PARTIAL FUNCTIONS DEFICITS WITH PUPILS WITH SPECIFIC LEARNING DEFICIENCIES IN MATHEMATICS

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Specific learning difficulties are usually defined as the inability of an individual of average intelligence, having suitable socio-cultural opportunities, to learrn how to read, write, and calculate through the generally used teaching methods. The following are the basic kinds of such deficiencies: dyslexia (deficiency in reading), dysorthography (deficiency in spelling and grammar), dysgraphia (deficiency in writing, and in graphical output) and dyscalculia (deficiency in calculating, in mathematical abilities). Some partial functions necessary to learn reading, writing, and calculating are usually impaired with all these pupils. These include mainly perception, cognitive, and motoric functions. For the diagnosis and the following re-education of the specific learning difficulties, it is important to know which functions are damaged and/or underdeveloped , to what extent and in what combination.

In the following, we will focus on the possible influence of the partial functions deficits on the success of the pupil in mathematics. In mathematics classes, the teachers should not focus exclusively on the pupils who have been diagnosed with dyscalculia, but also on those who have other specific learning difficulties. After reading the report from the pedagogical and psychological consultancy, the teacher should focus on the deficient partial functions and know how these deficits can influence the pupil's learning in mathematics. The diagnose of the concrete deficit of a partial function can contribute also to the more direct remedial teaching. If we, for example, know that the pupil's abilities in visual recognition are bad, we can use a wide variety of exercises focusing on visual recognition, which helps in overcoming this partial deficit. From the manifestation of this deficit we can then anticipate in which areas of mathematics the pupil will encounter difficulties and can opt for suitable teaching methods and compensation aids. In remedial teaching, we always proceed from simple exercises (tasks, exercises) to the more complex ones.

The ability to learn calculation is thus not connected only to the pre-number images of the pupil, but also with partial functions that are necessary not just for learning to calculate, but also for reading and writing. These functions include *sensory perception* (perception function), *cognitive functions,* and *motoric functions*. Apart from that, the coordination of the individual functions is also important. Table 1 gives a better image of the categorization of the partial functions.

Table 1
Partial functions of the mathematical abilities

Function	Areas	Partial functions
Perception function	Visual perception	– spatial orientation – right-left orientation – visual differentiation – visual analysis and synthesis – visual memory – sharp eye
	Auditory perception	– auditory analysis and synthesis – auditory differentiation – perception and reproduction of rythm

	– auditory memory
Cognitive function	– attention – memory – thinking – speech – pre-number and number sense
Motoric functions	– gross and fine motor skills – sensomotoric co-ordination – visual-motoric co-ordination – graphofomotorika

Visual perception

Deficit in *visual perception* is mainly found among pupils with *dyslexia*, further also among pupils with *dyscalculia* and *dysorthographia*. Among pupils with *dyslexia*, visual perception is often impaired (e.g. of the mirror images and tiny details, distinguishing between the figure and the background, perception of colours), it is quite common that it is accompanied by the right-left confusion (in macro- as well as in micro-space). impairment of visual analysis and synthesis, and the impairment of visual memory. Pupils with *dyscalculia* often also suffer from the right-left confusion and spatial disorientation.

Deficit in *visual perception* can be manifest in different ways. The pupil for example perceives e.g. the shapes of numbers in a distorted form Confusion of digits (6 – 9, 3 – 8) and of other signs with similar shape is typical. The pupils have greater difficulty in distinguishing similar shapes and minute differences – they do not perceive small differences between two pictures, cannot fill in the missing element in the picture, cannot determine what makes two pictures similar. They have difficulties finding objects on a varied background. These difficulties can be projected for example in geometry in distinguishing the geometrical shape and auxiliary lines, axial and central symmetry. They have problems assessing distances and in determining direction, which becomes visible through lower orientation on the line, in a paragraph, in a column, on the page, and in the text in general. Problems with spatial orientation can be visible in orientation in writing (writing down the mathematical operations), in the table, in the graph, etc. For the sake of clarity, we sum up the manifestations of the deficits of partial functions of visual perception in Table 2.

Table 2
Manifestations of deficits of partial functions of visual perception

Deficit of the partial function of visual perception	Manifestation of the deficit
Spatial orientation	– difficulties in orientation on the page – the child has difficulties in orientation in macro- and micro-space (up – down, in front of – behind, first – last) – transfers in number writing (swapping the order of digits) – transfers in written addition, subtraction etc., with digits for the orders of magnitudes not in the matching columns – difficulties in orientation on the number line – difficulties in writing down the analysis of word problems

	– difficulties with assessing the distance – limited ability to define the order of elements in a line, to order elements according to certain criteria – difficulties in orientation in time (on the time axis) – difficulties in solving equations – difficulties in writing down formulas – difficulties in orientation in co-ordinate axes (in a graph) – difficulties in understanding the depiction of a spatial situation in a plane through projection (e.g. free projection)
Left-right orientation	– children confuse the sides of some digits, e.g. 1, 3 – they e.g. change the order of digits in a number (86 – 68) – difficulties in writing down numbers with more digits – difficulties with orientation on the number line, with understanding the relationships on the number line – difficulties in geometry (e.g. with axial and central symmetry) – difficulties in orientation in a graph
Distinguishing visually	– difficulties in recognizing external qualities – colour, size, shape – difficulties in recognizing the figure and the background – difficulties in recognizing similar and axially symmetrical shapes – children confuse similar digits (e.g. 3 – 8, 4 – 7) – children confuse digits that are axially symmetrical with horizontal axis (6 – 9) – static inversion – childred confuse (swap) the order of digits in numbers (24 – 42) – kinetic inversion – difficulties with recognizing geometrical shapes (the pupil can classify them neither according to the shape, nor size) – difficulties in recognizing operation signs and mathematical operations (e.g. greater – less than)
Visual analysis and synthesis	– difficulties in reading (the child must be able to compose the word from letters and decompose the word into letters) – inability to read mathematical symbols (digits, numbers, ordering signs, signs for operations) – difficulties in reading more-digit numbers – difficulties in reading mathematical signs – difficulties in writing according to a dictation, rewriting and copying (inability to write math. signs in dictation or copying)
Visual memory	– difficulties in remembering and recalling individual digits – difficulties in remembering the read text and its reproduction – difficulties in reading (visual memory is important for reading for the ability to perceive sign or letter and remember it for a certain amount of time) – learning difficulties (child cannot recall what was written in the exercise book, what in the textbook, what caption went

with which picture, what was highlited, etc. and by association fill in also the missing information)

Remedial teaching for visual perception

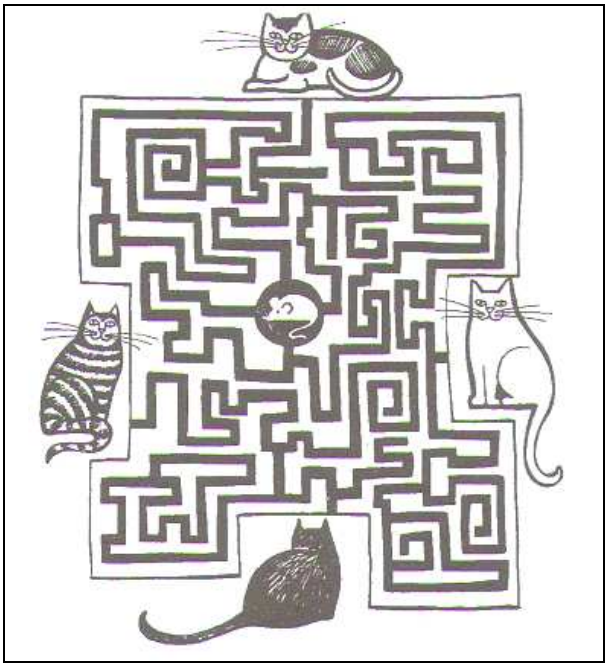
During remedial teaching for visual perception, we always proceed from perception of concrete objects and manipulation with them to their depiction (pictures of concrete objects, later we can opt for more complex, so-called story depiction). In the next phase, we concentrate on abstract shapes and symbols and finally we devote attention to more complex schemes (we use geometrical shapes, shapes resembling letters, and the letters themselves).

For the development of the individual functions of visual perception, we may use a whole scale of remedial teaching exercises (see Zelinková, 1994; Zelinková, 1996; Zelinková, 2003; Michalová, 2001; Janečková, 2004; Bednářová, 2003; Bednářová, 2004b; Žáčková, & Jucovičová, 2007; Jucovičová, & Žáčková, 2008, Pokorná, 2011; Balharová, & Bubeníčková, 2011; Balharová et al., 2014). Here, only a few examples of the exercises are given.

- **practising spatial orientation**

To practise spatial orientation in macrospace, we can use the game „Leading the blind". During this game, the pupils go through a path (at school, in a forest) in pairs, in which one child's eyes have been covered with a scarf, while the other child leads the first one by the arm and gives walking directions in words (NB, we have to take care of children's health and safety). At the end of the walk, the child that could not see guesses to which place they have been led. The game has positive impact not only on spatial orientation, but also on empathy of the children. In order to practise orientation in microspace, we can use for example various kinds of „ways through mazes" in pictures (Figure 1). We let the children start with simple mazes and go on to more complex ones.

Figure 1
Way through the maze



- **practising right-left orientation**

Practising right-left orientation belongs to the most difficult practices, which is confirmed by frequent examples of people who suffer from right-left confusion even as adults. We can practise right-left orientation through finalizing or filling in pictures – pupils follow out instructions and finalize the picture, fill in what is missing on the right- or left-hand side of the picture (or at the top or bottom of the picture, ...). An interesting aid for stimulation is a special memory game, in which pupils do not seek just one pair of identical cards, but two (for example, an ice-hockey player has the hockey stick on the right-hand side in one pair, and on the left-hand side on the other – pupils have to find both alternatives and match them correctly).

- **practising visual distinction**

For practising colours, we can e.g. use the game „Mr. Stork Lost His Hat." And the hat was of the colour.... blue (we can use any colour in the place of the blue). Immediately after the colour has been mentioned, the player starts and attempts to catch somebody. Other players quickly try to hold on to anything that is of the given colour. If they are holding on to some thing of the given colour, they are safe. If the „Stork" does not catch anyone, he or she repeats the rhyme again. If he or she catches somebody, that person becomes the „Stork" and recites the rhyme.

For practising visual distinction, we can also use „Origami". Folding paper. By folding and twisting the paper, by creasing it and partly decreasing it, we can forma various shapes – fish, birds, animals, pieces of furniture, masks, ornamnets, ... With children, we start with the simplest patterns and gradually move on to the more complex ones.

- **practising visual analysis and synthesis**

When practising visual analysis and synthesis, we focus on various kinds of construction kits, mosaics, puzzles, cut pictures (first with colours, later black and white – colours make the orientation easier), geometrical shapes of letters and digits. We first use the simples types. We construct things first with the use of a master pattern, then only with a short-term exposition of the master pattern (the pupil finishes the work on the basis of his or her memory) and finaly without the master pattern.

- **practising visual memory**

We train visual memory by several-seconds long exposure of various objects, pictures, letters, digits, etc., which the child should then describe. When working with more pupils, we can ask the pupils to write down what they remember. For this practice, the so-called „Kim's games" are useful. We show the pupils a set of various objects, which we will then cover and the pupils say what they have seen, or, alternatively, we can take away or add some objects and the pupils guess what has changes. We start with a small number of objects and we add gradually, or sometimes show less objects. Another game that we can play is the game „What has changed?" The pupils guess what has changed in the room, on the blackboard, on the table, on the teacher or a child. They write down or draw the changes

Auditory perception

It is mainly the pupils with *dysortography* and also pupils with dyslexia who most often suffer from the deficit in *auditory perception* is. Pupils with *dysortographia* mainly suffer from a deficit in auditory distinguishing (theseare mainly concern distinguishing sounds, their height,

depth, and length of tones, individual vowels and consonants, syllables, and words), further, the auditory analysis and synthesis, auditory orientation, and auditory memory are impaired. Pupils with *dyslexia* usually suffer from deficient auditory analysis and synthesis.

Imprecise auditory perception deforms and makes more difficult the perception and understanding of the spoken language, e.g. the exposition and explanation of the teacher and other information transmitted in auditory way. The pupil often asks about things that have just been told and does not remember the spoken orders. Impaired auditory memory can significantly complicate the learning process through audition. For pupils with impared or insufficiently developed auditory perception, written expression often presents great difficulty. (especially when visual support is excluded – e.g. during a dictation). As a result of this, specific mistakes occur. Pupils with this deficit often have weaker verbal memory, which is manifested in all subjects. For the sake of clarity, we sum up the manifestations of the deficits of partial functions of auditory perception in Table 3.

Table 3
Manifestations of deficits of partial functions of auditory perception

Deficit of the partial function of auditory perception	Manifestation of the deficit
Auditory analysis and synthesis	– difficulties especially in writing (specific mistakes occur) – incorrect writing of digits and numbers during dictation – difficulties in writing mathematical signs by dictation – difficulties may occur also in reading – forgets beginings and ends of words
Auditory perception	– difficulties especially in writing (specific mistakes occur) – incorrect writing of digits and numbers during dictation (e.g. confusion of 80 and 18, 3 and 4) – difficulties in writing mathematical symbols by dictation – difficulties may occur also in reading
Perception and reproduction of rythm	– difficulties when counting by one – difficulties in orrientation on the number line – difficulties in observing regularities, dependency
Auditory memory	– difficulties in written tests, when the pupil needs to keep the task in memory and only write down the result – difficulties in remembering the dictated task – the child has difficulties to remember the order, sentence, or its part (e.g. during a dictation) – difficulties in learning nursery rhymes, poems – difficulties with learning exclusively in the auditory way (when the subject matter is explained only orally, they remember almost nothing)

Remedial teaching for deficits in auditory perception

During remedial teaching for auditory perception, we always start with using the stationary source of the sound and slowly move to the moving source of the sound. We first concentrate on the non-spoken sounds (first natural, then artificial, reproduced – e.g. recorded on a tape recorder. If the child masters this, we move towards sounds of speech. The sounds should be clear to start with, which we slowly substitute with less clear sounds, where greater receptiveness and greater contradistinction is necessary. In the beginning, we perform the exercise in favourable acoustic environment (silent room, slow and clear speech), later, we can use worse environment (there is accompanying music, we speak faster, more people speak at the same time etc.)

For the development of the individual functions of auditory perception, we can also use a large number of remedial teaching exercises (see Zelinková, 1994; Zelinková, 2003; Michalová, 2001; Žáčková, & Jucovičová, 2007; Jucovičová, & Žáčková, 2008, Pokorná, 2011). Here, only a few examples of the exercises are given.

- **practising auditory analysis and synthesis**

For practising auditory analysis and synthesis, we may use various forms of „word football". The following word starts e.g. with the last letter(vowel or consonant) of the preceding word (tree – egg – gum – mother – road; key – yarn - nod). We can also use pictures – children name them and order them in a corresponding way (e.g. the name for the following picture begins with the same syllable with which the preceding picture ends). We can also use the game of E. T.'s: pupils change into extraterrestrial beings (E.T.'s) and they communicate by spelling out all the words (G-i-v-e-m-e-y-o-u-r-h-a-n-d). In the game of robots, they cut the words into the individual syllables (Give-me-your-hand).

- **practising auditory distinction**

When practising auditory perception, we may use the exercise when the child should perceive the voice of the speaker in an environment where outside sounds are present (e.g. noise from the street, music). To start with, the intensity of the irrelevant sounds should be low and we gradually increase is. We can also use a recording in such a way that the pupil listens to the narration accompanied by music.

- **practising perception and reproduction of rhythm**

Perception and reproduction of rhythm can be practised with exercises focusing on clapping out the rhythm of well-known songs. Later, pupils may guess what song it was. We can also use the game when pupils sit one behind another – we tap the rhythmic sequence to the first one, the pupil transmits it in the same way to the pupil sitting in front of him, etc. The first one than claps the rhythm out. The game of foreigners is also suitable, when the pupils listen to a foreign language and then they are asked to emulate it. We focus on the intonation and speed of talking. The pupil repeats the rhythm we have performed (clapping, tapping, stamping, etc.).

- **practising auditory memory**

We develop auditory memory through nursery rhymes, where the rhythm supports the remembering of short poems. For older children, we prepare interesting quotations, proverbs, etc., which they are to learn by heart. To develop auditory memory, we may also use the memorizing of various stories. The pupils listens to a story (its extent and difficulty should be

adequate for the child) and then answers the question (in the beginning, the pupils knows the question in advance, but not in the more advanced stages).

Cognitive functions

Deficit in cognitive function is found especially with pupils suffering from *dyscalculia*, further with pupils suffering from *dyslexia* and *dysorthography*. Pupils suffering from *dyscalculia* usually usually have deficit especially in mathematical abilities that are not influenced by a deficiency in mental abilites or by incorrect teaching methods, since the centers connected with mathematical functions maturity are usually defect. Memory is usually defect in pupils with *dyslexia* and *dysorthography* (dyslectic pupils have the visual memory defect, while dysorthographic pupils have the auditory memory defect) and they also suffer from the deficit in concentration and attention.

Cognitive functions include congnition processes and operations that are important in teaching mathematics, e.g. the level of concentration and attention, memory, and thinking. Cognitive functions belong to the essential mental processes, through which the interaction of the individual with the outside world takes place, they are the means for processing information – its reception, storage, and processing. Solving of any mathematical task requires full concentration and unsuccessful attempts to solve the problem may be caused, for example, by the inability of the child to focus on the problem. For the sake of clarity, we sum up the manifestations of the deficits of partial functions of the cognitive function in Table 4.

Table 4
Manifestations of the deficits of the partial functions of the cognitive function

Deficit of the partial function of the cognitive function	Manifestation of the deficit
Attention	– child has a short attention span, does not finish tasks – child takes long to achieve the sufficient concentration level, after that, they can evenfinish the task
Memory	– difficulties with short-term memory, which enables the child to remember dictated numbers and tasks, perform intermediate sums and store them in memory (e.g. when multiplying 4 x 28, we proceed thus: 4 x 20 = 80, 4 x 8 = 32, 80 + 32 = 112) – difficulties with working memory (when weaker, the child cannot keep more facts in memory concurrently, which is manifest in inability to apply facts acquired in various areas) – difficulties with long-term memory (learned facts that are not constantly repeated are forgotten by the child and we always have to start from the beginning) – deficits in acquiring memory connections
Thinking	– difficulties in logical thinking (in reasoning correctly according to the laws of formal logic) – difficulties in abstract thinking (in transfer from the concrete to the abstract)

Speech	– children cannot formulate the thoughts in mathematics in their own words (if they have learned the matter correctly, they understand the essence of the problem, then they can express it in words)
Pre-number and number notions	– difficulties in pre-number and number notions (inability to connect a number with the amount of elements), not understanding the notion of a natural number – difficulties in understanding mathematical relations, e.g. dependencies in number sequences (children e.g. cannot name the number sequenc, they do not understand the notions greater than – less then,and have especially grave difficulties in transferes over ten – disorders of time orientation (difficulties in understanding the units of time and their transfers; understanding the relations on the clock and the linear elapse of the time, with reading time data written digitally) – difficulties when performing mathematical operations (confusing mathematical operations, e.g. division – multiplication, tens and units during addition) – impaired ability to perform mathematical operations with natural numbers (but also with other kinds of numbers) – confusion of the individual operations – inability to respect priority of operation when performing more operations of differing parity – problems with written algorithms for individual operations – deficit in understanding mathematical notions and their mutual relations – deficit in generalizing

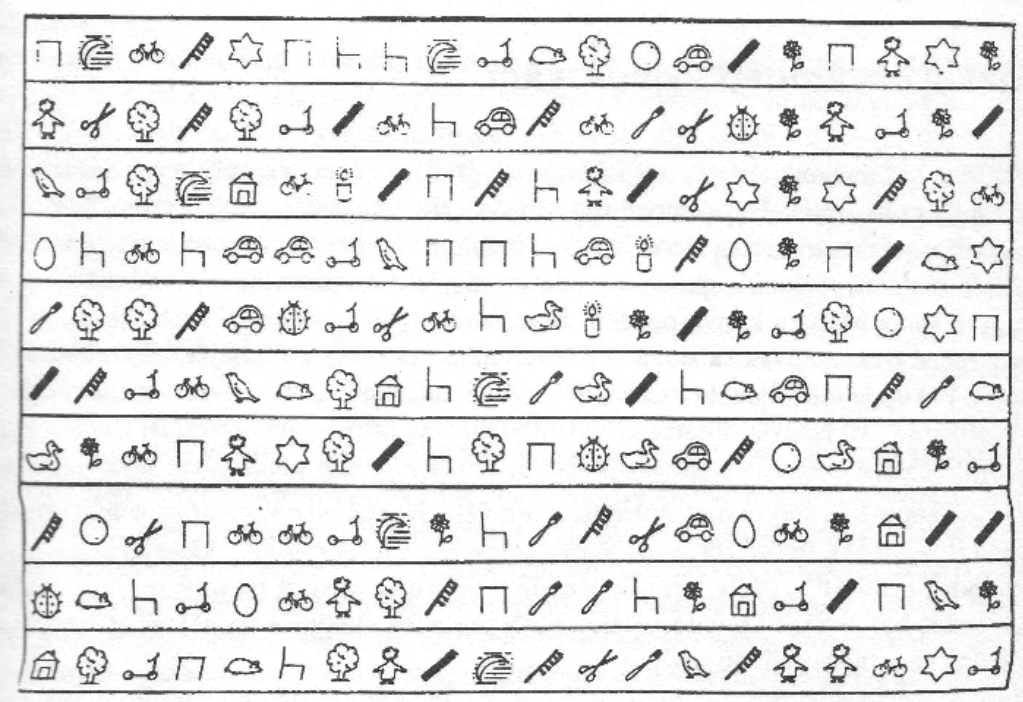
Remedial teaching for cognitive functions

For the development of the individual functions of the cognitive function, we can also use a large number of remedial teaching exercises. Here, only a few examples of the exercises are given and these are focused on the improvement of the attention span, memory, thinking, and speech (see Zelinková, 1994; Zelinková 2003; Michalová, 2001; Lynch, & Kidd, 2002; Havas, 2005; Havas, 2006; Žáčková, & Jucovičová, 2007; Mathias, 2007; Jucovičová, & Žáčková; Pokorná, 2011; Balharová, & Bubeníčková, 2011; Balharová, & kol., 2014). The development of pre-number sense and number sense (see Blažková, & al., 2000; Blažková, 2009; Blažková, 2010; Blažková, 2013; Novák, 2000; Novák, 2004; Bednářová, 2004a; Bartoňová, 2005; Simon, 2006) forms an important and rather wide-ranging area in this context. In this text, however, we will not deal with it for the sake of brevity of the text.

- **practising concentration and attention span**

These exercises require precision when performing the task. Therefore the pupils should be asked to be perform the task carefully and with precision, and if we see that the quality of their work diminishes, we should rather interrupt the exercise. In the given exercise (Figure 2), the pupil is asked to cross out one to four pictures (the task should be neither easy, nor hard for the pupil). The difficulty of the task lies in the choice of pictures.

Figure 2
Worksheet to practise concentrarion



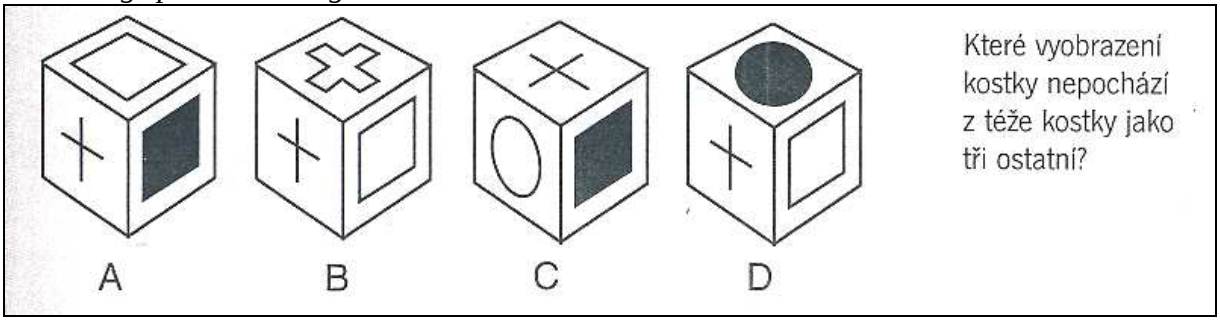
- **practising memory**

Through different exercises, we can improve visual memory (see the part practising visual memory), auditory memory (see the part practising auditory memory), and kinesthetic memory. Kinesthetic memory can be developed through sets of exercises, dancing steps and figureys. Tactile perception and memory can be developed e.g. in the following way: the pupil is asked to distinguish between different materials only by touching them and recognize them again. With closed eyes and bare feet, the pupil is led across a path that is made of stone cubes, logs, sand, soil, metal foil, saw dust, etc. The pupil determines the material of the path.

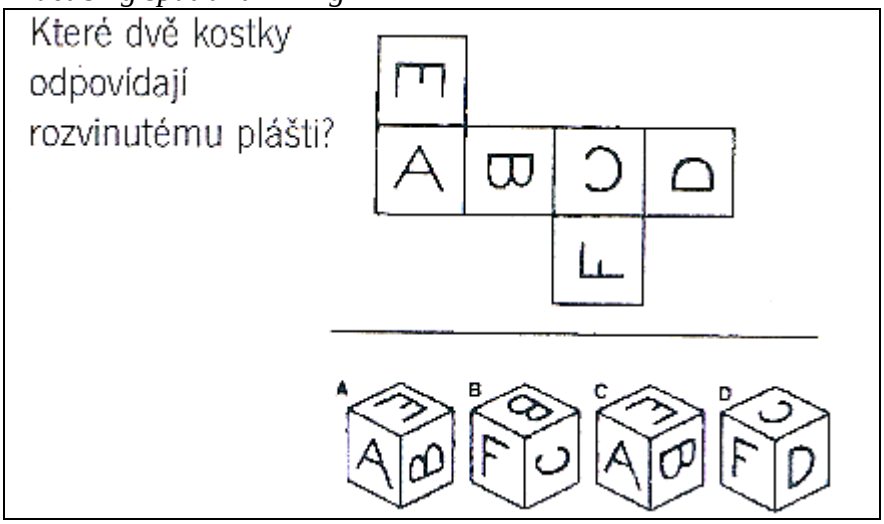
- **practising thinking**

A classical exercise for developing logical thinking are the tasks to determine not fitting object(s) in a set of similar objects. Another level of tasks of this kind is filling in logically constructed sequences, e.g the following task: which is logically the next letter in the sequence A B A C A D A E A ? Which letter will follow? a) A C E G I ?, b) Y X V T R ?, c) A Y B Z C ?. Spatial thinking can be practised by a variety of tasks similar to the ones show in Figures 3 and 4.

Figure 3
Practising spatial thinking 1



Figurek 4
Practising spatial thinking 2



- **practising speaking**

To practise speaking, we may for example use the following games: „Finish the story.“ We ask the pupil to finish a short story; we may start by asking him to finish individual sentences. „Where is the mistake?“ We relate short stories to the pupils and intersperse them with nonsence (nonsensical words, words that do not fit the story or are not suitable for the story). The pupils try to find the wrong words and remove them. „The Poet“. We seek rhymes. At first, we let the pupil fill in a suitable rhyme in the nursery rhyme or a sentence, later we proceed to seek rhyming word pairs (say – day. hen – ten, ...).

Motoric function

Deficit in motoric function is especially found with pupisl suffering from *dysgraphia* and further also pupisl suffering from *dyscalculia.* Pupils with *dysgrafia* usually suffer from impaired motor skills, most often the fine graphomotoric skills, sometimes also in combination with gross motor skill. These pupils often also suffer from the disorder of motoric co-ordination and from difficulties sensory and motor area. Pupils with *dyscalculia* usually suffer from the disorder in motor skills and sensory and motor co-ordination.

Motor functions include the genral motor skills of the whole body. In teaching mathematics, gross and fine motor skills and graphomotoric skills are the most important ones. For the sake of clarity, we sum up the manifestations of the deficits of partial functions of the motoric function in Table 5.

Table 5
Manifestations of the deficits of the partial functions of the motor function

Deficit of the partial function of motoric function	Manifestation of the deficit
Gross and fine motor skills	– deficit in manipulation with concrete objects or symbols, difficulties in manipulative activities for establishing basic notions and operations – deficit in creating groups of objects

	– difficulties in number writing – difficulties in writing down operation algorithms – difficulties in technical drawing
Sensomotoric coordination	– difficulties with concurrent sensory perception and motion
Visual-motoric coordination	– difficulties with concurrent visual perception and motion
Graphomotorics	– difficulties in writing mathematical symbols (digits, numbers, etc.) – difficulties in writing several-digit numbers – difficulties in writing numbers below each numbers (keeping the digits of the same order in the same column) – difficulties in writing (writing slowly) – difficulties in writing numbers (especially when learning the shapes of the digits) – difficulties in writing operation algorithsm – difficulties with drawing shapes with ruler and compass

Reemedial teaching for motoric functions

To develop the motoric functions, we can use a large number of remedial teaching exercises (see Zelinková, 2003; Jucovičová, & Žáčková, 2008). Here, we again mention some of the exercises to illustrate the point

- **practising gross motor skills**

To practise gross motor skills, we can use e.g. exercises that focus e.g. on arm movement: waving, circling (flying bird, mowing the lawn, swimming free style), alternating raising arms up and sideways, circling with forearm (forming a ball from yarn) or movements with palms: forward, back, left, right, circling with palms (waving, shaking), pressing palms against themselves and relaxing, closing the fist and opening it again, alternating hitting the table with palm and fist.

- **nácvik jemné motoriky**

There are many exercises to develop fine motor skills, e.g. modelling, tearing out and folding paper, bead work, colouring books.

- **practising sensomotory co-ordintation**

Activities and exercises that can be used to practise senso-motoric co-ordination are e.g. pasting a piece of coloured paper into a preprinted contour, into the shape cut out from a foil (packaging, cellophane), weaving braids, cutting (to start with, we use paper that is not too thin, we hold the paper and we move the paper when the direction of the cutting changes, not the scissors), first in any direction, then between two straight lines, along a thic line, and only then along a thin line, and after mastering this, we move to curved lines,…

- **practising graphomotorics**

Practising is always accompanied by oral explanation (we use rhyming, give clear explanation of the writing procedure). The pupil repeatedly practises by emulating what we do (in the air –

also with eyes closed), „writes“ with the whole body, follows the line with finger, chalk, etc, describese the procedure aloud. To practise writing, we can include e.g. the following elements: free drawing on the paper (the ball is round, the car follows a winding road, the snake is winding etc.); yarn balls; circles; spirals; ovals,; arcs; waves; loopholes; „eights“; snakes. We may also introduce surface exercises (delineating various elements on a surface) or line exercise (delinating picture elements on a line).

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