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Running head: OVP EFFECT IN BEGINNING AND DYSLEXIC READERS

The Optimal Viewing Position Effect in Beginning and Dyslexic Readers

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Abstract: The present study compared the reading ability of first-grade and dyslexic children using an experimental paradigm known to elicit the optimal viewing position (OVP) effect in skilled readers. Word frequency and initial fixation location were manipulated in a word identification task. The results showed an OVP effect for both groups. However, word-recognition performance was lower for the dyslexic than for the first-grade group. In addition, whereas beginning readers obtained the typical inverted J-shape curve, dyslexics had a symmetric curve. These results were corroborated by a letter-report analysis showing that dyslexics failed to report word endings, even when fixating at that location. Robust effects of word frequency were also obtained for both groups. But unlike adult readers, this factor did not interact with fixation position.

Key words: reading acquisition, developmental dyslexia, OVP effect, visuo-attentional and lexical processing.

Normal reading in alphabetic languages begins with the perception of the letter units that make up words. Except for this first stage of the process, there is no consensus about the mechanisms necessary for skilled reading or how they might be impaired in the specific reading disability (developmental dyslexia). Previous research has been largely devoted to specifying the role of phonological skills in learning to read (e.g. Goswami & Bryant, 1990; Sprenger-Charolles et al., in press). However, reading also requires an accurate visual analysis that allows for the precise decoding of the written words. This is usually accomplished by shifting from distributed attention to more focused attention, which is also useful for minimizing the effect of laterally distracting information (Lalonde & Brown, 1989). It follows that the ability to orient the focus of attention as well as the ability to control its size are assumed to be deeply involved in reading (Morris & Rayner, 1991). Whereas it is likely that both phonology and visual attention contribute to skilled reading acquisition and its dysfunction, few studies have been conducted to examine visuo-attentional processes related to word recognition skills in children as they learn to read. Similarly, although it is widely accepted that one of the major causes of developmental dyslexia is a phonological deficit (e.g. Bradley & Bryant, 1983), there is still a great deal of argument about whether dyslexics' visuo-spatial attention disorder actually causes a reading deficit. In addition to poor performance on tasks requiring phonological awareness, dyslexic children can show visual perception deficits (e.g. letters in a wrong or inverted position, words that are distorted or overlapping) and/or visual attention impairments (e.g. problems focusing attention) when they attempt to read (Facoetti et al., 2003). These deficits cannot be attributed to a purely phonological dysfunction. Therefore, the aim of the present study was to examine the relationship between lexical and visuo-attentional processes in beginning and dyslexic readers.

Previous studies on skilled readers have suggested that the variable viewing position paradigm can be used to investigate visuo-attentional and lexical processing in reading (e.g. Kajii & Osaka, 2000). A typical finding about the perception of written words in adults is that the ease with which printed words are recognized depends on the position where the eyes initially fixate. Word-recognition performance is maximal slightly left of the word's center and decreases on both sides of this optimal viewing position (OVP) (O'Regan & Jacobs, 1992; O'Regan, Lévy-Schoen, Pynte, & Brugailière, 1984; Vitu, O'Regan, & Mittau, 1990). This position is optimal for word recognition because it lowers the probability of refixation and thus shortens recognition time, with a delay of 20 ms for each letter away from this position. This OVP effect has been reported for a variety of dependent measures. Naming

latencies and lexical decision times are the shortest when the eye starts to fixate the word near its center (O'Regan & Jacobs, 1992; O'Regan et al., 1984), and the correct identification percentage is the highest for fixation at the OVP (Farid & Grainger, 1996; Nazir, O'Regan, & Jacobs, 1991; Nazir, Jacobs, & O'Regan, 1998). Researchers seem to agree that the major determinant of the OVP effect is the decrease in visual acuity outside the center of fixation, so letters viewed centrally will benefit from higher resolution and thus better visibility than those that fall near the edge (Jacobs, 1979). If the drop in acuity was the only significant factor, the OVP would be located at the word's midpoint. The off-center location of the OVP might be explained by three additional factors, namely, a) the fact that in languages like English and French, words are read from left to right; b) the fact that for these languages, most words can be guessed from their beginning (since word beginnings allegedly provide a higher degree of lexical constraint¹ than word endings; for a discussion, see Farid & Grainger, 1996; O'Regan et al., 1984); and c) the fact that reading induces perceptual learning at early stages in the visual pathway (Nazir, 2000). Another aspect that is relevant to our discussion concerns the strength of the OVP effect for high- and low-frequency words. Using a lexical decision task, O'Regan and Jacobs (1992) showed that the penalty for not fixating the OVP seems to be greater for low-frequency words, thus suggesting an interaction between fixation position and frequency². If this interaction is real, it is conceivable that it might be explained by saying that for high-frequency words, the ability to infer poorly-seen letters may be greater, and the cost may be smaller as the eye gradually deviates from the OVP.

Arguments for a relationship between reading ability and visuo-attentional processes are provided by the view that fixating the OVP aids word recognition (see O'Regan & Jacobs, 1992) and that this position may vary as a function of lexical factors (O'Regan et al., 1984). It therefore seems plausible that less-than-optimum reading caused by failure to fixate the OVP is related to reading ability. The recognition performance of a beginning reader can vary, for instance, with the ability to identify individual letters in words and/or with the degree to which the child can take advantage of redundancy in the structure of written language. Using the fixation-contingent display, Aghababian and Nazir (2000) showed that in beginning readers, the OVP effect emerges very early during acquisition, thus suggesting that beginning readers extract visual information from print in much the same way as proficient readers do. Note however that the lexical processing performance of these first-grade children was not examined. Conclusions regarding the processing of information beyond the center of fixation may not apply to readers diagnosed as dyslexic, and differences related to the OVP may be found between normally-reading children and those undergoing treatment for reading

problems (see Aghababian, Nazir, Lançon, & Tardy, 2001, for the use of this paradigm in the case of a deaf beginning reader). The following study assessed the reading ability of dyslexics and first graders, using a word identification task in combination with the variable viewing position technique.

EXPERIMENT

As seen in the introduction, the OVP phenomenon in recognition accuracy for briefly presented words is likely to result from a combination of visuo-attentional and lexical factors, the contribution of lexical factors varying with visuo-attentional factors. Our aim in the present study was thus to further investigate the visuo-attentional and lexical processing of first-grade and dyslexic children, using the OVP paradigm. More specifically, we wanted to determine whether word-frequency and fixation-location effects would occur in both dyslexic and first graders. Our second aim was to further describe the nature of the reading deficit that characterizes developmental dyslexia. Note that theoretically, the presence of an OVP effect implies that there is a position where all letters in a string can be processed in a minimal number of fixations (optimally, one). This point is important with respect to dyslexia. If dyslexic readers are unable to process all letters in a word rapidly, as normal readers do, they should not show the typical OVP effect. Dyslexic children might compensate for their reading deficit by referring to local salient features in the words or to letter clusters. As these salient features are randomly distributed across words, the viewing position (VP) curves should therefore be flat. If the system that supports normal reading is functioning at least partially, we should find a VP-curve that differs from that of normal beginning readers only by shape or height.

Method

Participants. Thirty-five children were tested: 20 were first graders (mean age 6.8 years) and 15 were dyslexics (mean age 9.3 years). They were selected from a neurological rehabilitation ward on the basis of their reading level (i.e. 6.8 years) assessed with the Alouette's standardized reading test (Lefavrais, 1965). Thirteen were diagnosed as phonological dyslexics in reading aloud and spelling tasks (EVALEC, Sprenger-Charolles, Colé, Béchenec, & Kipffer-Piquard, submitted): their performance with pseudowords were more than 1.65 standard deviation below average readers of the same age.

Materials. A pool of 120 critical words was selected from Manulex (Lété, Sprenger-Charolles, & Colé, in press). Manulex is a computerized lexical database which provides frequency-based lists of non-lemmatized and lemmatized words compiled from the 1.9 million words found in the main French primary school reading books. Frequency³ is given

for four levels: 1st grade, 2nd grade, 3rd to 5th grades, and all grades combined. The stimuli for this study were extracted from the first grade lemma lexicon: 60 were high-frequency words (mean = 406 per million) and 60 were low-frequency words (mean = 16 per million). In each frequency set, there were 93% of nouns, 4% of verbs, and 3% of adjectives. All words were 5 or 6 letters long.

Task and procedure. Stimulus presentation was on a 17" color monitor connected to a Pentium III laptop computer running the DMDX software package (Forster & Forster, 2001 version 2.9.01). The stimuli were displayed in lowercase in 24-point Courier font. Each word was divided into five equally-wide zones (i.e. 1 letter wide for five-letter words and 1.2 letters wide for six-letter words). Words were presented in such a way that subjects initially fixated the center of each zone (hereafter called positions P1, P2, P3, P4, and P5). Across all participants, each word was seen from all five fixation positions. Exposure time for the target was determined individually for each participant, depending on his/her correct identification score on a training session (in which we looked for the presentation duration that produced scores ranging between 50-75% correct four-letter word identification, i.e., about 175 ms for first-grade children and 250 ms for dyslexics). Each trial consisted of the following sequence of events. Participants were first instructed to look at a fixation point at the beginning of each trial, and not to move their eyes. After 500 ms, the fixation point was replaced by a target word that was displayed on the screen for the duration previously determined for that particular child. The word was displaced laterally with respect to the fixation point according to its position condition. Then the word was replaced by a backward mask which consisted of a string of hashes. The task was to identify (name) the target word. If not possible, participants were asked to report as many letters as they could in the correct position. The experimenter manually recorded each participant's response. The mask remained on the screen until the experimenter pressed the spaced bar to trigger the next trial.

Results

Correct word identifications. The mean percentage of correct word identifications was calculated for all participants and all items pooled. In each group, a 2 (Lexical Frequency) x 5 (Fixation Position) ANOVA was conducted with subjects (F1) and items (F2) as random factors. Lexical frequency was treated as a between-factor in the by-item analysis. Figure 1 summarizes the correct word identification results as a function of lexical frequency and fixation position for the first-grade and dyslexic children. In the first-grade group, the ANOVA revealed a significant effect of lexical frequency, F1 (1, 19) = 165.69, $p < .001$, MSE = 212; F2 (1, 118) = 65.35, $p < .001$, MSE = 1612. More high-frequency words than

low-frequency words were identified (76% vs. 50%, respectively). A significant effect of fixation position was also found. There were more correct identifications when the viewing position corresponded to the middle of the word (79% in P2 and P3) than to the beginning (62% in P1) or the end (59% and 39% in P4 and P5, respectively), $F_1(4, 76) = 69.25$, $p < .001$, $MSE = 158$; $F_2(4, 472) = 65.45$, $p < .001$, $MSE = 503$. No interaction was found between the two factors (see Figure 1), $F_1(4, 76) = 1.89$, $p = .12$, $MSE = 165$; $F_2(4, 472) = 1.86$, $p = .12$, $MSE = 503$.

 Insert Figure 1 about here

The dyslexic children also exhibited a main effect of lexical frequency. High-frequency words were identified with more accuracy than low-frequency words (36% vs. 14%, respectively), $F_1(1, 14) = 49.38$, $p < .001$, $MSE = 382$; $F_2(1, 118) = 48.27$, $p < .001$, $MSE = 1466$. A main effect of fixation position was found, $F_1(4, 56) = 9.72$, $p < .001$, $MSE = 162$; $F_2(4, 472) = 14.13$, $p < .001$, $MSE = 490$. Dyslexic children identified 34% and 29% of the words at P2 and P3, respectively vs. 20% at P1 and 16% at P5. Again, no interaction was found between these two factors, $F_1(4, 56) = 1.78$, $p = .15$, $MSE = 112$; $F_2(4, 472) = 1.67$, $p = .16$, $MSE = 490$.

As can be seen in Figure 1, the results also revealed systematic differences in the height and shape of the first-grade and dyslexic children's VP curves. With respect to height, word recognition performance was lower for the dyslexic group (25%) than for the first-grade group (64%). With respect to shape, first-grade children showed more asymmetry between P1 and P5 (23%) than did dyslexic children (4%) (note that a floor effect could be suspected for low-frequency words but not for high-frequency words). An ANOVA restricted to positions P1 and P5 in both groups confirmed this result with a significant interaction between position and subject group⁴, $F_1(1, 33) = 17.03$, $p < .001$, $MSE = 176$; $F_2(1, 118) = 18.17$, $p < .001$, $MSE = 594$ and for high-frequency words only, $F_1(1, 33) = 6.32$, $p < .05$, $MSE = 252$; $F_2(1, 59) = 7.66$, $p < .01$, $MSE = 783$.

Correct letter reports. To further investigate this qualitative difference in the shape of the two VP curves, the correct letter-report percentage was computed for each letter in the stimuli in each fixation position condition, when participants failed to identify the target word. A letter was only considered to be correctly reported if it was in the right position. In addition, for clarity, three stimulus zones were defined: the beginning (1st and 2nd letters), the

middle (3rd and 4th letters) and the end (5th and 6th letters) of the word. Figure 2 presents the percentage of correct reports at each fixation position for each zone.

 Insert Figure 2 about here

In case of failure to identify the word, both groups correctly reported the beginning of the word at least 50% of the time, whatever the fixation position. However, the results revealed differences between beginning and dyslexic readers for the middle and the end of the word. For first-grade children, the highest report accuracy was observed for letters around the fixation location, independently of where the eye first fixated. However, dyslexic children did not benefit from proximity to the fixation position, particularly for reporting the last two letters in the word.

GENERAL DISCUSSION

In the present article, we investigated the reading ability of beginning and dyslexic readers, using an experimental paradigm that is known to elicit a highly stable pattern of performance in skilled readers. This pattern consists of a systematic variation in reading performance as a function of the position of the eyes in the word: word recognition performance is best when the eyes fixate slightly to the left of the word's center and decreases when the eyes deviate from this OVP and moves towards the beginning or the end of the letter string (Nazir et al., 1991; O'Regan & Jacobs, 1992).

Visuo-attentional processing. In line with Aghababian and Nazir (2000), our results confirmed that very early during reading acquisition, the typical OVP effect is already present. No difference between beginning and skilled reading patterns was apparent. Recognition performance was best when the child fixated regions in the word where the greatest number of letters could be recognized and where most words could be guessed, that is, left of center. Visual-field asymmetries comparable to those observed with adults were evident by the end of the first year of reading instruction. Like beginning readers, dyslexic children exhibited a systematic variation in reading performance when their eyes were fixating different locations in the word, suggesting that the system that supports normal reading was at least partly functioning. However, the shape of this VP function was qualitatively different from the norm. Whereas beginning readers showed the typical inverted J-shape function with a difference between fixating at the beginning and the end of the word, dyslexics had a symmetrical curve. The presence of a significant effect of fixation position indicates that dyslexics did not compensate for their reading deficit by referring to local salient features in the words or to letter

clusters. According to Nazir et al. (1991), asymmetries in the VP curve might be caused by a difference in the ability to identify letters in the left and right visual fields. Note that, in a target detecting task, Brannan and Williams (1987) showed that good readers and adults were significantly more accurate when the target appeared on the right side of a fixation point (RVF enhancement), but poor readers were equally accurate on the two sides. The absence of the characteristic left-right asymmetry thus suggests abnormal processing of information outside of foveal vision for dyslexics. It may be that skilled readers develop an automatic bias towards information processing in the RVF while less skilled readers fail to do so. This idea is strengthened by our analysis on letter reports, which revealed that dyslexics are very poor at reporting letters situated near the end of the word, even when the initial fixation is imposed at this location. It remains to be seen whether this deficit results from particular scanning strategies (Brannan & Williams, 1987) or from a narrow perceptual span (Aghababian & Nazir, 2000).

Lexical processing. Robust effects of word frequency were obtained for first-grade and dyslexic children. As can be seen in Figure 1, the VP curves of the two groups differed in height, which indicates a poor lexicon for the dyslexics. However, it is interesting to note that the magnitude of the effect was comparable in the two groups, thus suggesting that activation of lexical knowledge is not impaired in dyslexics. Unlike adult readers, no interaction was found between fixation position and frequency. For first-grade children and for dyslexics as well, visuo-attentional and lexical factors were additive, in that frequency increased height equally for all viewing positions. We thus conclude that, although lexical competence was clearly poorer for the dyslexics, the mental lexicon seemed to be used in the same way by both groups in word recognition.

In conclusion, the present data clearly show that the reading system of dyslexics is functioning at least to some extent. Dyslexics exhibited a strong frequency effect and an OVP effect, although the shape and height of their VP curve was not conventional. Under fast exposure durations, words can be read and lexical knowledge can be activated in a single fixation. The only qualitative difference between beginning and dyslexic readers consists of non-RVF enhancement in dyslexics, thus suggesting a deficit in visuo-attentional processing.

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AUTHORS' NOTE

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FOOTNOTES

1. Lexical constraints are what determine the number of possible words one can correctly infer from a limited quantity of information.

2. Note however that according to Nazir's model, variables that affect the word as a unit (e.g. frequency of occurrence of a word) have an additive effect on the OVP and change the total height of the VP curve without altering its shape (see Aghababian & Nazir, 2000, for a discussion).

3. The frequency computations are grade-level-based and weighted by an index of dispersion among the schoolbooks. This led to a better estimate of the true frequency that would be found in a corpus of infinite size. The database was developed as in the *Educator's Word Frequency Guide* (Zeno, Ivens, Millard & Duvvuri, 1995) used for the English language. In a study on age of acquisition, Zevin and Seidenberg (2002) used the sum of the grade-level frequencies and found that the Zeno et al. counts were more closely correlated with latencies than were earlier counts such as those extracted from adult corpora like Kucera and Francis's (1967) norms, suggesting that, for language acquisition research, precise child norms must be used to measure how often words are experienced by children during their exposure to print.

4. Note that the global interaction between position and subject group was significant too, both for high- and low-frequency words [$F_1(4, 132) = 11.68, p < .001, \underline{MSE} = 160$; $F_2(4, 472) = 12.03, p < .001, \underline{MSE} = 541$].

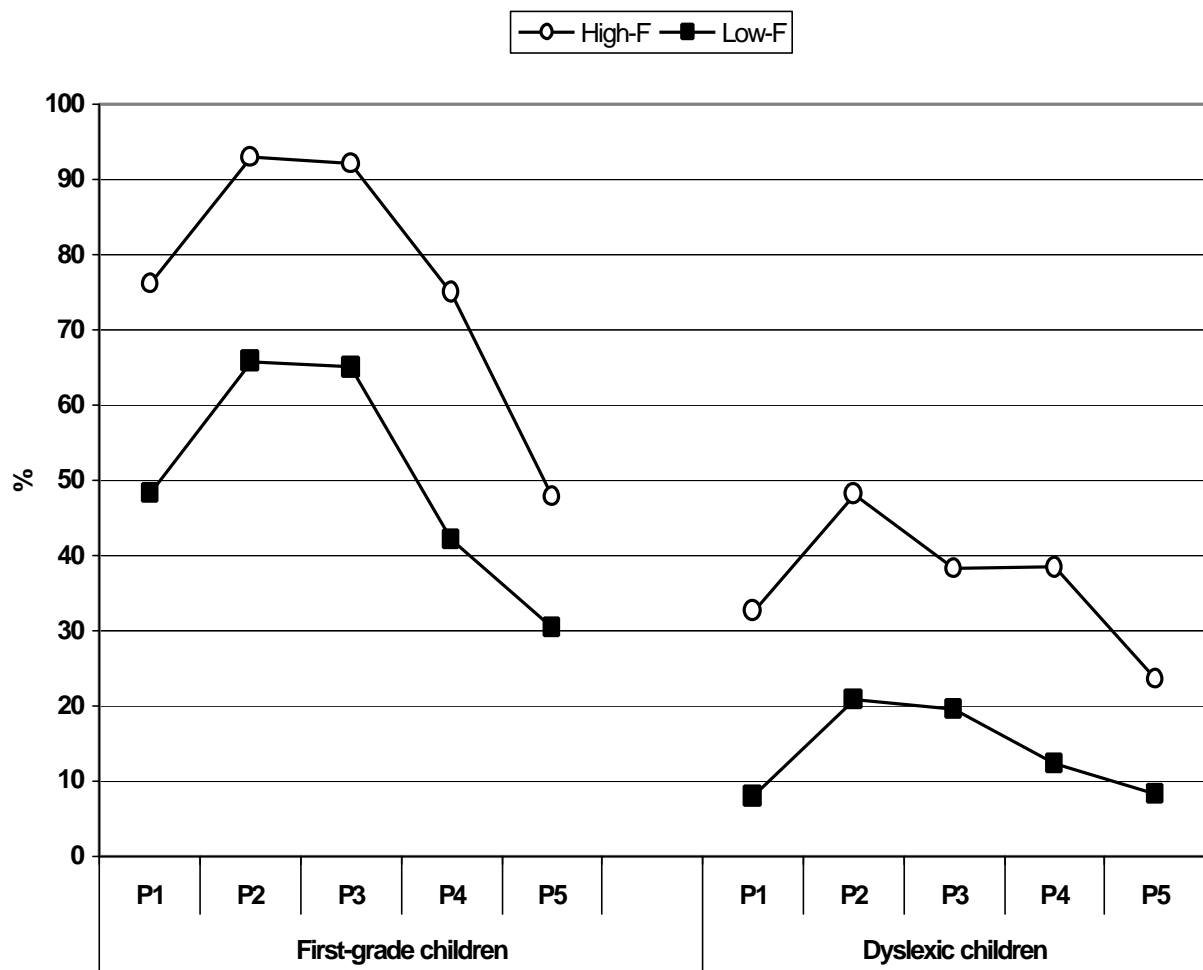


Figure 1. Correct word-identification percentage as a function of lexical frequency and fixation position, for first grade and dyslexic children.

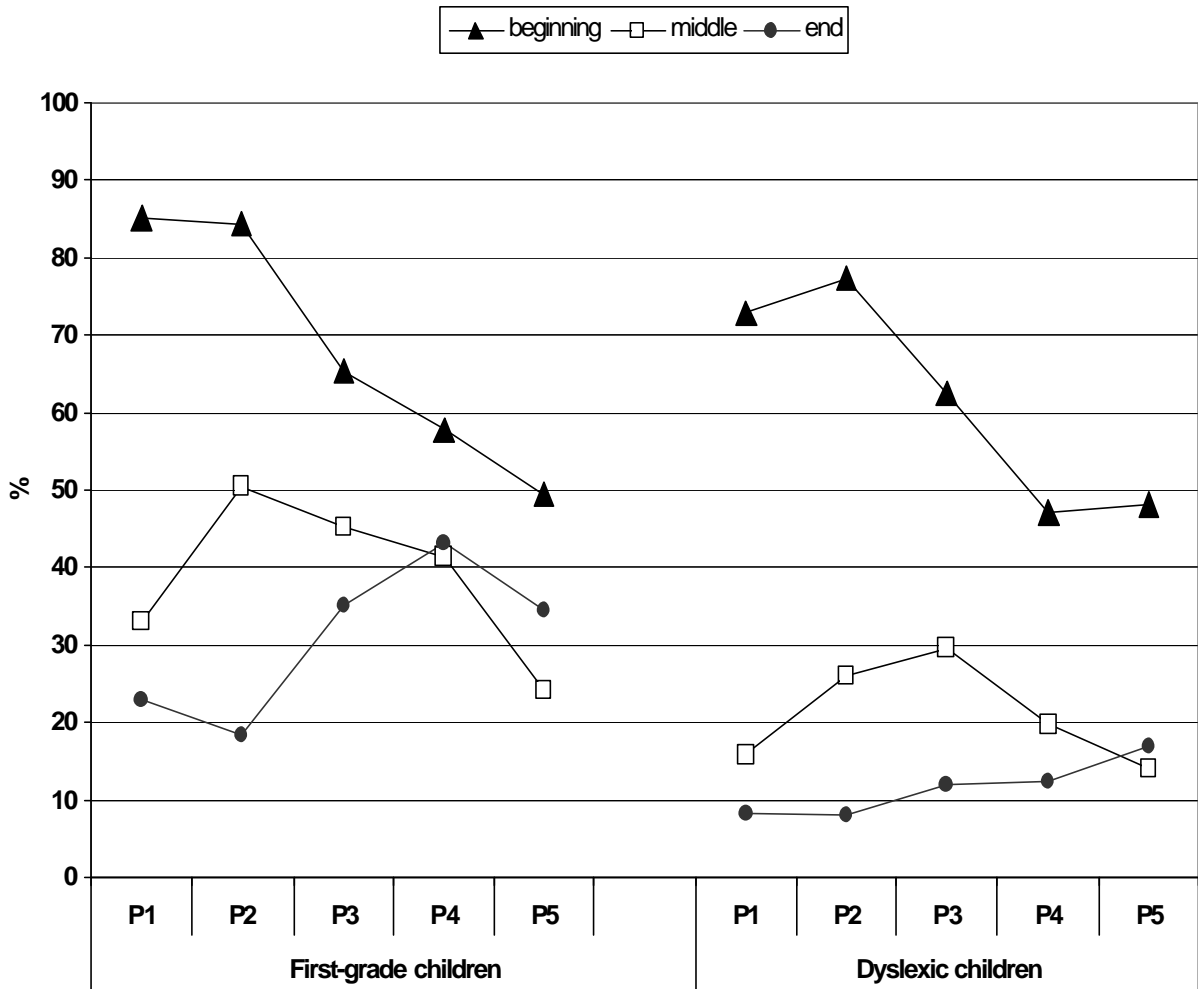


Figure 2. Correct letter-report percentage as a function of stimulus zone and fixation position, for first grade and dyslexic children.