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Integration of the InTime Technique in the Neurodynamic Program of Assistance to Children with Learning Disabilities

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Abstract

The article describes the results of application of the *inTime* neuroacoustic training by Advanced Brain Technologies (USA) when they were organizing assistance to children who had learning disabilities. This training optimizes the functional state of the brain by using sounds of various frequency and rhythm. The effectiveness of the *inTime* technique was monitored by the Complex Auditory Subcortical Evoked Responces (CASER) functional diagnostic test developed by the specialists of the Prognoz Children's Neurological Center (St. Petersburg, Russia). The article shows that the inTime program improves the effectiveness of intervention to overcome learning disabilities. This method is suggested to be used in schools in order to support learning process of children with learning disabilities as well as to prevent to help children of the risk group.

Keywords: learning disabilities, dyslexia, dysgraphia, neuroacoustic training, learning difficulties, prevention of learning disabilities, multi-disciplinary approach

1. Introduction

According to the Institute of Age Physiology of the Russian Academy of Education, 15-40% of elementary school students who do not have expressed intellectual, sensory, or motor disorders have learning disabilities (Bezrukikh, 2013; Manchinskaya et al., 2013).

Currently in Russia, there is no generally accepted term to define this group of students as well as no unified model of teaching these children. Students with reading and writing disorders (dyslexia, dysgraphia) and children with the attention deficit hyperactivity disorder (ADHD) are placed in different groups. Speech therapists treat children with dyslexia and dysgraphia, and those who have ADHD go to a psychologist. However as a rule this intervention is not enough, as the causes of learning disabilities are complex, and they are displayed in quite diverse ways.

Actually, most students with learning difficulties do not receive any specialized care; adults believe the learning difficulties that these children face are the result of their laziness or lack of discipline. However usual disciplinary measures applied to these children do not result in any significant improvements.

Although learning difficulties may arise as a result of various external factors, such as inefficiency of school curricula, too high intensity of teaching/learning process, etc., numerous studies show that in most cases children with learning disabilities have dysfunctions or immaturity of certain parts of the nervous system (Geary, 2004; Nicolson & Fawcett, 2001, 2007; Chidekel & Budding, 2010; Koziol & Budding, 2012, 2013; Johnson, 2012; Batshaw et al., 2013). Therefore, multidisciplinary approach to providing assistance to this group of children that involves joint work of teachers and neurologists seems to be very promising.

This approach has been successfully implemented in the Logoprognoz Center (St. Petersburg, Russia). The team of professionals dealing with children includes neurologists, functional diagnostics doctors, speech therapists, psychologists, massage therapists, music therapist, an art therapist, and specialists in adaptive physical education.

The set of activities used at the Logoprognoz Center is based on the theory of Russian physiologist Nicolay

Bernstein about the multilevel activity control (Bernstein, 1947).

Bernstein believed that any human activity (simple or complex) was simultaneously controlled by the brain at several levels. The activity control occurs cyclically through feedback. The researcher distinguished the following levels of the control.

A–the level of muscular tone and posture. The anatomical substrates of this level are spinal cord, brainstem, hypothalamus, paleocerebellum, the central part of the vegetative apparatus;

B–the level of habitual actions, automatisms. This level is controlled by thalamus and basal ganglia;

C–the level of spatial field. This level is subdivided into two sublevels: C1 (thalamus, striatum, cerebellum), C2 (primary motor and sensory cortex);

D–the level of semantic actions with objects (tools)–anatomical substrates: basal ganglia, cerebellum, the primary motor and sensory cortex;

E–the level of abstract thinking, intelligence, and creativity. The control is provided by the cerebral cortex. Each level of activity control is provided by the functioning of certain neural structures which gradually ripen in ontogeny. It does not happen automatically, but only through active actions of the child adapting to the changes in the environment. By approaching school age (7 years in Russia), the first four levels should be sufficiently mature: A, B, C, D.

Using this theory the specialists of our center developed a neurodynamic program aimed at stimulating the development of all levels of activity control. The focus is on activating background levels of the activity control: A and B.

Modern neuro research demonstrates that children who have learning disabilities show subcortical dysfunction of the nervous system (brain stem, cerebellum, basal ganglia), i.e. those divisions that are anatomical substrates of the background levels (Schmahmann, 2004; Nicolson & Fawcett, 2001, 2007). The neurodynamic program is aimed at activating these levels, as they are the basis for all activities.

As a rule, the weak point of the techniques implying improvement of the brain functioning by teaching methods or aimed at improving sensory processes is the inability to assess objectively the functional status of certain brain structures before and after the intervention.

At the Logoprognoz Center, the effectiveness of teaching influence is monitored by the method of Complex Auditory Subcortical Evoked Responses (CASER).

The evaluation of the auditory signal transduction in the central nervous system using the technique of auditory brainstem response (ABR) is widely used in neurological practice (Roncagliolo et al., 1994; Chiappa & Hill, 1997; Levy, 1997). Usually during the diagnostics the latent periods of occurrence of the first five peaks of the auditory brainstem response upon stimulation with a frequency of 500 Hz are evaluated.

Specialists of our center found that the analysis of the value of the latent period of the sixth peak during stimulation with a frequency of 4,000 Hz showed that there was a relationship between the disorder of the auditory signal transduction from the cochlea to the medial geniculate body of the thalamus and the learning disabilities in children. They concluded so as a result of the practical work that had been carried out by our neurologists since 1999. During this period, over 60,000 children with various speech disorders and learning difficulties have been examined (Efimov et al., 2014).

Thus the classical ABR technique was complemented with the study of the 6^{th} peak on both sides with auditory stimulation at the frequency of 4,000 Hz. In addition, all the children underwent cerebellar examination with stimulation at 40 Hz and examination of the cognitive function P-300. The results of the Complex Auditory Subcortical Evoked Responces (CASER) also allow assessing the functional state of the cerebellum, the brain's ability to respond to new information, and the level of attention.

Thus we have a tool that allows to compare the functional state of the subcortical regions of the brain before and after the intervention. The relationship of various learning disorders with the ability of the brain to process auditory information is now actively discussed in the special publications, as well as the possibility to improve the central processes of the auditory information processing using special programs (Sharma *et al.,* 2009; Kraus, 2011).

In 2014, the program of assistance to children with learning disabilities in our center was complemented by the inTime technique developed by a team of specialists of Advanced Brain Technologies (USA). The producers are occupational therapist Sheila Allen, composer and musician Nacho Arimany, and author, founder & CEO of

Advanced Brain Technologies, Alex Doman.

The inTime is the neuroacoustic training that combines two kinds of stimulation: stimulation with sounds of different frequencies and rhythmic stimulation. Besides listening to music using special equipment, training includes special rhythmic exercises using the body, the voice, and a drum.

2. Methodology

The aim of the study is to look for methods that optimize the learning ability of children experiencing problems with cognition functions. The present study involved children from 7 to 10 years of age whose parents applied to the Prognoz Neurological Center, and the Logoprognoz Speech Therapy Center (St Petersburg, Russia) because their children could not cope with the school program in one or more subjects and needed constant assistance of adults with their homework, were easily distracted in class, and did not have sufficient motivation to improve their learning skills. All the tested children had problems with developing writing and/or reading skills. Parents also faced difficulties in organizing learning activities while children tended to stop doing the work without finishing it.

So far, the study has involved 36 children with learning problems. 18 of them were included in the experimental group and 18 in the control group.

Inclusion criteria:

- Age: 7-10 years,
- Public school,
- Difficulties in the educational sphere in 2 or more subjects according to the teacher,
- Conclusion of neurologist, speech therapist, psychologist,
- Male sex.

Exclusion criteria:

- Intellectual violations,
- Genetic syndromes,
- The presence of considerable motor and sensory impairments (vision, hearing),
- The presence of organic brain pathologies.

Control and experimental group consisted of children whose parents applied to the Prognoz Neurological Center for the development of difficulties in children at school. In the experimental group children were recruited by the wish of their parents.

All children underwent examination by a neurologist and functional neurological diagnosis in the Prognoz Center.

The functional diagnostics using the Complex Auditory Subcortical Evoked Responces (CASER) technique was performed before and after the neurodynamic program.

Diagnostics conducted before the beginning of the sessions showed that the children in the experimental and control groups had the following disorders. The speed of transduction of the auditory information by the brainstem structures was reduced by 15-25% of the normal value; most children showed decrease in the functional activity of the cerebellum; the ability to focus and the speed of response to new information were reduced (presumably, these are the responses of the hippocampus to auditory information).

Educational assessment identified the following problems:

- Difficulties in the implementation of multistep instructions;
- Inability to coherently express their ideas in writing;
- Difficulties to express their ideas orally clearly and consistently whenever necessary;
- Problems with self-organizing;
- Difficulties in timing;
- Low self-esteem in relation to their ability to learn.

Most of the children also demonstrated postural problems and difficulties with bilateral coordination and motor planning.

The sessions in the experimental and control groups lasted for 16 days, seven days a week. Children in the experimental group attended 5 sessions daily, the duration of each session was 40 minutes. The program included sessions with a speech therapist, full body massage with emphasis on the collar area, neurodynamic gymnastics, exercises with a music therapist and an art therapist. All sessions were conducted individually: one child − one adult.

Children in the control group who also have learning difficulties attended the same sessions as the children in the experimental group, but without using the inTime.

When developing the inTime training program for children in the experimental group, we used the modified protocol A. In contrast to the variant proposed by the program developers which assumed listening to music twice a day, the children listened to 9-minute music modules 5 times a day. One session cycle consisted of 80 musical modules.

At the beginning of each session, the children of the experimental group listened to a 9-minute inTime module using the multisensory Sound Waves™ audio system through headphones which in addition to air conduction of sound provided bone conduction. The music was uploaded to iPod. The children had the opportunity to choose comfortable music volume themselves.

While listening to music, the children were asked to choose any kind of activity: they might lie on sports mats, in a chair or in a hammock, on swings, play ball, paint, etc. The inTime equipment was put in a small backpack on the back, which allowed a child to move freely with no restrictions.

After listening to a nine-minute musical module and a two-minute break (preparation for the next stage of the training), the children of the experimental group went on with a regular program (sessions with a speech therapist, a specialist in adaptive physical education, etc.). Exercises with a drum were performed during a training session with the musical therapist once a day. Other specialists included in their sessions body percussion (special exercises involving rhythmic tapping all over one's body). For example, body percussion was always conducted during massage. During these exercises, the music was off, but the rhythm which was heard by the child in the music module was used for body percussion.

The inTime training combines two aspects important for brain development: stimulation with sounds of specific frequency and stimulation with rhythm.

All children in the experimental group liked the inTime percussion music. While listening to music children as a rule preferred moving spontaneously and rhythmically, and many of them were humming something. Professionals working with children noted that listening to music modules always helped create the necessary working mood needed for subsequent sessions.

The inTime music had been specially composed and recorded for the program by the composer Nacho Arimany. This is what distinguishes the inTime program from other neuroacoustic methods, such as, for example, the Tomatis method which used acoustically modified licensed records of classical music.

Recording of the inTime music had been performed in a studio, thus providing the best sound quality and the conditions close to the natural acoustic environment. During the recording process, more than 100 kinds of percussion musical instruments from all over the world were used. For the program, the instruments with frequency sounding range meeting the necessary requirements were initially selected. Therefore, there was no need to carry out substantial acoustic modification of the music as it sounded quite natural.

3. Results

After the neurodynamic program, children in both groups showed positive dynamics, both in learning activities and in the results of functional diagnostics.

During the analysis of the latent period of ABR sixth peak during stimulation with a frequency of 4,000 Hz in 30 children of 7-10 years old in normal conditions (without learning disabilities), it was found that the peak latency had an average value of 7.24 ± 0.02 ms both on the left and on the right sides. In children of 7 to 10 years with learning disabilities the sixth peak latency was equal to 8.25 ± 2.49 on the left and 8.30 ± 2.68 on the right side. This was significantly ($p < 0.001$) higher than the normative values. After InTime course the sixth peak latency decreased to 7.69 ± 2.79 ms on the left side (the differences before and after treatment were significant: $t(17) = 10.8$, $p < 0.001$), and on the right side - to 7.67 ± 3.26 (the difference before and after treatment were significant: $t(17) = 8.6$, $p < 0.001$). At the same time the latency of the sixth peak in children with learning disabilities was higher than the standard values after the treatment as well.

On cerebellar examination by means of frequency following response (FFR) with stimulation at 40 Hz we assessed the degree of violation of the response pattern (based on the dispersion of interpeak intervals and amplitude characteristics of the response): 3 points–severe disturbances, 2 points–medium disturbances, 1 point–mild disturbances, and 0 points–no disturbances. In children with learning disabilities before the treatment, the mean value of assessment of FFR disturbances was 2.4 ± 0.7 points on the left side and 2.2 ± 0.5 points on the right side. After a course of InTime therapy the severity of FFR disturbance decreased down to 0.7 ± 0.6 points on the left side (difference before and after treatment were significant $t(17) = 10.9$, $p < 0.001$), and on the right side–to 0.7 ± 0.5 points (difference before and after treatment were significant $t(17) = 8.4$, $p < 0.001$).

According to the study of neurophysiological correlates of cognitive function and concentration by P300 method, an average latency of P300 wave in the group of the surveyed children was 350 ± 29 ms at baseline and 335 ± 25 ms after the treatment (the difference was not significant $t(17) = 1.73$, $p > 0.1$). An amplitude of P300 wave was 102 ± 3.2 mV at the baseline and 9.8 ± 2.8 mV after the treatment (insignificant differences $t(17) = 0.52$, $p > 0.6$). At this time in the initial state an average latency of P300 wave was at the upper boundary of normative range.

Qualitative changes noted by parents and teachers were evaluated on the basis of checklists filling in one month after the experiment.

Table 1. Comparative evaluation of the results of applying the InTime methodology in the experimental and control groups according to the survey data

Parameter	Experimental group (n=18)	Control group (n=18)	Significance of differences
Sense of rhythm	18 (100%)	1 (6%)	p<0.0001
Attention	9 (50%)	3 (17%)	p=0.044
Motor planning	12 (67%)	2 (11%)	p=0.0015
Handwriting	9 (50%)	0 (0%)	p=0.0015
Timing	16 (89%)	2 (11%)	p<0.0001
Memory	6 (33%)	5 (28%)	n.s.

n. s.–non significant.

The significance level for the difference between two proportions was computed based on t-value (two-sided) for the respective comparisons (Table 1).

4. Discussion

The inTime technique integrated into our center's neurodynamic program has an obvious advantage. The advantage is that during the training there is an active but physiologically natural stimulation of the nervous system of the child with the help of music and rhythm at all levels of activity control according to the Nicolay Bernstein's theory.

The A and B levels are associated with the perception of one's body and are activated by low-frequency "grounding" sounds and simple rhythms which make the body move rhythmically and naturally. This work contributes to the development of the body's attunement with the rhythms of the environment. Special exercises involving rhythmic tapping of one's body (body percussion) complement this training with proprioceptive sensations necessary for activation of the background levels of activity control–A and B.

The level C is activated during exercises with a drum. The level D is activated by rhythms that are more complex when a child continues rhythmic patterns and then makes them more complicated. Finally, a child passes over to drum improvisation and invents tunes based on the auditioned rhythms, which is independent creative work, level E.

Obviously, the inTime training has significant stimulatory effects on cerebellum. Modern studies using neuroimaging demonstrate that the cerebellum is responsible not only for the coordination of movements, but is involved in all cognitive processes (Schmahmann, 2004). Most researchers are inclined to think that it is the cerebellum that provides the feedback necessary for learning. Besides, the cerebellum and basal ganglia apparently carry out millisecond timing of processes occurring in the brain, thereby ensuring their synchronization. Not surprisingly, the timing processes improvement occurs during neuroacoustic training, because as far back as in the 19th century, the outstanding Russian physiologist Ivan Sechenov called hearing the "time analyzer." Perhaps, it is the immaturity of the brain mechanisms, which is responsible for subconscious perception of time that is the cause of the learning difficulties in children (Merzenich et al., 1996; Ivry & Schlerf, 2008; Efimova, 2013).

According to Nicolay Bernstein, the evolutionary path from one level of control activity to another is taking place. Probably, the inTime training has the maximum impact on level B.

At level B, time exists in the form of rhythm. Nicolay Bernshtein believed this level is the most interesting and important of all five levels. After it, "the evolution makes a certain step back: the next upper and obviously new level C is less important and more limited."

The main objective of level B is to provide movement in time orderly and harmoniously. This level is closely linked with rhythm, because many movements are the reproduction of a certain rhythmic pattern. This happens, for example, with such movements as walking and running. Level B sets the rhythm of movements controlled by higher levels. In many cases, if the rhythm of movement is disrupted, the movement itself is also disrupted. For example, at writing, the "illiterate" level B provides the rhythmic fluctuations of hand, and higher levels D and E create letters and words from these movements.

Many movements, which we learn first with the help of the cerebral cortex, e.g., dressing, lacing shoes, car driving, playing a musical instrument, etc., gradually become skills and descend to the level B, i.e. the brain switches the control over these movements to the automatic mode.

Bernstein compares level B with a mechanic who maintains operation of all internal systems of a plane. The airplane is controlled by a pilot (level C), but with a good mechanic he no longer has to worry about the work of the engine. That is, level B provides internal control of movements, and the higher levels take over piloting.

It seems that the inTime training effectively adjusts the performance of level B which is the background for the normal functioning of all higher levels of control necessary for successful learning activities and developing all academic skills.

Modern neuroscientific studies demonstrate an important role of the subcortical structures of the brain in the human cognitive activity. It turned out that the brain structures which have been assigned the modest role of regulators of movement for a long time are actively involved in the thinking processes and their proper functioning is necessary for the development of academic skills (Nicolson & Fawcett, 2001, 2007; Schmahmann, 2004; Koziol & Budding, 2009, 2012, 2013). Thus many of the assumptions of Nicolay Bernstein and Ivan Sechenov are currently supported by the results of modern research.

Nicolay Bernstein coined a new term, which is now widely used in various fields, i.e., biofeedback.

Motor skills are acquired by a human in the course of life. The brain works like a huge network having a huge number of communication and feedback channels. The way these channels interact with each other has not been yet entirely understood by scientists.

The proper function of all levels (from A to D, and later to E) is essential for a child to perform such complex actions as writing, reading, problem solving, etc.

Learning difficulties may be caused by both disorders on "technical" levels and lack of motivation. But most often, the problem can be detected on the lower "floors" addressed there.

Listening to rhythmic music engages multiple areas of the brain. Therefore, the inTime is working even when the child is not performing any additional exercises on drums and is just listening to music.

We find the program efficient in terms of communicative orientation of the training which is implemented through the interaction of the child and the instructor during exercises with the rhythm and improvisations on drums. Unfortunately, nowadays, the use of any technology may hinder normal communication with the child during the training in case if one relies solely on the effect of the stimulation devices. But the inTime keeps a dialog between the child and the adult during most part of the training.

5. Conclusion

The first stage of integration of neuroacoustic inTime training in the program of teaching children with learning disorders showed very encouraging results. The research is still in progress. Now the inTime program is applied by the Logoprognoz Center to children who have autism spectrum disorders, to children with intellectual disorders, and children with various disorders of speech and language development.

It seems reasonable to provide the inTime training at school. Currently, researchers note that among Russian first graders, there are more and more children whose brains are not physiologically ready for school (Bezrukov, 2013; Manchinaskaya et al., 2013). However, these children go to school and must meet the same requirements as do more "mature" students. Most modern studies indicate that learning difficulties usually have a neurological origin. In fact, the brain of a child with learning difficulties is the brain that cannot work effectively. This can be recognized by using measurable indicators that reflect the brain's ability to process information.

From our perspective, it is necessary to identify children at risk and create conditions for the functional maturation of their nervous system as early as possible, during the first weeks of school (or even in pre-school years) to prepare them for the load of teaching/learning process. This is where the inTime training can be very useful. It does not take long and can be arranged in any school that has appropriate equipment and specially trained instructors.

We find it important to highlight the main ideas contained in the article:

- Learning difficulties in children with normal intelligence without pronounced sensory or motor disorders are of neurological nature.
- Using the Complex Technique Subcortical Auditory Evoked Responses (CASER) allows identifying abnormalities in the functioning of the subcortical brain regions.
- The study performed in the Logoprognoz Center demonstrates the effectiveness of using the inTime training during the comprehensive work to overcome learning difficulties.
- Most likely, the inTime's effectiveness is determined by the stimulating effect of the training on the cerebellum and other subcortical structures of the brain.
- Currently, the study of the effectiveness of inTime application is ongoing.

Ethics

According to medical case history from protocol No. 8/04 of Ethics committee of the State Budgetary Educational Institution of Additional Professional Education Kazan State Medical Academy of the Ministry of Health of the Russian Federation dated April 1, 2015, the present article does not contain any information that is not allowed to be published in the press. There are no ethical violations in the submitted article.

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