To Investigate the Association between Vestibular Maturity and Partial Auditory Abilities in Children Aged 4-8 Years

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Abstract

This study is a part of my doctoral research, in which we examined the possibilities of sensorimotor development. We also conducted an impact assessment on the development of sensorimotor development, and auditory and visual skills. Auditory skills are essential at certain speech perception stages, speech perception, speech comprehension, and speech training. The same applies to auditory learning skills and several other skills which form the basis of school learning. It is essential to know which foundational factors, in addition to organic maturity, are necessary for the perfect functioning of auditory sub-skills. One such factor may be vestibular maturity. Over a period from 2018 to 2019, we studied the association between vestibular functions and partial auditory abilities in 391 children aged 4–8 years. In the research, we found a strong, positive significant correlation between vestibular maturity and partial auditory abilities.

Keywords: Development; Kindergarten; Learning skills; Elementary school; Sensorimotor.

1. Introduction

In the research, I hypothesized a significant positive relationship between vestibular functioning and the functioning of auditory sub-abilities required for learning. The children included in the research were selected in a two-stage sampling, in which 391 healthy children aged 5–8 years were included. Of these, 63 were in the control group and 328 in the experimental group. The proportion of girls to boys was 53%-47% in the control group and 57%-43% in the experimental group. In the experimental group, children participated in a program of sensorimotor development 3-5 times a week for 6-7 months, one element of which was vestibular development. Kindergarten teachers and teachers held the sessions. The control group had regular PE lessons rather than the sensorimotor development program. Vestibular maturity was measured by examining static and dynamic positional balance and by examining post-rotational nystagmus. The partial auditory abilities examined were: delayed verbal memory, relational vocabulary-orientation, serial auditory memory, auditory perception, grammar, conceptualization, contrasts.

2. Theoretical background of the research

Sensing the position of one's own body requires the coordinated operation of several organs. Different body position are essential to learn how to and interpret our environment, and our brain constantly registers how much contraction of the muscles it is necessary to maintain so that the body position does not change, or how we can quickly react to a new situation with our posture and movements (F. Molnár, 2019).

The organ which senses and directs the position of our body, the perception of balance, is a vestibular or balance sensing organ located inside the inner ear, which begins to mature during weeks 8-10 of fetal development. At birth it can already sense a change in the position of the head. With the help of the labyrinth organ, elementary movement patterns are realized, such as elementary gait, sitting without elemental support, and elemental creep (Katona, 2001).

After birth, the basis for the continuous adaptation to the earth's gravitational field is the information coming from a large number and different places, which on the one hand determines the motor adaptation and, on the other hand, senses the direction from which the stimulus comes. From birth, countless stimuli and motor responses train the vestibular system. Rocking, rocking, lifting, and placing the baby in the crib contribute to developing one's weight perception, just like lifting the child's head, turning back and forth from the abdomen, or later stages of movement development (Berényi & Katona, 2014).

How is this tiny organ structured and how does it function? How does it allow us to overcome the difficulties caused by gravity, to be able to orient ourselves in space, all of which affect the functioning of almost all parts of our body to some level?

The parts of the balance-sensing organ are the tubule (sacculus) and the sac (utriculus) in the bony vestibule and the three semi-circular arches in the three perpendicular planes of the space. The hose and bag detect the spatial position of the stationary head. The inside of both organs is hollow, with hair cells covered in a gelatinous sheath. There are tiny lime crystals (otolith) in the gelatinous shell. The thick envelope bends when the head is tilted - lime crystals increase the compressive force - and the protrusions of the hair cells are deformed and become irritated (Vizkievicz, 2019).

The semi-circular arches are tubular formations in three perpendicular planes of space. They have similar gelatinous-coated hair cells in their widening as inside the tubing and sac. When the head is displaced, in an arc in the plane of displacement, the gelatinous fluid moves, and the protrusions of the hair cells deflect, thus becoming irritable. Hair cells sense accelerating or slowing the motion of the head. From the receptors of the positioning organ, the stimulus passes across cranial nerve VIII, through the medulla and the pons to the midbrain and then to the thalamus. From the thalamus, the information enters the primary sensory part of the wall lobe of the cerebral cortex, where the sensation develops. The vestibular system has several functions. It is responsible for regulating and maintaining equilibrium and adjusting muscle tone to gravity. Its sensory receptors are found in the utricle and the saccule and the semicircular arches, but the system receives information from the eye, muscles (muscle spindle), tendons (tendon spindle), and the mechanoreceptors of the skin (Oláh, 2004).

The movement centers of the brainstem coordinate and control eye movements in connection with a change in the position of the head, and they play a role in fixing the gaze.

Post rotational nystagmus is often used to test the vestibular system. Róbert Bárány, an Austrian doctor of Hungarian origin, was awarded the Nobel Prize in 1914 for his research into the vestibular system. The post-rotational test is also called the Bárány Test after its discoverer (Bárány, 1906).

Several researchers have addressed the relationship between post-rotational nystagmus and learning difficulties. Billy Ann Cheatum tested children between 1986 and 1989. Among children with learning disabilities, 61% had inadequate post-rotational nystagmus. In the control group, this indicator was 21% (Cheatum & Hammond, 2000).

The other main task of the vestibular system is to adjust the tone of the skeletal muscles and thus the posture, which it performs by coordinating the stimuli of vision, balance, and pressure. The connection between the balance sensing system and the cerebellum also plays a role in this. The cerebellum is also involved in coordinating movements (Cheatum & Hammond, 2000).

The central adjustment of muscle tone applies to the musculoskeletal system and the adjustment of the tongue and face muscles. Often, because of “weak,” i.e., hypotonic language and facial muscles, a child has a speech training problem or cannot swallow properly. Toned tongue and facial muscles can cause other problems in addition to articulatory problems. The child cannot swallow properly, as a result of which she pushes her tongue against the forward teeth rather than against the roof of the mouth. After a time, this type of swallowing causes permanently poor position of the teeth, leading to a speech development problem. In this case, the orthodontist is not the solution as long as the tongue-swallowing swallow exists (Sarlós, 2021).

The malfunction of the balance sensing system has caught the attention of several researchers working with children. Dr. Julio B. Quiros was one of the doctors who believed he had discovered a link between vestibular system disorders, dysfunction, and learning difficulties. Quiros studied more than two thousand children in the 1950s and 1960s and followed their development for three years. He found that children with vestibular problems lagged in the development of movement, perception of balance, language development, reading, and writing skills (Quiros, 1976).

Auxter, Pyfer, and Huetting also stressed that children with weakly-functioning vestibular systems have a poor sense of balance, significant and subtle motor movement issues, and problems with movement coordination (Pyfer, Auxter & Huetting, Auxter, 1996).

Jean Pyfer and Johnson observed that children with delayed balance development have problems learning various new movements (cycling, ball riding, skiing, skating), reading and writing, and later speaking and comprehension. (Pyfer & Johnson, 1981).

One explanation for the relationship between the vestibular system and speech comprehension is the muscle tone regulating function of the vestibular system because there are two tiny muscles in the middle ear. One is the tympanic tension muscle attached to the hammer, holding the tympanic membrane tight. The stretched eardrum is capable of precisely transmitting sound waves. By contrast, imagine a drum with no stretched surface. It is hard to imagine that a drummer could generate any sound from a drum in this condition (Vizkievicz, 2019, Sarlós, 2021).

The other tiny muscle is the stirrup muscle, which connects the stirrup and the oval window. Intense noise causes the stirrup muscle to contract, making the auditory bone chain stiffer, so it conducts less sound. The tone of this muscle is thus able to regulate the amount of sound entering the inner ear. If the muscle tone is not adequate, any sound can enter the inner ear and the amount of incoming noise is not reduced. This is an overload and, together with the previous problem, makes auditory perception more difficult (Vizkievicz, 2019).

Since children learn their mother tongue only by hearing, we can imagine that if they do not hear people's voices clearly and at the right volume, they will not pronounce the words correctly. It significantly impacts their speech development and speech comprehension (Sarlós, 20219.

Julio B. De Quiros, who has researched dyslexia, published a study in 1986 that drew attention to the link between the dysfunction of the vestibular system and learning difficulties. He proposed to alleviate and eliminate the problem. He recommended that unique vestibular maturation and developmental practices be incorporated into the education and development of children with problems in the vestibular system (Quiros, 1976).

In the following, based on Cheaum and Hammond, as well as our own experience, we list the symptoms which are associated with impaired functioning of the vestibular system:

2.1 Vestibular hypersensitivity

The child:

- does not like to watch or do rotating activities,
- has dizziness when traveling, sliding, jumping,
- does not like to play playground games (swing, slide, spinning games, trampoline),

- often loses balance while moving,
- has nausea in while in moving vehicles,
- prefers to sit in the front of the car,
- feels dizzy in a lift or on an escalator,
- avoids adults who want to throw them in the air,
- their coordination is uncoordinated,
- often do not like sports,
- usually retire to read, or like to be in a quiet "corner",
- are almost always good learners.

(Cheatum & Hammond, 2000; Sarlós, E., 2021)

2.2 Vestibular under-sensitivity

The child:

- has poor muscle tone and body awareness,
- has a poor sense of balance and has frequent falls,
- displays awkwardness, uncoordinated movement, and failure in sport,
- has poor muscle control, inability to sit still on a chair or stand for a long time,
- loves to spin, spin, roll,
- is never dizzy when spinning,
- has a problem with laterality, e.g. cannot do an Indian jump exercise where the arms move independently from each other and the legs,
- has speech training problems,
- has difficulty reading and/or writing,
- has poor ability to control the eye muscles making learning difficult and causing poor coordination in sports,
- usually does not like sports.

(Cheatum & Hammond, 2000; Sarlós, E.,2021)

3. The method of the research

3.1 Mathematical, statistical procedures

Given the ordinal nature of the data, we used order statistical procedures, i.e., the Mann-Whitney test, the Wilcoxon test, the Kruskal-Wallis method, and studies related to the calculation of Spearman's rank correlations (Nahalka, 2000).

In each case, in addition to the significance levels, we also determined the effect sizes. In the research methodology literature, solutions using only hypothesis testing have long been the subject of serious criticism in analyzing differences, changes, and impacts (Cumming, 2014). The requirement to define effect sizes for differences is already significantly present in international publication requirements. We determined the appropriate effect magnitudes in each difference and correlation study. Due to the ordinal nature of the variables, we calculated the Cliff delta effect size using unique formulas, which is often used in statistical procedures (Macbeth, Razumieczyk, and Ledesma, 2011). For Mann-Whitney tests, the magnitude of the effect is a

$$d = \frac{2U}{MN} - 1,$$

(U is the test statistic for the Mann-Whitney test, the SPSS, M determines its value, and N is the number of items in the two samples).

For the Wilcoxon test the

$$d = \frac{Z}{\sqrt{N}}$$

(Z is the test statistic for the Wilcoxon test, SPSS calculates its value, N is the number of items in the sample) using Excel formulas.)

The value of $\eta 2$ calculated for the Kruskal-Wallis method is always between 0 and 1, values less than 0.06 have very little or no effect, the effect is medium between 0.06 and 0.14, and any value greater than 0.14 indicates a significant effect.

In regard to the correlation coefficient, we consider values around 0.1 to be minor, meaninga lack of correlation. In pedagogical studies, values around 0.3-0.4 are usually worth analyzing, and those higher than 0.5 are considered significant.

4. Results

There was no significant difference between the vestibular maturity of the experimental and control groups in the input measurement, with a $p > 0.001$ difference, and the magnitude of the effect was 0.052. The output measurement was $p < 0.001$, with an effect size of 0.306. These results demonstrates that the impact of the sensorimotor development program is great.

It should be emphasized that we did not separately develop the partial auditory abilities of the children during the performance of the sensorimotor training (6-7 months).

The values in the table below show that vestibular maturity strongly correlates with the level of auditory abilities. The correlation is significant, $p<0,001$, and the magnitude of the effect also indicates a significant effect, $d=0,268$.

Table 1:Correlation, significance level and impact magnitude between the vestibular development and auditory abilities

SensoryMotor Development and Components	Auditory Abilities		
	Spearman's correlation coefficient	Significance level	Impact magnitude
Vestibular development	0,518	p < 0,001	0,268

5. Conclusion

Based on the obtained results, it can be said that there is a positive, significant correlation between the level of vestibular maturity and the level of partial auditory abilities in the examined children aged 5-8. The magnitude of the effect of the change due to the sensorimotor exercises performed by the experimental group is significant.

As the examined auditory abilities are the basis of successful learning processes, it is worthwhile to deal with children before starting school, since this has a beneficial effect on the maturation processes.

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