VISUAL SELECTIVE ATTENTION AND READING EFFICIENCY ARE RELATED IN CHILDREN

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Abstract

We investigated the relationship between visual selective attention and linguistic performance. Subjects were classified in four categories according to their accuracy in a letter cancellation task involving selective attention. The task consisted in searching a target letter in a set of background letters and accuracy was measured as a function of set size. We found that children with the lowest performance in the cancellation task present a significantly slower reading rate and a higher number of reading visual errors than children with highest performance. Results also show that these groups of searchers present significant differences in a lexical search task whereas their performance did not differ in lexical decision and syllables control task.

The relationship between letter search and reading, as well as the finding that poor readers-searchers perform poorly lexical search tasks also involving selective attention, suggest that the relationship between letter search and reading difficulty may reflect a deficit in a visual selective attention mechanisms which is involved in all these tasks.

A deficit in visual attention can be linked to the problems that disabled readers present in the function of magnocellular stream which culminates in posterior parietal cortex, an area which plays an important role in guiding visual attention.

Key words: attention, reading disability, visual search

Introduction

It has often been suggested that reading problems may depend on a sensory visual deficit (Lovegrove, Bowling, Badckock et al., 1980; Lovegrove, Martin and Slaghuis, 1986, Slaghuis, Lovegrove and Davidson, 1993; Slaghuis, Twell and Kingston, 1996).

This view has often been criticised on the basis of the argument that visual deficits cannot be a cause of reading disability and the two deficits are not related (Hulme, 1988; Jorm, 1983; Vellutino, 1979). This argument is strengthened by the difficulty in interpreting data showing a relationship between visual and reading performance. A positive relationship between reading and visual performance could indicate a simple correlation between reading rate and visual efficiency and tell nothing about the direction of causality. For example, better readers could be faster in selecting letters in a background of similar letters because they are more used to process letters or reading material. Despite the difficulty in demonstrating the causality between visual and reading processes, there is increasing evidence of an apparently strange association between these two processes (Slaghuis, Lovegrove and Davidson, 1993; Slaghuis, Twell and Kingston, 1996; Marendaz, Valdois and Walch, 1996; Borsting, Ridder, Dudeck et al., 1996; Eden, VanMeter, Rumsey et al., 1996).

One example of this association is the finding that low performance in tasks involving visual selective attention is related to low performance in reading. This association is usually shown by comparing visual performance in a group of disabled readers or dyslexics with a group of normal readers chronologically age matched. It is usually found that the capacity to perform the visual search tasks is reduced in disabled readers with respect to normal readers. One of these tasks is the visual search in which the observer has to identify multifeature elements like a letter (Williams, Brannan and Lartigue, 1987; Casco and Prunetti, 1996) or a shape (Ruddock, 1991) in a background of similar elements. When using multifeatures elements, the time required to identify the target element usually increases with the number of elements in the background. Another selective attention task in which disabled readers fail is visual acuity for identifying a letter when it is crowded by other letters in the surround. In this task, the ratio of the size of the smallest crowded letter identified to the size of the smallest single letter defines visual crowding (Flom, Health and Zakahaski, 1963).

A common feature of all these visual attention tasks is that attention to the target is degraded by the presence of surrounding objects. It is possible that the related performance in visual selective attention and reading tasks occurs because in both tasks a target, like a letter or word, is degraded or masked by non-targets in the surround and this could be due to a difficulty of inhibiting stimuli that are not the focus of attention (Morris and Rayner, 1991). We have investigated this possibility in the present study.

This hypothesis is also suggested by the observation that visual selective attention abilities develop at about 5 to 6 years of age and, in this respect, they are different from difficulties in other visual sensory functions like acuity, contrast sensitivity, binocularity, orientation discrimination etc., which are fully developed at about one year of age (Atkinson and Braddick, 1981a; Sireteneau and Rieth, 1992a, 1992b). Therefore, since visual selective attention and reading abilities develop in parallel it is likely that a relationship between visual selective attention and reading performance exists because similar visual operations are involved in these two tasks.

We addressed this issue in a novel way. First, we selected groups on the basis of visual selective attention abilities and then compared these groups in reading abilities. This has never been done before.

However, simply to test vision before reading, as opposed to the more usual practice of first establishing reading performance, does not necessarily offer a new perspective on causality. In our study we attempted a direct test of direction of causality. That is, when the relationship between reading and visual performance existed, we looked for a dissociation in linguistic tasks different from reading.

We predicted that if a group present a conjoint deficit in visual selective attention and reading due to a deficit in a visual operation involved in both tasks, this same group should also present a deficit in other linguistic tasks involving this visual operation but not in linguistic tasks not requiring this operation. One common visual operation is that allowing conjunction of features to locate and segment these features from those in the background. The integration operation is a capacity-limited process which requires visual attention (Treisman and Gormican, 1988). Since the same operation provides the input to the word recognition system (visual word form), a deficit in this operation should selectively affect performance in linguistic tasks not involving the integration operation.

An alternative possibility is that the conjoint deficit in visual attention and reading is not due to a relationship of causality between the two tasks. For example it could well be that good readers are faster in selecting letters in a background of similar letters because, since they are fast readers, they are also more familiar with letters or reading material. In this case poor readers should present a non visually-specific reduced performance in linguistic tasks different from reading.

To summarise, in the present study we first tested children in a visual selective attention task using highly similar letter pairs. These stimuli are likely to produce contour interaction so that the inhibition of stimuli which are not the focus of attention is more difficult. We then tested reading abilities to establish whether visual selective attention and reading performance were related. Finally, we involved the subjects in tasks like lexical decision or segmentation of a word in syllables on the assumption that performance in these tasks should not be affected if the underlying deficit is visual.

EXPERIMENT 1: THE SEARCH TASKS

The aim of Experiment 1 was to classify children according to different efficiency levels in a visual selective attention task. Visual selective attention tasks are often used in neuropsychological assessment of diffuse brain damage, acute brain condition or more specific defects of inattention (Lezak, 1995). The basic format consists of rows of letters or numbers randomly interspersed with a designed target number or letter. The patient is instructed to cross out all target letters or numbers. The performance is scored for errors and for time to completion; if there is a time limit, scoring is for errors and number of targets crossed out within the allotted time (Diller, Ben-Yishay and Gerstamm, 1974). We have used a similar task to test visual selective attention performance in children.

Children of a relatively older age (11 to 12 years old) were chosen because at this age performance in both visual attention and reading tasks does not differ from adults (Atkinson, 1991; Sireteanu and Rieth, 1992a, 1992b). For this reason we assume that low efficiency in these task after 10 years reflects a long-term difficulty of the mature visual system in visual selective attention.

We employed, as is usually the case in selective attention tasks, uppercase letters as stimuli. The stimuli consisted of three pairs of target/background letters, one example of which is shown in the Figure 1. The pair were selected on the basis of a veridical similarity index computed by using rating scores of 32 subjects (Boles and Clifford, 1989). This procedure is rather different from that

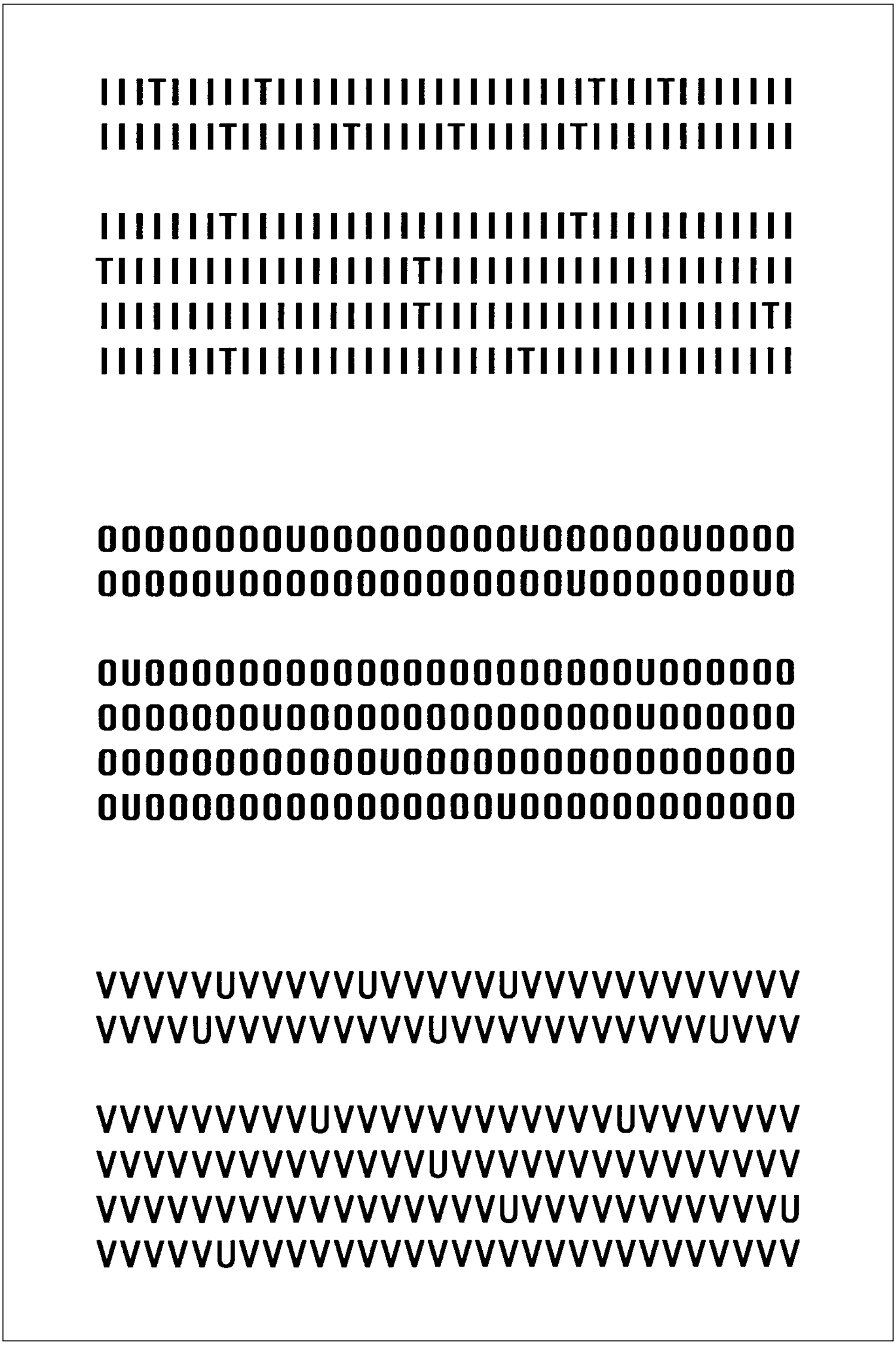

Fig. 1 – *Examples of stimuli used in the visual search task.*

used in visual literature in which visual similarity is derived on the bases of template overlap, feature similarities, spatial frequency etc. Veridical similarity matrices are instead computed on the bases of subjective similarities. Analysis of subjects' ratings of letter similarity using the non-metric multidimensional scaling shows the adequacy of fit of three physical dimensions. The first is related to upper vs lower case status of letters. Since upper case letters were used, this dimension does not affect similarity in our stimuli. The second dimension refers to angular components (acute vs. vertical angles). The elements of the three letter pairs we used had the same value as dimension 2. Thus, dimension 2 did not affect perceived similarity between these pairs.

The third dimension is appropriate for labelling curvature and orientation. We used this dimension to differentiate our elements in a pair.

In the UV pair both target and background have a similar angular components (–.32 and –.38) and this may produce contour interaction. However, the target and background differ on the basis of a straight slanted component (.09 and .77) and this may contribute to target discrimination.

In the UO pair both target and background have a very similar angular component (–.32 and –.34) and these may produce contour interaction. However the background elements have a curved component (–.78) which is absent in the target elements (.09) and this may contribute to discrimination.

In the IT pair both target and background have the same angular component (.74 and .72) and this may produce contour interaction. However the target has a straight horizontal component which is absent in the background elements (–1 and .1) and this may affect target discrimination.

Materials and Methods

Subjects

Five hundred and ninety 11 to 12 year old children (mean age and standard deviation expressed in months are 135.4 and .67, respectively), participating in a National project on Psychological Risk in Adolescence, were tested. Two hundred and ninety-two were males and two hundred and ninety-nine were females.

All subjects were free of neurological and sensory problems and had an I.Q. above 85 as measured with the PMA battery (Primary Mental Abilities Battery, Thurstone and Thurstone, 1965).

Apparatus

Each stimulus was constructed on a Macintosh classic computer using a paint program (MacPaint) and then printed on cards with a Laser Writer II.

Three sets of cards were constructed. Within a set, each stimulus condition consisted of 12 target letters embedded in a background of similar letters. The number of distractors varied in independent stimulus size conditions: 120 (Condition 1), 240 (Condition 2), 360 (Condition 3), 480 (Condition 4). All elements in the array were arranged in a rectangular matrix and the targets position was chosen randomly within the matrix. Matrix size, expressed in number of background elements, was equal to 60×2, 60×4, 60×6 and 60×8, in conditions 1, 2, 3 and 4, respectively (See examples in appendix). The distance between the card and the subject (about 30 cm) was such that one centimetre on the card corresponded approximately to 2 deg of visual angle. The width and height of the matrix were equal to 28×2, 28×4, 28×6 and 28×8 deg in conditions 1, 2, 3 and 4 respectively.

The target and background consisted of the following letter pairs: Ts in a background of Is, Us in Os, Us in Vs, in the sets STIMULUS 1, STIMULUS 2, and STIMULUS 3, respectively. Element size (both target and non-target) was equal to .3 × .7 deg of visual angle (H × V). Element separation was about .3 deg.

Procedure

For the visual search task, subjects were tested in small groups of 5-6 participants, in a separate room in their school. The PMA battery was also applied to groups ranging from 4 to 10 subjects. Block trials grouped 12 trials (four size conditions × 3 stimulus conditions). To avoid practice effects the trials were presented in random order.

During the experiment the children sat at a table. Before viewing the stimulus matrix, subjects were asked to observe for a few seconds the target-background elements pair, presented singly above the centre of the top row centre of the stimulus matrix which was covered with a card. This fixation interval ended with the experimenter's signal. At this signal the subject uncovered the stimulus matrix and started to search for the target matches within the stimulus area. Every time a target was found, the child was instructed to mark it with a red pen. So, rather than using a reaction time paradigm, we used a very familiar technique in neuropsychological testing, the cancellation task. This allowed the test to be given to all children in a group simultaneously. Each stimulus size condition on a card was presented for 10 seconds. The choice of presentations resulted from pilot observations with six subjects of the same age. As can be seen in Table I, in a pilot experiment this duration corresponded to the mean time (averaged across subjects and stimulus conditions) required to find all 12 targets in the second condition of stimulus size (240 non-targets). Stimulus card duration was interrupted at the experimenter's second signal. After this signal, subjects covered the test card with a mask. The mask contained a randomly located set of single features similar to those defining the stimulus (oriented and curved line segments, circles, etc.). In this way lateral contour interaction cannot be confused with contour interaction due to backward masking between letters in successive cards. At the end of this interval a new card with another combination of stimulus and set size was presented.

TABLE I

Time (in sec) Required to Find 12 Target Letters in a Background of 240 Distractors for 6 Subjects and 2 Non-target/Target Configurations

	Stimulus configuration		
Subjects	TI	OU	Mean
S1	11	13	12
S2	6	9	7.5
S3	9	15	12
S4	8	9	8.5
S5	9	12	10.5
S6	8	14	11
Mean	8.2	12	10.25

Task

Children were given the following instructions: "This is a game called "Find it". On each card you will see a group of letters that we call non-targets. Your job is to find letters like these (the experimenter points to the target drawn on the blackboard) which are hiding among non-targets. This letter is called the target and when you find one of these, you should mark it with your pen as fast as you can. We are interested in finding out how good you are at this game. At the end of the game we will count the number of target letters that you have been able to find".

Results and Discussion

The difference between the three stimulus pairs is not significant. This is expected because the distance in the dimension which produces discriminability is the same in at least two out of three pairs of letters. Since the difference between the three letter pairs was not significant, the data obtained in the three stimulus conditions were pooled together.

The mean number of correct responses obtained in the four set size conditions of the search task was divided into four quartiles. In order to avoid ceiling effects, we eliminated all subjects (238) scoring 36 (maximum) and 35. IQ and scores in the other tasks tested (see experiment 3) were not statistically different from those obtained by the group of subjects (354) included in the analysis. Table II shows mean scores, standard deviations and number of subjects in each quartile. Each quartile was considered a category of visual search efficiency.

TABLE II

Mean and Standard Deviation on the Visual Search Tasks of the Four Groups of Visual Searchers

	Mean	S.D.	N.
Cat1	16.55	3.41	89
Cat2	23.97	3.33	92
Cat3	27.5	2.83	87
Cat4	30.91	2.25	84

Although all subjects have an IQ within the normal range, in order to exclude that differences in visual selective attention tasks were due to different levels of general cognitive efficiency, the IQ scores obtained from PMA battery were treated as covariated. As expected, results yielded a significant main Category effect: $F(3, 559) = 1336.70$; $p < .0001$.

In Figure 2 the number of correct responses for each set size is shown independently for each group.

The figure clearly shows that the number of correct responses decreases as set size increases, at least for the first three size conditions. This confirms that the underlying search strategy is serial, involving the shift of visual selective attention over the visual field. Indeed, visual search for multifeature elements is usually serial (Treisman and Gelade, 1980). The slope coefficient of the regression line fitted to the data is indicative of the search efficiency as a function of the set size. The measure of the slope coefficient is equal to 3.4, 2.7, 1.2 and 0.17 for categories 1, 2, 3 and 4 respectively. This suggests that as efficiency increases, selective attention can be focused on large groups of stimuli, allowing the subjects to search in parallel within this group (Treisman and Gormican, 1988).

Experiment 2: Visual Selective Attention Skills Are Related to Reading

In the second experiment, we investigated the relationship between visual selective attention and reading performances. The relationship between this level of visual processing and reading was analysed in the opposite way to that

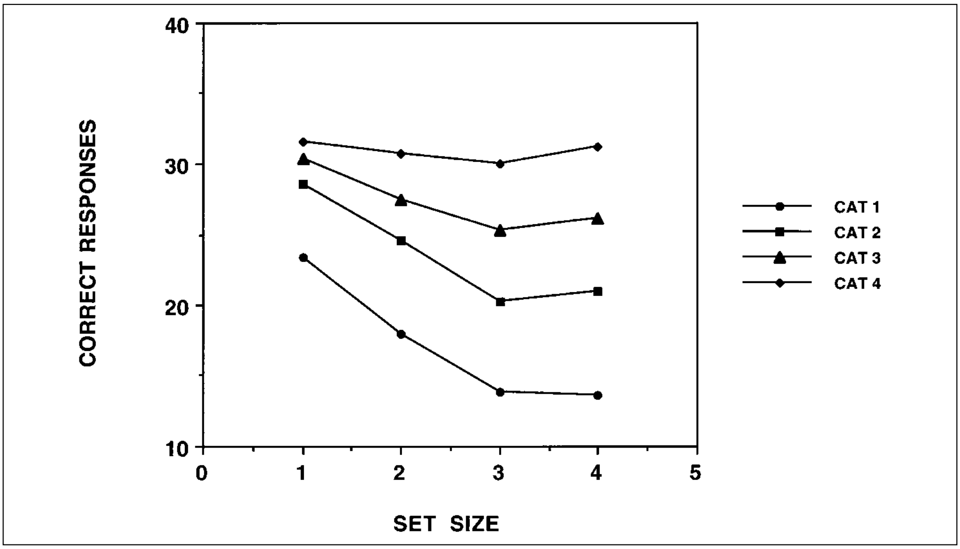

Fig. 2 – *Number of correct responses as function of the set size for the four groups of visual searchers: Cat1, Cat2, Cat3 and Cat4.*

commonly used in the literature. In previous studies, experimental groups with different reading efficiency were tested to show qualitative differences in visual processing. In this way it was shown that children with reading problems could also present one or other visual problem but no information was obtained on whether, and to what extent, children with a particular visual problem were likely to be disabled readers or not. In the present study we attempted to answer this question. Groups with different levels of selective efficiency in the visual attention task were tested for reading performance in conditions where the experimenter was blind as to whether the subjects were reading impaired.

Materials and Methods

Subjects

Two groups of subjects were invited to our laboratory to participate in the experiment. The first group, made up of 19 subjects belonging to Category 1, had a very low performance in the search task. The 19 children of the second group belonged to Category 4, except 2 who belonged to Category 3. These children had a good performance in the search task. Originally, 30 children within each group were invited but not all accepted the invitation. The children attended one of three schools randomly selected from the whole set of schools to which the original sample belonged. Note that the experimenters were completely naive about the reading abilities of selected samples. The selection was made on the basis of a computer list which indicated only the name, IQ and performance in the letters search. The mean IQ was not statistically different in the two groups.

Tests and Procedure

As a measure of reading ability, the most psychometrically valid test of reading Italian text (Cornoldi and Colpo, 1981) was used. The test allows determination of two reading scores: reading speed, expressed in syllables × min, and number of errors. Subjects were required to read the text aloud. They were given the following instructions: "I am asking you to read aloud the story printed on this sheet of paper. I want to see if you read well. I am going to time how long it takes you, but don't try to go too fast. I want you to read the best you can, making few errors, like when you do your best".

Reading comprehension was not used as a dependent variable even thought it was assessed by asking subjects to respond to four questions in order to establish whether their level of comprehension reached an arbitrary criterion of 75% correct responses.

The experimenter noted the time required to read the text. He also monitored the errors the subject made while reading. To grade the errors more accurately, tape recordings of reading performances were made for each subject so that the errors recorded during reading could be checked later. Each incorrect word was calculated as one error. Furthermore, the number of letters misread, omitted or added in each word was calculated.

Results and Discussion

Reading rate in the two groups (see Figure 3) was compared using a "t" test. Results, $t(1, 36) = -4.82$; $p < .0001$, show that the two groups differ significantly in reading rate.

In the present study we have investigated the possibility that the association between visual selective attention and reading performance may reflect a difficulty in a visual operation involved in both tasks. This hypothesis is supported by the finding that experimental groups selected on the basis of visual selective attention efficiency also differed in reading efficiency. This finding is important because although from previous findings it could be expected that disabled readers present similar visual problems it is less evident why children with visual selective attention difficulties should also present reading difficulties. This can only be possible if visual difficulties and reading problems have a common base. This possibility was investigated by analysing reading errors,

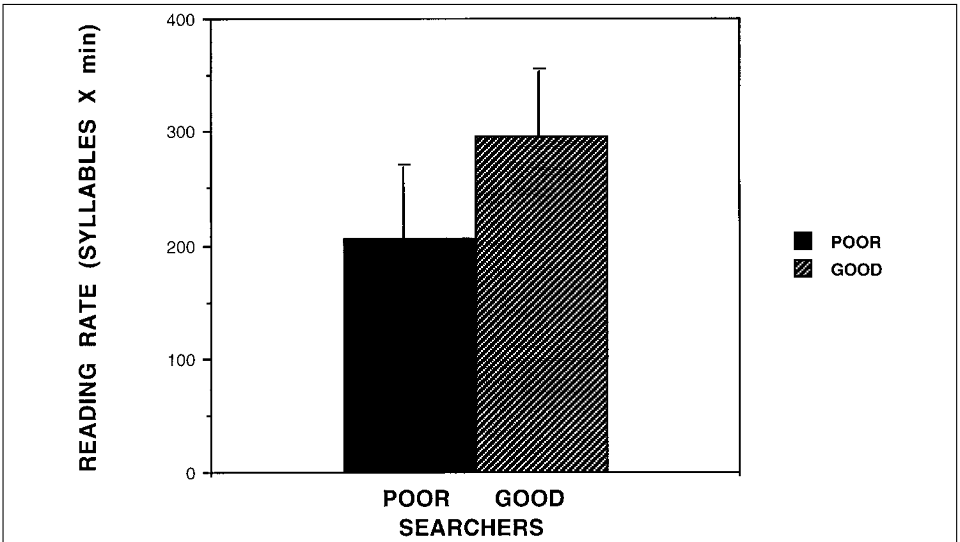

Fig. 3 – *Reading rate, expressed in syllables × min, for poor searchers (black bars) and good searchers (bars filled with diagonals lines). Standard deviation is indicated for each group.*

choosing a post hoc criteria for error analysis. This is a rather difficult task because the errors are often difficult to classify. Snowling, Stackhouse and Rack (1986) distinguished between visual and non-visual errors. Visual errors occur when the misread word shares 50% or more of its letters with the target. This criterion is valid for languages with orthographic transparency higher than English like French (Valdois, Gerard, Vanoult et al., 1995) and Italian (Lucca, Vio and Job, 1992).

Moreover, to avoid confusion between visual and morphological errors we did not consider substitution errors which occurred at the end of the word because these are likely to be morphological errors. Similarly, to avoid confusion between visual and phonological errors we did not consider substitution errors of the single letters "p-b-d" which may be interpreted as phonological errors. It is worth mentioning however, that only about 5% of these substitution errors could not be classified as visual errors. Following this procedure, we analysed whether the number of visual errors in reading significantly differed in the two groups. A 2-way ANOVA with one between-subjects factor (good vs. poor searchers) and one within-subjects factor (type of errors: visual vs. non-visual errors) was carried out. Both main effects (groups and type of errors) were significant (subjects: $F(1, 36) = 8.92$, $p < .005$); visual vs. non-visual errors: $F(1, 36) = 12.5$, $p < .001$) and the interaction between them was also significant ($F(1, 36) = 8.13$, $p = .006$). These results are shown in Figure 4, in which it appears that visual to non-visual error ratio is almost double for poor searchers.

Interpretation of these results is not straightforward because in Snowling et al. (1986) study, visual errors occurred at word level and were made by readers with a low level of reading performance and low reading age (age equivalent of 6-7 years) rather than by older normal readers. However, our results suggest

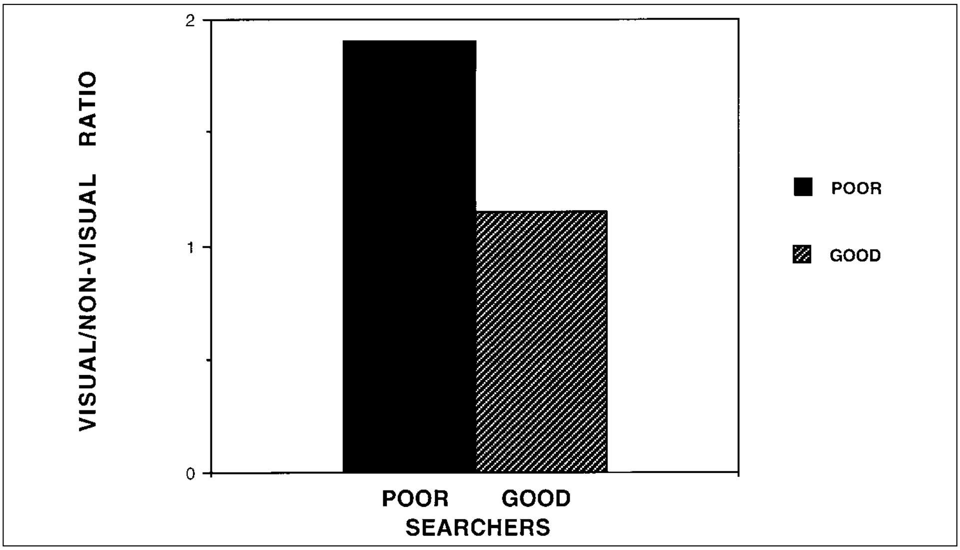

Fig. 4 – *Ratio between visual and non visual error for poor and good searchers.*

that, at least in part, some of poor searchers' reading problems depend on a visual difficulty which also affects performance in visual attention tasks.

Experiment 3: Further Analysis of Linguistic Difficulties

The results of the previous experiments indicate a relationship between letter search and reading performance. Indeed, the data show that children with poor performances in a letter cancellation task seem likely to be poor readers with respect to children with good performance in the letter search task. The question is whether children who present impaired letter search performance also present poor performance in other linguistic tasks. On the basis of our hypothesis we expected a difficulty in linguistic tasks involving visual selective attention only.

Materials and Methods

Subjects

The same subjects who participated in experiment 1 were asked to carry out a set of tests aimed at determining their abilities in different linguistic tasks.

Tests and Procedure

The following three linguistic tasks were submitted to the subjects:

(1) Lexical decision task. This task assessed the subject's capability to discriminate between words and non-words on the basis of orthographic rules. Subjects were presented with strings of 80 items randomly presented; forty were words and forty legal non-words. The observer's task was to mark the non-words, that is the string of letters with no meaning in Italian. Time available was 2 min.

(2) Syllable control task. This task assessed the efficiency of mechanisms underlying segmentation of words on the basis of orthographic and phonological rules. Subjects were presented with a list of 12 words segmented in syllables and their task was to mark those with the wrong syllable segmentation. Time available was 2 min.

(3) Lexical search task. This task assessed the subject's ability to find a word embedded in a string of letters forming a legal non-word, i.e. BOROLTO: the embedded word was ORO (gold). Time available was 2 min.

All tests were administrated collectively to the children of each class, in the presence of the teacher.

Results

Although subjects have an I.Q. within the normal range, to exclude that the differences between the four categories were due to different levels of general cognitive efficiency, the I.Q. score obtained from the P.M.A. battery was treated as covariate. We planned the following contrasts between the four categories: cat1 vs. cat4; cat2 vs. cat4; cat1 vs. cat3 to maximise the power of the analysis.

Statistically significant differences between the four categories were obtained only for the lexical search task in the comparison between Category 1 and Category 4, $F(1, 344) = 2.01$; $p < .05$. The linear trend was also significant $F(1, 344) = 3.73$; $p = .05$. Table III shows the adjusted means and the standard deviations obtained by each of four groups in the three linguistic tasks. The results of the lexical search task are also presented in Figure 5. As the figure shows, the number of errors decreases linearly from Category 1 to Category 4.

TABLE III

Adjusted Means and Standard Deviations of the Results of the Four Groups of Visual Search in the Three Linguistic Tasks

	Lexical search (errors)		Lexical decision (errors)		Syllable control	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Cat1	2.6	2.7	3.2	2.3	13.9	8.7
Cat2	2.06	2.4	3.7	1.9	13.6	8.3
Cat3	2.03	2.2	3.6	2.2	12.2	7.7
Cat4	1.87	2.3	3.7	2.2	12.4	8.1

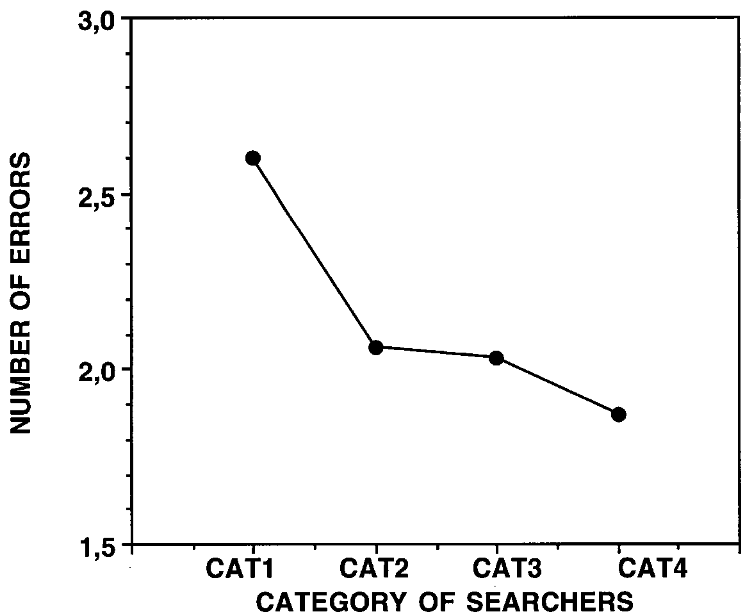

Fig. 5 – *Number of errors in the lexical search task of the four groups of searchers. Mean and standard deviations are shown in Table III.*

These results indicate that the two groups of visual searchers differed in one out of three linguistic tasks only, the lexical search task.

Why is performance of the poor searchers worse in this than in the other task? What is the difference between this and the other linguistic tasks that could explain a selective deficit? At what level of processing does this difference occurs? Our results suggest that poor searchers present a visual selective attention difficulty that makes the whole word segregation process required to perform the lexical search task difficult.

General Discussion

The rationale of this empirical work was to provide data to decide whether letter search and reading performance are related and whether this relationship depends on a mechanism activated in both tasks.

The aim of experiment 1 was to classify children on the basis of their level of efficiency in the search task. In all groups efficiency in the letter search task decreases as the number of surrounding target letters increases. This indicates that the task involves selective attention. However, variability in display size effect amongst groups indicate that as efficiency increases selective attention can be directed to large groups. The results of the second experiment show that not efficient searchers present a significantly slower reading rate and a higher number of reading visual errors with respect to children who are fast searchers. This indicates that performance in a visual selective attention task like the letter cancellation task is related to reading performance. Results also show that the two search categories, good and poor searchers, differ mainly in visual errors, confirming the relationship between reading and visual selective attention functions. Reduced velocity and a high number of visual errors in reading may be related to a selective visual attention difficulty in poor searchers. Thirdly, the results of experiment 3 show that the four groups of searchers do not differ in efficiency in lexical decision tasks nor in the syllable control task but differ significantly in the lexical search task. To explain this difference, it has to be considered that visual and lexical searches present strong similarities. In both tasks, the subject had to select one stimulus surrounded by other stimuli. We suggest that poor searchers present a general difficulty in this operation and that this may affect performance.

These results all suggest that performance in specific visual functions involving visual selective attention is related to reading performance. To explain how this relationship occurs, the role of selective attention in visual crowding, letter searching and linguistic tasks, has to be analysed.

There is now a good deal of evidence that basic attributes of the visual array, such as colour and line orientation, are registered effortlessly and in parallel in separate retinotopically organised maps (Treisman and Gormican, 1988). However, to see objects as distinguished from other objects requires an integrative process allowing conjunction of feature as a function of location. The integration of visual features information is a capacity limited process that requires “selective attention”. By means of selective attention deployed over a limited area of the visual field the separately analysed visual features are bound together. To do this, attentional capacities must then be deployed serially across the array to achieve an integrated representation (e.g. Treisman and Gormican, 1988); this entails shifting visual attention from one locus to another.

The integration of features across feature maps is achieved by means of a visual analogue representation in which coherent regions of the array are represented as surfaces, and attributes such as depth and orientation are encoded. The visual analogue representation which is computed after each fixation and lasts for no longer than 300 msec, provides the input to object and word recognition systems (“structural descriptions” and “visual word forms” respectively).

When the visual system has to select an object surrounded by similar objects, it first has to determine the site where the spotlight of selective visual attention should initially be deployed. Many studies have attempted to define the mechanisms underlying the initial deployment of selective attention. It has been shown that deployment of selective attention is influenced by grouping principles (Prinzmetal, 1981) and it is slowed by the presence of other elements in the array (Kahneman, Treisman and Burkell, 1983). Treisman, Kahneman and Burkell (1983) showed that the presence of non-verbal distractors significantly increases the time required to read a single word, suggesting that most or all visual stimuli are, at least briefly, analysed.

A deficit in selective attention may produce visual difficulties like simultagnosia, crowding and a change in visual search strategy. Simultagnosic patients have difficulty in interpreting complex visual arrays despite preserved recognition of single objects. Crowding is associated with a reduced visual acuity when letters are surrounded by other letters. In the visual search a deficit in selective attention may produce illusory conjunction recombining features from different objects in the display. The resulting perceptual effect would be contour interaction between target and background elements. This, may in turn determine a difficulty in using the normal strategy of search serially through subgroups of distractors and checking in parallel within subgroups (Triesman and Gormican, 1988). This leads to the need to reduce the size of subgroups or attending nontargets one at a time. The behavioural effect of this change in strategy would be an increase in linear functions relating latency to the number of items in the display which is indeed often found in disabled readers (Casco and Prunetti, 1996).

To conclude, from the results of the present study it appears that a related difficulty in visual selective attention and reading may be due to a deficit in a visual selective attention mechanism which may have the effect of producing perceptual interaction of target and background elements. To our view, this finding is important for two reasons. First, reading difficulties may be detected early on the basis of visual selective attention performance. Indeed, difficulties in visual tasks involving selective attention can usually be detected in pre-school children before they learn to read. Second, a training scheme for reading difficulties involving practice in visual attention tasks may be developed for pre-school children. For example, Sireteanu and Rettenbach (1995) have found that search strategy improves with practice and this improvement could be transferred to other search tasks. Thus, since visual search and reading skills develop parallel and since a visual deficit can be detected earlier than a reading deficit it could well be that extensive practice in tasks involving selective attention in pre-school children may improve reading abilities.

One may ask how the hypothesis of this study is similar to, or different from, other hypotheses that have suggested that reading problems may occur on a visual basis. Lovegrove et al. (1980) exploited the possibility of distinguishing psychophysically between magno and parvocellular functions in dyslexics and showed that many dyslexics have slightly reduced contrast sensitivity at low spatial frequencies and low luminance levels favoured by the magnocellular system, particularly during flicker. At high spatial frequencies, served by the parvocellular sustained system, the contrast sensitivity of dyslexics is normal. In addition, several studies (Casco, 1993; Cornelissen, Richardson, Masson et al., 1995) showed another magnocellular transient deficit in disabled readers, namely impaired motion perception even at high contrast and illumination levels.

Magnocellular impairments found in dyslexics are very mild and are usually found in viewing conditions which are unusual for reading and the question is how such slight impairments could lead to a difficulty in reading. The link between a visual attention deficit and a magnocellular deficit can be made by considering that the anatomical projection of the magnocellular system is the posterior parietal cortex, a visual area dominated by m-like properties: sensitivity to direction of movement and sensitivity to direction of gaze. The posterior parietal cortex is known to be important in normal eye movement control, visuo-spatial attention and peripheral vision – all important components of reading (Stein and Walsh, 1997). It is also a region which, if damaged, results in acquired reading disorders.

Our results support the suggestion that disabled readers may be impaired in a range of attention tasks that depend on parietal cortex functioning: spatial attention task (Brannan and Williams, 1987), perceptual grouping (Williams and Bologna, 1985), visual search (Casco and Prunetti, 1996; Ruddock, 1991) and also inhibition of stimuli that are not the focus of attention (Morris and Rayner, 1991). It is clear that many of these attention related functions contribute to reading. Indeed, selective attention to a word or string of words requires concentrated focal attention and controlled shift of attention.

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