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The Mediated Reading Process of the Partially Sighted

The model presented extends current theorizing about reading by relating the underlying processes of skilled and average readers to those of poor readers. While the non-mediated reading process for skilled readers is immediately directed to the meaning of a word, the reading process for poor readers is mediated by the interpretation of the individual letters constituting the word. The continuous interaction between the interpretation of single letters and reading for meaning of the word is what determines the slow reading rate for poor readers. An empirical study was carried out to demonstrate the viability of the present approach. A series of measures were derived to compare the reading process for good and poor partially sighted readers. The locus of the difference in reading rate between the two groups of subjects was confined mainly to the peripheral subprocesses of reading whereas the deeper and more semantic levels of the reading process were less affected.

The general purpose of the present paper is to present a theoretical model of reading which takes into account the principal differences between skilled and deficient readers. The experimental study reported was primarily concerned with the latter. The general contention is that the reading processes for these two groups differ quantitatively and qualitatively but that these processes can be linked together in the present model.

It is becoming more clear that a great deal of research is necessary in order to understand what kind of psychological processes underlie the process of reading. Recent investigations (e.g., Calfee, Chapman & Venezky, 1972; Estes, 1975; Gough, 1972; Kolers, 1970; La Berge & Samuels, 1974; Posner, Lewis, & Conrad, 1972; Smith, 1971; and Thompson & Massaro, 1973) have provided interesting and important beginnings. Theoretically, these contributions have been based on an information processing framework; empirically, the most characteristic feature has probably been the use of skilled or average readers as subjects in the experiments. Little research on reading has been carried out using poor readers. According to Smith (1971) there is an important qualitative difference between poor and skilled readers. The former most commonly use a strategy that is characterized by a mediated reading process; the strategy for the latter is typically nonmediated. Mediated reading of a word, for example, means that each letter constituting the word has to be read and interpreted; nonmediated reading means that the reading directly accesses the meaning of the word. In the same way a mediated reading with respect to some larger unit, a phrase or a sentence, is carried out via the reading of its constituents, i.e., the words. In nonmediated reading the reader can gain access to the meaning of the phrase or sentence directly, not via the words separately.

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In the context of a general information processing framework, the present paper aims at proposing a reading model for one particular group of people: the partially sighted. The most typical feature of the reading process for this group of individuals is a word-by-word mediated acquisition process or an acquisition process which is mediated by a letter-by-letter reading. The model to be presented is an attempt to conceptualize such mediated reading processes.

The model postulates a general information processing system that encodes the information into increasingly deeper conceptual levels. This system is assumed to consist of a perceptual system and two memory systems. One of these memory systems is dominated by an orthographic-phonological character and the other by a semantic-cognitive character. The information held in the former is successively encoded into new chunks by means of abstract rules. When this chunking takes place, the locus of the new memory representation is changed to a more semantic level. In a very general sense the rules are extracted knowledge about the world. In a more specific sense these rules are assumed to be organized in levels from simple orthographic-phonological to complex semantic-cognitive ones.

The perceptual system is probably best described as a window through which information is passed to a limited capacity-temporary buffer, the orthographic-phonological memory. This window is moved by an active agent in accordance with both the information actually stored and the specific rules used. The information in the orthographic buffer is assumed to remain at this level until it can be integrated and hence encoded into new chunks at deeper levels. When the information in the buffer storage is encoded and transferred to a deeper level, the buffer memory is emptied and the new information can be perceived and subsequently encoded. The information in the semantic memory system is assumed to be processed in much the same way. The information is buffered until it can be encoded into new chunks at still deeper levels.

This level-of-processing model (c.f. Craik and Lockhart, 1972) will be used here as a frame of reference for the present study of the reading process for the partially sighted. One important bottleneck in their processing of information is at the perceptual phase. Their reading is characterized by a very limited perceptual window and a slow process of registration. Another critical aspect is how well the information in the orthographic store is integrated and passed on to the semantic store. One could expect that the limits of their temporary buffer often will be exceeded as a consequence of the small pieces of information registered. The partially-sighted reader is then supposed to be engaged in an interaction between information processing at the orthographic and semantic level in order to be able to encode the information into a new chunk at a deeper level.

It is assumed that the limited perceptual ability and the subsequent interaction between information processing at different levels are the critical factors responsible for the very slow reading of the partially sighted. Based on the model outlined, one would not expect any difficulties at deeper levels of information processing due to the visual handicap. However, most partially sighted have very little experience of reading and thus there might be considerable difficulties in using various semantic rules.

At this stage of research it would be premature to try to test the model outlined above by means of deduced hypotheses. Instead, the present investigation was designed as a descriptive study of the reading process of the partially sighted within the framework of the model proposed. Then, measures reflecting information processing at different stages had to be defined. This was done by comparing actual reading performance with the reading performance of a system that simply added chunks on one level to new chunks on a deeper level. In this reading system orthographic reading time (ORT) for a m-letter word could be written

$$ORT_m = \frac{m \cdot T_p}{n_p} \qquad m > n_p \qquad (1)$$

where n_p is the number of letters that the perceptual system can grasp at one fixation (i.e., one perceptual chunk) and T_p the time needed for this process. Accordingly, orthographic reading time for k words could simply be computed by adding ORT for each word.

The semantic subsystem adds orthographic chunks, i.e., words to larger units semantic chunks. Semantic reading time (SRT) for k words is then

$$SRT_k = \frac{k \cdot T_s}{n_s} \qquad k > n_s \qquad (2)$$

where n_s = the size in words of one semantic chunk and T_s orthographic reading time for n_s words.

It should be mentioned again that the mathematical system described above is not intended to be a model of reading; it simply serves as a tool for defining the measures used. The measures used were based on two reading rate functions showing reading rate in seconds/letter as a function of word length and length of sentences respectively (Figure 1).

The perceptual measures derived from these functions were: the amount of information that can be grasped into one fixation (field of fixation, n_p) and the time needed for this process (fixation time, T_p). Fixation time was measured as reading rate for one-letter words. If fixation time is assumed to be constant, then reading rate in seconds/letter should decrease with increased word length up to the point where the length of the word is larger than the amount of information that can be grasped during one fixation. Hence the fixation field could be defined as the length of the word corresponding to the first minimum point in the word reading rate function.

Ability to integrate information on an orthographic level (orthographic integration ability) was defined as the difference between actual reading rate for long words and orthographic reading rate of the additive system described above. According to (1) the reading rate of this system is T_p/n_p independent of word length. T_p/n_p could therefore be computed from the word reading rate function as the reading rate for words of optimal length.

A mediated reading without intervening transformations into semantic chunks at a deeper level by means of semantic rules would imply that reading time for k-word sentences could be predicted by simply adding reading time for each word, as in the additive system described above. Reading rate for words and sentences would then be the same. Thus by computing the difference in reading rate between words and comparable sentences a measure could be derived that reflects degree of mediation. This measure, referred to as semantic interpretation ability, was defined as the difference between mean reading rate for sentences of varying length and mean reading rate for isolated words of the same length as those in the sentences.

Ability to process information on a semantic level was also measured by comparing actual performance with the performance of the additive system described above. The measure derived (semantic integration ability) was defined as the difference between actual reading rate for long word sentences and semantic reading rate of the additive system which, according to (2), is independent of the length of the sentences. It was then assumed that one semantic chunk (n_s) corresponded to the optimal length of sentences, i.e. to the minimum point in the sentence reading rate function.

Thus the purpose of the present investigation was to describe the reading process of the partially sighted by means of the measures proposed. More specifically, the objective was to test the relevance of this description by comparing good, average, and poor partially-sighted readers, and by studying how training in reading and the visual handicap affected the reading process.

Method

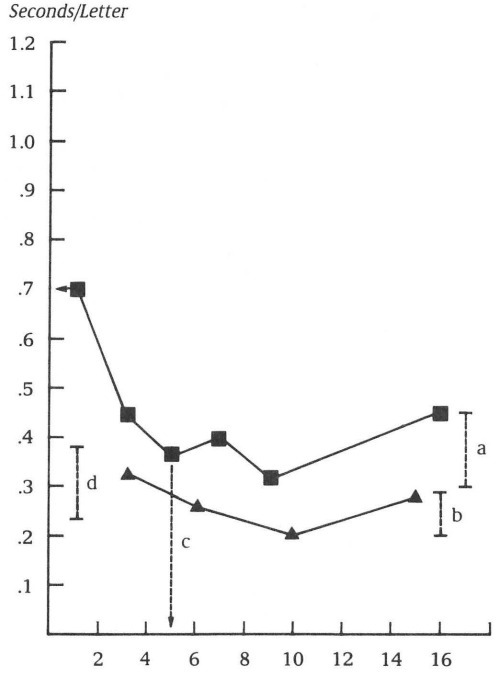
For the purpose of the present experiment, a test package was constructed that included a letter test, a word test, a sentence test, and a paragraph test. Reading rate in seconds/letter in each test was measured and plotted against number of letters/word and number of words/sentence respectively. From these reading rate functions the measures proposed above were derived at as shown in Figure 1. In addition three classification measures were registered: reading rate for isolated words, sentences, and papagraphs.

Figure 1

Idealized reading rate function describing how the reading measures proposed were determined.

■ reading rate as a function of letters/words
▲ reading rate as a function of words/sentences

Note: (a) orthographic integration ability, (b) semantic integration ability, (c) fixation field, (d) semantic interpretation, (e) fixation time



Test Material

The letter test simply consisted of five randomly selected uppercase letters (A, D, N, R, T). The word test consisted of five different subtests each of which consisted of five different Swedish nouns. The five subtests consisted of words of varying length (words of 3, 5, 7, 9, and 16 letters). The words were selected from a large Swedish wordbook and were, according to the authors' best judgement a study of the familiarity of Swedish nouns within taxonomic categories, (Nilsson, 1973), considered as being common.

The sentence test consisted of four subtests, each consisting of three different sentences. The length of the sentences within each subtest was constant but varied across subtests (3-, 6-, 10-, and 15-word sentences). The three sentences within each subtest consisted of words of varying length (3-, 5-, and 9-letter words for the three sentences respectively in each subtest). Thus, in sentences with three words the first sentence consisted of three 3-letter words, the second sentence consisted of three 5-letter words, and the last sentence involved three 9-letter words. The first sentence containing six words consisted of six 3-letter words, the second sentence consisted of six 5-letter words, and so on to the last sentence of 15 words, which consisted of 15 9-letter words. A few minor deviations from this principle were necessary in order to obtain meaningful sentences. The rationale for the use of this type of sentence construction was to make comparisons between word and sentence tests possible.

The paragraph test consisted of two different text passages from a Swedish novel by W. Moberg. According to the authors' best judgement and an index of readability (LIX, Björnsson, 1968), the paragraphs selected were considered as being of average difficulty. The two paragraphs were assumed to vary only in length: the first consisted of approximately 50 words; the second was about 100 words long. This particular novel was selected because it is fairly uncommon, the rationale being that subjects should not be aware of the text prior to the experiment. (Questioning the subjects after the experiment revealed that no one was familiar with the text. In addition to this test package (referred to as test A) a parallel test was constructed (test B) with other words and sentences but designed according to the same rules.

In summary, the format of the test given to each subject was a series of twelve subtests: one letter test, five word tests each consisting of five different words, four sentence tests with three different sentences for each test, and two paragraph tests (about 50 and 100 words long, respectively). The overall duration of a test session (including all twelve subtests) varied between 20 and 30 minutes per subject.

Subjects

The investigation was carried out at a rehabilitation center for the partially sighted and all subjects participated in the experiment individually during their course in reading. A total of 41 subjects were tested with the reading tests. All subjects were partially sighted and most of them had obtained new optical reading aids at the center. These aids were used during the tests. Various types of visual handicaps were represented. The visual acuity measured with conventional distance test charts varied from about 0.05 to 0.3. The age of the subjects varied between 20 and 50.

Procedure

Thirty subjects were tested with test A (group A1) and eleven with test B (group B1) at the beginning of a course in reading. At the end of the course, eleven of the subjects in group A1 were tested with test B (group A1B2) and four of the subjects in group B1 were tested with test A (group B1A2). The number of subjects in each group was not experimentally controlled but was a consequence of practical-circumstances.

All tests were given to the subjects in the same order. The reason for this was to successively increase the difficulty for each subject. The order of the tests was the description outline above. Each test was presented to the subjects on a sheet of paper and the subjects were instructed to read each test aloud. Reading time for each test, measured by a stop watch, was the time required to read the test aloud from the beginning to the end. The comprehension of the sentences and paragraphs was controlled immediately after each test by means of a simple recognition test and recall test, respectively. The duration of the whole test session varied between 20 and 30 minutes.

Results

The Effect of Reading Ability

In order to study the effect of reading ability, the partially-sighted subjects in group A1 were subdivided into three separate groups with respect to the performance for the paragraph test. Inspection of these data showed that the cut off points 35 and 60 words/minute gave three separate groups (Figure 2) referred to as poor, average, and good readers. Mean performance scores are shown in Table I.

Table I reveals two striking effects. First, for each group the reading of letters seemed to be much slower than the reading of words, sentences, and paragraphs. Second, the poor readers could not utilize the semantic content in the text. On the contrary, the reading of sentences was slower than the reading of words. The opposite was true for good readers; they read sentences faster than words. The differences discussed were significant as shown by the analyses of variance carried out on these data (Table I). The fact that poor readers could not utilize the semantic content suggests that their reading was more of a mediated character than that of the good readers.

Figure 2

Histogram over reading rate in the paragraph test for group A1.

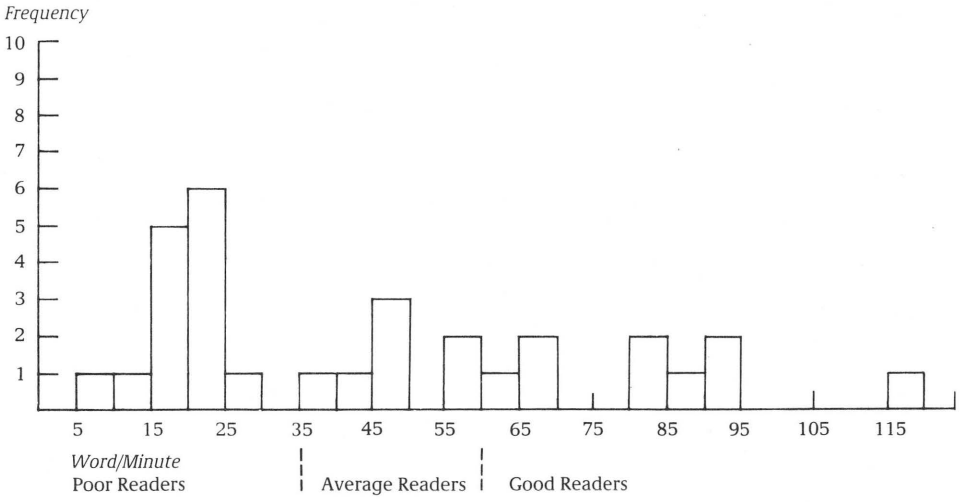


Table I

Mean performance (measured in seconds per letter) for the partially sighted (group A1) with good, average, and poor reading ability in the four different tests concerning the reading of letters, words, sentences, and paragraphs.

Subjects	Letter test	Word test	Sentence test	Paragraph test	Significance
Good (n = 9)	0.66	0.18	0.15	0.15	$p < 0.01$
Average (n = 7)	0.54	0.25	0.24	0.24	$p < 0.01$
Poor (n = 14)	0.87	0.51	0.58	0.66	$p < 0.01$

Figure 3

The reading rate functions obtained for poor (○), average (△), and good (□) readers in group A1. Means over groups are given.

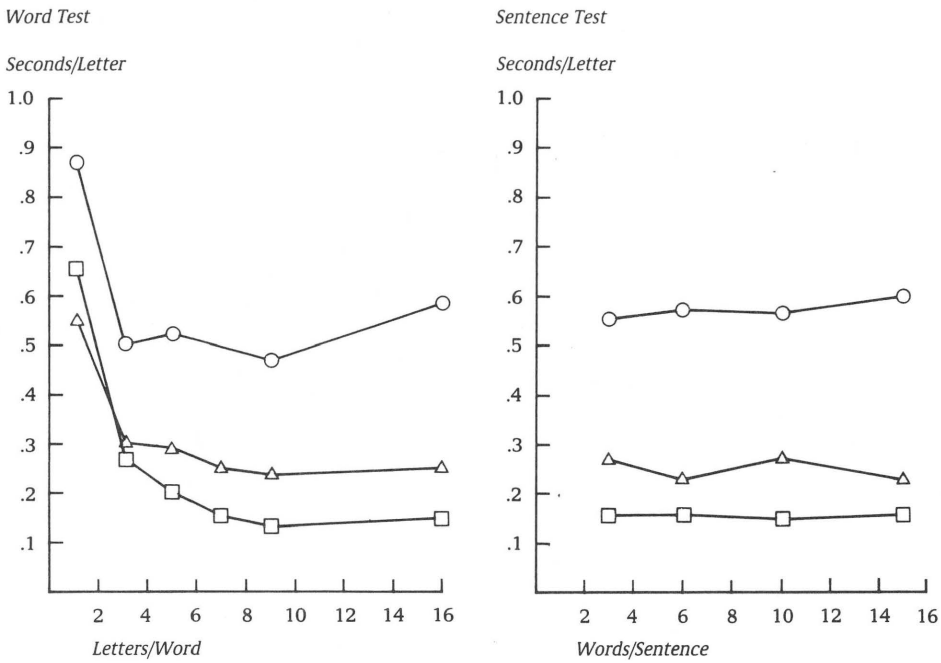


Figure 4

The reading rate functions of the poorest (■) and best (▲) reader in group A1.

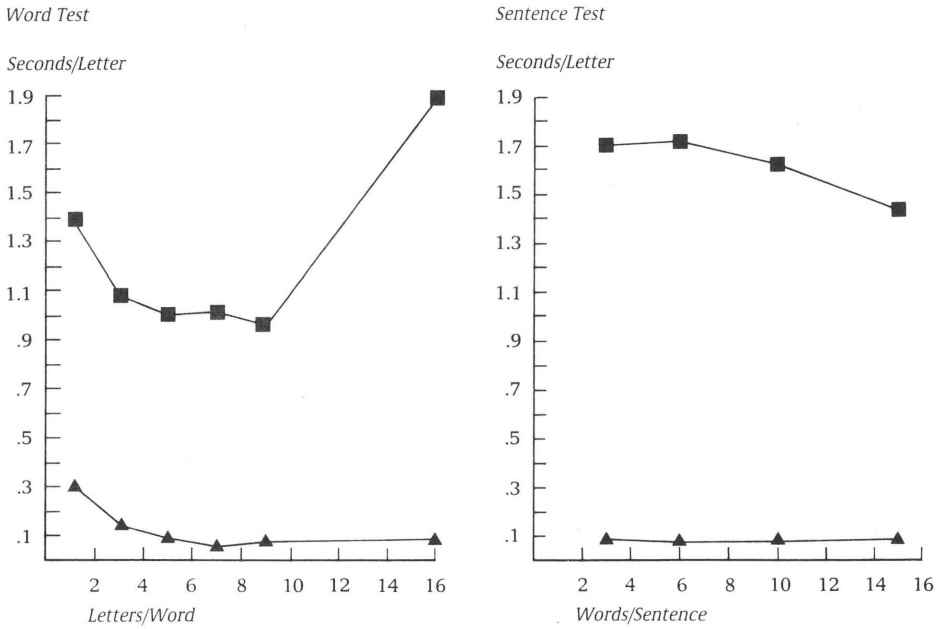


Figure 3 shows the reading rate functions obtained for the poor, average, and good readers, and Figure 4 shows an example of two individual curves (the best and poorest reader).

The reading rate function for the poor readers demonstrates a typical "window effect" in the registration process. Reading rate increases within the fixation field, decreases when the window is moved, then increases again, and so on. Table II shows the measures proposed and the result of an analysis of variance (Kruskal-Wallis one-way analysis of variance).

Figure 3 and Table II point to some interesting differences between poor and good readers. First there was a significant difference with respect to the fixation field (the first minimum point in the word reading rate function). The fixation field increased systematically with reading ability from about five letters in the poor group to about twelve in the group of good readers. However, fixation time (reading rate for one-letter words) did not differ significantly. Next, a striking difference was found for the two measures of orthographic and semantic integration ability. Poor readers had a much lower reading rate for long words and sentences — as compared to words and sentences of optimal length — than good readers. Thus the reading process of poor readers could not be described simply as an addition of chunks on one level to new chunks on a deeper level. Good readers on the other hand obtained integration values close to zero, which means that the formation of new chunks produced only a slight decrease in reading rate. The importance of the integration process (especially at an orthographic level) was also demonstrated by the correlations between reading rate in the paragraph test and the measures discussed, and by a multiple analysis of regression (Tables III and IV). Finally, there was also a slight (Table IV) but significant (Tables II and III) systematic difference for the measure semantic interpretation. Poor readers had a faster reading rate for words than for sentences, while the opposite was true for good readers. Accordingly it does not seem necessary for good readers to read each word in order to form semantic chunks.

Table II

Summary table for partially sighted (group A1) with respect to the assumed processes of registration, integration, and interpretation.

Subjects	Fixation field	Fixation time	Orthographic integration ability	Semantic integration ability	Semantic interpretation
Good (n = 9)	11.89	0.66	0.02	0.02	0.05
Average (n = 7)	6.43	0.54	0.05	0.03	0.03
Poor (n = 14)	4.57	0.87	0.21	0.15	−0.08
Significance	$p < 0.001$	$p > 0.05$	$p < 0.01$	$p < 0.01$	$p < 0.01$

To summarize, the results of this study indicate that important properties of the reading process of the partially sighted are both the ability to register information *and* the ability to integrate the information registered to orthographic and semantic chunks.

Table III

Correlations between reading rate in the paragraph test and the processes of registration, integration, and interpretation (n = 30)

Fixation field	Fixation time	Orthographic integration ability	Semantic integration ability	Semantic interpretation
−0.56*	0.42*	0.83*	0.38*	−0.53*

*$p < 0.05$

Table IV

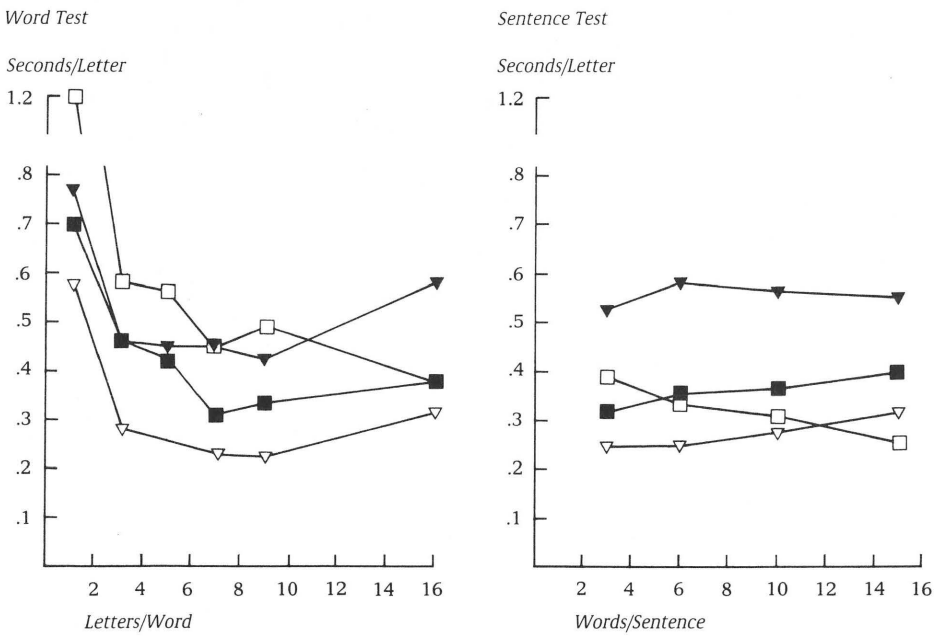
The results of a multiple regression analysis (n = 30) with reading rate in the paragraph test as the dependent variable and the subprocesses of registration, integration, and interpretation as independent variables.

Dependent variable: Reading rate in the paragraph test.
Multiple correlation coefficient: 0.96

Beta weights:	*1 Orthographic integration ability*	*0.77*
	2 Semantic integration ability	*0.24*
	3 Fixation time	*0.24*
	4 Fixation field	*−0.22*
	5 Semantic interpretation	*0.08*

Figure 5

The reading rate functions for readers with (1) good visual acuity and a normal field of view (△), (2) good visual acuity and narrow field of view (□), (3) low visual acuity and normal field of view (▲), and (4) low visual acuity and narrow field of view (■).



The Effect of the Visual Handicap

An attempt was made to study the effect of visual acuity and field of view on the reading process by subdividing the subjects in group A1 according to their medical diagnoses. However, a medical diagnosis was available only for 20 subjects. These subjects were subdivided into four groups: (1) high visual acuity-normal field of view, (2) high visual acuity-narrow field of view, (3) low visual acuity-normal field of view, (4) low visual acuity-narrow field of view. The reading rate functions of the four groups and the measures derived by these functions are given in Figure 5 and Table V.

The results of this analysis should be considered with caution because of the low number of subjects, the unequal cell frequencies and the complexity of the eye diseases described in terms of visual acuity and field of view. However, the main differences between the four groups may tentatively be summarized as follows: (1) A low visual acuity was a more serious handicap with respect to reading than a narrow field of view. (2) The main differences between the four groups of readers concerned their ability to integrate information on an orthographic level and their ability to form semantic chunks. Orthographic integration and semantic interpretation ability decreased with decreased visual acuity and increased with a decreased field of view. (3) There were also several interesting interactions between visual acuity and field of view, e.g., the long fixation time and large fixation field characterizing subjects with a high visual acuity but a narrow field of view. However, these sparse data do not allow such detailed analyses.

Table V

The results of the effect of visual acuity and field of view on the different reading measures.

Visual acuity	High*	High	Low	Low
Field of view	Normal	Narrow	Normal	Narrow
n:	8	4	6	2
Paragraph test	0.35	0.33	0.56	0.49
Sentence test	0.29	0.33	0.56	0.37
Word test	0.32	0.61	0.52	0.43
Fixation field	7.63	9.50	7.50	6.00
Fixation time	0.58	1.20	0.77	0.70
Orthographic integration ability	0.12	0.00	0.24	0.08
Semantic integration ability	0.08	0.04	0.08	0.15
Semantic interpretation	−0.03	0.22	−0.12	0.03

* *High visual acuity:* 0.1 — 0.3
Low visual acuity: < 0.1

Thus, it seems that readers with a low visual acuity have serious difficulties in encoding the information into new chunks, while the opposite seems to be true for readers with a narrow field of view. The main problem of the latter may be traced to the fixation process. These findings should be regarded as preliminary and should therefore be given further consideration in future research. The result was unexpected and suggests that unreliable but unrestricted information (low visual acuity) is relatively more difficult to encode into new chunks than reliable but restricted information (narrow field of view).

The Effect of Training

The course in reading was focused on practice to fixate, eye movement practice, and practice in the usage of optical reading aids. The effect of this training on the reading process of the partially sighted was studied by matching the four subjects in group B1A2 to four subjects in group A1B2. That is, the members of a matched pair were tested according to the following schedule. *Subject 1:* Test A — course in reading — Test B; *subject 2:* Test B — course in reading — Test A. By this design the differences between subjects and tests were under control. Reading rate in the paragraph test given at the beginning of the course was used as the matching variable. The course lasted for about 40 hours. The reading rate functions obtained before and after training are shown in Figure 6; the individual measures are presented in Table VI.

Figure 6

Reading rate functions before (○) and after (□) a course in reading. Means over groups and test versions are given.

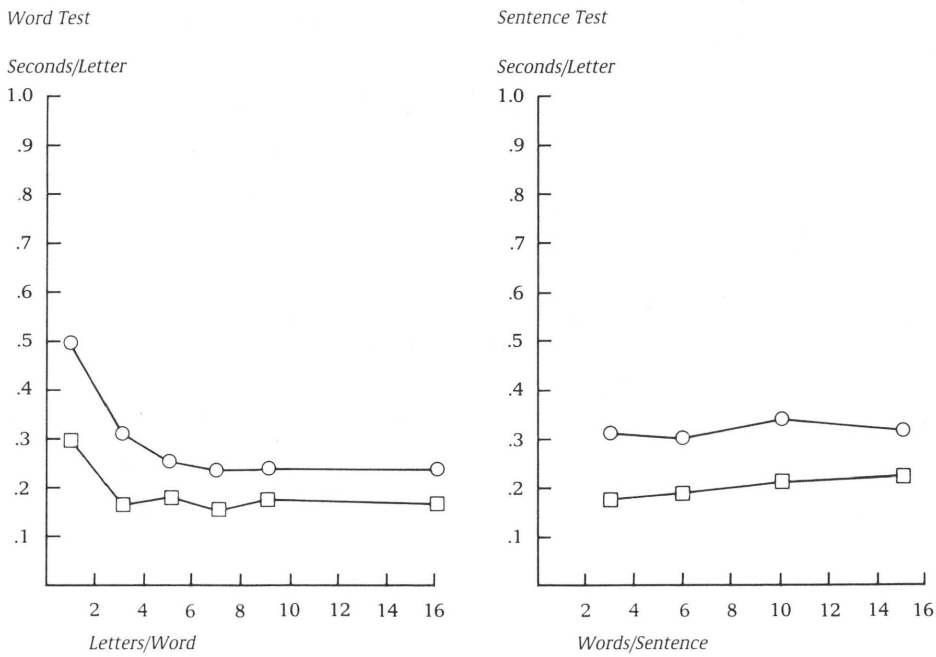


Table VI and Figure 6 show that the course in reading resulted in an increased reading rate on paragraphs, sentences, and words. However, only the measures fixation time and orthographic integration ability were affected by the training method used. It should be mentioned that most of the increment in reading rate could be explained from the decrease obtained in fixation time, which was very large as compared to the increase obtained in orthographic integration ability.

The result of this analysis thus demonstrates that exercises to fixate for the partially sighted increase reading rate mainly as a consequence of decreased fixation time. This fact points to the importance of the fixation time variable in the mediated reading process of the partially sighted, although other properties of the reading process may be more important, as suggested by the analyses of the effect of reading ability and visual handicap on the reading process.

Table VI *The effect of a course in reading training*

Subject	Reading group	Paragraph test	Sentence test	Word test	Fixation field	Fixation time	Orthographic integration ability	Semantic integration ability	Semantic interpretation
Before course in reading									
1	A1	0.30	0.47	0.47	3	0.60	0.00	0.00	0.02
2	A1	0.24	0.21	0.23	7	0.40	0.06	0.06	−0.02
3	A1	0.24	0.20	0.29	9	0.80	0.05	0.08	0.00
4	A1	0.43	0.31	0.25	3	0.40	0.12	0.14	−0.09
5	B1	0.47	0.38	0.28	3	0.40	0.09	0.20	−0.13
6	B1	0.24	0.21	0.18	3	0.20	0.11	0.03	−0.05
7	B1	0.23	0.20	0.26	5	0.60	0.00	0.07	0.02
8	B1	0.58	0.57	0.46	5	0.60	0.02	0.04	−0.11
		0.34	0.32	0.30	4.75	0.50	0.06	0.08	−0.05
After course in reading									
1	B2	0.37	0.35	0.27	7	0.40	0.00	0.20	−0.08
2	B2	0.17	0.20	0.20	3	0.40	0.02	0.04	−0.03
3	B2	0.24	0.19	0.18	7	0.40	0.00	0.07	−0.04
4	B2	0.35	0.28	0.20	5	0.20	0.10	0.12	−0.09
5	A2	0.27	0.28	0.21	3	0.20	0.10	0.08	−0.08
6	A2	0.16	0.13	0.16	5	0.20	0.06	0.08	0.00
7	A2	0.14	0.14	0.16	3	0.40	0.00	0.05	−0.01
8	A2	0.13	0.10	0.11	5	0.20	0.01	0.08	−0.01
		0.23	0.21	0.19	4.75	0.30	0.04	0.09	−0.04

Subjects no. 1 and 5, 2 and 6, 3 and 7, 4 and 8 are matched.

Discussion

The present work was designed as a descriptive study of the reading process of the partially sighted within a levels of processing framework. This model was operationalized by means of two reading-rate functions describing reading rate as a function of word length and length of sentences, respectively. From these functions a number of measures were derived assumed to reflect different levels of information processing. The reading rate functions obtained from the partially sighted indicated that:

(1) Important properties of mediated reading include both the ability to register information *and* the ability to form chunks at deeper levels by integrating the information registered with already stored information both on a peripheral and semantic encoding level.

(2) Reading rate of the partially sighted is mainly determined by their ability to integrate information at a peripheral level but can be improved by fixation and eye movement practice. This practice primarily influences fixation time, leaving the other more important properties unaffected.

(3) A low visual acuity is more critical for reading than a narrow field of view. This is inferred mainly from the measures reflecting the ability to integrate information at a peripheral level and the ability to use the semantic content of the text.

It is concluded from the present study that an understanding of the reading process of the partially sighted has to consider both peripheral and cognitive processes. For some visual handicaps the main problem in reading seems to be related to the process of integration of information, for other to the fixation process. However, these processes are in a complex way interrelated to information processing at a deeper cognitive level and these relations have to be understood in order to design effective training procedures.

The level-of-processing model of mediated reading proposed in this paper served only as a conceptual tool and was not tested in any critical way. However, the results were quite encouraging with respect to the usefulness of such a model. It was possible to isolate the reading process at different levels and to trace differences between different groups of readers to differences in information processing capabilities at these levels. Finally, the model focused the analyses on the interaction between perceptual and cognitive information processing, which is rather a neglected area of research.

Obviously, more empirical work is needed before definitive statements about the proposed model can be made. The present study has shown that the model is useful as a descriptive tool at least with respect to the mediated reading process of the partially sighted and it might be as relevant for readers without a visual handicap when they read in a mediated way.

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