What is dyscalculia?

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A chapter from e-book “What is Dyscalculia” by Dr Bjorn Adler

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INTRODUCTION

A Book addressing Difficulties in Mathematics

This is a book about mathematics; understanding what mathematics is really about. Mathematics cannot be separated from the particular cognitive processes in operation whenever we apply our minds to a mathematical task. My aim in this book is to examine and illustrate the most common reasons that people have mathematical difficulties.

Many people have mixed feelings about mathematics, even those who did well at it at school. Very often the cause of these feelings is the way the subject is taught: it usually isn't presented in an inspiring or exciting way. Many students feel that mathematics is boring, and can't see its relevance to everyday life. Such experiences are unfortunate and misleading. Mathematics is an important part of life. It is impossible to ignore it, because situations arise nearly every moment in our day to day life which requires us to make calculations, systematize information and make decisions. This is what mathematics is really about.

There is no other school subject to which we lend so much weight as mathematics. Even if a student performs well in other subjects and is generally successful, with many friends and good family relationships, they are often likely to be insecure about mathematics. Students commonly question their own mathematical ability: *"Why can't I do this math? Why am I not as good as my friends? Maybe I'm just really stupid!"*

Even if these questions are not spoken aloud they are formed in the mind of students who experiences mathematical difficulties. The experience is devastating for the self esteem and if it continues unchecked, can eventually impact upon the entire experience of childhood. It can destroy a child's school years and lead to the later development of psychiatric symptoms.

In my field I meet many children and youngsters with their self esteem shattered because of their mathematical failures. It really isn't strange: who can handle failure after failure every day and still keep up their self confidence? The feeling of being a failure and being different to everyone else is extremely common in people who repeatedly experience failure without ever having the opportunity to overcome it. In school, almost every day in is filled with moments in which students must use their mathematical thinking. When you see it this way, it is not very strange that many students give up altogether and refuse to work with mathematics at all. Often older students start to play truant from classes. They stop doing their homework and do everything they can to thwart the well-meaning efforts of their parents. All of this is an understandable human reaction to repeated failure and shattering of one's self-esteem. We simply decide that enough is enough: "*I cannot handle anymore!*"

Many people with mathematical difficulties can testify how misunderstood and different they have felt during all their years in school. But I also meet some people who, in their adulthood, have refused to let their failure beat them. They start studying mathematics again and prove, not least to themselves, that they actually are not stupid. Many of them succeed! They win back their self-esteem, and many experience for the first time inspiration and enthusiasm for the subject. They find themselves thinking: *"Maths isn't too bad after all! It's actually fun! Now I finally understand the use of mathematics."*

This book addresses important issues concerning dyscalculia, and it has been my aim to present what we in the field now know about the subject in a clear, understandable way. The following chapters look at reasons for dyscalculia, diagnosis, and above all, how to provide the right kind of help. But before I begin my examination of dyscalculia, I want to first say something about what mathematics is really about.

HOW DOES MATHEMATICAL ABILITY DEVELOP?

All human knowledge, particularly that of a logical and mathematical character, originates in our interaction with the environment. The interaction begins long before enrolment in school. It basically begins at birth. Even when only a few days old, the infant can distinguish between two objects and one, even if unable to express this in words. *Understanding of numbers*, such as comprehending how many objects one perceives, is an important element in mathematics, an element present in rudimentary form already at birth.

At the moment of birth a sorting process begins through which the child, on the basis of *categories* and *prototypes*, makes the world more understandable, bringing order out of chaos. These efforts to create order and gain understanding involve the creating of relationships, the development of feelings, and the use and presence of objects of many kinds. In a multitude of encounters with others, the child learns to distinguish between the joy and distress of other individuals. Being confronted with the joy of the parents and of many other individuals, for example, leads to the child's acquiring a prototype or a general picture of how joy tends to be expressed and can be recognised. This is equally true for feelings of sorrow, dejection, grief, and dissatisfaction, as well as feelings of many other types. These *prototypes* become increasingly differentiated during a person's lifetime so that one becomes able to gradually distinguish, for example, between different types of distress. In ways such as this, subcategories are created, subordinate to main categories. Categories and subcategories are formed both for feelings and for concrete objects. The infant investigates many things by use of its body. It grabs hold of things, tastes things and hugs other individuals. Things also are given names. In the beginning ”mum” refers both to the mother and to all individuals who are similar to her. Later the concept of ”mum” becomes unique and denotes only the child's own mother. The child also meets other women referred to as ”mum” but sees these as being mothers of other children. In this process of increasing knowledge, the child begins with general categories but becomes increasingly able to specify subcategories. At the beginning, vehicles of all kinds may all be referred to as ”car” and all pieces of furniture the child sits on as ”chair,” but these categories are gradually divided up into those of truck and car, of red car and yellow car, and of sofa and chair. In its search for both main categories and subordinate ones, the child may first group in terms of cars being one category and trees another, but soon groups these in terms of *size*, *colour*, *form* and whatever.

At the age of about 1½ years, the child gains insight into the fact that objects exist even if the child is unable to see them. O*bjects* having become *constant* now, the child is able to thinks and talk about them even if they cannot be seen at the moment. This is the first step toward being able, by about the age of starting school, to replace concrete objects by numbers. The number ”2” for example, can replace two apples the child is unable to see but thinks about.

From 1½–2 years of age, the child begins to have a genuine understanding of there being objects that have certain characteristics in common quite apart from colour, form and size, for example. A ”car”, a ”bed” and a ”glass” each have special characteristics of its own. In a playful way, the child practices applying the knowledge it has just gained, systematizing everything it imagines or encounters in terms of the categories it has learned. The child also uses ”what” and ”why” questions to increase its knowledge of the world.

It is first at the age of 3–4 years that the child is able to determine numerical quantities of varying size. The child ”sees” whether there are 2 toy cars or 3 lying on the table. The child begins to *count*. Initially, counting has more of a chance character. In counting what are in fact four things, the child may count ”one, two, five, ten” The child soon learns the correct sequence, however, and then counts ”one, two, three, four”. Yet considerable time ensues before the child begins to understand that the number ”4” is to be equated with there being four objects. If one shows a child the five fingers on one’s hand during this period, it is able to count them one to five but still has difficulties in generalising this. If one shows the child one’s other hand, the child again begins again to count them, ”one, two, three, four, five”. It is first at the age of five or so that child is able to say how many fingers there are on a hand without using the strategy of counting them.

During the pre-school years, an understanding of certain more complex concepts is attained, such as of what is meant by *opposite*. Already at the age of 2½–3, the child can distinguish two objects as being ”little” and ”big,” provided the difference between them is sufficient. Insight into the distinction between ”long” and ”short” and between ”high” and ”low,” however, is not achieved before about the age of 6–7 years. An understanding of which of two numbers, for example *17* and *19*, is larger than the other is not achieved before about another year.

The examples just given illustrate certain important functions that form the basis for the child’s mathematical abilities both before and at the time of entering school. It is important then that the skills that the child has learned become *automized* so that the child has no need of pondering, for example, the question of how *9* and *6* are to be read or be written. The child needs to be able to invest it’s energy and thought into mathematics as such, without having to wonder about what form individual numbers assume.

We often expect that by the age of seven or so children can begin to work with numbers. Nevertheless, many children of this age are still unable to do so. They can learn perfectly well to recognize and write individual digits and can learn simple computations such as *2 + 3 = 5* or even *12 – 3 = 9*, but they do not yet have a deeper understanding of what numbers really are or how the number series is built up. Insight into the fact that it represents a system in which each number is separated from the adjacent number by 1 first develops about a year later. Thus, early arithmetic training traditionally deals with getting the child to remember that *2 + 3* is *5* and the like. If a child is readily able to learn and remember such things, simple arithmetic is no serious problem.

When entering school or shortly thereafter, many children are able to count from 0 to 100 or even beyond. This does not necessarily mean, however, that they have an adequate *understanding* of numbers. A child may easily be able to *count* without having any deeper understanding of the fact that each number can be seen as representing a particular *quantity*, for example that the number ”12” can be divided up in such ways as that *6+6=12* or that *12=11+1*, at the same time as it is the 12th number in the number series. Those children who have not yet grasped the deeper meaning of numbers in this sense can nevertheless perform simple arithmetic calculations, but do it more mechanically. They simply learn that *6+6* is always *12*. The math that is taught could be said to deal more with remembering than with mathematics as such. A child may have considerable difficulties when faced with mathematical tasks that are decidedly more complex. If the child’s progress in math is held up at this point, this can result in severe disappointment both for the child and for its parents.

Counting provides an aid for the child in remembering where in the number series various numbers are located. This can also help the child determine, for example, which of the two numbers ”17” and ”14” is the larger of the two. This provides no automatic understanding, however, of the relationship between a *number* and the *quantity* it also represents, such that the number ”125,” for example, can be seen as consisting of 125 different parts, each with the size of *1.* Being able to count is also not necessarily coupled with insight into the *number system* being constructed so that each number is separated from the next by a distance of *1 (one)*. Insight into this is not achieved before the age of 9–10 years.

The fact that five ants are more than four elephants, despite elephants being much larger than ants is the sort of thing that an *understanding of numbers* deals with in part at this stage.. In the early school years a child can continue confusing questions of the number and the size of objects. The child can believe that *20* coins are greater in number when spread out over a tabletop than when gathered in a pile. This reflects a lack of insight into the principle of *number constancy*, i.e. that *20* coins are the same in number regardless of how they are grouped, and similarly that the size of the coins has no effect on how many they are.

Since numbers can serve as symbols of concrete things, they gradually replace the things themselves in the child’s mathematical thinking. At 10–12 years of age, a child who already knows that the number ”35” consists of *35* parts may begin dividing it into *7* parts of *5* each, and into *5* parts of *7* each, ”discovering” multiplication and division in this way. Before this can lead much further, however, the child needs to have a clear conception of how numbers represent symbols of concrete things.

During this period, math begins getting a face-lift for the child, who becomes increasingly aware of math dealing with more than simply adding, subtracting, multiplying and dividing and gaining somewhat more of the visual character typical of ”higher” mathematics. The tasks the child is given are more frequently concerned now with the reading off of figures from tables and diagrams and with problems of volume or area. The four types of arithmetic operations are seen increasingly as simply a means of solving mathematical tasks, emphasis being placed increasingly on being able to visualize things and obtain an overall view of a problem, and being conscious of the structure of things. In doing math assignments, the child is increasingly expected to find its own solutions to problems and to search in the books available for the principles or methods needed to complete a task. This calls for both *problem-solving ability* and *ability to plan.*

HOW DO WE RECOGNIZE DYSCALCULIA?

In my contact with children and youngsters who have difficulties with maths, I am most often struck by the great frustration that they and their friends and family experience. Rapid swings between hope and despair are a common experience. One moment the student can handle a particular task, but a moment later, or the following day, they may fail with the exact same task. On the one hand the student may be a high achiever with a quick mind, while on the other they may be stumped at any moment by a simple counting problem such as 5+4, for which they must count on their fingers.

Many parents of these students have spent countless evenings tutoring their children in basic mathematics such as the multiplication tables. The knowledge seems to be there, but the next day when the child goes off to school, it is completely gone! It is then understandable that parents may begin to believe that their child simply does not want to learn. It is not unusual for parents to wonder: *"Is she playing games with me? Why else would her results be so uneven? Everyone else seems to think she is as smart as all her friends…"*

It is very common for people surrounding the student with dyscalculia to experience a strong sense of powerlessness. The student's performance in school can vary dramatically; climbing to great heights but then dropping swiftly again like a roller coaster. One moment the student has the knowledge and ability to perform a task, and the next moment everything is gone, only to re-appear again a couple of days later as accessible knowledge again. In other cases the student cannot remember this knowledge at all. Initially this might seem to be a memory problem, but the information is in fact stored in the long-term memory. The student in this case has problems automatically retrieving the information when it is needed. They have to concentrate extremely hard to access stored information such as the multiplication tables. It is therefore understandable that many children with this type of difficulty get tired of doing maths, and eventually give up on mathematics altogether.

At this point I want to clearly state that dyscalculia indicates *specific or special learning difficulties in mathematics.* Students with specific difficulties do not have problems with all mathematics. Usually, though, their ability across the whole subject suffers, and it is very common for the student suffering from dyscalculia to gradually form a picture of themselves as "stupid", because they are not as successful in mathematics as their friends.

Students with specific learning difficulties in mathematics obviously differ from those who display more general learning difficulties. This latter usually performs more evenly over time. They perform at the same level whether it is Monday or Thursday in the school week. Their difficulties are characterized mainly by their need for extra time in the learning process. The use of simplified learning materials may be necessary. However, this is not always the case with those who display specific learning difficulties with mathematics. Their difficulties are characterized by uneven performance: sometimes they exceed all expectations and perform brilliantly, but then a moment later drop to a very basic level where they need to count on their fingers to handle the simplest calculation.

People with dyscalculia generally have normal intellectual capabilities, but have problems with certain thought processes (cognitive processes). They have difficulties with certain types of thinking. This is especially noticeable in the subject of mathematics, but is also evident in both everyday situations and other school subjects.

It is common for these difficulties to first appear in problems with telling the time (with analog clocks), problems with temporal orientation (knowing what time it is), and problems with planning and remembering to keep appointments. The nature and severity of the problems may vary from child to child, but it is possible to identify whether or not they suffer the *specific* forms of difficulties typical of dyscalculia.

How do the Difficulties begin?

Before starting school most children have an expectant and positive attitude to counting. The beginning of school means to most children that they are going to be taught how to read and count. For most students this proceeds in a relatively simple and uncomplicated way. They learn both to read and to count by whatever teaching methods are in use. Some children, however, develop counting problems right from the start. They may have difficulties in writing down the numbers, or with understanding that each number represents a fixed amount, e.g. that the number “4” represents four units. They may have problems with number order, and then run into difficulties with fast calculations, which require knowing, for instance, that “10” is two more than “8”. For these children all calculations are made with great difficulty. They simply do not get a “natural flow”, and every calculation takes an enormous amount of effort. In this case, a lot of short breaks are needed during the school day. If the student does not get these short breathing-spaces to rest their mind for a moment, they usually provide pauses for themselves by thinking about other things or walking around the classroom.

Before school has even started, many children already have clear ideas about what will be easy or difficult. During pre-school children are prepared for counting and writing, and those children that have problems early on soon begin to avoid counting and writing. They sense their own difficulty and create a kind of resistance or emotional blocking. Unfortunately, such blockings create serious obstacles to the learning process once school starts, and they might affect the child's attitude to schoolwork throughout their school career.

When a teacher identifies a child's difficulties in counting, once school has started, the child is usually offered help. The help may be specialized help from an informed psychologist or teacher, and it may be offered separately, in a group or in a class.

When mathematical difficulties are discovered, rigorous practice in the problem areas generally commences, both in school as well as at home. It is not rare that the student practices the problem areas several hours a day, during the daytime in school and in evenings at home. This practice is well-intentioned. However, the problem becomes more and more obvious after several years' practice without any discernable development in mathematical ability. After years of hard work, the child begins to lose her motivation. She simply refuses to do anything that has to do with mathematics once she discovers how minimal her progress is considering all the years of hard work. It is not uncommon for the gap between such students' abilities and those of other children of the same age to increase rather than decrease, despite the long hours of practice.

What begins as difficulties with quickly and easily remembering and writing down numbers often develops during school years into a general problem with the whole of mathematics. Knowledge-gaps arise because the student eventually refuses to work with anything that has to do with maths, because of their continual experience of disastrous failure. This usually leads to poor self esteem, with verbalized thoughts about being stupid or different and perhaps even non-verbalized thoughts about not wanting to live anymore. If this seems like too strong a reaction, we must consider that it has been preceded by years of daily failure and frustration. In this situation it is easy for children to acquire a picture of themselves as being worthless, and to begin to wish that they could simply disappear.

The strong reactions described usually occur when the child reaches adolescence. At this age, the child often rebels against all help from teachers, student assistants and parents. He longs to be able to manage on his own without any help. This in itself is a healthy and normal wish for a child in the process of developing into an independent adult.

Initial specific difficulties in mathematics often develop into more general learning problems by the end of primary school. The reason for this is that the student sets up emotional blockings for herself at the same time as she suffers from increasing knowledge-gaps. By adolescence it can therefore be hard to discover whether a student has more general or specific difficulties. The answer lies in the child's personal school history.

I have here been describing an example of a course of events at its worst. Unfortunately, it is a quite common story. I am mentioning it to thereby point out the need of initial assessments, but also the importance of correct help. It is crucial to understand what the student should avoid to practice and what they really need to practice more, in order to ensure progress. It is success during practice that creates motivation. It generates the desire to learn more in the subject.

Some children have problems with early mathematics. They can have problems with the 4 basic calculations: addition, subtraction, multiplication and division. Others first develop problems at the age of 10-12 when the mathematics partly changes form and becomes more visual. On the other hand, some of the children that had problems with early mathematics might blossom later, becoming much more successful when they begin to work with higher and more visual mathematics. This is providing they are given opportunities to work with higher mathematics and not only practice tasks of a basic level with which they have difficulties.

Dyscalculia and other Mathematical Learning Difficulties

The name "Dyscalculia" is a contemporary derivative of the Latin "dys", which means a form of special difficulties – not inabilities! - and the Greek "calculus". Freely interpreted this word means "counting-stone". Out of this combination, "dyscalculia" was created, to refer to difficulties with counting.

Dyscalculia is characterized by specific difficulties with certain types of mathematics, and this is what differentiates it from other mathematical learning difficulties. If a child has problems with the four basic types of calculation, this will indirectly affect their ability in higher mathematics. If there are difficulties in understanding basic numerical facts, more complex calculations will also be affected. It simply takes the person with dyscalculia a much longer time to complete different mathematical tasks. It is important to remember that many people with dyscalculia are able to solve complex tasks in mathematics, but they usually have difficulties in solving the task fast. This indicates the importance of giving students with dyscalculia tasks at the right level. Practice at too low a level can be degrading and disheartening, and can diminish motivation. It can rather contribute to the child finally giving up altogether, and according to my experience this is an all too common course of events.

I think it is meaningful to talk about at least four different forms of difficulties in mathematics:

- Acalculia
- Dyscalculia
- General difficulties in mathematics
- Pseudo-dyscalculia

Different mathematical learning difficulties have different cognitive and psychological causes, and these each require different remedial work. For this reason, differential diagnosis, as used in medical health care, is particularly valuable. Students have different kinds of difficulties and therefore need different kinds of help. It is entirely possible that the ability of a student with dyscalculia will get worse with too much practice in the wrong areas. Likewise, children with Acalculia will certainly fail if they are taught mathematics according to traditional methods.

In cases of Acalculia, the student displays a total inability to carry out any mathematical tasks at all. The total inability to count usually indicates brain damage. The problem is apparent when the child, even despite intense practice, is unable to learn the basic principles of counting. This may be evident in the inability to learn the order of numbers 1-10 or to carry out simple additions such as 4 + 2 = 6. The group of people with Acalculia constitutes less than one percent of the population.

The diagnosis *dyscalculia* is comprised of a group of related and highly specific mathematical learning difficulties. Dyscalculia is the mathematical correspondent of the reading and writing difficulty *dyslexia*. Most children with dyscalculia suffer from a straight forward variant, where reading ability and ability to understand text is not at all affected. About 20-30% of people with dyscalculia have a mixed variant in which they might display problems with both reading *and* counting. These children are unable to attain fluency in reading, and cannot recall numerical facts quickly during calculations. Simple tasks take them a lot of time, and often they have to count on their fingers far into their school years. This kind of learning difficulty is called *automatisation-difficulty.*

Children with dyscalculia usually have normal intellectual capabilities, but often display spectacularly uneven results in intelligence tests. The causes of these difficulties are not emotional or psychological, but can be traced to problems with certain specific (cognitive) thought processes.

I have mentioned automatisation-difficulties as an important causal factor of dyscalculia. Another can be *language difficulties*. This is shown by problems with understanding mathematical concepts. A seemingly talented student may be incapable of understanding the general concepts of numbers and mathematical relations, or the written representation of these in mathematical symbols.

A third variation of dyscalculia involves *difficulties in planning,* which surface during the carrying out of calculations. The student with this type of dyscalculia has problems in following their own line of thought when solving a mathematical task. The student easily gets lost, or stuck in a non-functional sequence. It is not unusual for them to suddenly lose the thread of a good strategy and find themselves sitting inactively. Problems with *visual perception* can also lead to problems with logical ability, and can affect counting as well. This type of difficulty we often see in children who have problems learning to read the ordinary analog clock, with hands.

A child with *general learning difficulties in mathematics* displays general problems with all learning, not only mathematics. As a rule these children take a longer time than normal with all learning. Usually the child benefits most from working at a slower pace and with simplified teaching material. In intelligence tests, children with more general difficulties usually perform below average, but with a quite even result. In other words, these children are even in their difficulties, from one subject to another, and also from one day to another. Children with more general difficulties usually do not experience as much frustration in their learning environment as those with dyscalculia. There is a general agreement that they simply need more time to learn things.

Pseudo-dyscalculia is a big and important group in which learning difficulties arise from emotional blockings. Children with pseudo-dyscalculia have the cognitive ability to succeed in mathematics, but despite this, they run into problems. They may have committed themselves to the idea that they absolutely cannot be successful in the subject. This thought can be deeply rooted, and perhaps linked to ideas that they are not smart enough. All personal failures in mathematics confirm this view for these students.

In these cases, the nature of the difficulties may be very similar to dyscalculia. However, students with pseudo-dyscalculia are not primarily benefited by special classes or remedial work. Instead the best help for these students might be private talks with the teacher, or in tougher cases with the school psychologist, where emotional blockings can be faced and overcome.

Girls form an overwhelming majority of the students with pseudo-dyscalculia. Despite having average intelligence, this group nonetheless has severe difficulties with mathematics. Because the percentage of girls is so large, I personally believe that teachers should consider teaching girls and boys separately in this subject. It has been proven that girls have increased self-confidence when there are no boys in the classroom, and there is no risk of negative comments from the boys, which unfortunately is the common occurrence.

Sometimes the cause of emotional blockings can have its origin in past failures that the student gradually becomes afraid of repeating. It becomes convenient for the student to explain these failures to themselves in terms of not being smart enough, and gradually they start avoiding everything to do with mathematics.

Pedagogical Signs

How then do we recognize dyscalculia in everyday life? In mathematics? In the child's day to day life? Below I present a simple check-list of problems that might be indications of dyscalculia. To determine conclusively whether a child really suffers from dyscalculia or not, a thorough assessment in collaboration with an informed psychologist or doctor is necessary.

The following list should not be seen as a complete analysis, but it contains examples that are common when the specific mathematical difficulties that characterize dyscalculia are present. You can most often recognize some of the signs the person with dyscalculia might have. However, if a person displays problems relating to most of the points in the checklist this indicates that their difficulties are general mathematical difficulties, and *not* dyscalculia.

Difficulties with reading and comprehension:

- Mixing up similar-looking numbers in reading e.g. ***6*** and ***9*** or ***3*** and ***8***.
- Inability to comprehend the space between numbers, so that for instance ***9 17*** is read as ***nine hundred and seventeen***.
- Difficulty in recognizing and therefore using calculation symbols i.e. plus, minus, multiplication and division symbols.
- Difficulty with reading numbers containing more than one digit. Numbers with zeroes can be especially difficult, e.g. ***1004*** or ***7069.***
- Confusion of reading direction, i.e. reading numbers in such a way that ***12*** becomes ***21***. It is not unusual for some children to shift the direction of reading so that some numbers are read accurately, from left to right, while others are read back to front.
- Problems reading maps, diagrams or tables.

Difficulties with writing:

- Written symbols, often numbers, are reversed or rotated.
- Problems copying numbers, calculations or geometric figures from a set picture.
- Problems recalling numbers, calculations and geometric shapes from memory.
- Difficulties remembering how numbers and calculations are written. In this case it can be easier for the student to spell the number with letters.
- Difficulties remembering how mathematic symbols are written, e.g. "+" or "–".
- Inability to correctly write down numbers containing more than one digit. Just as with reading problems, it might occur that zeroes are lost, e.g. that ***one thousand and seven*** is written as ***107***, or that ***seventeen*** is written down with the seven first as ***71***, or that ***four thousand five hundred and thirty five*** is written as four separate numbers: ***4000, 500, 30, 5***, i.e. the number has been divided into its component parts.

Problems with understanding concepts and symbols:

- Difficulties understanding mathematical symbols, e.g. difficulty remembering how the minus ("-") should be used.
- Problems with understanding the concepts of weight, space, direction and time.
- Problems with understanding and answering oral or written problems that are presented with words or in a text or picture.
- Difficulties understanding concepts of numbers as "much-more-most" or quantity measures.
- Problems with understanding the concept of 'amount', where numbers are used in conjunction with units to signify amounts in measurements, e.g. ***100 meters***. Problems can also arise in understanding, that is, under-standing and stating a numeral's place in a sequence, e.g. first, third, seventh. Finally, there may be problems with understanding the relations between units of measurement, e.g. centimeters to meters to kilometers.

- Problems with the practical application of mathematics, for instance: Ann's house is 1 km from her school. Linn lives twice as far away. What distance does Linn have to travel to get to school?

Problems with number sequence and mathematical facts:

- Difficulties with arranging numbers by size. Also problems with number positions, e.g. whether 16 comes before or after 17.

- Problems with number sequence, so that the child can not automatically understand that ***74*** is five more that ***69***, or is unable to place the numbers 8 or 27 in a numerical series. These children need to count on their fingers to manage basic calculation.

- Bad memory of simple numerical facts, e.g. the multiplication tables.

- Difficulties doing mental calculations, due to memory problems which cause the student to "lose" the relevant numbers being used in the calculation.

- Problems with counting backwards, e.g. ***four short of 100***.

- Taking a long time to solve simple mathematical tasks, even though they are written down.

Problems with complex thinking and flexibility:

- Rigidity in thinking, shown by the inability to choose the right strategy in problem-solving, and having difficulty changing strategy if the chosen one does not work.

- Problems following the different steps in a mathematical task.

- Problems making reasonable judgments, e.g. estimating measurements to make rough calculations, and arriving at reasonable answers.

- Difficulty with following one train of thought when solving mathematical problems, including the inability to stick to strategies that work.

- Difficulties with planning, i.e. problems with planning how to proceed in a task before it is actually attempted.

- Problems in shifting from a concrete level to more abstract thinking. This is shown in difficulties in switching from concrete objects to mathematical symbols.

This can also relate to an inability to understand mathematical concepts and relations and to do mental calculations. The symbols lack meaning for the child. They can read them, but they do not understand the meaning of them.

The criteria presented here should be used with great care. This check-list is not intended to provide the basis of a careful and comprehensive assessment of a student's difficulties. It is most important to first examine and discover the causes of the child's difficulties, and then to apply the appropriate remedial method.

Let me give an example:

Lisa does not have many difficulties with basic mathematics. She is quite good at division and multiplication. Despite this, however, she has difficulties with solving written maths problems. In this she often fails. An examination of her general reading and comprehension ability shows that she has at least average performance in both reading and writing. A closer analysis of her problem shows clearly that Lisa has difficulties with identifying essential facts in the text. She is simply unsure of which numbers are relevant to the mathematical task. She is even unsure of which type of calculation is required. Is it addition or subtraction? It is apparent that Lisa's main difficulty is with planning, and that she needs help to find good strategies to handle mathematical tasks. She needs practice in planning to solve mathematical tasks step by step in a continuous sequence.

If an uninformed teacher, parent, or psychologist had focused on Lisa's symptom, difficulties with written mathematical tasks, they probably would have assigned her remedial reading work. However, a closer analysis reveals that her problem is not at all related to primary reading difficulties, and this understanding demands a different focus for remedial work.

Characteristics of Dyscalculia in everyday life

In day to day life it is common for a competent child to surprise us by running into sudden difficulties with mathematics.

It is common for the person with dyscalculia to have had (or have) problems with learning how to tell the time. It may be that they have eventually learned to, but the skill took them a long time to acquire.

To one who knows how to read the time, it may seem simple to read a normal analog clock. But this skill puts demands on many different cognitive functions. First we have to read the angle and direction of the hands. Then we have to calculate what the actual time is. The clock does not actually show us that it is *twenty to two* in the afternoon. Or that it is *five past nine* in the morning. It merely provides signs that enable us to calculate this.

The reading of an analog clock (with hands) puts demands on our visual perception, working memory and understanding of the language.

To many people with dyscalculia it can be considerably easier to read a digital clock, where the time is told by simply reading the numbers in one sequence from left to right, e.g. *01:40 pm*. The digital clock does not show that the time is *twenty to two*. This translation we have to do by ourselves.

It is not only telling the time that many people with dyscalculia have problems with during their adolescence. Many also have difficulty with temporal orientation (knowing what time it is). This can express itself as a problem with estimating how long an hour or 24 hours is. In this case, planning ability is invariably affected, as are all activities the student pursues, indirectly. Difficulties with temporal orientation often revolve around understanding the time sequence of a course of events.

We are not born with a built-in conception of time. Instead it develops and is maintained through continual practice. In this way we gradually learn, for example, how much we can accomplish in one hour. But the knowledge is never perfected, as for instance when we learn how to swim or ride a bicycle, or even wash the dishes. It has to be continually in use for us to develop good *time-planning ability*.

Difficulties with temporal orientation lead to serious problems when the child is required to plan a homework schedule and other things by herself. This becomes especially clear when the task is not to be completed in one day but for example over two weeks. It is common for students to overestimate the time they have at their disposal, without having dyscalculia. But the person with dyscalculia may have additional difficulty in working out in which order they need to complete the tasks.

However, difficulties in day to day life are not limited to the planning of homework. They are manifest in *all* planning, even in concrete situations such as how the tidying of their bedroom should be planned and carried out. Many children with dyscalculia need a rigid structure in their day to day life. Unfortunately, it is very few of them who ask for help and discipline by themselves.

The ability to make rational judgments is necessary for all normal everyday activities. It is not limited to use in mathematical calculations. Every day we mentally ask ourselves innumerable questions: What can I reasonably achieve in an hour? When might I reasonably be home again after having played football in the evening? How much food can I reasonably eat, i.e. how much food should I put on my plate?

The ability to make rational judgments is also necessary when we consider human relationships. Judgment is needed to work out how to proceed in a new intimacy, or to think of a good answer when you come home too late in the evening. Rational judgments are based on information gained from previous experience. Using this information imaginatively, we can visualize several different alternatives and solutions and then pick out the one that seems best.

Many people with dyscalculia have problems with handling not only time but also money. If a person has difficulties with understanding numbers in general then it can be difficult to make a good reasonable judgment of monetary value. How can they tell whether one liter of milk should cost 1 dollar or 10 dollars? This problem might stem from the fact that they cannot comprehend which of the numbers 1 or 10 is the biggest and how large the difference is. That is why it may seem reasonable to a person with dyscalculia that the milk costs 10 dollars if someone tells them that it costs that much. In the same way it can seem reasonable to this person that the distance between New York and London is 600 km or even 6000 km.

Many people with dyscalculia suffer from a poor memory. They not only forget what they were about to do, but they also forget agreements they have made with other people. If they are asked to do three things in succession they often only remember the last one mentioned. The other two are forgotten. This explains part of the difficulties these children have in mathematics. On top of this they bear the emotional burdens that arise if they are not getting the right treatment and help. Because of this combination, it is not uncommon for a child to be quiet and well-behaved in school but release all of their frustrations once they are home. Parents and siblings see a totally different child than the teachers and school friends do. The teachers might describe a student who has many learning difficulties but works diligently and is full of energy. But when the school day is over often the child has run out of energy, and the bad temper and violent mood swings occur. This adds extra strain on the relations at home.

Many parents try to help their children by encouraging them to practice what they find difficult in mathematics. This can have varying success. Frequently parents have a hard time getting their child to work at all. This after-school practice time usually tends to drag on for longer than planned, and the child often develops attitudes and behavior of dislike and avoidance. If they are left alone for a moment with their mathematical tasks, their mind instantly wanders. This home practice is thus very demanding on both parents and children. On top of this, it rarely produces good results.

Over all, the adolescent with dyscalculia is recognizable in that they need a lot of support and help in everyday life. They can have obvious difficulties not only with mathematical calculations, but also when it comes to planning, pursuing hobbies and socializing with friends in spare time.

How long has Dyscalculia existed?

Difficulties in mathematics have been observed for at least 100 years. The first medical studies published observations about a group of patients with serious neurological brain damage. A German doctor, Henschen diagnosed this group with *Acalculia*. This diagnosis primarily resulted from their complete inability to manage the simplest mathematical tasks. This initial group had obvious neurological injuries.

Another German, Gerstman, was the first to use the term *dyscalculia* during the 1940s. He saw a practical value in separating the inability to count from more specific learning difficulties in mathematics. These specific difficulties related only to particular areas of mathematics.

The notion of *developmental dyscalculia* was first put forward by L. Kosc in the 1960s. At the time he was a leading scientist in the United States.

The concept of developmental dyscalculia has two aspects. Partly it identifies mathematical difficulties that do not have a psycho-social explanation, but are genetically determined. In other words the social or family environment does not contribute to the difficulties in counting, which primarily have a biological basis dictating delayed development. The concept also conveys that this type of difficulty is linked to childhood development, and therefore is neither static nor permanent. The nature of the problem changes during the child's development. With the right treatment, the right practice and above all with neurobiological maturity, the difficulties gradually lessen.

L Kosc and other mathematical scientists in the field of neurological research were strongly influenced by the neuropsychologist and neurologist Alexander Luria. He expounded a theory that the brain can be divided into three functional blocks which develop and collaborate in a very special way. This theory has become a building block for neuroscience around the world.

According to A Luria's theory, the brain consists of collaborating blocks, where block 1 is a *regulating* block that governs basic functions necessary for survival. This part is comprised of mainly the brainstem and the middle brain. Block 2 *analyses* incoming information from the surrounding world and consists of mainly the back part of the brain (parietal lobe, occipital lobe and temporal lobe). Block 3 is the ruling block. It is here, in the frontal lobe, that planning is carried out and our actions are governed. The frontal lobes rule our thoughts, and through this rule our behavior.

A Lauria described many different variations of mathematical difficulties. The three most important are:

- Lack of logical understanding.
- Lack of planning ability.
- Inability to manage simple mathematical tasks.

Lacking of logical understanding is usually caused by problems with spatial perception, i.e. problems interpreting visual information. This leads to difficulties with even reading an analog clock. Reading the clock is a tricky but logical multi-step process.

Lack of planning ability is obvious in problems with planning and carrying out different mathematical tasks. It is common for the child to “lose” strategies that work well, or to continue to try to apply wrong strategies despite several failures. With lack of planning, he gets easily lost and therefore has difficulties understanding the solutions to tasks.

When there is an *inability to manage simple mathematical tasks,* the child runs into difficulties with even the simplest mathematical tasks such as 2+4. This expresses itself most obviously in the continuing need for the child to count on their fingers throughout their school years.

As recently as the 1990s, Israeli child-neurologists headed by R Shalev developed knowledge about dyscalculia through large-scale studies of children’s comparative reading and writing abilities. They did a sex-analysis to determine the proportions of girls to boys and developed a long-term follow-up for children diagnosed with dyscalculia. They posed the important question: *Is it possible to overcome dyscalculia with the right remedial work?* I myself have been carrying out similar studies in Sweden over the last few years, with the objective of determining whether the right remedial work contributes to people with dyscalculia developing their mathematical thinking.

In the medical world, dyscalculia is accepted as a diagnosis in Sweden as well as the rest of the world. Dyscalculia exists, in the beginning of the 21st century, as an established concept, and diagnoses a special form of mathematical difficulties in which an average or talented overall student may still run into difficulties with mathematics.

How many people have Dyscalculia?

In the 1980s N Badian conducted a large study that showed that *6.4 %* of primary school children had problems with counting and other mathematical tasks, while *4.9 %* had problems with reading. The study revealed that the group displaying mathematical difficulties is very large, perhaps even larger than the group with reading difficulties. This is understandable when you consider that mathematical tasks require several separate skills, including reading skills, which must all function together.

In the 1990s R Shalev and V Gross-Tsur headed a large study, with child-neurologists and child-psychologists examining over 3000 school children. This study diagnosed *6.2 %* of the children with dyscalculia. They also show in their study that there are about as many girls as boys with dyscalculia. In other words the proportion of girls to boys is roughly 50/50. Here the percentages diverge from other difficulties like dyslexia and AD/HD where we usually find two thirds to three quarters are boys.

Although there are approximately as many girls as there are boys with dyscalculia, I have found in my own experience that very few are discovered. Even when they are, they are often treated in a “lump” together with students with other forms of mathematical difficulties.

Today it is common to talk about numbers of children with dyscalculia at around *5-6%*. If we add other types of mathematical problems, in which general difficulties and emotional blockings constitute the two large groups, the numbers leaps to 15-20%! By far the largest group is that of students who have emotional blockings despite average or above-average intelligence.

What is the Value of a Diagnosis?

I believe there is a great urgency to discover dyscalculia early in children. A full diagnosis cannot be made until at the earliest 10-12 years of age, but this should not stop us from discovering early on the particular form of mathematical difficulties the child suffers from.

There is an ongoing debate as to whether the diagnoses of dyslexia, dyscalculia, or ADHD/ADD have any real value. Certain precaution is entitled, since it can be harmful to diagnose all forms of mathematical difficulties as dyscalculia, and likewise all difficulties with concentration as ADHD/ADD. However, doubt should not lead to the refusal to make any specific diagnosis at all. We then run into the obvious risk of not providing relevant help to children who are certainly in need of it.

I could easily illustrate this point by telling the stories of all the misunderstood children and youngsters that I meet as a child psychologist. They have mathematical difficulties, or difficulties with reading, and gradually have acquired a very negative self-image. Their self-esteem and self-confidence is shattered. Some express thoughts of suicide. These children alone should be sufficient reason to justify the need for accurate and specific diagnoses. A good diagnosis affects several individuals and groups positively:

- The child itself
- The parents
- The teachers
- Psychologists and doctors
- Society

It is extremely rare that we meet a young school child requesting their own diagnosis. However, the older they get, as they continue to fail in mathematics, the more they wonder. Above all children ask themselves*: "What is the actual reason for my difficulties in maths? How can I be so good at so many other subjects, and hopeless at mathematics?"* Their situation becomes frustrating and incomprehensible.

A diagnosis allows most older children to understand the reason for their difficulties. This also helps the parents. Most of all, it helps them to help their child in the correct manner, but also to be able to put demands on the school to provide appropriate remedial resources.

For teachers and school psychologists the diagnosis is valuable because it enables them to plan the right remedial work and avoid areas of unprofitable and frustrating practice. This may well improve the success of lessons. The diagnosis formally states the need of resources, which can support the claims of teachers and principals when they seek resources for the school.

Sometimes teachers express worries about a diagnosis. They are afraid that the child is going to relax with the diagnosis and stop trying to actively work with mathematics, thinking: "*Well, I have dyscalculia! Then I can't do maths anyway!"* The doubts usually disperse once the teacher starts a dialogue with the child and their parents. In a good dialogue, the child's difficulties are made obvious, but so too are possible ways to work with mathematics. Just this pointing out of possibilities makes assessments well-founded. They should provide a built-in guarantee that the child will receive proper treatment. At the same time we eliminate the risk that she will develop psychiatric symptoms like depression and suicidal thoughts. This in itself is a value to psychologists and doctors, not least in psychiatric health care.

A diagnosis is of great importance to both schools and society in general when we plan both remedial work and goals and achievements. Decision-makers and community managers need to know how large the group of people with dyscalculia is. This knowledge is currently very deficient. What you do know, as a decision-maker or planner, is that very many students are failing at mathematics, a much larger proportion than those who have difficulties with languages. This calls for close examination.

If we are reluctant to make a diagnosis then we may prevent children from getting the right help. It may be that we don't want to "brand" the child with a diagnosis from which it can be difficult to escape. Ultimately, however, this benevolence can lead to misunderstanding, inappropriate 'help', and years of failure, to no end.

In today's health care system, diagnosis is essential. Diagnoses dictate the direction of the treatment, and are rarely questioned. While this attitude is seeping into the field of education, a common acceptance of the value of diagnoses is yet to be achieved.

A good diagnosis consists of a summarized description of the individual's difficulties. From this summary one can draw conclusions about the nature of the best possible remedial support. The method of diagnosing a condition in order to specialize treatment uses comparisons with previously observed cases to determine treatments that have been successful in similar cases.

Many people with dyscalculia struggle with their difficulties for years before they undergo a proper assessment, and possibly receive a diagnosis. In my experience, it usually puts the student at considerable ease when someone finally identifies the problems they have been having for so long. Their diagnosis doesn't cause them to give up. Quite the opposite! They are suddenly inspired to start working with mathematics in a new way. And the fantastic thing is that they now, as adults, can feel that they can actually succeed. What an incredible feeling!

We humans have a tendency to let our imagination blow things out of proportion whenever we have a difficulty. We usually imagine the worst. This is no less true when some of us encounter difficulties in mathematics. We tend to think that we are stupid, untalented, lazy, unfocused and totally hopeless. However, understandable reasons for our failure have the ability to overcome these negative thoughts. All of a sudden the child does not need to spend so much energy thinking about why they are failing at mathematics. This energy can instead be used to work with the mathematics in a successful way. In this search for understanding the cause of the child's difficulties, a diagnosis can be very valuable.

I mentioned before that a final diagnosis cannot be made before the child is about 10-12 years of age, the same as for dyslexia. However, this should not stop us from beginning appropriate remedial work before this! Above all we have to learn to communicate openly with the child about their difficulties and experiences. The problems they report may not be the same as your own perceptions of their problems. Although we cannot be certain about the exact nature of their difficulties, it is necessary to commence remedial work immediately. If we wait until the child is old enough for a proper diagnosis, we may have wasted precious time and caused the child many unnecessary years of struggle and failure. Specific learning difficulties in mathematics rarely overcome themselves. Help is needed.

What is the Difference between Dyscalculia and Dyslexia?

Many people ask me: "*Where do you draw the line between dyscalculia and other types of difficulties with mathematics? What is the difference between dyscalculia and dyslexia? Can you have both? Is there a mixed variant? In that case, what is this called? Is it called dyscalculia* ***and*** *dyslexia?"*

These questions illustrate thoughts that frequently arise when people first encounter the term dyscalculia and need to define it in relation to other diagnosis groups. I will expand on this subject later in the book (see the heading "The Investigation of Dyscalculia"), but I now want to highlight a few similarities and differences between the two largest diagnosis groups, *dyscalculia* and *dyslexia*.

A simple definition primarily identifies dyslexia with difficulties in reading written text fast and fluently. Dyscalculia, on the other hand, refers to difficulties with handling and carrying out specific mathematical tasks. Here the differences are very obvious. However, there are also some points of overlap.

There is a variant of dyscalculia that could be called *dyslexic dyscalculia*. This problem manifests primarily in reading difficulties which then lead to mathematical problems for the child. These can be problems with reading numerical symbols and configurations in written tasks or difficulties with reading multi-digit numerals, so that 12 become 21. With an error like this in the reading of the task, then obviously the solution will be incorrect, even if the calculations are accurate.

There are in fact several similarities between difficulties with reading and counting. One of the more significant, and most disabling, is the previously mentioned *automatisation-difficulty.* This can be recognized in the lack of "flow" or fluency in reading words such as *and, that, to,* and *as* may not be "automatic", hindering the fluency of reading. Difficulties that correspond to this in mathematics concern the ability to quickly retrieve numerical facts such as the multiplication tables from the memory.

There are several other indirect similarities between difficulties with reading and mathematics. A poor *working memory* is one of the more obvious. In reading, the problem can be recognized when a child reads slowly but steadily, but then cannot remember the word or the text they just read. The professional term for this inability to recall the beginning of a task while you are completing the end of it is called the *phonological loop.* Mathematical problems caused by working memory are evident in tasks that must be solved mentally, in the head. The student may run into great difficulties keeping different numbers in the memory while he is doing the calculation. In other cases, the student may have problems remembering longer instructions or commands. Maybe she will only remember a part of what was supposed to be done. The rest is forgotten, because the information was never stored in her memory.

The Israeli child neurologist R Shalev has shown in his studies that about 17% of people with dyscalculia also have dyslexia. My own research indicates that the number might be a little bit larger, maybe even up to around 30%. However, even if the percentage is this high, it is still the case that most people with dyscalculia display only mathematical difficulties. They have a highly specific form of learning difficulty, and many are very good at reading and languages.

The occurrence of *both* dyscalculia and dyslexia at the same time is nowadays diagnosed as *ICD – 10*, or *mixed learning disturbance*. ICD – 10 is a diagnosis system that is used in the medical field. It is defined by the United Nations and the World Health Organization, and today is globally applied.

In the more pure forms of dyscalculia, common difficulties include problems with number order i.e. being unable to quickly work out which of two numbers is the biggest. Difficulties can also involve the understanding and use of mathematical concepts. A large proportion of people with dyscalculia display problems with following multi-step calculations to reach a correct solution. They easily lose track of their strategy, and therefore run into problems with more complex mathematics. People with dyscalculia often have difficulties in making reasonable estimations and lack an adequate capacity for rational judgment.

Many students with dyscalculia are able to complete mathematical tasks, but within a longer than average time frame. They are unable to retrieve numerical facts from their memory fast enough and must expend a lot of energy doing so.

Can Dyscalculia be cured?

Parents as well as teachers have important questions about dyscalculia. Frequently asked questions include:

- What kind of difficulties does dyscalculia refer to?
- Have we done something wrong?
- What kind of help is needed?
- Can dyscalculia be cured?

It is important that these questions are answered early on, to prevent unnecessary anxiety.

Obviously, parents want to know what kind of difficulties their child has. They often ask*: "Do professionals recognize this kind of difficulty? Have you met other children with similar problems?"* It is important to be honest. If you have not met children with the same kind of difficulties, the parents must be told so. You might have to say: "*I myself have not met many children with this kind of problem, but I will get more information and possibly refer you to a specialist."*

Many parents blame themselves for having done something wrong or maybe for not doing enough. Most parents can give an accurate description of what their child's difficulties are. However, like teachers, they often find themselves in a situation where they are encouraging too much practice with not much success. Practice is necessary, but it must be the right kind of practice. If the difficulties become too developed, they interfere in the child's hobbies and social life, which are important for their development.

Is dyscalculia curable? The simple answer is yes! The diagnosis dyscalculia is only ever a description of the present stage of development, applicable for a maximum of one year. As the child develops, the difficulties that existed in the previous year can have minimized or may almost disappear.

My own research supports the long term studies of Shalev, to indicate that many children with dyscalculia outgrow their diagnosis after some years.

If the child is getting the right treatment and help, the possibility of development in mathematical ability is greatly increased. However, often some parts of the difficulties remain in a milder form, for example, difficulties with recalling numerical facts. It is usual that the student will continue to have features of those difficulties, in a mild form, throughout adult life. Ability to concentrate, however, usually considerably improves, and with that often comes the understanding of mathematical concepts and symbols.

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