

THE POSSIBLE EXISTENCE OF PHONEMIC READING IN THE PRESENCE OF BROCA'S APHASIA: A CASE REPORT

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(Received 1 March 1982)

Abstract—This case study examined phonemic reading and reading comprehension in the presence of Broca's aphasia. The patient, T.B., a 16 yr old male, suffered an occlusion of the middle cerebral artery. Spontaneous speech was limited, naming difficulties were apparent, and comprehension was mildly impaired. Though the patient could read only a small number of words aloud, he was able to read silently for comprehension on a standardized instrument. Moreover, T.B. was able to match orally-presented pseudowords to their written analogs, a finding which suggests that phonemic processing for nonlexical material was to some degree intact. The results were contrasted to the reading patterns usually reported to be present in "frontal" alexia and deep dyslexia. The possible existence of a dissociation between phonemic processing in reading and speech behavior as well as its mechanism was discussed.

INTRODUCTION

THE QUESTION of whether the comprehension of written words requires phonological mediation is of continuing interest to psycholinguists and experimental psychologists. Support for the position comes from the existence of a mechanism which operates both to produce and receive speech signals [1]. Support also comes from findings that covert "sounding out" aids comprehension of difficult material [2] and that proofreaders make more errors on unpronounced as opposed to pronounced letters [3]. Also, GLUSHKO [4] found that "exception" words and pseudowords took longer to read aloud than regular words and pseudowords and that regular but inconsistent words took longer to pronounce than regular consistent words. He proposed that words and pseudowords are read aloud using similar kinds of orthographic and phonological knowledge. The presence of an "inner voice" has been an oft-reported phenomenon. However, there is a considerable body of evidence to the contrary. Much of the work is based on investigations of reaction times to lexical decision tasks [5, 6] and shadowing tasks [7]. Certainly the existence of logogram systems of writing (Chinese, Japanese *Kanji*) speaks against an invariant speech recoding hypothesis. Theories in which there is flexible dual encoding (dependent upon the difficulty of the passage, instructional technique, and experience of the reader) are promising [6].

Alexia in the presence of aphasia has been intensively studied [8, 9]. More recently, studies of aphasic reading patterns have attempted to delineate phonological and nonphonological reading routes. BENSON [10], on the basis of the clinical features in 61 patients with relatively pure Broca's aphasia and attendant anterior pathology, proposed that a form of alexia can be distinguished from the two types recognized by DEJERINE [11]. Patients were able to read single words correctly but were unable to name individual letters of words and had difficulty comprehending written sentences. BENSON [10] suggested they read by visual gestalt. Sequencing and ability to interpret grammatic structure were also impaired. PATTERSON and

MARCEL [12] found that two patients with Broca's aphasia could repeat nonwords but were unsuccessful in their attempts to read them. Also, on a lexical decision task, the patients were not slowed by nonwords homophonic to real words. These patients, stated the authors, had visual access to the internal lexicon. SAFFRAN and MARIN [13] reported on a nonphonological route from print to meaning. They stated that phonemic dyslexia is a result of isolating a mechanism which recognizes orthographic structures from another, damaged mechanism involved in grapheme-to-phoneme conversion. Their patient, V.S., retained a reading vocabulary estimated at 16,500 words but had difficulty reading nonsense words, recognizing rhymes and homophones, and accessing lexical entries from homophonic equivalents. Performance appeared to proceed by matching letter strings with meanings. Interestingly, the patient was able to match orally presented pseudowords with their written analogs at the 70% level. The retention of this ability in a context of severe language deficits is not easily explained. K.F., a patient with phonemic dyslexia studied by SHALLICE and WARRINGTON [14], was better able to orally read concrete nouns than abstract nouns. Also, he was largely unable to read function words. Errors were of the "visual" variety. K.F. was not tested on pseudoword reading. SAFFRAN [15] has further stated that the reading of deep dyslexics is not configurational but is based on orthographical regularities in letter strings. The model, however, has difficulty accounting for reading (or matching) of pseudowords.

ALBERT *et al.* [16] stressed the necessity to assess silent reading comprehension, as well as expressive output in aphasia. Their patient, J.H., was unable to sound out written words he could not immediately identify. Yet, while the phonemic element of the written word appeared to be lost to him, the whole word as a visual configuration had semantic value. J.H. showed he understood the meaning of words in a number of challenges. The findings demonstrated that the inability to name a symbol is not a sufficient test of reading and that phonemic and semantic processes may be distinguished in the processing of written language.

It has been suggested that the right hemisphere might support reading abilities using a different, visual-spatially oriented process. YAMADORI [17] found that *Kanji* logographic reading was relatively well preserved after a left hemisphere injury rendered *Kana* reading dysfunctional. However, ELMAN *et al.* [18] found that the concreteness of *Kanji* nouns effects the direction of lateral asymmetry.

The distinction between reading aloud and the ability to comprehend written material is essential. Patients with deficits in expressive language may have relatively stronger abilities in the comprehension of visually processed materials [19, 20]. The present case, reported below, not only highlights this distinction but demonstrates that despite expressive aphasia, naming difficulties, and a mild comprehension deficit, the patient, T.B., was able to match unfamiliar written pseudowords to their spoken analogs.

PATIENT INFORMATION

The patient, a 15.6 yr old white male, was in good health until the date of admission. At school, after running track, he became limp, especially on the right side of his body, collapsed, and was taken to a community hospital. Though conscious, he was unresponsive to verbal stimuli, but responsive to painful stimuli. His speech was sparse and described as "slurred". Transferred to Children's Hospital of Michigan, he was awake and alert but did not follow verbal commands or answer questions. His speech consisted of single words, usually inappropriate.

Weakness of the right side of the body and the right face were present. Sensation was diminished on the right side. A Babinski reflex was present on the right side and a right hemianopia was also present. On the day after admission, the patient became more responsive and alert and was able to comprehend simple commands. The patient has continued to improve in the neurological and linguistic areas. After one week the patient was transferred to the rehabilitation unit where he received daily speech, occupational and physical therapy, and special education.



FIG 1. Left internal carotid arteriogram demonstrating a basal occlusive disease of the middle cerebral artery (MCA) and posterior cerebral artery (PCA).

The arrow indicates an occlusion at the base of the left MCA. The artery supplies the greater portion of the convexity of the cerebrum as well as the basal ganglia and internal capsule. Superior, inferior and medial regions are unaffected.

The second arrow indicates a diminished flow and distal occlusions (including a branch to the inferior temporal lobe) of the left PCA. Infarcted regions include the posterior pole, the medial posterior third of the left hemisphere, and the inferior portion of the temporal lobe. Branches to the basal ganglia and midbrain would also be affected.

A number of studies were completed three days after the onset of the symptoms. No hematological or CSF abnormalities were found. An arteriogram revealed complete occlusion of the left middle cerebral artery 5-6 mm from its origin (see Fig. 1). The left posterior cerebral artery's flow was diminished and distal branches were occluded. The etiology of the occlusions was unknown. Collateral flow into the left middle and posterior arterial territories occurred via hypertrophied leptomeningial feeders from the left anterior cerebral artery complex. The angiographic pattern was similar to that reported in other basal occlusive arterial vascular diseases [21]. An E.E.G. showed random irregular slow waves and rhythmic discharges of 3 to 4 Hz in the posterior left cerebral hemisphere. Occasional sharp discharges in the parietal, occipital, and temporal regions were noted. The CT scan revealed displacement of the lateral ventricles rightward and a hypodense area deep within the left cerebral hemisphere in the region of the thalamus, basal ganglia and internal capsule.

The patient's birth history was unremarkable. At 3 yr of age he had a febrile seizure. School achievement was fair. The patient had never been retained, nor had he received special education services. However, his mother thought him to be one or two grades behind in reading.

NEUROPSYCHOLOGICAL TESTING

Neuropsychological testing took place over a two week period, commencing approximately three weeks after the cerebrovascular accident. The patient was alert, oriented and cooperative throughout. He was not distracted by extraneous stimuli and was able to work in a goal-directed manner.

Spontaneous speech was limited. Phrases were short and usually telegraphic. Infrequent literal and verbal paraphasias were noted. Gross word finding difficulties were apparent. Comprehension of spoken language was good on simple material and more complex material that did not involve prepositions and conjunctions. Shortly after the stroke, the Porch Index of Communicative Abilities in Children [22] was administered. In general, verbal and written responses were wrong, unrelated, unintelligible, or perseverative. However, T.B. was able to match written words to objects, though he was unable to follow written directions involving prepositional phrases.

When seen initially for neuropsychological testing, the patient had no difficulty performing praxic tasks, including those of an ideational nature. The Purdue Pegboard Test [23], an instrument used to assess lower level psychomotor performance, was administered. Nonpreferred left hand skill was within normal limits. Unsurprisingly, preferred right hand performance was markedly subnormal at three standard deviations below the mean. On the Double Simultaneous Stimulation Test [24], performance was inconsistent. On twenty challenges, four errors were made. The patient performed between a 7.5 and 8.5 yr level on the Right-Left Orientation Test of the McCarthy Scales [25]. Finger gnostic abilities were unimpaired. A right hemianopia was diagnosed upon confrontation of the visual fields, but no right-biased error pattern on visual spatial material was noted.

Testing of Language Abilities

Comprehension

The patient was administered the Peabody Picture Vocabulary Test [26], a measure of receptive vocabulary in which the person is asked to point to one of four pictures which best "describes" an orally-presented word. Peabody Mental Age was 11.33, IQ was 77 and percentile was six. On the Token Test—Part V [27], the patient successfully followed 12 of 22 commands (e.g. Touch the blue circle with the red rectangle). Longer, sequenced commands proved most difficult for T.B. Normal subjects above the age of 10 rarely commit more than two errors. T.B.'s performance on the Auditory Discrimination Test [28] was within the average range, at percentile 50. Thus, T.B. was able both to discriminate sameness or difference and access the phonological concept underlying such distinctions. (T.B. responded by pointing to the printed words "same" or "different".)

Expressive language

Visual-oral naming. In general, naming was severely impaired upon visual confrontation. Spontaneous expressive speech was limited and phrases were short and stereotyped. No circumlocutions were apparent. A sample of T.B.'s expressive language is presented in Table 1.

A naming test [29] consisting of 30 items was administered. T.B. was able to verbally

Table 1. Expressive language samples

Visual stimulus	Language sample
TAT card Farm scene	She's going to school. That girl . . . other one. Watching him. The man is watching . . . I can't say it. The house. I can't say it. (Points). The house. The house. Um . . . that's it.
TAT card Harbor scene	Boats. The house. The bridge. The girl. The sun. They're using them. I don't know. Holding a barrel. Whatever.
TAT card Man embracing woman Clothes on line (picture) Shovel (picture)	The man. The lady. I can't say no more. Arm. I can't say nothin! The clothes. I . . . out and dry. You use the shovel . . . to . . . in the . . . I can't say it.

identify eight of 30 colors, utensils, body parts and household items. The Oldfield–Wingfield Picture Naming Test [30] was administered with similar results. T.B.'s most frequent reply was, after briefly initiating a sound, "No, I can't say it". Thus, he misidentified 32 of the 36 pictures. When cued phonetically after failures on the first 18 pictures, he succeeded on four more items. Contextual cueing did not lead to great accuracy. Over the second half of the test, contextual cueing led to a single additional success. Follow-up phonetic cueing led to no further accurate responses. Paraphasic errors were infrequent.

Serial speech. When asked to recite the days of the week, T.B. said, "Monday, Tuesday, Wednesday, Thursday, Friday, Saturday," then stopped. After the cue, "One more," he said, "Sunday." Alphabet recital was disturbed. After proceeding from A to T flawlessly, T.B. hesitated and then said, "U, R, S, T, E, V, E." T.B. was able to count from 1 to 20 without undue difficulty. Verbal fluency, as assessed by requesting the patient to name words in a given semantic category, elicited markedly impaired performance.

Written language

Reading aloud. The patient was administered Level II Reading of the Wide Range Achievement Test [31]. He had no difficulty visually matching upper-case letters, though naming letters was quite difficult for him. Six of thirteen were correct. T.B. was able to read the words "milk" and "in" aloud but no others before the test was discontinued after 12 consecutive failures. His grade level was 1.7 and percentile was 0.06.

The Peabody Individual Achievement Test—Reading Recognition subtest [32] elicited a performance level of Grade 0.03 (below percentile 1). T.B. could match letters and words visually. Because T.B. could only name one of six letters, the test was discontinued.

Comprehension in reading. Of five simple written commands (e.g. Touch your right eye), T.B. performed all flawlessly. The PIAT Reading Comprehension subtest [32] elicited a performance at the Grade 3.2 level (slightly below percentile 1). The patient had some facility matching (via a pointing response) a written sentence to that one picture of four which best corresponded to the written sentence. On the written version of Part V of the Token Test, T.B. was able to follow 14 of 22 commands (which represented a slight increase over aural performance).

To further test the patient's ability to match oral, visual and written stimuli, he was requested to match a written stimulus to another stimulus. When matching a written word to one of the three spoken words, T.B. worked without error on all five items. For example,

presented with the written word "comb", three words—"come", "has" and "comb"—were spoken by the examiner. The patient was then asked to indicate whether the first, second, or third was equivalent to the written stimulus. Reversal of the above task in which one word or letter presented orally was to be matched to one of three written words (one visually confusable, one phonetically confusable, and one dissimilar to the target) also elicited flawless performance. Moreover, the patient had no difficulty matching a single picture to the one of four words to which it corresponded. Performance on ten consecutive items adapted from the Peabody Picture Vocabulary Test (binocular through globe) was perfect.

The discrepancy between the patient's expressive output and the ability to read silently for comprehension was striking. For instance, on the WISC-R Information subtest [33], in which the person is asked to respond verbally to questions regarding commonplace knowledge, T.B. obtained a Scaled Score of 1. When the test was adapted so the patient had to select his answer from one of four written responses to a question, T.B. obtained a Scaled Score of 10. In fact, he was able to answer such questions as, "Who discovered the electric light bulb?" and "Name the two countries that border the United States", in this way.

Pseudoword reading. To determine if the patient could read unfamiliar words that were orthographically regular, T.B. was presented with pseudowords spoken by the examiner. T.B. was asked to point to one of four written words which best correspond to the initial spoken stimulus. T.B. worked at the 80% level ($\frac{4}{5}$). For instance, after "lork" was spoken, T.B. pointed to the written version, disregarding "bork", "lark" and "nep". (One of the choices rhymed with the target word, the other was different only in its medial vowel, while the third was unlike the target word. Order of alternatives was random.) When the format was changed so that T.B. had to indicate which of 10 written pseudowords was being spoken, performance fell only slightly to the 70% level.

Graphic and spelling skills. The patient was able to copy written material only with difficulty. Sometimes he used his left hand, but in general preferred his right, paretic hand. The patient's productions are pictured in Fig. 2. Regarding written fluency, the patient was requested to write as many words as he could in a given semantic category. He produced a maximum of five. Written spelling of spoken words on the Wide Range Achievement Test was at a Grade 2.4 level (percentile 1). Though T.B. could spell such words as "circle" and "shout", he could not undertake more difficult items (e.g. "heaven" or "educate"). The patient was easily able to point out the written version if they were spelled aloud by the examiner. He could not spell aloud even simple words that were spoken to him.

Verbal memory

Requested to repeat digits, the patient was able to vocalize three digits after the examiner had done so. When asked to point to written numbers, the patient's digit span increased to five. The patient's ability to repeat sentences was severely impaired, below the level of a 6 yr old. He was able to repeat a sentence of six but not eight syllables. Long-term verbal store was apparently intact, as performance on an adaptation of the WISC-R Information subtest was within normal limits.

Testing of Visual Spatial Abilities

The WISC-R Performance tests were administered and T.B. obtained a Performance IQ of 80 (percentile 9). Scaled scores were as follows: Picture Completion—6, Picture Arrangement—6, Block Design—8, Object Assembly—12, and Coding—3.

T.B.'s performance on the Raven Coloured Progressive Matrices [34], a test of nonverbal

Copying

In an attempt to collect such data

Right hand:

In an attempt to collect such data

I studied three types of pencil

Left hand:

I studied type of pencil

Dictation

The grass is green over the hill

Right hand:

The grass of green

Left hand:

The

How the Hill

FIG. 2. Graphic productions.

visual synthesis and ideational reasoning, was above the mean level of the performance of an 11 yr old (the ceiling of the test). The same held true for T.B.'s work on the Southern California Figure-Ground Test [35] in which masked embedded figures had to be matched to an array of target shapes. It should be noted that both the Raven and Figure-Ground tests involve only a minimal motor component in the response mode. On the Benton Visual Retention Test [36], T.B.'s immediate visual memory was in the Defective range. He was able to reproduce five designs without error. The patient had no difficulty copying any of the designs, including those on which he erred during the memory administration.

DISCUSSION

Alexia cannot be defined as the inability to name written material. The patient described above, T.B., was unable to read linguistic material aloud but was able to read silently and comprehend written sentences, as well as indicate which written pseudoword corresponded to its spoken analog.

In summary, the patient's spontaneous speech was limited. Vocalizations involved short phrases and single words. Overall, the patient's comprehension was mildly impaired. While his performance on the Token Test was subnormal, he was able to understand questions about commonplace information, match pictures to orally presented words on a receptive vocabulary task, and follow spoken directions. Also auditory phonetic discrimination was intact. Naming abilities upon visual confrontation were severely impaired.

The patient could read only a small number of words aloud. PIAT Reading Recognition performance was below percentile 1. However, T.B. was able to read silently for meaning as PIAT Reading Comprehension (in which a sentence was first read silently, then matched to one of four pictures) was approximately at percentile 1. T.B. could also match a written word to one of four spoken words and a spoken word to one of four written words. Moreover, T.B. was able to indicate which of an array of unfamiliar one- and two-syllable pseudowords corresponded to its spoken version at a level well above chance performance.

The patient's ability to spell aurally received words was minimal and appeared to reflect his naming difficulties. Written spelling was at a somewhat higher level, and graphic abilities for copying visually presented material were better still.

Verbal repetition of digits was grossly defective. However, the patient's performance increased considerably—from three to five digits—when he was allowed to point to numbers sequentially. His ability on a sentence repetition task was also severely limited. Verbal fluency in spoken and written response modes was defective as well.

The patient can be considered to be manifesting Broca's aphasia and, because of his age, he can be considered adult in regard to language lateralization [37]. The amount of speech on the part of the patient was limited and it was dysfluent and telegraphic in nature with a disturbed grammatic structure. Severe naming difficulties primarily involved defining articulation programs rather than semantic retrieval. (Anomia occurs with some frequency in frontal, as well as temporal, lesions [38].) T.B.'s retrieval deficits could be attributed neither to phonetic discrimination recognition or end-point articulation problems. Auditory phonetic discrimination was intact; speech was intelligible and only slightly dysarthric. Rather, the patient's error pattern appeared to represent a breakdown in the motor programming of phonemic articulation. The region dependent upon the middle cerebral artery includes the frontal speech area, the sensorimotor strip, and the lateral aspect of the temporal lobe. The clinical profile and the presumed extent of the infarction conformed closely to motor aphasia that MOHR [39] has termed a syndrome of the upper division of the left middle cerebral artery.

JACKSON [40] reported that writing is disturbed in nearly every case of aphasia and that the degree of writing defect varies with the degree of speech defect. SMITH [41] reported that writing is typically more disturbed than speech in aphasia. The present case differs somewhat, in that the patient's writing (in copying and spelling) was at a level greater than oral reading. Also, the patient could write words he could not say.

The discrepancy between reading capacity as indicated by routine testing procedures and T.B.'s capacity to read silently and demonstrate comprehension of material has been commented upon. The patient's ability to process pseudowords with the possible implication that they were being matched to an articulatory command program suggests unsuspected compensatory potential, given the verified damage to Broca's area. That the supplementary motor area, which lies outside the region of the middle cerebral artery, takes on the role of an encoder in reading might be considered. Regional cerebral blood flow studies have demonstrated its activity in reading and internal speech [42, 43]. Electrical stimulation of the area during speech leads to vocal arrest; damage to transient or permanent aphasia.

In short, the results suggest that when challenged by an orthographically regular nonword with no lexical address, the patient was able to initially match a sound trace or its acoustic-phonemic equivalent to the phonemic analog generated by the visual graphemic array: (It was unlikely that an aurally received pseudoword generated a representation of a letter array, which could then be matched to a written target word. If this were so, T.B.'s spelling would probably have been better.) Even when confronted by individual letters, the patient could not name a majority of them. Yet, phonemic elements which he could not express still had analytic value for him. SAFFRAN [13] stated that an important characteristic of deep or phonemic dyslexia is the inability to read nonsense words or real word homophones. Those deep dyslexic patients described in the literature [12–15] tend to show considerably worse performance than T.B. on tasks requiring non-lexical translation from grapheme to phoneme, but their reading comprehension is at least as good as T.B.'s and their oral reading better. In addition, phonemic dyslexics have great difficulty reading functor and abstract words. While T.B.'s reading of real words might involve use of orthographic regularities or (less probably) configurational cues, his reading of orthographically regular letter strings that were meaningless suggests the availability of a phonological route. Certainly, T.B.'s reading of real words might have been mediated by knowledge of orthographic rules.

Phonemic processing in expressive language and phonemic processing in silent reading may be distinct, at least in this aberrant situation. DEROUESNE and BEAUVOIS [44] made a similar point. They stated that though some patients make phonemic paraphasias when speaking, they are able to point out written pseudowords upon request. Since the patients could carry out phonemic processing necessary for analytic reading, they believed a dissociation between phonemic processing in reading and speech behaviour was present.

Though T.B. might be considered to have sustained a frontal alexia, he did not read by visual gestalt. Like a large minority of frontal alexics, T.B. was able to comprehend written sentences, though prepositions and conjunctions, as well as sequencing, proved difficult for him.

The argument could be advanced that the pattern of spared and impaired abilities noted in T.B. simply derives from the recovery process and is transient. If one is in agreement, however, with the objectivity of the findings, then the phenomenon might be considered "actual" and so it requires an explanation irrespective of the time period in which it occurred. It is possible that the condition might also exist in a stable form. At the present time it is unknown whether the profile observed will continue to evolve or remain static. Another issue concerns the equivalence of the tests. Some were standardized, others were not. The results of widely used instruments were reported in percentile form so that comparisons could be made more easily, though it is recognized that equating scores based on distinct standardization groups is less than optimal. The validity of the measures developed for clinical use hinges on the fact that the assessment instruments required different modes of response, though their actual content appeared to be of similar or, in selected instances, precisely the same difficulty. It remains to be seen whether the findings delineated above will be replicated in other patients with occlusions of the left middle cerebral artery.

Acknowledgements—We wish to thank Dr MICHAEL NIGRO for allowing us to examine his patient and providing us with neurological results and Ms JEANNIE SLOWLY for administering and interpreting the PICAC test of linguistic functioning.

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RESUME

Chez un sujet présentant une aphasie de Broca, on a examiné la lecture phonémique et la compréhension du matériel lu. Le malade, T.B., un garçon de 16 ans souffre d'une occlusion de l'artère cérébrale moyenne. Le langage spontané était limité avec des difficultés de dénomination et une compréhension faiblement perturbée. Bien que le malade ne pût lire à voix haute qu'un petit nombre de mots, il pouvait lire silencieusement et comprendre ce qu'il lisait. En outre, T.B. était capable d'apairer des logatomes présentés oralement avec leurs analogues écrits, ce qui suggère que le traitement phonémique du matériel non-lexical était en partie préservé. Ces résultats contrastent avec le type de lecture habituellement rencontré dans l'alexie "frontale" et dans la dyslexie profonde. L'existence possible d'une dissociation entre le traitement phonémique dans la lecture et le comportement de langage, ainsi que ses mécanismes, sont discutés.

Zusammenfassung:

In dieser Fallstudie wurde das phonematische Lesen und das Lesesinnverständnis bei Broca-Aphasie untersucht. Der Patient T. B., männlich, 16 Jahre alt, erlitt einen Verschuß der A. cerebri media. Spontansprechen war eingeschränkt, es bestanden Benennungsstörungen, das Sprachverständnis war mäßig beeinträchtigt. Obwohl der Patient nur eine kleine Zahl von Wörtern laut lesen konnte, war er zur Lösung von Aufgaben bei einem standardisierten Test auf Lesesinnverständnis in der Lage. Darüber hinaus war T. B. fähig, akustisch dargebotene Pseudowörter ihrem Schriftbild zuzuordnen. Dieser Befund zeigt, daß das phonematische Verarbeiten nichtlexikalischen Materials in gewissem Ausmaß intakt war. Die Ergebnisse wurden dem Leseverhalten gegenübergestellt, das normalerweise bei "frontaler" Alexie und Tiefendyslexie vorliegt. Es wird eine mögliche Dissoziation zwischen phonematischer Verarbeitung beim Lesen und Sprechen und deren Mechanismen diskutiert.