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Introduction

The need to stimulate speech development in pre-school children, including in particular children with verbal functions development problems, is indisputable now. Language competences are some of the most valuable skills affecting the intellectual and social progress of a human being. However, despite the broad range of stimulating and therapeutic tools available, we still too rarely make use of the achievements of neurobiological research on the development of the human brain. The brain controls all the cognitive functions which make it possible for us to learn new things. Some of the aspects connected with these processes include the asymmetric structure of the brain and functions phylogenetically assigned to each of the cerebral hemispheres. They manifest themselves, among other things, in lateralization of paired organs, especially in handedness. Educators who work with pre-school children should pay particular attention to lateralization, because it is closely connected with speech development. Delayed lateralization is in many cases accompanied by speech disorders. Therefore, any measures taken with a view to help overcome language difficulties cannot ignore the need to stimulate lateralization. It is also important that the preference a child shows for one side of the body over the other is correctly recognised and evaluated.

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Asymmetry in the structure and chemical composition of cerebral hemispheres as a factor affecting lateralization

Every human body is asymmetric to a greater or lesser extent. The same is true of the human brain. It is made of two cerebral hemispheres, which are connected by nerve fibres and which seem pretty much alike. However, the similarity is only superficial. In fact, the two halves of the brain differ not only in their structure, but also in terms of cytoarchitectonics, chemical composition and, most primarily, their functions (Cieszyńska, Korendo, 2008, p. 266). "There is plenty of evidence showing that the left and right hemispheres of the brain are not identical in function and structure, and that the differences between them lie in these higher mental processes that cognitive neuroscience is most concerned with. It has been shown, for example, that the asymmetry in how the cerebral hemispheres function manifests itself in the different ways they produce and comprehend language or process complex spatial relations" – free trans. (Springer, G. Deutsch, 1998, p. 16).

The Sylvian fissure, which divides the frontal lobe and parietal lobe from the temporal lobe, is a good example of how asymmetric the brain is. In the left hemisphere of the brain it is straighter and about 1 cm longer than in the right hemisphere, where it is, additionally, hooked upwards (Cieszyńska, Korendo, 2008, p. 270). An especially important role in language processes is played by the asymmetric *planum temporale*, a small cortical area in the temporal lobes on both sides of the brain in the back of the Sylvian fissure. It is an auditory association area involved with language expression, as well as with visual and spatial functions (Bednarek, 2002, p. 4; Cieszyńska, Korendo, 2008, pp. 266–269). In normal brains, the *planum temporale* is clearly larger in the left cerebral hemisphere already in the prenatal period, which helps it specialize in sequential language processing later on. However, as physiological and anatomical studies show, individuals with dyslexia have symmetric *planum temporale*, and in some cases the structure is even larger in the right hemisphere than in the left one (reversed asymmetry) (Bednarek, 2002, p. 4).

In terms of cytoarchitectonics, the difference between the cerebral hemispheres lies in the distribution of various cells (Cieszyńska, Korendo, 2008, p. 268). The two halves of the brain also show different chemical compositions – they have different types and numbers of neurotransmitters and neural encoding and decoding programs (Budohoska, Grabowska, 1994).

All these features have an influence on the complementary specialization of the right and left cerebral hemispheres. In other words, each hemisphere has evolved to perform different but complementary functions, which altogether form our overall psychological activity (Springer, Deutsch, 1998, p. 28). The results of the latest research on brain asymmetry confirm that this fact is associated with cognitive consequences (Kenneth Hugdahl, Richard J. Davidson, 2004; Kenneth Hugdahl, Rene Westerhausen, 2010).

Specialisation of cerebral hemispheres and language organisation

A majority of the human population have language faculty, responsible for speech, reading and writing abilities, located in the left cerebral hemisphere (Bragdon, Gamon, 2006, p. 57; Cieszyńska, 2005, p. 26). It is connected with the sequential, analytical and relational functioning of this part of the brain. Specialist literature on brain lateralization says that the **left cerebral hemisphere** (quote by: Cieszyńska, Korendo, 2008, p. 271–272 and Cieszyńska, 2005, p. 26–27):

- works analytically and relationally;
- arranges information sequentially – bit by bit;
- compares stimuli by making relations between them;
- records the time from the internal clock;
- is guided by logic in identification of stimuli;
- holds memory with general knowledge of the world;
- processes familiar stimuli.

All of these have an influence on language processing, which is dominated by the left hemisphere. This part of the human brain:

- receives, identifies and differentiates sounds of speech;
- processes information in silent reading;
- recognises rhymes;
- performs complex verbal activities.

The right cerebral hemisphere specialises in:

- receiving and processing stimuli globally and holistically;
- processing new stimuli;
- identifying stimuli on the basis of the physical resemblance of the entire stimulus rather than its individual elements;
- processing visuo-spatial information, e.g. recognising faces;
- processing and storing mathematical and musical information;
- recognising geometric shapes;
- recognising basic features of stimuli (colour, contour, brightness);
- perceiving emotionally-charged stimuli (reading social kinesic signs and verbal emotional behaviour).

Although not totally excluded from language processing, the right hemisphere does it a bit differently from the left hemisphere. Because the holistic aspect dominates its functioning, it:

- comprehends globally heard or read concrete nouns (in nominative);
- identifies and differentiates vowels;
- controls intonation, accent and rhythm of speech;
- helps understand the context of a message;
- reads metaphors;
- controls the culture-bound direction of text (left-to-right in our culture).

In view of the above, it is easier to understand the problems of people suffering from dyslexia, as this disorder is usually caused by malfunctions of the left hemisphere of the brain (Bragdon, Gamon, 2006, p. 57), as well as people with difficulties in linear processing of the language, which is so important in reading and writing (Cieszyńska-Rożek, 2010, p. 40). "The left cerebral hemisphere is more prone to underdevelopment during foetal life, because it develops later and far slower than the right hemisphere; furthermore, it is more susceptible to various factors, such as increased testosterone levels, twin sibling rivalry, drug abuse by the mother, or breech delivery" – free trans. (Bragdon, Gamon, 2006, p. 58). These facts lead to another important conclusion. As many experts emphasise, both sides of the brain participate in our cognitive processes. They are integrated and cooperate with each other, and the fact that they specialize in different areas of the processes is necessary for us to function properly.

Brain asymmetry and lateralization

The pathways from cerebral hemispheres to the body are crossed, or contralateral. Therefore, left-handedness indicates that the right hemisphere of the brain dominates in controlling the muscles, movements of the body and psychological functions, whereas right-handedness indicates a dominant role of the left hemisphere of the brain (Bragdon, Gamon, 2006, p. 64). The functional asymmetry of paired organs is physiological in nature and is called *lateralization* (Kurowska, 2011, p. 33). There are three models of lateralization (quote by: Kurowska, 2011, p. 33):

- unilaterality (dominance of either the right or the left side of the body) – the preference to use the hand, foot, eye and ear on the same side of the body, caused by the dominance of the opposite hemisphere of the brain;
- mixed laterality (also called cross laterality) – mixed preference for using motor organs and sense organs (e.g. right hand but left eye);
- ambidexterity – lack of dominance in any paired organs.

Mixed laterality and ambidexterity are frequently connected with disorders like dyslexia, indicating malfunctioning of the brain. This phenomenon was noticed by S. Orton. He noted that children who tended to swap letters while reading or to do mirror writing usually did not have a definite handedness (Orton, 1937, after Springer, Deutsch, 1998, p. 280). Similarly, looking for the causes of autism, researchers point to the relations between autism and brain dysfunctions. There are also hypotheses that autistic people demonstrate atypical cerebral hemisphere asymmetry (Springer, Deutsch, 1998, p. 289). Research published in 1984 in "Psychological Bulletin" shows that about a half of autistic children have undetermined handedness or are left-handed (Fein, Humes, Kaplan, Lucci, Waterhouse, 1984, p. 258–281). Bilateral activation of the brain hinders language learning. Therefore, children who continue to show no definite symptoms of either right- or left-handedness after the age of 3 need treatment, as such a situation is considered abnormal (Korendo, 2010, p. 55). Cross laterality (but also left-handedness) may also cause problems in the development of cognitive functions and – very frequently – language abilities. According to J. Cieszyńska and M. Korendo, cross laterality featuring dominance of the right hand and the left eye is particularly unfavourable (2008, p. 280).

Studying left hemisphere dysfunctions and their influence on learning in children, M. Korendo arrived at the conclusion that "if the left hemisphere of the brain does not become dominant for language functions during natural development or as a result of therapy, the child (…) may have development problems and difficulties in using a language system, which will eventually affect other cognitive spheres too" – free trans. (Korendo, 2010, p. 56). As a confirmation of her statement, the author quotes the following negative consequences of left dominance of paired organs (quote by: Korendo, 2010, p. 57):

Consequences of left-eyedness:

- confusing the direction in which a person analyses space (and also the direction of reading and writing);
- confusing the direction of making signs (e.g. drawing from bottom to top);

- neglecting the left side of space;
- difficulty in focusing on a given material;
- reluctance to make drawings;
- hyperactivity.

Consequences of left-handedness:

- delayed development of manual skills (clumsiness in movement, low precision);
- reluctance to perform manual tasks;
- confusing the direction of making signs;
- difficulty in using tools;
- hyperactivity.

Consequences of left-earedness:

- impaired phonemic hearing (difficulty in differentiating speech sounds);
- longer time needed to process verbal messages;
- tendency to experience negative emotions;
- difficulty with reading comprehension;
- speech disfluency;
- speech impediments.

Consequences of left-footedness:

- motor problems (e.g. delay in walking);
- reluctance to ride a bicycle;
- difficulty repeating a sequence of steps (dance routines);
- reluctance to play team games (e.g. football);
- awkward movements.

Measuring lateralization

When working with a child who has language problems, whether phonetic, phonologic, morphologic, syntactic or lexical, it is very important to

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know what laterality the child developed. It is a prerequisite for appropriate treatment and is particularly important in the case of children with ambidexterity. Therefore, if possible, the laterality of paired organs should be measured and assessed. The table below sets forth three items for determining the laterality of each hand, eye, foot and ear and shows how to record the results. When compiling the table, the author of the paper relied on the suggestions made by J. Cieszyńska and M. Korendo (2008, p. 279–280).

Table 1. Measuring laterality

Hand dominance	**RH**	**LH**	**BH**	**Notes**
putting beads into a bottle				
drawing a circle				
cutting sticks of Plasticine with a plastic knife				
Eye dominance	**RE**	**LE**	**undetermined**	**Notes**
looking into a bottle				
looking through a keyhole				
taking pictures with a camera				
Foot dominance	**RF**	**LF**	**undetermined**	**Notes**
kicking a ball (child should stand in one place rather than run up to the ball)				
jumping on one leg				
jumping on one leg into a circle				
Ear dominance	**RE**	**LE**	**undetermined**	**Notes**
listening to a clock ticking (without touching the clock with your hands)				
listening to the swooshing sound in a seashell (without using your hands)				
listening to knocks on the door				

Conclusion

Information on the dominance of hand, eye, ear and foot is important in evaluating the level of speech development in a child. Not only is it connected with the functional asymmetry of the cerebral hemispheres, but also with the holistic approach to how the human body works. A prolonged lateralization process means that speech and other psychological functions will need more time to develop. Delayed lateralization implies delays in the development of motor skills. Motor skills are primary to the ability to process visual and auditory stimuli or perceive and express language (Kamińska, 2011, p. 88). Furthermore, functional asymmetry, which manifests itself in laterality, is connected with the motor skills of speech organs. "Clinical research confirms that the left hemisphere is very involved in copying the articulatory movements (…). Other data confirms that within Broca's area of the brain there are certain sites which control speech muscles, e.g. lip muscles, and sound production" – free trans. (Kamińska, 2011, p. 89). In patients with ambidexterity or cross laterality, the left cerebral hemisphere does not usually develop a strategy to process stimuli. As a result, such patients do not have the ability to join movements (including articulatory movements) into sequences or to think and remember sequentially, which is necessary in reading and writing (Kamińska, 2011, p. 89; Cieszyńska, Korendo, 2007, p. 294). In such cases, a therapy should include exercises stimulating the choice of the dominant side of the body (Kamińska, 2011, p. 92).

Handedness is a phylogenetically-determined feature. That is why a significant majority of the population is right-handed. It is, of course, connected with the division of functions between the right and left hemispheres of the brain (Springer, Deutsch, 1998, p. 126). The experience of therapists and researchers shows that left-handed children have problems with the sequential processing of language more frequently than right-handed children (Kamińska, 2011, p. 88). The way they process language information may be similar to the strategies adopted by people with ambidexterity or cross laterality. However, a left-handed child should never be told to use the right hand as the dominant one. Empirical studies make it

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clear that "any attempts to convince (…) a child to use the right hand or foot may cause even more difficulties with school education, may be a source of negative emotions for the child and may lead to low self-esteem" – free trans. (Cieszyńska, Korendo, 2007, p. 282). If a child is diagnosed with left-handedness, we should start working on developing the correct patterns for space analysis, in accordance with the culture-bound direction of reading and writing (from left to right) (Kamińska, 2011, p. 92). The therapy should also cover all the mental functions necessary to achieve competence in language use (i.e. memory, concentration, analytical, synthetic and sequential thinking, development of motor skills, visual and auditory perception).