

EXAMINING THE RELATIONS BETWEEN DANCE AND MATHEMATICS AMONG FIRST GRADE STUDENTS

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Abstract

Dance and mathematics are seemingly very distant concepts at first glance. In the theoretical parts of our study we show how strongly mathematics and spatial abilities are interrelated, including the correlation between dance and spatial abilities as well. Consequently a hypothesis derives that dance develops spatial abilities, through which it develops mathematical skills at the same time. Our research focused on first year primary school students.

During the one month course we applied creative children dance and tasks of movement from drama pedagogy. Children's abilities were measured pre- and after the course classes with a test of both mathematical and spatial skills. According to this research, we could show some improvement in mathematical skills as a result of the development, but there is no significant improvement in spatial skills. We attempted to find out about the reasons of the results we found.

Keywords: spatial abilities, dance and mathematics, first grade students

1. INTRODUCTION

1.1. Spatial abilities

Spatial abilities are named with several terms: *spatial abilities* (Tosto et al., 2014), *spatial skills* (Uttal et al., 2013), *visuospatial abilities* (Crollen & Noël, 2015). The conceptual problem is caused – as seen by Crollen and Noël (2015) – by the multitude of partial abilities, which can be grouped under the term as indicated by the usage of plural (spatial abilities). Furthermore, the definition of spatial abilities is also problematic. Having surveyed the studies on the development of spatial abilities between 1984-2009, Uttal and his colleagues have concluded that there is no generally accepted definition for spatial abilities.

Uttal et al. (2013) introduced a two-dimensional classification model where instead of providing a definition, they recommend classifying different spatial experiences along dimensions. When classifying various spatial experiences they adapted the method of Newcombe and Shipley (2015) who use two dimensions, the *intrinsic*

sic-extrinsic one, and the *static-dynamic* one. These two dimensions describe four spatial abilities (see. *table No.1*). The *intrinsic-static* ability refers to the spatial actions with which we code the spatial configuration, perhaps the shape of objects. The *intrinsic-dynamic* ability is related to the activity when we transform the spatial code of things, e.g. we enlarge or reduce the size of objects, turn them, transform from 2D into 3D. The *extrinsic-static* abilities are the ones when we code the spatial position of objects in relation to other objects or a reference framework. The *extrinsic-dynamic* ability refers to visualizing all the objects from a different viewpoint.

Spatial abilities	Definition	Examples	Examples for devices of measuring
intrinsic – static	Coding the shape and spatial configuration of objects.	foot or arm positions	embedded figure test
intrinsic – dynamic	Transforming the spatial code of objects; (e.g. increasing its size, turning it, transforming from 2D into 3D)	pirouette	mental rotation test
extrinsic – static	Coding the spatial position of objects in relation to other objects or a reference framework	the position of one dancer in relation to the other	water level test
extrinsic – dynamic	Visualizing a group of objects from a different viewpoint. Transforming the relation among objects.	perspective taking	tests based on perspective taking

Table 1. - Describing the four spatial abilities along dimensions (based on Uttal et al., 2013)

We also know from the meta-analysis of Uttal et al. (2013) that spatial abilities can be modified, the training aimed at improving them is effective and transferable. Although, developing abilities has an age limit. Miller and Halpern (2013) have provided a training course for students of physics whose spatial abilities and exam results have both improved. However, the good results due to the training course did not prove to be long lasting as they disappeared within 6 months. This supports the 18- years-of-age as the upper limit to develop spatial abilities, set by Séra, Kárpáti and Gulyás (2002).

1.2. The interrelation of spatial and mathematical abilities

Brain areas in connection with calculus overlap with the area responsible for spatial representation in the parietal lobe (Hubbard, Piazza & Dehaene, 2005). So if one area is activated, it will also affect the other. Therefore, numerical and spatial abilities are related to one another at the level of behaviour as well. This has been justified among

various age groups and with various tests, e.g. among 0-3 day neonates (De Hevia, Izard, Coubart, Spelke, & Streri, 2014). Spatial abilities at the age of 5 significantly predict achievement at the age of 8 in calculus, addition and subtraction (Gunder-son, Ramire, Beilock, & Levine, 2012). A 4-year longitudinal examination with primary school children has shown the connection between spatial and mathematical abilities (Lachance & Mazzocco, 2006). Studying university students the tests have revealed the connection between mental rotation exercises and numeric abilities (i.e. comparing and sizing numerals) (Thompson, Nuerk, Moeller, & Kadosh, 2013).

Once spatial and mathematical abilities are connected and if spatial abilities can be improved, one can deduce that with the development of the former, the latter will also improve. Two studies have examined this in the past few years. Cheng and Mix (2014) have found that 6-8 year-old children after 40 minutes of mental rotation exercises produced better results in mental rotation tests as well but not in the spatial relations test. It is interesting that in certain mathematical tasks children practicing mental rotation were better (supplementing, e.g. $3+_=8$) but not in one- and more-digit operations.

Krisztián, Bernáth, Gombos and Vereczkei (2015) examined whether 11-12 year-old children with mathematical learning difficulties can be developed with origami and folding 3D shapes. Their theory is based on the idea that folding origami, playing with three-dimensional shapes develops eye-hand coordination, the perception of directions, orientation and space sensing. The latter can have a positive effect on calculation. Children in classes 5-6 were examined in the experiment. Children were randomly assigned to one experimental and two control groups, with one half of the children diagnosed with mathematical difficulties being placed in the experimental group and the other half in the first control group. The children who had no mathematical difficulties were in the second control group. The experiment lasted 10 weeks with 60 minute origami sessions per week. The results showed that because of the development spatial abilities have improved so significantly in the experimental group that they were able to catch up with the normal control group and achieved better results in calculation as well.

Generally saying better spatial abilities help you solve mathematical problems, e.g. in case of text assignments they produce a more exact mental model which then eases the process of task solution (Mix, 2019).

1.3. Spatial abilities and dance

In the psychological research of the past two decades, the examination of movement imagination has become more intense (Bernáth, Krisztián, & Séra, 2018). From a dancer's viewpoint, literature has revealed interesting facts. Finke (1979) wrote about the hypothesis of functional equivalence. According to that, mental imagination is functionally equivalent, i.e. from a functional viewpoint it equals the actual object or event. Mental training, so popular with dancers and sportsmen was based on that, meaning that certain movements, techniques are „played in mind” without actually executing them. (Moran, 1996).

Ideokinesis is associated with Mabel Esworth Todd; with its help learning and

teaching dance can easily have a common denominator (Phyllis, 2015). Todd relied on the fact that directions, flatness, horizons, images and comparisons projected in the brain can be related to the real physical positions and movements. This method has supplied a very good base for dance techniques by giving dancers fewer, more abstract but more straightforward instructions. To execute a spin it may be enough to say "Imagine you are a spinning top!" Instead of going on with „ Pull your stomach in! Lift your head! Hold your centre! Straighten up! Stretch your knees! Tend upwards! Hold your arms!" etc.

In 2013 Jansen, Kellner and Rieder elaborated creative dance trainings to develop spatial abilities, especially mental rotation. Divided into two groups, 31 second grade girls and 34 second grade boys took part in the experiment. The control group attended P.E. lessons, while the experimental group had a creative dance training for 5 weeks. Such and similar creative sessions activate the mind and the body with the help of dance and music. In creative dance, children can create movements, express their personalities, and utilize their imagination instead of learning a particular choreography. The leader of the experiment elaborated a new topic in class each time. Results have shown that mental rotation skills developed in both groups but more in the experimental group.

Preceding contemporary research, a pioneer of the 20th century, Rudolf Lábán was also interested in the relations of dance and space. He devoted his life to opening horizons and giving form to the then new interpretation of movement (Fuchs, 2009). Grasping the forces of movement, he elaborated a system already known in mathematics but in a decisively different way in his special coordinate system. Whereas a two- or three-dimensional, orthogonal coordinate system is applied in mathematics to define a numeral, an equation, a function, a plane-figure or a spatial formation, in Lábán's system four-dimensional space provides the framework for movements (Fügedi, 2008). These four guidelines are *weight* (heavy or light), *space* (with inexperience or without direction), *time* (naturally slow or fast) and *flow* (free or restricted). With extremums belonging to the four dimensions, he tried to describe the quality of movements.

Furthermore, Rudolf Lábán created a scale of impetus composed of 12 movements in which the last movement always returns to the starting position (Fügedi, 2008). These movements were created with the help of an imaginary icosahedron surrounding the human body. In his theory the diagonals spanning between the apexes of the icosahedron provided for movements. The movements that he preferred to call impetuses resemble vectors known in mathematics. Vectors show the direction and size of displacement, furthermore the angle of two vectors can be calculated enabling us with further opportunities to study spatial formations. Lábán strove to produce an equally precise and exact description for dance as used in mathematics. His ideas were genuinely unique.

1.4. Dance and mathematics

Zoltán Dienes a world-famous Hungarian-born researcher of the methods of teaching mathematics, who has used dance and music in teaching mathematics probably for the first time, combined his mathematical heritage from his father, Pál Dienes, and the

eurhythmics heritage from his mother, Valéria Dienes. He showed his students the similarity of abstract mathematical and musical structures through the movements of the pupils' own movements (Benedek, 2018).

American researchers (Shaffer & Stern, 2001; Simanta, 2014) have developed several methods to make the studies of mathematics more creative and interactive, be it the age group of pre-school children or adults. The learner will be more effective, successful resulting in better self-esteem and developing social skills.

According to a 2011 report by the US Department of Commerce only 24% of people taking up careers in science, technology, engineering or mathematics were female (Katie, 2014). The same report confirms that women working in fields of STEM (Science, Thechnology, Engineering and Mathematics) earned 33% more on average than other women. Relying on these statistics Kirin Sinha aimed at helping and encouraging girls to choose a STEM career. The SHINE (Supporting, Harnessing, Inspiring, Nurturing, and Empowering) program combines dance, movement and mathematics. Its base is the so-called kinesio-learning (or movement learning), presuming that the regular movement of the body results in better information record in students.

Secondary school girls were recruited from Boston and Cambridge and mentors invited from MIT (Massachusetts Institute of Technology) to work with the girls and help them perform mathematical tasks, embedded in movement (Simanta, 2014.) For example:

They held hands and formed spatial formations on a square grid placed on the floor. Then they changed positions to produce symmetrical axis reflection of the given formation. Or let us take the algebra example of $3x+y$ where x means a spin and y means a jump. The girls' task was to create the short choreography where 3 spins are followed by a jump. Next the mentors set a new task, e.g. with adding brackets: $3(x+y)$. The girls are expected to realize what should be changed in the choreography.

Such playful tasks helped them understand the secrets of linear algebra and probability calculation. Dance movements put into choreography in turn illustrated the basic principles of trigonometry. Based on what they had learnt they solved problems at the blackboard. Lessons were finished with dancing for fun. After the 8-week training results were inevitable (Katie, 2014). Mediocre performance became excellent, task-solving abilities improved nearly 300% and self-esteem 100%.

Shaffer and Stern in their book (2001) collected methods with which to support both teachers of mathematics and choreographers. One method is as follows:

In the game „Clap your name” children can get to know with the concept of rhythm without any musical grounding. The exercises last 15-60 minutes and can be done anywhere if each participant has enough space around. The leader of the game asks the children to show their first name in rhythms, clapping the vowels and beating the consonants in their names. E.g. M-A-R-I-A is beat-clap-beat-clap-clap. They keep practicing until it takes no more thinking and the length of claps and beats is equal. Next they are asked to emphasise the initials of their names and form pairs. They should begin their rhythms and keep going at

the same pace without interruption. As the first letter, that is a pattern (e.g. clap 'c', beat 'b') is emphasised and returns at intervals, the question arises, after how many paces their stressed initials will meet, i.e. when will they begin the set all over again? If one of the names is made up of 4 paces, the other of 6, they will meet after 12 paces. Therefore, that is the least common multiple of the numbers 4 and 6. Beats and claps can be replaced with full body movement, so a little choreography is born to dance their names.

Although dance has been used for a long time to develop mathematical skills, its impact assessment is included in very few studies. One of them is the research in Hajdú's (2012) thesis in which he held weekly folk dance sessions for first graders throughout a year. When compared to the mathematical achievement of children participating only in P.E. lessons the former group showed better results by the end of the year.

Our presupposition is that dance with improving spatial abilities does develop mathematical skills. Therefore, we have elaborated a system combining creative dance and movement games of drama pedagogy to improve the mathematical skills of first year schoolchildren.

2. METHODS

2.1. Persons in the experiment

First grade children aged ~7 took part in the experiment. As this age group develops well in a month without special training as well a control group was involved. The experimental group consisted of 8 girls and 16 boys. The control group was made up of 9 girls and 9 boys. Both groups did the task sets.

2.2. Procedure

The childrens' abilities were tested with a two-component test. The first set was composed of tasks of estimation, equality, inequality and specific mathematical operations, the other had tasks to measure their spatial abilities. After the input test, the group in the experiment took part in a training of 45 minutes twice a week for four weeks. The control group had P.E. lessons during the same time. After the end of the programme, they repeated the somewhat modified test with similar tasks as in the first one.

The programme was compiled to have creative children's dance and movement-based drama pedagogical components. Music played an essential part in the lessons.

2.3. Creative children's dance and movement-based drama pedagogical games

Both techniques primarily suit 4-12 year old children. Creative children's dance is the expression of feelings and thoughts with dance, enabling the development of motor skills, creativity, emotional and social skills (Kézér, 2018). Besides developing mental and social skills, these playful and imaginative exercises introduce the use of space, rhythm, various musical styles, the didactic composition of a dance lesson and even the process of making a choreography.

The fundamental difference between the two methods is the amount of information given to the child when setting the task. When it comes to drama pedagogical games, you can specify the task, cast the roles or point at the different possible solutions. On the other hand, in a creative children’s dance class you should provide them with as little information as possible, just the essentials. The task is drawn up in a short, clear-cut way to make them understand it, the rest depends on them. It is their job to select roles, to decide how deeply they invest into a character or to what extent they get involved. It is the teacher who is supposed to collect and invent games according to a certain set of criteria. Based on those you can classify the games into the warming-up, the main or the ending part of the lesson and assess their abilities at different fields. These are coordination, using space (levels of space, directions, planes etc.), the usage of time (the dynamics of movement), the sense of rhythm, the position of oneself and mates, the use of weight, flow etc. (Kézér, 2018).

2.4. Input and output task sets

The set of tasks examining mathematical ability, based on Hajdú (2012), consisted of the following elements: testing estimation (Figure 1. and 2.), filling in inequality, inequality (Figure 3.) and specific operations (Figure 4.). In the latter one, result implementation and missing-term problems can be distinguished. The first two tasks are in connection with the working of the analog magnitude representation system, and the third one is related to exact computation (Dehaene, 1992; Deheane, Spelke, Pinel, Stanescu, & Tsivkin, 1999).

The input and output task sets were very similar, but there were some differences to prevent pupils to remember the results. Figure 2 shows an example of it. A rough time limit was given for each task, but in most cases the children were ready before the limit.

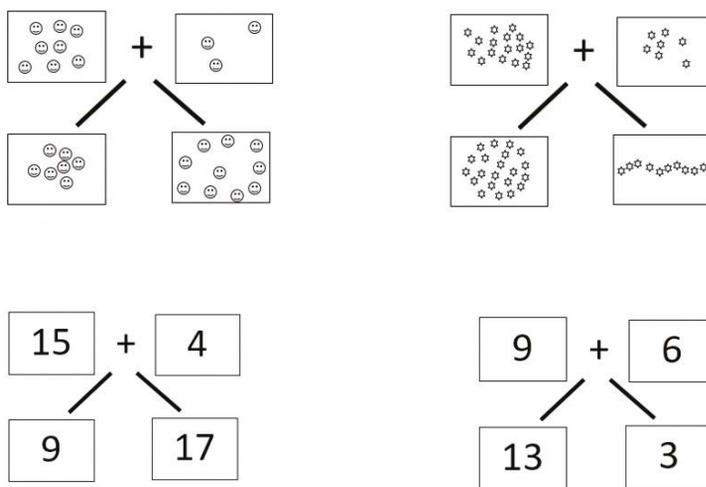


Figure 1. An example measuring estimation – from the input set

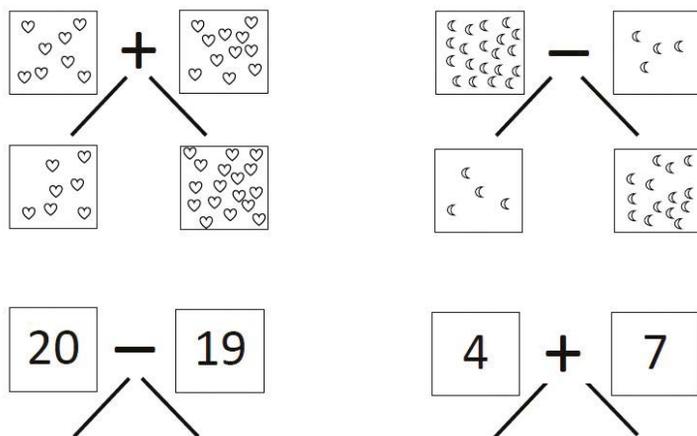


Figure 2. An example measuring estimation – from the output set

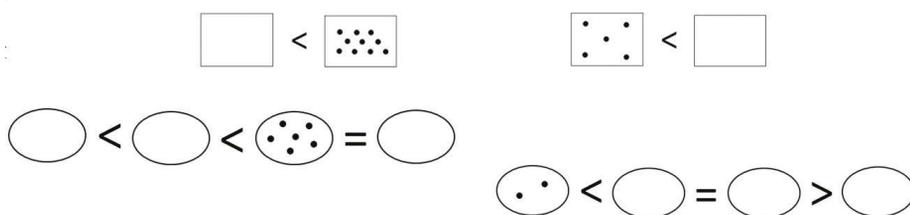


Figure 3. An example for filling in equality and inequality

$$\begin{array}{rcl}
 12 + 6 = \square & & 17 - 4 = \square \\
 7 - 2 = \square & & 9 - \square = 4 \\
 \square + 8 = 10 & & \square - 6 = 3 \\
 12 + \square = 18 & &
 \end{array}$$

Figure 4. An example for specific operations

The first table illustrates spatial skills test tasks used in the experiment. An embedded figure test to put it in first graders' language, implies e.g. finding little figures in a larger, more complex picture. (Figure 5. – woojr.com, 2020). Following the study of Jansen et al. (2013), for testing mental rotation, characters from tales and printed capital letters were applied (Figure 6.) Compared to the model figure three out of four choices are rotated 90°, 180° or 270°. One is mirrored and somewhere rotated so

with simple rotation, it cannot be matched with the original figure. As a horizontal test, according to Piaget and Inhelder (1956), the children had to 'fill up' 5 overturned bottles by colouring water in the bottles (Figure 7.) The perspective taking test was adapted to children from Kozhevnikov and Hegarty's exercises (2001) for adults. They were asked to imagine themselves into the position of a plush toy and choose the one option out of four how (s)he can see the objects lying in front of them. (Figure 8.)

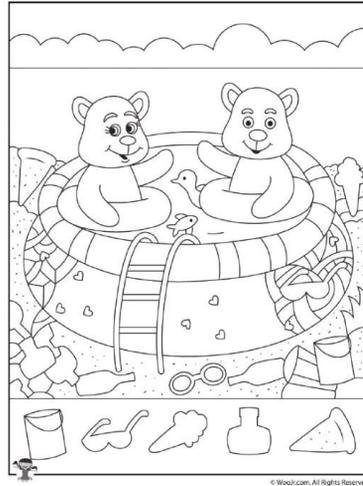


Figure 5. An example for the embedded figure test

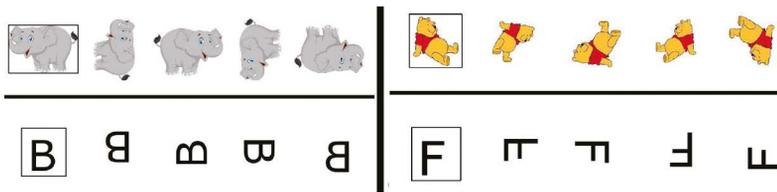


Figure 6. An example for mental rotation tasks

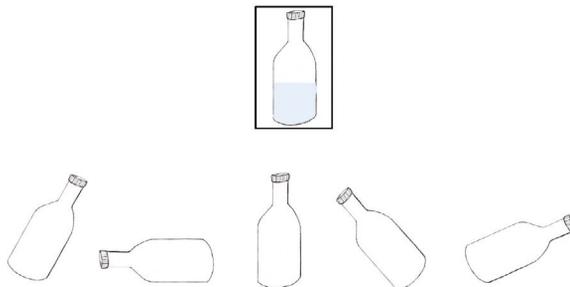


Figure 7. An example for horizontal tests



Figure 8. An example for perspective taking tasks

2.5. The course of the training

When defining the criteria for the games Rudolf Lábán's theories of movement analysis (Lábán, 1926/2008), Gabriella Kézér's classroom notes (2018) and Katalin Gabnai's book (1987) were used. We payed attention to one aspect or the combination of several aspects in terms of reference as follows here:

- The use of space – levels of space, planes, directions, axes, positions in relation to one another
- Time – slow- fast movement
- Weight – the relations of weight and force
- The relations between parts of the body – coordination, skilfulness
- Rhythm – musical knowledge
- Style – sense of style

An example for a movement drama pedagogical game:

Paired mirrors – this game requires two children, (preferably choosing a pair of the opposite sex). They have to stand face to face and imagine there is a full-size mirror between them. One of them is the leader, the other is the follower. The leader begins to move and dance to music, the follower is supposed to imitate their pair as if a mirror image. Then they change roles.

An example for creative children's dance:

A game with skewers – First we converse about what shapes they know and then they are divided into groups of 4-5 and given skewers. As a group, they have to create a shape. Nice and recognizable triangles, squares, rectangles, rhombuses and octagons were made. In the game they have to dance moving in the space and when approaching a certain shape they have to 'depict' it with some part of their bodies. In this task, geometry and dance were strongly interwoven. It was a pleasure to watch them dance mathematics.

3. RESULTS

The input and output results of the mathematical and spatial tasks are seen in *Tables 2. and 3.*

Experimental group N=24	Average	Standard deviation
maths in	12,62	3,04
maths out	13,62	2,26
spatial in	11,79	2,57
spatial out	14,08	2,50
estimation in	3,12	1,11
estimation out	3,16	1,16
(in)equality in	3,04	1,16
(in)equality out	3,25	0,94
counting in	6,45	1,69
counting out	7,20	0,83
familiar perspective taking in	1,08	0,88
familiar perspective taking out	1,58	0,58
perspective taking new situation in	1,37	0,64
perspective taking new situation out	1,04	0,90
perspective taking in	2,45	1,31
perspective taking out	2,62	1,37
mental rotation in	2,12	1,45
mental rotation out	2,75	1,39
water level in	2,21	1,02
water level out	3,71	1,08
hidden figure in	5,00	0
hidden figure out	4,99	0,02

Table 2. Descriptive statistical data of the experimental group

Control group N=18	Average	Standard deviation
maths in	13,88	1,45
maths out	13,38	2,09
spatial in	11,22	3,33
spatial out	13,77	2,53
estimation in	3,72	0,46
estimation out	3,44	0,70
(in)equality in	3,16	0,92
(in)equality out	2,94	1,10
counting in	7,00	0,97
counting out	7,00	1,02
familiar perspective taking in	1,44	0,70
familiar perspective taking out	1,72	0,46
perspective taking new situation in	1,05	0,87
perspective taking new situation out	1,00	0,76
perspective taking in	2,50	1,29
perspective taking out	2,72	1,07
mental rotation in	1,88	1,49
mental rotation out	3,16	1,15
water level in	2,00	1,45
water level out	3,17	0,98
hidden figure in	4,83	0,51
hidden figure out	4,72	0,57

Table 3. Descriptive statistical data of the control group

Summing up the results of the mathematical tasks and spatial tasks the results show weak relations $r=0,285$ $p=0,06$. The analysis of the given exercises has revealed moderate correlation between counting and perspective taking in a familiar situation $r=0,415$ $p<0,01$, out of the three mathematical and four spatial tasks. Those who were better in perspective taking, were better in counting as well and similarly weaker perspective came along with weaker counting achievements.

The effectivity of the development was analysed with mixed analysis of variance, where the overall mathematical results were compared in the input and output test with both the experimental and the control group. The interaction between groups and measurements is significant – $F(1,40)=4,44$ $p<0,05$ $\eta^2=0,100$ – the creative dance group performed better in the output test than in the input one but the control group showed no difference. Checking the spatial tasks also, mixed analysis

of variance was applied. Output results have improved compared to the input test - $F(1,40)=56,39$ $p<0,01$ $n_p^2= 0,585$. The two groups have not shown differences - $F(1,40)=0,31$ $p>0,05$ $n_p^2= 0,008$, and improvement was the same in both groups (with no interaction) - $F(1,40)=0,16$ $p>0,05$ $n_p^2= 0,004$.

4. DISCUSSION

The link between spatial and mathematical skills is due to the neuronal overlapping of brain areas responsible for these abilities (Hubbard et al. 2005). This link can be observed at the behaviour level as early as pre-school age (Gunderson et al. 2012). Earlier research has proven that spatial abilities can be developed (Uttal et al. 2013). Creative dance being an option (Jansen et al. 2013). With the development of spatial skills mathematical ones also improve (Cheng & Mix, 2014; Krisztián et al. 2015).

We presume that dance develops mathematical abilities by the development of spatial abilities. We have elaborated a complex method combining creative dance and drama pedagogical games to target the mathematical skills of first graders. Results have shown that there is a moderate connection between perspective taking in familiar situation tasks (extrinsic-dynamic spatial abilities) and exact, counting mathematical exercises. Furthermore, the mathematical results of the experimental group were better in the output test than in the input one, while the result of the control group did not change significantly. However, this result should be treated with caution because the rate of improvement is minimal. As far as spatial skills were concerned both groups performed better in the output test. These results seem to underline the existence of some sort of connection between certain tasks but the entire experiment does not prove our original hypothesis.

The reasons for that can be the following:

1. The number of children in the experiment, i.e. the sample size was very low. There were 8 girls and 16 boys in the experimental group and 9 girls and 9 boys in the control one. To get results more apt for a statistical analysis it would be necessary to include more children.
2. At certain points, the results show a ceiling effect as the children have performed extremely well in certain tasks. This suggests that both in the input and output set these exercises were too easy, e.g. in case of the embedded figure test. Other tasks however, turned out to be too difficult for them, e.g. the ones with mental rotation where most children have received 0 points, as they were unable to solve them.
3. In the estimation task, we have noticed the children were starting to count the figures and then comparing the results, offering an entirely different way of solution from the planned route.
4. The input test set was written on a Monday in the morning, the output one 4 weeks later on a Friday afternoon. The two times of the day could induce different mental conditions so in similar experiments nearly identical circumstances

- are desirable. Furthermore, it is worth keeping in mind to have the same person to make them do the test, both in the experimental and the control group. Supplementary instructions may be useful as this age group is just learning to read so understanding the task is not necessarily easy for each of them.
5. It is possible that the time of the trainings was too short or not intense enough. In a similar experiment Jansen et al. (2013) dealt with the children for five weeks, three times 45 minutes per week. Hajdú (2012) was studying them throughout an entire school year while teaching folk dance to the control group. Our experiment lasted for 4 weeks with twice 45 sessions per week.
 6. Building up and conducting creative children's dance, as well as movement-based drama pedagogical games requires special attention. In order to achieve real development in spatial abilities the systematic composition of tasks and the nature of instructions given to them are equally important. Children are supposed to use their imagination, their own inner mental representation especially in creative children's dance. Any extra information can disturb their process of creation.
 7. Finally, the fact that once a week every first grader takes part in folk dancing as part of their daily P.E. lesson at school is a further factor to be considered. This can explain outstanding results and little difference between the two groups.

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