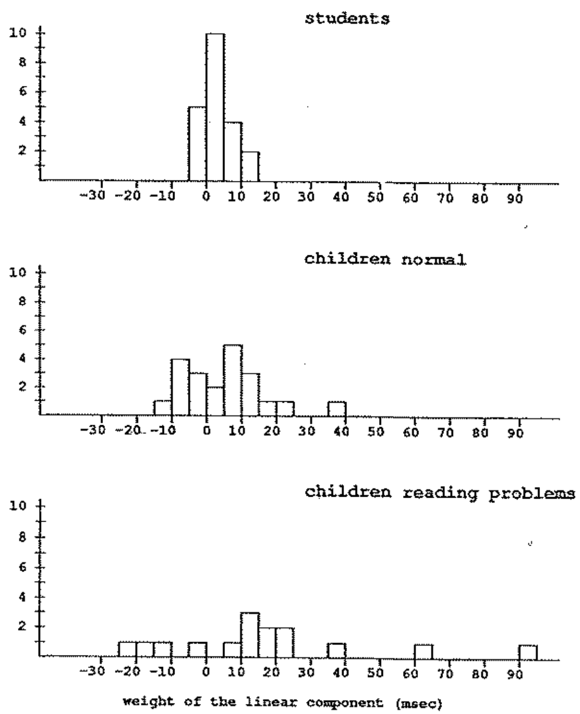

FIG. 4. Distribution of the linear slope b for the different samples.

The scatter of the data of the children with reading problems is in clear contrast with the results based on the group analysis (larger linear component for the poor readers than for the normal children and the students, see above). Data range from - 24.7 msec to +87.4 msec. As for the normal children there seem to be two groups, one with positive linear components and one with negative linear components. Also analogous to the normal children is the larger positive correlation between the absolute value of the linear slope and the constant ($r = .59$, $n = 15$, $p < .05$) than between the raw value of the linear slope and the constant ($r = .29$, $n = 15$, $p > .10$).

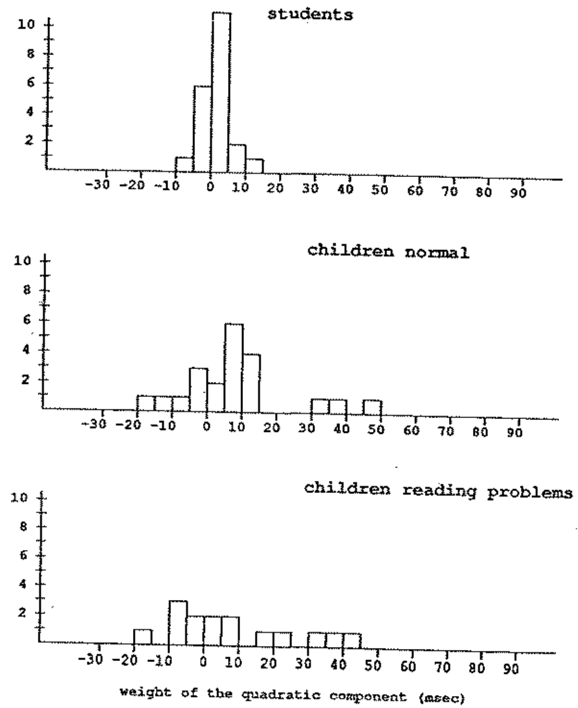

FIG. 5. Distribution of the quadratic component c for the different samples.

The quadratic component: Fig. 5 displays the distribution of the quadratic components (i.e., the c-values). For the students it is unimodal and quite narrow. Though not as clear as for the linear component, the distributions of the two children samples again appear to be bimodal. For some children (normal and poor readers) the quadratic component is clearly negative, whereas for others it is positive. A negative quadratic component means that words are processed more rapidly after a fixation at the very beginning or the very end of a word, and probably indicates that those children unlike adults prefer to process words by means of two separate fixations at the extremes. It would be interesting to test the above statement with an eye-tracking device, but because of practical limitations this has not yet been done. A further indication of the validity of the statement, however, is to be found in the correlation between the quadratic component and the school grade of the normal children. This correlation is negative and larger for the absolute value of the quadratic component than for the raw value (absolute value: $r = -.50$, $n = 21$, $p < .05$; raw value: $r = -.37$, $n = 21$, $p < .05$), which means that the importance of visual acuity decreases with increasing age. This correlation is not significant for the reading disabled children (absolute value: $r = 0.13$, $n = 15$, $p > .10$; raw value: $r = .05$, $n = 15$, $p > .10$). There is no covariation between negative scores on the linear component and negative scores on the quadratic component, either for the normal children (chi-square = 1.64, df= 1, $p > .10$), or for the poor readers (chi-square = 2.78, df = 1, $p > .05$).

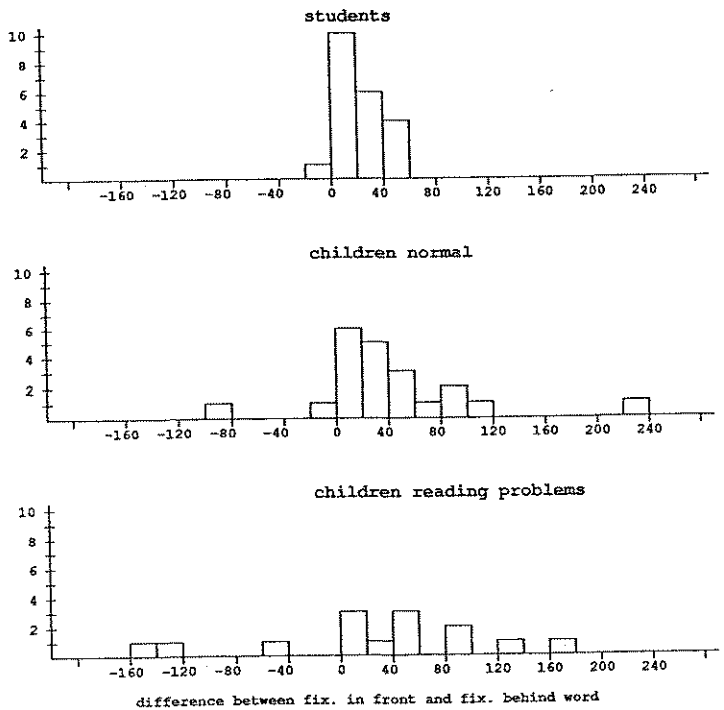

FIG. 6. Distribution of differences in reaction time after initial fixation behind and in front of the stimulus words.

The difference between fixations behind and in front of the words: Fig. 6 displays histograms of the differences in reaction times for fixations behind minus fixations in front of the words for all three groups. It was our expectation that this difference would correlate with the linear component of the model, as both components are the result of the same processes. However, only for the student population there is a moderate positive

correlation ($r = .34$, $n = 21$, $p < .08$); For the children, the correlation is negative, and even significantly so for the children with reading problems (normals: $r = -.26$, $n = 21$, $p > .10$; poor readers: $r = -.51$, $n = 15$, $p < .05$). On the contrary, the difference between fixations behind and fixations in front of the words is positively correlated with the quadratic component for all three samples (students: $r = .36$, $n = 21$, $p < .06$; normal children: $r = .36$, $n = 21$, $p < .06$; poor readers: $r = .68$, $n = 15$, $p < .01$). This seems to indicate that the difference between fixations to the blank spaces in front of and behind the words is more influenced by acuity constraints, and therefore by the tendency to make an eye-movement (certainly for the child populations). Again it would be interesting to have some eye-movement data on this (but see above).

DISCUSSION

This study compared undergraduates, normal 8 to 12 year olds, and 8-12 year old poor readers on a task where subjects fixated in different conditions on each letter position in five letter words. Naming latencies for each letter position were recorded. Adults have been shown to recognize words faster when allowed to fixate between the first and middle letters of a word (Fig. 1). This U/J shaped curve is assumed to be the result of a decrease of visual acuity outside the fixation location, left-to-right processing of the words, and cerebral dominance of the subjects.

The U/J shaped curve was also found in this study with free vision for adults, poor readers and their chronological age controls (Fig. 2). Data of the adults were very similar to those obtained in other studies with tachistoscopic (Fig.1) and free vision (Brysbaert & d'Ydewalle, 1991). Manipulation of the children's initial fixation location seemed to have a larger effect than manipulation of the adults' initial fixation location, despite the fact that the children's naming latencies were much longer, even after fixation on the optimal location. This was true both for the good and the poor readers. Although multiple fixations on the words were possible, children's performance depended to a large extent on the letter first fixated. This implies that more constraints are put on a child's oculomotor behaviour during reading, if a relationship between the optimal viewing position and the optimal landing position is assumed (Nazir, 1991b).

A complicating factor, however, was, that there were large interindividual differences between the children (both good and poor readers): Some children were faster after initial fixations on the beginning of the stimulus words, others after initial fixations on the end. Similarly, some children performed better after initial fixations on the middle of the stimulus, whereas others were faster after initial fixations on the extremes. This gave rise to bimodal distributions respectively on the linear (Fig. 4) and the quadratic (Fig. 5) component. Because these differences were not expected, at the moment we can only speculate about their origin. The linear component is thought to be the result of (a) left-to-right processing of words, and (b) the cerebral dominance of the subjects (see the Introduction). Both factors lead to expect a positive component in most of the cases, as was indeed true for the students. However, a considerable percentage of the children (about 33%) showed pronounced negative components, which indicate better performance after fixations on the end of the words. So, for these children either the last half of a word was the most informative part, or they took advantage of the word being presented left of fixation (i.e., in the left visual half field). It is not clear what the basis of the former statement could be, but the latter explanation is in agreement with Bakker's theory (e.g. Bakker, 1991) that hemispheric functioning alters during reading acquisition. According to this theory, initial reading skills are controlled primarily by the right cerebral hemisphere, but as readers become more advanced, the left hemisphere becomes dominant. More controlled studies are, however, needed before firm statements can be made about this matter, also because there was no significant relation between chronological age and magnitude of the linear component for either group of children; a relationship that might have been expected on the basis of Bakker's theory.

The bimodal distribution of the quadratic component, on the other hand, seems to be less difficult to account for, because both phenomena can be explained by the same principle: If the decrease of visual acuity outside the fixation location is substantial, then a considerable penalty time will be needed for fixations on the extremes of a word. However, from a certain point on it will become more advantageous to use a dual-fixation strategy to process the word; that is, processing time will be smaller after a fixation on the beginning and the end of a word than after a single fixation on the middle. Eye-movement registrations could accredit the validity of this statement.

The interindividual differences among the children do not invalidate the statement that the OVP effect is stronger for children than for adults. They only indicate that there is more variability with respect to the optimal viewing position itself in young subjects. This can also be demonstrated by considering the absolute values of the weights rather than the raw values: For the student sample, values remain approximately the same (the linear component increases from 3.3 to 3.7, the quadratic component from 1.7 to 3.3). For the samples of children, however, weights increase dramatically (normal children: linear component 9.4 instead of 4.2, quadratic component 12.8 instead of 8.5; poor readers: linear component 24.6 instead of 17.3, quadratic component 13.7 instead of 8.4). The differences between the student and the children samples in these analyses are all reliable ($p < .01$).

In the introduction it was mentioned that three outcomes could be expected with respect to the OVP effect in children on different grounds: either a similar effect, a smaller effect, or a larger effect. The last alternative was supported by the data. This indicates

that the children's performance is dominated to a larger extent by rather low level processes such as the drop of visual acuity outside the fovea and interhemispheric communication, despite the fact that their low order visual functioning is equivalent to that of adults (Gwiazda et al., 1989). Two mechanisms can account for this: Either there are less top-down influences in primary school children than in adults, or threshold values of the word recognition units are higher so that the system needs a better input before it can figure out what has been presented (the difference between the two mechanisms is that the latter can be implemented in a purely bottom-up system). Whatever the mechanism, it follows that the input must be of a better quality for a learning system than for a mature system, and more so for poor readers than for good readers. This has consequences for the interpretation of experimental results. For instance, the finding that (dyslexic) children recognize fewer letters and words after parafoveal presentation (Bouma & Legein, 1977) needs not indicate that something is wrong in the visual system. This study suggests that the same outcome may be found for deficiencies in the linguistic system. Similarly, the finding that the perceptual span during reading is smaller for children than for adults (Rayner, 1986) needs not be interpreted as a mere focusing of attention on foveal processing; It could also be due to the immature system requiring a higher quality of visual input. Other stimuli than letters and words must be utilized, if an experimenter wants to make firm statements about the importance of an adequate visual system or the focusing of attention in beginning readers. Another conclusion the results point to is that the same deficiency of the visual system will be more harmful for young readers than for skilled readers. Or to put it more positively, minor defects of the visual system that hamper reading in the beginning stages, may become tractable as the child's reading skills grow. This idea may have implications for remedial teaching, because it suggests that strengthening the linguistic capacities of a child may help overcome otherwise incurable weaknesses in the visual system.

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