Cerebral physiological aspects of the reading / writing functions

and their significance for the diagnosis and therapy of dyslexia

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The dyslexic syndrome

Dyslexia refers to an isolated reading and writing disorder. “Isolated” is to be understood causally and indicates that it is a specific disorder of only the reading / writing functions while not implying that this reading and writing disorder must also appear in isolation, as is often misunderstood and leads to misdiagnosis. After all, dyslexia, which occurs regardless of the level of intelligence and across all social strata, can indeed also lead to impairments in performance in other school subjects, e.g., in arithmetic, and then occurs together with these.

When we observe it during our consultations, it is usually accompanied by a plethora of behavioural and emotional disorders, with which these children react to their dyslexia-related failures, so that we really have to think of it as a dyslexic syndrome.

Depending on the temperament of the children, such a dyslexic syndrome may include aggression, depression, fears, phobias, compulsive acts, or psychosomatic reactions such as headaches, stomach aches, tic symptoms, bedwetting, sleep disorders or display behaviour. These acts are intended to compensate for their experiences of inferiority in performance and may range from the harmless (e.g., playing the classroom clown) to criminal acts (e.g., shoplifting as a test of courage and playing the role of the hero).

Therefore, when children with such behavioural and emotional disorders come to us, we should always consider dyslexia as a possible cause in our differential diagnosis.

Different aspects of the reading / writing functions

If we want to understand how dyslexia develops, what it looks like and how it is to be treated, we must first be aware that the reading / writing functions, as well as speaking and calculating, as specifically human as they may be, are not only mental functions in the sense of so-called cultural techniques, but at the same time also biological functions, namely cerebral functions. These functions undergo many different stages on their long, complicated, and still largely unknown journey from their basic biological origins in the brain cell to their differentiated mental end products, continually presenting themselves in different and increasingly complex ways from level to level. From the molecular biological level via the cerebral anatomical, cerebral physiological and sensory physiological level this stretches up to the intellectual level and its pedagogical, psychological, philological, and philosophical aspects. For this reason, dyslexia is always presented differently in literature, based on the levels the author considers and the academic standpoint from which it is viewed. These different opinions about dyslexia are thus nothing more than the different ways of looking at dyslexia and so do not mean that one view is right, and the others must be wrong.

It is thus not a question of “either X or Y”, but of “both X and Y”. This should be kept in mind before one starts to engage in pointless argument. One should also keep in mind that in this highly complex and multifaceted field – for, as mentioned above, there is not only a pedagogy of learning, but also a brain physiology, molecular biology and biochemistry of learning and learning disorders – all of us, whether we are pedagogues, psychologists, doctors, brain physiologists, molecular biologists, are still

Special edition „der kinderarzt“, 9. Jg. (1978) Nr. 4, S. 459-463 & Nr. 5, S. 604-609

largely in the stage of hypotheses or models of thought, in the stage of collecting and reviewing experiences and considerations. All this demands for academic modesty and tolerance.

Cerebral physiological aspects of the reading / writing functions

With this in mind, an attempt shall be made to present the reading / writing functions and their potential for malfunction not at the humanistic-pedagogic level, but at the very basic level of brain physiology and molecular biology, in other words, where we are not looking at the mental end product which these functions yield, but at the biological raw material which is then processed in the brain to yield this mental end product. It is precisely at this basic biological level that useful diagnostic and therapeutic starting points for dyslexia become apparent. If we compare the brain to a computer, this describes the level at which entered information is first saved to then be retrieved and processed in accordance with a specific program. The following ideas are possible:

Since all physical and mental functions are ultimately brain functions, be it at the level of the brain stem, the diencephalon or the cerebrum, the brain is incapable of managing this enormous variety in any other way than through division of tasks and specialisation. This is an ancient biological principle which has governed the entire evolution and which applies not only to the brain, but also to every cell with its specific organelles as well as the whole organism with its specific organs.

Specific brain centres

We know from recent studies in molecular biology (*Rensch, Creutzfeld*) that specific information is indeed stored in a strictly localised manner in the brain. We know from electrical stimulus experiments (*Hess*) that there are specific brain centres in the diencephalon for the unconscious and involuntary instinctual functions. We know from the deficits that occur when they are damaged that there are also certain brain centres in the cerebrum for conscious and voluntary functions such as speech, motor, tactile and sensory functions.

It may be assumed for the following reasons that there is **an independent brain centre for reading / writing** (as well as for calculating), which is not identical with the speech centre, neither with respect to function nor with respect to localisation, so that reading / writing and speaking do not originate from a single source:

For one thing, there are also specific disorders of the reading / writing functions (alexia-agraphia) in the case of certain cerebral cortical damages, but for another, it is precisely dyslexia that shows most clearly that there is probably an independent reading / writing centre on this basic biological level. After all, in dyslexia, even in the most severe cases, the functions of the speech centre, such as speaking and language comprehension, are absolutely intact (just as, in dyslexia, the functions of arithmetic, including the recognition and differentiation of numbers, are completely intact even when the recognition and differentiation of letters is severely impaired).

Finally, **the difference of the ontogenetic and phylogenetic functional maturity of the speech centre and the reading / writing centre may suggest a difference**: Ontogenetically, the speech functions become mature and functional already around the age of 2, whereas the reading / writing functions become mature and functional only around the age of 6. Phylogenetically, the need to communicate with each other by speaking must have developed first, and only later the need to record this spoken word for the future in the form of writing in order to make it reproducible in the form of reading at any time – the first form of extracerebral information storage.

Yet, evolution did not have the development of intellectual cultural techniques in mind, but, as always when new abilities evolved, nothing other than to improve the chances of survival of the human species, which throughout its entire phylogeny has only remained competitive thanks to its brain and

its group existence. And it was precisely for this group existence that the ability to communicate in a differentiated way using words and subsequently even writing was a crucial advantage.

The idea of an independent reading / writing center that is not identical with the speech center can be difficult because we have become too accustomed to viewing speech and reading / writing purely in humanistic terms, and to viewing both functions as joint partial functions of what we understand by the philological generic term of "language". And this is quite correct on the highest, the mental level of these functions. Here, both together serve the mental dimension of language.

On the lowest level, the biological level, however, where the biological origins of these functions are found in the brain cells, both functions apparently still exist independently with different localisation, different functional maturity, and also different functionality, as will be discussed later. Thus, we have to imagine that the reading / writing centre has a similarly differentiated structure as the speech centre with its motor and sensory parts, and that it is located like the latter and in its vicinity in the dominant hemisphere of the brain (i.e., on the left side in a right-handed person).

Disorders of brain maturation

For a brain centre to function optimally, it must first be substantially intact. Moreover, it must be biologically mature because immaturity, delay in development, retardation also mean functional incapacity. The maturation stages of the different brain functions can be quite different and often correspond to the phylogenetic stages of development of these functions in the phylogeny.

A developmental delay of brain functions can occur in different ways: either as part of a general developmental delay caused by retarding influences of a physical, psychological, or epochal nature, or as an isolated developmental delay of only one function, which is then often genetically anchored and can be found not only in the patient's own history but also in the family history. (Accordingly, we know motor, linguistic and social "late developers".)

A dysfunction of the reading / writing centre can occur in the same way: either if the substantial intactness is impaired, i.e., as the result of an early childhood brain damage, or if the biological maturation is impaired, i.e., as the result of a maturation delay, either as a general retardation (in this case, we will find other delayed developments in the patient's history, e.g., of speech), or as an often isolated, often hereditary partial retardation (congenital dyslexics belong to this group). And since – probably for epochal reasons – such maturational delays have increased significantly, dyslexia has inevitably increased as well because it also depends on maturation.

"Wiring problems" of the brain

For a brain centre to function optimally, however, it not only needs to be organically intact and biologically mature, but it also needs to be properly interconnected with the brain centres whose functions it requires as tools to fulfil its tasks. (Thus, for example, the speech centre depends on hearing and the motor function of the speech muscles, while the reading / writing centre depends on vision, hearing, the motor function of the eye movements and the motor function of the writing hand.) Consequently, dysfunctions of a brain centre can also occur due to faulty interconnections.

Given that the reading / writing centre forms an anatomically determined functional unit with the motor centre of the writing hand, dyslexic dysfunctions can occur if this functional unit is torn apart, e.g., by re-educating a left-handed person to write with the right hand. This is because in a right-handed person, using the right hand for writing is not a matter of coincidence or acquisition, but anatomically determined by the interconnection of the left-brain reading / writing centre with the motor centre on the same side of the brain, which, however, controls the right hand owing to the crossed pyramidal tracts. In many left-handers, however, the anatomical conditions are exactly

reversed. Therefore, the risk factor for dyslexia is not the left-handedness as such but the re-educated left-handedness.

Programming of the brain

Finally, the most important functional prerequisite for a brain centre: In order to function optimally, it must not only be organically intact, biologically mature and properly interconnected, but it must also be properly programmed.

Programming means that, first of all, the specific information which brain centres need as basic equipment, as raw material, as components for the development of their specific end functions must be stored in each of them. In other words, a brain centre must be equipped with specific storage elements, which are then retrieved and processed according to its particular programming in order to form the differentiated end functions of this centre. In the case of innate abilities, which consequently do not need to be learned by the individual human being because they were already learned by the human species in the long course of evolution, the respective programs and information are already stored ab ovo. In the case of the abilities, however, which have to be learned by each individual him- or herself, such as speaking, reading / writing and arithmetic, the required basic information must first be supplied to the brain areas pre-programmed for this purpose.

What does such programming look like in detail? How is the storing of information accomplished? How does the processing of the stored elementary information to the differentiated end functions of a brain centre work?

As for programming, the involuntary vegetative centres of the brain stem function according to the simple regulatory principle of reflexive stimulus response. Apparently, in the equally involuntary instinct centres of the diencephalon, – as electrical stimulus experiments show – it is not reflexive isolated reactions, but complex functional patterns that are holistically stored in order to be triggered by specific key stimuli of the environment at the corresponding stimulus threshold of the organism, and to run in accordance with the program – as always in evolution for the sake of survival and preservation of the species.

Contrary to this, a new ability seems to have been added to the human cerebrum in the course of evolution, viz., the ability not only to live in an automated way following predefined programs, but also to be able to create such programs according to one's own free will. Only the necessary components and construction plans are made available, but not the finished end product. For this reason, in the centres of the cerebrum, e.g., for the willful motor activity, speaking, reading / writing or calculating, not the finished end products are stored, but only a set of components from which these end products must first be created, i.e., elementary individual information which must be processed first to form the end functions. This can be compared to a piano, which also does not store complete melodies that run automatically when you switch it on, but which holds a constant set of single notes that can then be chosen at will and processed to the desired melody.

Thus, the motor centre of the cerebrum does not store complete sequences of movements as is done in the diencephalon, but individual motor information, which can then be retrieved and processed at will to form the differentiated sequences of movements – following a very complex process that, among other things, also involves the coordinating and controlling entity of the cerebellum.

Creative programming. It is probably only through this storage and processing principle of the cerebrum that humans have gained the ability and the freedom, for example, to use their motor skills no longer only for protection against danger and self-preservation, but also creatively for drawing, shaping, writing, or constructing. And similarly, we may imagine this to be true for other centres of the

cerebrum: The loss of whole words observed in aphasia indicates that whole words are apparently stored as components in the speech centre, to be then processed to the differentiated end functions of this centre, viz., speech and speech recognition.

Dyslexia as a flaw in programming

The deficiencies of dyslexia emanating from the single letter, i.e., their poor recognition and discrimination as well as their incorrect use as components for words, and possibly also the inability to recognise or write individual letters in the case of literal alexia-agraphia, indicate that apparently not whole words are stored as components in the reading / writing centre, but the individual letters of the alphabet, which are then retrieved and processed to the differentiated end functions of this centre, viz., reading and writing. This is based on the principle of being able to form a multitude of information (in this case the words) with a constant basic set of relatively few components (in this case the letters) by changing their sequence, the order they appear in – recall our example of the piano.

Nature has known this principle since time immemorial, for this is also how it stores a multitude of biological information in the smallest of spaces in the cell: through sequence modification in a basic set of a few protein and nucleic acid components. However, since speaking and reading / writing are not among the innate abilities, these components, these storage elements must first be supplied.

The provision of the necessary resources for the speech centre with a wealth of whole words begins with the very first word that the mother speaks to the child. The critical input of the basic set of individual letters required for the reading / writing centre, functional at a later stage, takes place in the first lessons in school.

Didactogenic dyslexia

It is therefore quite plausible that a dysfunction of the reading / writing centre in the form of dyslexia can develop if it is supplied long enough and one-sidedly enough with the wrong storage elements in this initial tuition, i.e., with whole words instead of with individual letters. This can then be called didactogenic dyslexia, in which case didactogenic does not only refer to whole-word approach as such, but also to its wrong, i.e., overly one-sided, application, which is fortunately being abandoned more and more today.

Apparently, only an optimally mature and functional reading / writing centre is able to correct a wrong input of its own accord by isolating and storing the individual letter from the whole words offered. However, a reading / writing centre which is retarded for whatever reason is not capable of this additional task and becomes dyslexic. For these children, therefore, initial teaching of letters would already be half the therapy, and it would do no harm to the others either.

Didactogenic dyscalculia

One may well assume that the centre for the arithmetic functions similarly needs a basic inventory of numbers in order to be able to function, and that a didactogenic dyscalculia can develop in a similar way if this basic inventory has not been properly supplied.

Some evidence suggests that such storage elements may even need to be stored in a fixed order so as to be molecularly retrievable and processable, and that thus the fixed order of the alphabet and the sequence of numbers is not coincidental, but as biologically necessary and expedient as the order of the protein and nucleic acid components in storing biological information.

Perhaps it is even important for permanent storage that the information is also supplied in a specific period of time, since it will not be stored optimally before and after that. What is so far known only

from some biological learning processes with such limited sensitive phases might one day become important for classroom learning as well.

On the phylogenesis of the reading / writing functions

If we look at the historical development of writing, it is obvious that this optimally economic principle of writing and reading based on a limited number of individual letters did not exist from the beginning, but that every word apparently had its own character at first, which meant an enormous amount of memorising. The Sumerian cuneiform script, the Egyptian hieroglyphs and the Chinese script are evidence of this phase.

The turning point was the invention of the alphabet, which was in use in Syria and Canaan at least as early as in the 16th century B.C., and from which, by way of the Greek alphabet, the European alphabets, which soon spread all over the world, descended. Remaining as a "fossil among the large scripts of the world" (Denys *Hay*) is only the Chinese script with its 50,000 characters, of which one must memorise at least 1,500 in order not to be illiterate, and of which a scholar may need as much as 20,000. Therefore, the Chinese are now also changing to the economic principle of an alphabet because only a minority succeeds in this enormous task of memorisation.

Information storage in the brain

We have sought to look at the reading / writing functions at their most basic biological level, i.e., where the components for these functions are stored and retrieved for further processing. How does this storage and processing work?

With regard to storage, the brain has long been thought to be an electrically operating computer, in which storage is based on the constant circling of an electric charge in a network of neurons (dynamic memory theories) until animal experiments involving supercooling demonstrated the independence of storage from brain waves. We now assume that **the brain is a chemically operating computer**, in which storage is based on specific nucleic acid and protein synthesis (both according to the aforementioned principle of sequence modification of a constant number of relatively few components). In this process, desoxyribonucleic acid (DNA) seems to be responsible for the storage of innate abilities, and ribonucleic acid (RNA) for the storage of acquired abilities, since it increases significantly during learning processes.

Stored information is therefore information which has become material in the form of stable and specific macromolecules, which in animal experiments have even been transferred to untrained animals. Incidentally, such a chemical storage principle is much more economical than the electrical storage principle as just a single RNA molecule is capable of storing as much information as is contained in approximately 1,000 books.

Information processing in the brain

As for the processing of such stored information, it is based on several factors:

First, on the aforementioned processing principle of generating a multitude of information from a basic set of relatively few storage elements by modifying their sequence, with one neuron being capable of converting 15,000 protein molecules per second for such a feat. Second, on the proper functioning of the transmitter substances between the synapses, the contact points that wire the brain cells together to multiple switching and functional circuits. And finally, on the number of synapses and thus on the number of synapses-forming dendrites, which are the extensions of the brain cells.

However, unlike the number of brain cells, this number of dendrites and thus synapses, on which the proper functioning of a brain depends, is not constant, but can multiply in the course of maturation as

well as through stimulation and training – perhaps even by medication. In a way, this ability of dendrites to multiply compensates for the inability of brain cells to regenerate.

Consequently, not every brain damage in early childhood must necessarily be irreversible. Moreover, not every low IQ must necessarily mean a permanent and definitive lack of intelligence (frequent misdiagnosis) but may also mean mere retardation, because the organic substrate of intelligence is the number of dendrites and synapses, so that like the latter it is also capable of development through maturation and training. Besides, since they cause biochemical blocking effects at the synapses, other factors can also lower the IQ, e.g., anxiety, inhibition, depression, neurosis, form on the day (also the examiner's).

Ways of recognising and misrecognising dyslexia

Types of errors

What does dyslexia look like? Schools expect dyslexia to exhibit so-called typical dyslexia errors. If it does not show these, then it is not dyslexia. But if we assume that dyslexia occurs because the letters, which are required as memory elements for the proper functioning of the reading / writing centre, are stored incorrectly in the reading / writing centre for one of the aforementioned reasons, and for this reason cannot be correctly recognised, distinguished and processed for forming or recognising words in the form of writing, or for recognising words in the form of reading, then it becomes understandable that in dyslexia there can be as many types of errors as there are possibilities to confuse or mix up the 26 letters of the alphabet, including their four variants (upper case, lower case, print, cursive).

In other words, dyslexia involves a wide variety of errors that may differ from child to child and even from age to age in the same child: omission of letters, confusion of upper and lower case letters, confusion of similar sounding or similar looking letters or laterally different letters, as well as confusion of letter order up to an illegible jumble of letters. What is decisive is thus not the quality, but the quantity of the errors. A persistent accumulation of so-called slips of the pen is always indicative of dyslexia.

Dyslexia occurring without reading difficulties

Schools furthermore expect dyslexia to affect reading and spelling equally. Someone who reads well is not dyslexic, no matter how many spelling mistakes they make. However, if we assume that the reading / writing centre is similarly differentiated as the speech centre with its sensory and motor parts, it becomes understandable that here, too, the key aspects of the disorder can be distributed quite differently. Thus, at one end of the spectrum, there are dyslexics who write poorly but read well, while at the other end, there are those who read poorly but write well, not to mention all possible combinations in between.

Different manifestation times

Schools also expect dyslexia to appear no later than in the second grade. If it does not, it is not dyslexia. Yet it does not adhere to this either, since it usually does not manifest until the third grade, which is when the first unpracticed dictations are written, while those that were practiced before were written almost without any errors. And there is even a group in which dyslexia becomes manifest only in the fifth grade, namely when the first foreign language is introduced, which can then suddenly no longer be coped with.

The consequence is that decisions about who is dyslexic and who is not must not be made too early or too definitely. In addition, identifying and treating dyslexia must extend far beyond primary school,

because that is where we find not only the late-onset dyslexics, but also the numerous dyslexics who were dragged along because their dyslexia was not recognised in primary school.

Effects on other school subjects

Schools furthermore expect dyslexia to occur strictly in isolation. If poor performance is also observed in arithmetic, it is not dyslexia. Once again, this is not true because dyslexia has a secondary effect on other areas of performance:

In arithmetic, poor performance can occur when symbols such as "+" or "-" are confused or numbers mixed up. However, dyslexia's reading deficiencies will occur no later than when the first math word problems come up, either because the texts are read incorrectly and not understood, or because too much time is spent in class tests on the laborious deciphering of the texts, time which is then not available for solving the assignments.

In foreign languages, not only spelling mistakes occur, but due to the dyslexic's reading deficiencies also grammatical and translation errors, when grammatically important word endings are read incorrectly or not at all. (With regard to the issue of foreign languages, it should be mentioned that the longer dyslexia was treated in primary school, the lower the risk that it will affect whichever foreign language is studied in the fifth grade, even if it has not yet been overcome in German.)

Finally, in sensitive children, constant dyslexia-related failures can lead to discouragement-related **failure in all subjects**.

The effect of dyslexia on handwriting should not go unmentioned. This is where the dyslexic's fear, tension and lack of time often come to the fore, and it is twice as much of a challenge to ask the child to write beautifully at this stage, especially as there is often a partial retardation of the fine motor skills as well.

The consequence is that a decline in performance in other school subjects should not be taken hastily as evidence of dyslexia but can also be a secondary effect of dyslexia. These children are in particular need of treatment, but instead they are often excluded from treatment.

Dyslexia and intelligence

Schools, i.e., school authorities in general, finally expect dyslexics to have a normal intelligence. Anyone who does not achieve an IQ of at least 90 is not dyslexic, no matter how many spelling mistakes they make. This rigid and more or less arbitrary threshold becomes questionable if one knows how inaccurate the merely statistical scores of a test are and that they can have a deviation of +/- 6 IQ points. It may thus solely depend on this random variance whether an IQ is below or above 90, i.e., whether a dyslexic person is recognised or not.

This threshold becomes even more questionable if one knows how many other factors can reduce an IQ (method of the test, the child's or the examiner's form on the day, anxiety, depression, retardation, pubertal crisis, hypotonic blood pressure, incipient flu etc.). However, the assumption that dyslexia is an intelligence-independent disorder, especially of the reading / writing functions, and that therefore neither high nor low intelligence can protect against it, makes the idea of using normal intelligence as a criterion for dyslexia absolutely dubious.

Consequence: It is necessary to treat dyslexia even in the case of a low IQ, i.e., also in schools for children with special needs, especially since experience has shown that these children have no less chance of success than the more gifted dyslexics.

Misdiagnoses

Dyslexia is often confused with laziness because the feeling of resignation and the defensiveness of many children appear like this, or with a lack of concentration because the errors accumulate towards the end of the dictation. However, this is often only an indication of the increasing time pressure faced by the dyslexic child due to all the thinking, crossing out, patching in, and crossing out again. Hence, whole parts of sentences are often skipped in order to get back on track. Moreover, there is no such thing as a lack of concentration that only manifests itself in reading and spelling and nowhere else.

In addition to these diagnostic restrictions, there are also therapeutic restrictions, e.g., when dyslexic children are identified but excluded from remedial measures because they are "still too good". This contradicts every therapeutic principle of early detection and early treatment, which here, as everywhere, improves the diagnosis.

Dyslexia symptoms at preschool age

Occasionally, children at risk with regard to later dyslexia can be identified at preschool age when the following factors come together: late development of speech and motor skills, low verbal quotient in the Hamburg-Wechsler intelligence test, dyslexia in the family history, or re-educated left-handedness. These children should learn using the letter method from the beginning.

Some educational political aspects of dyslexia

If one considers the large dark figure of unidentified and untreated dyslexics, which results from such a diagnostic and therapeutic restriction by the schools, and looks for the reasons, the suspicion arises that, apart from a lack of information, this is less a scientific matter than a matter of school policy, and that for those in charge of schools the actual question is not "How many dyslexics are there?" but "How many dyslexics should there be?" Thus, for example, *Angermeier* writes in his 1976 book on dyslexia, which is read primarily by teachers: "One will have to determine the limits of intelligence and orthography in such a way that a desirable percentage of dyslexics will result. After all, there is no point in setting these thresholds in such a way as to get more dyslexics than can be supported in schools. School policymakers must ask themselves what percentage of dyslexics should be supported, and the detection of dyslexia by means of tests must be based on that." So much for the quote.

If that is the case, it contradicts every principle of pedagogy, therapy, and equal opportunities. Using after-school measures, every effort must be made to help those dyslexic children who fall victim to such diagnostic and therapeutic restriction, and those in whose schools no measures at all are implemented for the detection and treatment of dyslexia.

If a well-seeing and well-hearing child who attends primary school or a special school for people with learning difficulties consistently makes ten or more errors in their school dictations (and only these are the touchstone), then it is no longer relevant how one defines this disorder, which name is given to it, which theory one considers wrong or right, or whether the IQ is above or below 90. Then all that matters is that this child is helped, and quickly, specifically and unbureaucratically. And in borderline and uncertain cases, it is better to treat too many children as dyslexic, which certainly does not harm them, than too few, which harms them more, for unidentified and untreated dyslexia not only makes people medically ill by causing an abundance of behavioural and emotional disorders, but also socially ill by leading to social exclusion. After all, as the preface to a spelling exercise book for schools states, "even today, spelling performance can be regarded as a yardstick for assessing mental ability in general." It is obvious what this means in terms of social exclusion for an unidentified dyslexic.

Special edition „der kinderarzt", 9. Jg. (1978) Nr. 4, S. 459-463 & Nr. 5, S. 604-609

Possible treatments for dyslexia

What might such after-school treatment look like? If we look at the errors in dyslexia, it becomes obvious that the following is impaired:

Individual letters are not correctly identified and distinguished, whether acoustically or visually, and they are not used in the correct order as structural elements for the word. A prerequisite for the correct recognition and differentiation of the individual letters and for their correct use as structural elements for the word, however, is that they are stored correctly in the reading / writing centre – recall the storage and retrieval principle of order and sequence –, and that they are not only stored correctly, but also permanently and stably. Only then they become recognisable, distinguishable and retrievable.

With regard to therapy, this means that any treatment for dyslexia must start from the individual letter which must be supplied to the – for whatever reason – dyslexic reading / writing centre in such a way that it is permanently and stably stored. In therapy, the letters are supplied via all possible input channels to the reading / writing centre, i.e., via the eye, the ear, the motor function of the writing hand, and, last but not least, via the sense of touch, whose vital role in braille shows that it is an additional input channel to the reading / writing centre that can be exploited therapeutically.

On the one hand, **permanent and stable storage** is achieved by the principle of synchronous input on as many access paths as possible. On the other hand, it is achieved by the principle of regular repetition, this being an ancient biological learning principle without which the entire evolution would not have been possible, and without which our brain cannot permanently store information in its long-term memory (and which, therefore, cannot be circumvented, no matter how much progressive pedagogues would like to do so). To divide dyslexia into a visual and an auditory form is pointless, both diagnostically and therapeutically, because the disorder does not lie in the access paths but in the centre itself.

Two methods, which I have described in the "Legastheniefibel" *("Dyslexia Primer", translator's note)*, **are suitable for achieving these therapeutic goals**, and both can be carried out quite easily without any organisational or financial effort:

Audio-visual-motor treatment

The audio-visual-motor program I described can be easily self-made using a tape recorder and a slide projector. It is suitable for group treatment and it implements particularly optimally the principle of synchronous input on as many channels as possible, which is important for permanent memorisation. Thereby,

- a slide series with the letters of the alphabet serves as a **medium for the optical access path** (each letter in all its four variants: upper case, lower case, print, cursive),
- an audio tape containing a recording of the same letters serves as a **medium for the acoustic access path**,
- the writing hand, which is used for writing at the same time (recall the anatomically determined functional unit between the writing hand and the reading / writing centre), serves as a **medium for the motor access path**,
- and plain plastic letters which have to be felt blindly serve as a **medium for the sense of touch**.

This program can be varied in many ways and can be carried out once, twice or three times a week, depending on the case.

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Treatment using a typewriter

The typewriter method I described is suitable as a daily individual treatment at home, to be carried out in parallel with the audio-visual-motor program. It involves typing a text with the index finger of one's writing hand for twenty minutes, strictly letter by letter.

The great therapeutic effect of this method is based on the fact that many things happen simultaneously in just one step. Each letter is memorised three times: in the text, on the key and on the sheet of paper. In addition, each word is broken down letter by letter and immediately put back together again, likewise letter by letter. Finally, it trains the cooperation of the reading / writing centre with the motor function of the eye movement, which is vital for reading and writing, since in this process, each letter is coupled with an eye movement. If the typed letters are then spoken at the same time, the audio-visual principle can also be incorporated into this method.

Both these methods train reading and writing, and often this elementary therapy alone is enough to get the dyslexic reading / writing centre going again if it is carried out long and consistently enough (not less than one year, otherwise the storage principle of regular repetition will not have an optimal effect).

Encouragement treatment

Along with this, an intensive encouragement program must be conducted in every case, which includes not only constant verbal encouragement, but also other measures such as

- being exempt from the depressing marking of dictations
- breaking down the mark for German in the mid-year reports
- repeating classes to create a sense of achievement
- extending the probationary semester
- counting the correctly written words and not the errors ("Out of 100 words, 80 are correct." sounds much better than "20 errors")
- correcting errors not in aggressive red ink but green ink, thus making the dyslexic's dictation book suddenly look no longer like a bloody battlefield but like a green meadow.

Since everything that passes through the dyslexic's intact speech centre works well, their oral performance should be marked higher than their written performance, and in arithmetic tests, they should not be made to read the texts themselves, but to have them read out to them, thus allowing the dyslexic to grasp them immediately, since this is, after all, an achievement of their intact speech centre.

Accompanying medicinal treatment

This whole treatment program can be supported and accelerated by an accompanying medical treatment based on the following ideas:

What distinguishes the child from the adult is the child-specific dimension of maturation, which also applies to the brain and its functions and which is thus an integral part of the child's organism, so to speak an additional brain function which no longer exists in the adult.

If there are drugs that are able to increase the cerebral metabolism in a physiological way by improving the cellular glucose and oxygen utilisation, such as Centrophenoxine (Helfergin), the oldest and best-studied representative of this group and also the one I have had the longest experience with, furthermore Pyrithioxine and Piracetam, then such drugs are also able, especially in children, to enhance not only the general cerebral functions, but also the maturational functions where they are retarded (e.g., a retardation of the linguistic, motor or social maturity, or a retardation of the reading

/ writing functions in case of dyslexia), be it by mobilising the dendrite proliferation or the transmitter function. This treatment, however, should always be combined with the respective orthopedagogic functional training (speech therapy, remedial gymnastics, play therapy, dyslexia therapy).

Ineffective treatment methods

Any method that focuses on the whole word is therapeutically ineffective, e.g., practice dictation, which often overwhelms the children, since dyslexia treatment must focus on the individual letter and not on the whole word, which, being a spoken whole word, primarily activates the speech centre and not the reading / writing centre. Reducing dictation is also therapeutically ineffective, for one also cannot cure a blind person by simply extinguishing the light.

Putting the cart before the horse, i.e., applying the therapeutic lever not to dyslexia but to its consequences, is also ineffective as cause and effect are confused, resulting in very costly psychotherapy where systematic dyslexia treatment would be appropriate.

After all, a lack of enthusiasm for learning, an aversion to reading and writing, or behavioural disorders are not the cause of dyslexia but its consequences. A dysfunctional family environment is often not the cause of dyslexia or its accompanying symptoms but its consequence. Dyslexia, resulting in constantly earning non-pass marks in dictation, as well as the manifold reactions of the children to these failures and the two-fold counter reactions of the parents, both to the poor marks and to the reactive behavioural problems of the children, and the ensuing vicious cycle can gradually transform the most intact family life into a disturbed milieu, which is then misjudged as the cause if we take a one-sided milieu-oriented approach.

Summary

The aim is to show that there are also cerebral physiological aspects of dyslexia offering viable diagnostic and therapeutic approaches, and that we can only tackle the problem of dyslexia, which poses a threat to the school existence and thus social existence of so many children, if we learn to understand and approach it together – parents, teachers, doctors – from all its different angles. Besides, we should use the theoretical, diagnostic, and therapeutic dyslexia model to help other partially underachieving children in a similar way, e.g., those children with isolated dyscalculia, who are also not few in number, and who have the same right to recognition, acknowledgement and support as the dyslexic children.

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Special edition "der kinderarzt", 9. Jg. (1978) Nr. 4, S. 459-463 & Nr. 5, S. 604-609