Phonological alexia: three dissociations

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SUMMARY Three dissociations were observed in a case of alexia: a disturbance of reading, without comparable disturbance of oral expression, oral comprehension, writing, or spelling aloud; a disturbance of the phonological reading process, without disturbance of the non-phonological reading process; a disturbance located at the level of the phonological stage, without disturbance of the perceptual and expressive stages. This pattern of results has been called phonological alexia.

Most research on alexia has until recently been carried out from a syndromic and anatomoclinical point of view. This has led to a broadly accepted classification of alexia in terms of the clinical symptoms which are usually found in conjunction with it. This classification conforms in essence to that of Dejerine (1891) with three varieties of alexia being distinguished (Benson and Geschwind, (1969): alexia with agraphia, aphasic alexia, and pure alexia (or alexia without either agraphia or aphasia). Each variety of alexia is ascribed to a distinct neuroanatomical locus of lesion in the left cerebral hemisphere—alexia with agraphia is ascribed to a parietal lesion, aphasic alexia to a temporo-parietal one, and pure alexia to a lesion of the left occipital lobe, associated by many authors with a lesion of the splenium of the corpus callosum. However, there are problems with this classification. Firstly, recently reported cases of alexia (Albert *et al.*, 1973; Benson, 1977) cannot be included in any one of the three varieties. Secondly, any one variety can be interpreted in several ways. For example, alexia without agraphia is thought of either as consecutive to a defect in visual perception (Alajouanine *et al.*, 1960; Lhermitte and Gautier, 1969) or to a visuoverbal disconnection (Geschwind, 1965). Thus, this classification can neither account for numerous reading impairments which result from cerebral lesions, nor permit distinction of reading disturbances caused by different dysfunctions in any one variety of alexia. For about 10 years, some studies on alexia have been carried out from a linguistic

or a psycholinguistic point of view. Three tendencies can be distinguished among them. Some investigators have attempted to find facts confirming or invalidating particular aspects of a general theory of linguistic competence (Marshall and Newcombe, 1966). Others, on the basis of a method of linguistic analysis, have tried to describe reading disorders more systematically. For example, following Hecaen (1967) in applying the principles of distributional analysis, Dubois-Charlier (1971, 1972) and Kremin (1976) proposed a classification of alexia according to linguistic level—they distinguished literal alexia, verbal alexia, and phrastic alexia. Finally, others have considered alexia as a means of studying the production of reading behaviour itself in terms of the information processing systems involved (Marshall and Newcombe, 1973; Shallice and Warrington, 1975; Patterson and Marcel, 1977; Saffran and Marin, 1977). The research reported here has been carried out from this last point of view.

In this report we use a model of the reading processes derived from an organigram proposed by Andreewsky (1974) and related to certain hypotheses on reading behaviour suggested during the previous few years (Albert *et al.*, 1973; Marshall and Newcombe, 1973; Shallice and Warrington, 1975; Patterson and Marcel, 1977; Schwartz *et al.*, 1977; Saffran and Marin, 1977). In the model, reading is assumed to involve at least two processes which must be distinguished at the perceptuovisual level as well as at the linguistic level.

The first reading process is analytical at the visual level and phonological at the linguistic level. The proposed sequence is as follows: first, there is an analytical, letter-by-letter or syllable-by-

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syllable visual processing; then a linguistic correspondence between these visually identified letters and explicitly or implicitly uttered sounds is effected; the word can be understood only when this analytical processing is effected for all or almost all of its letters. Thus, at the linguistic level success in this reading process depends on a phonological stage (grapheme-phoneme correspondence) which precedes and conditions lexical and semantic stages. This is why this process is called phonological reading process.

On the other hand, the second reading process is global at the visual level, and lexical or semantic at the linguistic level. The proposed sequence is as follows: at the visual level the different letters of a word are understood simultaneously and globally, and are recognised as a whole (or a subset of letters is understood and constitutes a clue which is sufficient to evoke the word); then a linguistic correspondence between this identified unit and a particular word is effected. At the linguistic level, success in this reading process depends first on a lexical or semantic stage which precedes and conditions the phonological stage, ie implicit verbalisation, so that the verbalisation of a word does not necessarily precede its comprehension; for Andreewski (1974) it is even probable that comprehension precedes verbalisation. Consequently, not all written stimuli can be read by means of this reading process; only lexical and meaningful ones can. This process is called lexical or non-phonological reading process.

In the last few years several neuropsychological studies bearing on cases of a reading impairment which has been called either deep (Marshall and Newcombe, 1973) or phonemic (Shallice and Warrington, 1975) dyslexia have contained arguments for the existence of two reading processes. Two types of research have been done. Firstly, the description of this type of alexia made it possible to postulate the existence of a non-phonological reading route. Experimental research then established that patients with deep dyslexia did manifest impairment of the phonological reading route (Patterson and Marcel, 1977; Saffran and Marin, 1977), which showed that their performances were certainly linked to the existence of a non-phonological route. At the present time some problems remain. Firstly, these researches were all carried out on aphasic patients. Consequently, these patients' errors were not necessarily related to the supposed impairment. For example, the presence of semantic paraphasias in reading aloud may be caused by an impairment of stages located after the establishment of the grapheme-phoneme

correspondence (related to aphasia) and not by a patient's inability to establish this correspondence. Secondly, the level at which impairment of the phonological route is situated has not always been specified experimentally. Thirdly, the possible effects of the disturbance upon other linguistic tasks have never been studied.

In this paper we report a neuropsychological study of a case of alexia without expressive or receptive dysphasia, which was carried out on the basis of the reading behaviour model previously described. The experiment was conducted to answer the following questions. 1. Can the two postulated reading processes work independently? In order to answer this, the question was asked whether serious but incomplete alexia could be due to a single reading process disturbance. 2. Was the reading process disturbed at the level of visual perception, verbalisation, or at the intermediate linguistic level? 3. Were other activities, which might have been assumed to involve the stage disturbed, normally performed by the patient?

Case summary

As the detailed case report and its anatomical data have been reported by Beauvois *et al.* (1978), only a short summary is given here.

The patient (RG) was a right handed, 64 year old man, a retired agricultural machinery representative. Two years before the neuropsychological study, he had been operated upon for a left parieto-occipital angioma. Computerised tomography scans showed a lesion involving the left angular gyrus, the posterior part of the second temporal convolution, the inferior longitudinal fasciculus, the geniculostriate fibres, and some fibres of the tapetum. At the time of this study, besides the alexia, he was still suffering from the following neurological defects: right inferior quadrantanopia, mild memory deficit, mild calculation impairment, minimal constructional apraxia, and astereognosia. On the other hand, he suffered from neither motor nor sensory defect; his oral expression and comprehension could be considered to be good, with the exception of the bilateral tactile aphasia previously reported.

The alexia was serious enough to prevent the patient from resuming his work, and had continued without any change for two years. While he had been a passionate reader, RG could no longer read a paper or a letter he had just written. The Alouette reading test (Lefavrais, 1963) confirmed his serious reading disability: his reading level was

that of a 6 year old child—that is, the level of the lowest class at primary school. This was due to very slow reading (in this text, RG could not read more than 62 stimuli in three minutes) and to the presence of numerous errors (40% of the stimuli were misread or not read at all) which involved particularly articles, possessive adjectives, conjunctions, and some verbs.

In contrast with his very impaired reading, his writing was fairly good with the exception of some spelling mistakes. He could write down a message and draw up a text on a particular topic, being impeded only by the fact that he could not read over what he had written.

Neuropsychological study

FUNCTIONAL INDEPENDENCE OF THE TWO READING PROCESSES

First procedure

Each of the two reading processes was excluded successively at the perceptual level, by experimental procedures making impossible either analytical or global word perception.

The patient was asked to read aloud two lists of nouns. In the first, the words were presented in handwritten form. The letters themselves were hardly recognisable, so that the word could be identified practically only from its global form. In the second, the word letters were very legible (they were capital letters in print form) but their order was reversed (for instance, BOUTEILLE was written ELLIETUOB) in order to prevent any global word recognition and to make an analytical perception necessary. Words were read aloud nearly perfectly by means of global perception (19/20); none was read aloud by means of analytical perception (0/20), although the patient was given several minutes to do so.

Second procedure

The phonological reading process was handled at the linguistic level. When the stimuli are meaningful, the lexical reading process is sufficient, and the phonological reading process is unnecessary; but when the stimuli are meaningless, the phonological reading process becomes necessary. Thus, the reading of meaningless stimuli—that is, arbitrary strings of letters or digits—was compared with the reading of meaningful stimuli—that is, nouns or meaningful numbers.

Test 1 Reading aloud of letter strings The subject had to read aloud a list of 40 nouns (each of five to nine letters) and a list of 40 non-words (each of four or five letters—for example, PUKO,

DIRMA). All the nouns were read correctly, compared with only 10% of the non-words. Nouns were read quickly whereas non-words were read very slowly. Misreading of non-words resulted from either a failed attempt to decode analytically or an attempt to reconstitute the non-word from a word which looked like it (VINA: “c’est presque vinaigre”, ie, “it’s almost vinegar”; FOTA: “on dirait presque football”, ie, “it looks like football”).

Test 2 Reading aloud of numbers The subject was asked to read aloud two lists of 10 four-digit numbers. In the first, the numbers had no obvious meaning (for example, 4358); in the second, they were meaningful (for instance, the year of the patient’s birth, the dates of the second world war). The patient was told that the numbers of the first list were meaningless and the numbers of the second meaningful. No meaningless number was read correctly; all meaningful numbers were correctly and quickly read.

Test 3 Pointing out a letter string corresponding to an orally presented stimulus The patient was asked to designate from 20 letter strings, the one corresponding to a stimulus pronounced by the experimenter. He had to point out 40 nouns and 40 non-words consecutively. All the nouns were pointed out correctly, compared with only 30% of the non-words.

Third procedure

The variables affecting the necessarily phonological reading of non-words were researched and it was verified that they did not affect the reading of words, which was assumed to be achieved by the lexical reading process. Two variables—stimulus length and syllabic composition—were manipulated.

Stimulus length The patient was asked to read aloud two lists of stimuli. The first list contained non-words: 40 single letters, 40 two-letter non-words, and 40 four- or five-letter non-words. The second list contained nouns including 20 short ones (three letters) and 20 long ones (six to nine letters). The longer the non-words, the worse they were read (Table 1). There was no significant difference between reading performance for short and long nouns.

Syllabic composition The order of vowels and consonants in a word could affect reading difficulty. Stimuli of simple syllabic composition—that is, in which each consonant is followed by one vowel (CVCV) might be easier to read than stimuli in which consonants were found in succession (CCVC). So, the effect of syllabic composition was studied in reading performance for

Table 1 *Effect of stimulus length on reading performance. Percentage of correct responses*

Type of word	Stimulus length		
Non-word	One letter 87%	Two letters 42%	Four or five letters 10%
Noun	Three letters 85%	Six to nine letters 100%	

words (nouns and adjectives) and non-words. The test on words was composed of two lists of stimuli. In the first list (20 words), the syllabic composition was assumed to be simple (for example, domino, sécurité). In the second one (40 words) the syllabic composition was assumed to be complex (for example, absolu, frustré). The two lists were equivalent as regards certain characteristics of their words; length, frequency, grammatical category. The test on non-words was composed of two lists of 40 stimuli. In the first, the syllabic composition was simple (for example, VORA). In the second, it was complex (for example, STO). The non-words having a simple syllabic composition were made up of four letters; the non-words having a complex composition were made up of three letters. Syllabic composition significantly affected reading of non-words. It did not affect reading of words (Table 2).

It is clear, both from the model proposed above, and from the results obtained in patients with deep dyslexia, that not all categories of words can be read aloud by means of the lexical reading process. From the model, the fact that words can or cannot be read by the global process would depend on their meaning (the words having little meaning would not be read), and the results obtained in patients with deep dyslexia are affected by variables such as frequency, concreteness, and parts of speech. Since the aim of this study was to show the opposition between the phonological and the non-phonological reading processes, and not to test the efficiency of the global process, all the words chosen for the tests described above were high frequency (20 per million; Gougenheim

Table 2 *Effect of syllabic composition on reading performance. Percentage of correct responses*

	Simple composition	Complex composition	Comparison χ^2 test
Non-words	eg: VORA 55%	eg: STO 32%	$\chi^2 = 5.54, P < .05$
Words	eg: FACILITÉ 75%	eg: FRUSTRÉ 75%	NS

S = significant; NS = not significant.

et al., 1964), concrete nouns (with the exception of the test studying the effect of syllabic composition), which were highly meaningful. It is important to underline the fact that this patient could not read all the single words, but only about 80% of them. The variables affecting his word reading, which were different from those affecting reading by patients with deep dyslexia will be presented in detail elsewhere.

These three kinds of experiment did establish the functional independence of the two reading processes in this patient. Indeed, on the one hand there was a disturbance of the phonological reading process without a disturbance of the lexical reading process. On the other hand, the variables affecting the reading of non-words did not affect the reading of words.

DISTURBANCE AT THE PHONOLOGICAL STAGE AND NOT AT THE PERCEPTUAL OR EXPRESSIVE STAGES

In order to determine whether the disturbance was actually located at the level of the phonological stage allowing the grapheme-phoneme correspondence and not at the level of the perceptual or expressive stages, it was necessary to establish two points: (1) that the analytical visual processing was performed—in order to test this we verified that the reading disturbance was not specific to the visual presentation, that the letters could be visually identified, and that it could be individualised in a word; (2) and that single letters and non-words could be pronounced in other tasks.

Experimental design on single letters

The aim of this experiment was to verify that the alexia was related neither to a specific (visual) mode of presentation of the stimulus nor to an (oral) response modality, but to an interaction between them both. A systematic design including six tests was thought of in order to manipulate two modalities of response (oral and visual) and three modalities of stimulus presentation (visual, gestural, and auditory). Because of this patient's bilateral tactile aphasia, the tactile presentation was not studied. In each test 40 letters were presented consecutively.

The three tests in which the response was oral were as follows: reading aloud of seen letters, reading aloud of letters presented by gesture, and repetition test. The three tests in which the response was visual were pointing out tests. The patient was asked to point out, on a board comprising 26 letters, the one corresponding to the target letter. The tests were pointing out upon spoken

request, visuovisual matching, and gesturovisual matching ("show me the letter which has the same name as the one I have just drawn with your hand"). In the latter two tests, the form of the stimulus (handwritten small letters in script form) was different from the form of the response (handwritten capital letters in print form). Thus these tests did not study simple perceptual information transmission from one modality to another.

The test in which the stimulus was auditory and the response was oral (repetition) was carried out perfectly (Table 3), as was the test in which both the stimulus and the response were visual (visuovisual matching). The results recorded for all the other tests were impaired.

Control tests on letters

The transmission of simple perceptual information from one modality to another was studied. In order to do this, it was tested whether the letter A drawn by the experimenter with the patient's hand could be matched with a visually presented A. The test included 40 matchings of identical letters. They were all done perfectly. This result means that the possible errors in matching between two modalities in the above experiment ($a=A$), must not be thought of as a defect of information transmission from one modality to another one.

Identification of a letter included in a non-word

Two tests were carried out. In test 1 the patient had to match a single small letter in script form with a capital letter in print form included in a 10-letter non-word (for example, a single f with F included in LOUFREVANT), and 50/50 correct responses were recorded. In test 2 the patient had to decide whether two non-words were identical or not. If they were not, he had to indicate precisely the nature of the difference. The non-words were composed of six to 10 letters. When two non-

words were different, their difference came only from one letter. Either they included a different letter (for example, ZANROLIER and sanrolier) or they included the same letters, but the placing of one of the letters was different (for example, PINFAGUE and pifangue). The test was constructed so that it was not possible to succeed by simple perceptual matching. For instance the letter which was different in two non-words was never i or o. The 20 proposed comparisons were executed perfectly. Whenever the non-words were different, the patient was quick to show the difference.

Repetition of 40 non-words (composed of eight letters).

All were repeated perfectly.

The results permit rejection of the hypothesis of alexia caused by a visual impairment, for the following reasons: (1) the reading defect was not restricted to the visual modality (reading aloud was as impaired with gestural presentation as with visual presentation); (2) visual identification of letters was well performed since the patient matched perfectly two visually different forms of the same letter; (3) individualisation of a letter in a non-word was performed perfectly.

The results also permit rejection of the hypothesis of alexia caused by a verbalisation impairment. On the one hand, the patient made mistakes in tasks requiring no verbalisation, that is, in tests involving pointing out upon spoken request (visuovisual matching excepted). On the other hand, he could repeat letters and non-words without any mistake. The reading impairment occurred whenever the task brought into play both letter form identification (no matter whether the presentation modality was visual or gestural) and the production of a sound corresponding to this form, or inversely, the identification of a sound corresponding to a letter form and the identification of this letter form. Thus, the reading impairment was located at the level of the phonological processing necessary to the grapheme-phoneme correspondence.

WAS THE DISTURBANCE SPECIFIC TO READING?

Study of other kinds of linguistic behaviour

Oral expression Spontaneous speech was correct. Articulation, intonation, and fluency were good, and sentences were constructed correctly. The patient repeated the 50 syllables, the 125 words, and the 10 sentences of the *Test pour l'Examen de l'Aphasie* (Ducarne, 1976) entirely correctly. He could repeat four two-syllable words in the correct order. He gave correct word definitions

Table 3 *Effect of the presentation modality and of the response modality on letter reading performance. Percentage of correct responses*

Response	Stimulus		
	Visual	Gestural	Auditory
Oral	Reading aloud seen letters 87%	Reading aloud letters drawn with the patient's hand 83%	Repetition 100%
Visual	Visuovisual matching 100%	Gesturovisual matching 75%	Pointing out upon spoken request 80%

(standard score 9 on WAIS Vocabulary Subtest). He easily constructed sentences using two or three given words (score 7/7 on the sentence construction test of the *Test pour l'Examen de l'Aphasie*). He quickly stated the opposite of a given word 49 times out of 50. He was able to name 50 object images out of 50 and 39 sounds of objects out of 40, but he could correctly name only two objects out of three when these objects were presented tactually. With the exception of this bilateral tactile aphasia, which has been previously reported (Beauvois *et al.*, 1978), the patient's verbal expression was normal.

Oral language understanding The patient was able to carry out correctly all the tests of "oral understanding" from the *Test pour l'Examen de l'Aphasie*—pointing out an object named by the examiner (35/35), carrying out instructions (9/10), and the Three Papers Test of Pierre Marie. The critique of irrational stories of the Terman Merrill Intelligence Scale was performed correctly up to the highest level. A discrimination test on closely related phonemes (Dérouesné and Saillant, unpublished) was performed correctly. Semantic discrimination was good (IQ: 98 for the Synonym Test of Binois and Pichot (1958) orally performed). Therefore, the patient's oral comprehension was good.

Writing The patient was able to compose and write a story, being impeded only by the fact that he could not read over what he had written. He could take down dictated words, sentences, and even a text. All this was performed correctly except for a moderate dysorthographia. The word transcription was always correct phonetically, but some spelling mistakes were observed (for example, enfant was written ENFANS, église was written AIGLISE). Thus, the patient's writing was not entirely normal although it was very much better than his reading.

Therefore, not all linguistic tasks were carried out perfectly by this patient since he had a bilateral tactile aphasia and a moderate dysorthographia. However, on the one hand these disturbances were very specific and on the other hand they appeared to have no direct relation with his reading impairment. With the exception of the language impairment observed when objects were tactually presented, his oral expression and comprehension were completely normal, and it is hard to conceive what relation except a contiguous one could exist between tactile aphasia and alexia. The writing disturbance consisted only of a mild dysorthographia. This excepted, writing was completely normal, and in particular the phonetic transcription which involves phonological process-

ing was normal in all the clinical tests. However, some verifications were done in order to establish that phonological processing was actually carried out in other different tasks bearing on written language.

Experimental study of phonological processing involved in tasks bearing on written language

This was studied by means of the following tests.

Writing from dictation The patient had to write from dictation 40 non-words composed of six letters. All were written perfectly.

Copying The patient had to copy 40 non-words composed of four or five letters. Stimuli were written in print form letters, and the patient had to write them in script form. They were copied very badly (22% correct responses), and most of the errors were similar to those made in reading.

Pronunciation of words and non-words orally spelled out by the experimenter The experimenter spelled out a string of letters and asked the subject to pronounce the non-word corresponding to that string. The test included 40 non-words composed of four or five letters. Performance was good enough but not perfect (83% correct responses). The minimal difficulty in carrying out this test was only due to the fact that the patient had difficulty in keeping in mind five or more letters. Indeed, all the four-letter non-words were pronounced perfectly, while with long non-words either one letter was forgotten or the end of the non-word was wrongly guessed.

Spelling aloud The patient had to spell aloud the letters corresponding to a stimulus pronounced by the experimenter. The test included 40 non-words composed of six letters. All were spelled correctly.

The only test which was wrongly carried out was the one involving reading (copying); all other tests were done correctly. Therefore phonological processing was carried out in all the tasks bearing on written language which did not involve reading.

Discussion

The results recorded for this patient can be summarised into three essential dissociations: (1) a disturbance of the phonological reading process, without disturbance of the lexical reading process; (2) a disturbance located at the level of the phonological stage that permits grapheme-phoneme correspondence, without disturbance at the perceptual and expressive stages (3) a disturbance of reading without comparable disturbance of oral expression, oral comprehension, writing, and spelling aloud.

Such a pattern of results, which we have chosen to call phonological alexia, has important implications for the understanding of normal behaviour as well as of reading impairments resulting from cerebral lesions.

READING IN NORMAL SUBJECTS

Independence of the two reading processes

The chief result of this study concerns the experimental validation of the possible independent functioning of two reading processes. Our patient was found to be suffering from a disturbance of the phonological reading process, but without disturbance of the lexical reading process. This disturbance was related to a dysfunction of the phonological stage which allows grapheme-phoneme correspondence. Thus, these results confirm data concerning a non-phonological route in reading, obtained in deep dyslexia (Marshall and Newcombe, 1973), also called phonemic dyslexia (Shallice and Warrington, 1975; Patterson and Marcel, 1977; Saffran and Marin, 1977). These data mean that firstly, the lexical reading process does exist and is likely to function independently from the phonological reading process, and secondly, that this independent functioning involves the intermediate linguistic stages and not only the visual or expressive stages.

However, one of our results differs from data obtained by these authors. Words which were used (nouns and adjectives) were read nearly perfectly, so that the often reported semantic errors were not observed. In our view, this is because our patient had only a very specific language disturbance which has been called tactile aphasia, but had no expressive or receptive aphasia, contrary to the other reported cases. Indeed, if an alexic patient is also aphasic, presumably some of his lexical disturbances (for example, difficulty with word evocation, semantic paraphasia) will impede the functioning of the lexical reading process. In this case, it was not possible to determine if the word misreading was due to the dysfunctioning of the lexical reading process, or to the fact that this process in itself did not allow the subject to read words perfectly. Our results provide evidence in support of the idea that the lexical reading process is sufficient to read at least the words used in this study. Thus, the problem of how our patient can read words, and what sort of words he can read, is an important matter in establishing the degree of efficiency of the global reading process.

Independence of speech compared with reading

Bilateral tactile aphasia excepted, the patient's speech was completely normal. This means that the phonological processing necessary to the

grapheme-phoneme correspondence in reading is completely different from that necessary to oral expression and comprehension.

Independence of writing from dictation compared with reading

Non-words which were not read aloud were written perfectly from dictation. The discrepancy between normal writing and severely impaired reading has often been described since it characterises what is called alexia without agraphia. In this kind of alexia, the disturbance is thought to be located at the visual level or at the level of visuo-verbal transmission, so that it is easy to imagine that there is no agraphia since visual perception is not very important in writing. Thus, it could be imagined that writing and reading were symmetrical activities involving the same stages but in reverse order, and differing only by their end points—visual perception and graphic realisation. In particular one could assume that writing and reading involve the same linguistic stages. This concept is illustrated by some explanations of alexia with agraphia. Hécaen (1967), for example, thought that the reading impairment was caused by the same disturbance as the writing impairment, that is, a loss of grapheme-phoneme correspondence. Our experiments showed that a loss of grapheme-phoneme correspondence may be found in reading and not in writing. Consequently, writing and reading can no longer be conceived as symmetrical activities. This emphasises that a written grapheme is not equivalent to a seen grapheme. It is not merely more difficult to produce a grapheme from dictation than to identify it visually. These activities are completely different, in particular at the linguistic level.

Relationship between copying and reading

Confronted with letters and non-words, the patient copied correctly when he was asked to write a stimulus in the same written form as that in which the stimulus was presented (copying without retranscription). He copied with many mistakes when he was asked to change capital letters in print form into small letters in script form. This contrasts, on the one hand, with good writing from dictation and on the other hand with the retained ability to match two visually presented different forms of the same letter or of the same non-word. It is possible that the copying impairment was related to another disturbance than that which provoked the alexia. However, it is hard to imagine what phonological stage could be involved in copying and not in writing from dicta-

tion and in reading. It is more probable that the copying impairment was related directly to the disturbance provoking the phonological reading impairment. This should mean that a normal subject carries out the correspondence between a seen letter and a drawn letter of different form by means of phonological processing. Gestural production of a grapheme from a different visually presented form of this grapheme requires first the evocation of the corresponding phoneme.

Independence of spelling aloud compared with reading The patient, who could not read non-words, could spell them perfectly aloud if they were orally presented. This means that spelling aloud does not necessarily involve the evocation of the "visual image" of the stimulus whose letters would be then read one after the other. Indeed, the patient had some difficulty in reading letters, but none in spelling aloud non-words presented orally. Thus, in order to spell aloud a word or a non-word, other strategies than the evocation of the "visual" image are efficient; for instance the subject can implicitly pronounce (or hear) the stimulus and cut it up into phonemes, which will be translated into letter names.

READING DISTURBANCES (ALEXIA)

Phonological alexia differs from the different forms of alexia that have already been described.

Firstly it differs from each of the three usual syndromic or anatomoclinical varieties of alexia. It cannot be included under *aphasic alexia*, since, with the exception of a bilateral tactile aphasia, this patient had no language impairment. It is hard to imagine what relationship (except a contiguous one) could exist between tactile aphasia and alexia. Besides, the patient showed no sign usually found in conjunction with aphasic alexia (Alajouanine *et al.*, 1960; Benson and Geschwind, 1969; Lhermitte and Gautier, 1969). Some tasks generally more disturbed than reading tasks in alexic aphasic patients were, in the present case, done well enough—spontaneous writing, writing from dictation, spelling aloud, and the pronunciation of non-words orally spelled out by the experimenter. The problem of comparison with *parietal alexia* (also termed *alexia with agraphia*) may be raised because of the locus of the lesion (angular gyrus) which was the one usually reported in patients suffering from this sort of alexia. But there is an important difference. Our patient had no agraphia, but only a mild dysorthographia, and, contrary to what has often been described in alexia with agraphia, his writing disturbances did not resemble his reading disturbance. Whereas in reading, he could not carry

out the grapheme-phoneme correspondence necessary to the phonological reading process, he could do so perfectly in writing. Words were always well written phonetically, and he could write down non-words from dictation. Finally, this patient's reading impairment differs from *pure alexia*. In pure alexia, letters and syllables are usually better read than words, whereas the reverse pattern was observed here; in pure alexia, words are read analytically, letter by letter or syllable by syllable (Alajouanine *et al.*, 1960; Lhermitte and Gautier, 1969). Our patient proceeded in a reverse way by trying to guess non-words from words which looked like them. Besides, the interpretation of this disturbance does not fit the usual interpretations of pure alexia. It was clearly established that the disorder reported here cannot be thought of as consecutive to a visual processing defect as postulated in pure alexia (Lhermitte and Gautier, 1969), since every strictly visual test was carried out perfectly. Neither can the alexia reported here be considered as consecutive to a visuoverbal disconnection (Benson and Geschwind, 1969) in the common understanding of this term. This disconnection could not be general since written words could be read aloud. It should concern only analytically and phonologically processed information. This is theoretically possible since two independent reading processes have been postulated, but does not correspond to what is generally implied by the term visuoverbal disconnection. Besides, the locus of the lesion does not fit that of pure alexia. The computed tomography scans (Beauvois *et al.*, 1978) showed a left hemispheric parietal lesion, and there was no evidence of occipital or callosal lesion. In addition, the patient only had a quadrantanopia, so that visual information reached the left occipital area.

Secondly, phonological alexia differs from the two forms of alexia which have been distinguished according to the linguistic level of disturbance—*verbal alexia and literal alexia* (Wernicke, 1974; Hécaen, 1967; Dubois-Charlier, 1971, 1972; Kremin, 1976). The reading impairment for non-words which characterises phonological alexia has sometimes been included in verbal alexia (Dubois-Charlier, 1971). This was because non-words were thought to be located at the same linguistic level as words. Obviously, for us, phonological alexia, as described here is completely different from verbal alexia since words were read almost perfectly. But more often, phonological alexia has been confused with literal alexia, probably because the impaired reading of non-words or syllables was then conceived as consecutive to impairment

of letter reading. In fact, in the case reported here, when letters had to be read one by one, they were read well enough. It was when they had to be integrated into syllables, and *thus had a phonological value*, that they could not be read. This emphasises an important differentiation in studies of alexia. There are two possible strategies in reading letters, one phonological, the other lexical. Each of these strategies is adapted to a particular kind of stimulus. When the subject has to read a single letter, the most efficient strategy is the lexical one, since he is asked to name it. When he has to read a letter included in syllables or non-words, the most efficient strategy is the phonological one, since he has to make grapheme-phoneme correspondence. Thus, the term literal alexia is confusing.

Finally, from a descriptive point of view, phonological alexia differs from deep (Marshall and Newcombe, 1973) or phonemic dyslexia (Shallice and Warrington, 1975). Indeed, for some authors "the key to the demonstration of phonemic dyslexia is the appearance of semantic errors" (Schwartz *et al.*, 1977). Yet, our patient did not make any semantic errors. On the other hand, the interpretation of phonemic dyslexia is similar to the interpretation of phonological alexia since it should be caused by an impairment of the "phonemic" route, the semantic route being spared. If this is the case, the term phonological seems to us better than the term phonemic. In the studies carried out up to now, the impairment has been located at the level of the phonological stage allowing grapheme-phoneme correspondence without there being anything in the experiments which permits us to decide if it is on the phonemic side rather than on the graphemic side. The distinction between two kinds of phonological impairment in reading (the graphemic and the phonemic) is discussed by Déruesné and Beauvois (1979).

But in spite of this similarity, there is an important difference between phonemic dyslexia and phonological alexia. The first is a clinical entity, the other a theoretical concept. Phonemic dyslexia (Shallice and Warrington, 1975) was originally defined by means of a list of errors (semantic, derivational and visual ones) and of stimuli supposed to be misread (for example, abstract words, function words) which have no direct relation with the location of the disturbance on the reading model. They are reported only because they have often been found in association with the phonological impairment. By contrast, phonological alexia is defined only in relation to the reading model (one reading process is disturbed, the other

is not). Phonological alexia has been revealed here in a spectacular manner thanks to a rare patient who could be considered as a "pure case". In most clinical cases, phonological alexia is probably associated with other disturbances. In particular, it is probable that the association of phonological alexia with lexical alexia (ie, impairment of word reading) gives the clinical picture which has been called phonemic dyslexia.

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