Journal of Innovation in Psychology, Education and Didactics	Vol. 19, No. 1 2015	15 - 36

DOES PHYSICAL MOVEMENT IMPACT THE QUALITY OF PUPILS' LEARNING? - AN EMPIRICAL STUDY ON MOTION SEQUENCES' EFFECTS ON COGNITIVE ABILITIES IN BIOLOGY CLASSES

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Abstract

The study at hand deals with the question of whether the regular performance of motion sequences in school lessons has a positive influence on the students' learning ability. Learning ability is largely affected by one's attentiveness and ability to concentrate, which can be summarised as cognitive abilities. Based on the theoretical background proving positive effects on cognitive abilities due to physical activity, motion sequences were developed and tested in Biology lessons. In order to examine the effectiveness of this intervention, the d2 test of attention by Brickenkamp (2002) for the determination of attention and concentration performance was conducted in a test-retest-design and further accompanied by a self-developed questionnaire. Due to a disturbance variable, the hypothesis could not be validated. Still, the students' personal feedback was uniformly positive, which goes along with results of other authors who detected various factors in teaching connected to physical activity that increase the students' learning ability and the willingness to learn.

Key words*:* attention, Biology, classroom, concentration, physical movement

Introduction

The results of PISA (Programme for International Student Assessment) indicated that German pupils perform poorly with regard to cognitive abilities in comparison to other nations. From that, the logical necessity to gain insights into how the learning performance in school can be improved arose. An undeniable fact is the existing correlation between school performance and

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the ability to concentrate, since this is considered one of the most important prerequisites for initiating, promoting and facilitating learning processes during childhood. Consequently, pupils who are able to concentrate fairly well have an advantage in processing new information and maintaining the process of cognitive learning over a longer period of time (Memmert & Weickgenannt, 2006, p. 79). This is why it is assumed that the ability to concentrate also influences the general learning ability and school performance (Barchmann & Kinze, 1991, p. 89).

Taking all this into account, the findings on the degree of pupils' ability to concentrate seems alarming. Bös, Opper and Woll (2002) conducted a study on primary school children's fitness and proved that 50 % of a total of 1500 pupils showed difficulties in concentrating (p. 10). According to Weineck (2007), the causes are cognitive overload and, at the same time, less and less physical activity. He thinks that a chronic lack of physical exercise, caused by sitting and concentrating for too long, leads to a decline in the ability to concentrate and in the willingness to learn, thus entailing limited learning outcomes (p. 6).

This poses the question of whether there are any measures and possibilities to increase the pupils' ability to concentrate. Raising the awareness of a physically more active school routine is one option. Teaching should not only address the brain but also the whole body in order to attain positive cognitive results, a premise which is considered throughout the whole study.

Theoretical background

This chapter provides the theoretical foundation for the conception of the motion sequences. Firstly, the concept of *cognition* is viewed from different perspectives, before *concentration* and *attentiveness* are addressed. Further, the existing correlation between physical activity and cognition will be investigated from a neurobiological and physical-medical viewpoint. Eventually, the focus will be on the connection of all these factors.

The concept of c*ognition*

The term cognition is used throughout various academic disciplines which makes it difficult to refer to a common understanding of the concept. Due to this study's focus, *cognition* will be looked at from a pedagogical, biological and physical-psychological perspective.

In a pedagogical context, according to Tenorth (2007, p. 408), cognition comprises all mental processes such as perception, thought, memory, conceptualisation and problem-solving that are involved in knowledge acquisition.

From a biological point of view, Campbell and Reece (2006) define cognition as the knowledge about or the understanding of something. Those processes also imply an individual's conscious perception and judgment. Thus, Campbell and Reece (2006, p. 1251) assume that cognitive abilities encompass learning, decisions, awareness and an integrated sensory environmental perception.

The physical-psychological definition of *cognition* is slightly different. Additionally to the already mentioned relevant processes, Gabler (1993) suggests that the ability to concentrate is an important aspect of cognition. However, he finds that 'working focused on something' and 'attentiveness' itself are ambiguous terms (Gabler, 1993, p. 165). Even though there is no analytical separation of the individual cognitive subareas, the ability to concentrate will be highlighted. This will also allow a closer look at how concentration and attentiveness are related.

The terms *concentration* and *attentiveness*

Just as there is no universal understanding of the term *cognition*, this also applies to *concentration* and *attentiveness*. Academic discourse currently differentiates between three approaches. In the first, concentration and attentiveness are separate concepts (e.g. Büttner & Schmidt-Atzert, 2004). The authors justify this by the common differentiation in everyday use. The crucial difference, however, is that attentiveness is only related to awareness processes, hence serving the selection of stimuli and information. Concentration, on the other hand, is the ability to work quickly and precisely under conditions that would normally impede cognitive performance (Büttner & Schmidt-Atzert, 2004, p. 10). In a school example this would mean that capturing the teacher's work order is a simple attentive task, whereas just the quick and precise realisation of the order challenges one's concentration ability. Thereby attentiveness regards perceptive and concentration working processes (Büttner & Schmidt-Atzert, 2004, p. 11).

In contrast to that, advocates of the second approach abstain from a differentiation of attentiveness and concentration. This is mostly the case in English language countries. Concentration and attentiveness are both entitled as 'attentiveness' (Memmert & Weickgenannt, 2006, p. 80).

The third approach, to which this study will adhere, is somehow a compromise of the first two views. It sees concentration and attentiveness as related constructs that are yet not similar. Both terms involve the process of selection; however, they make a difference concerning the type of structural relationships and their specific intensities (Berg & Imhof, 2001, p. 42). This is particularly relevant in Brickenkamp's view (2002). For the term 'attentiveness' he sticks to the minimalist definition of Rützel, namely that attentiveness is selection (Rützel, 1977, as cited in Brickenkamp, 2002, p. 6). Brickenkamp and Karl (1986) define the construct of concentration as a performance-related, continuous and focused stimuli selection, as an individual's ability to turn selectively to relevant internal and external stimuli, meaning neglecting irrelevant stimuli and analysing the relevant ones quickly and correctly (as cited in Brickenkamp, 2002, p. 6). When transferring this approach to the example mentioned earlier, grasping the work order would not only be an attentive performance, but already a demand on one's concentration. Fulfilling the task then means challenging concentration only. Since stimuli have to be selected permanently throughout mastering the task, this also challenges one's attentiveness. Thus, the example shows that this perspective does not allow for a strict differentiation of concentration and attention performance.

Acknowledging the third approach in this study, a test embracing both attentive and concentrative abilities will be used for proving the positive effect of motion sequences on the students' cognitive abilities.

The importance of physical activity for cognitive performance

From a neurobiological point of view, there is a close connection between physical activity and the promotion of cognitive abilities. This is to be explained based on the brain's development (Busche, Butz & Teuchert-Noodt, 2006, p. 40). Findings on the maturing of neurons, neuronal networks, transmitters and hormones suggest that those do not only evolve in the pre- and perinatal stage, but also, in weakened form, throughout an individual's whole life which entails a continuous development of the brain. The maturation of transmitter pathways in sensorial and motoric areas is of great importance for the emergence of cognitive abilities.

Already during childhood an individual is provided with the necessary stimuli through crawling, walking and climbing phases and later due to balancing and swinging. On the basis of those early sensorimotor experiences, the fundamental connections between nerve cells are built, preserved and enhanced, which are required for lasting learning effects (Busche et al., 2006, p. 40). In that regard, coordination challenging movements seem to have a particularly positive impact on cognitive abilities.

Coordination is defined as the interaction of the central nervous system and skeletal muscles throughout a specific motion sequence (Hollmann & Hettinger, 2000, p. 132). According to Zimmer (2002), the performance of specific exercises with a high coordinative demand will make for a purposeful and environmentally adjusted connection of synapses (as cited in Kühner & Vaaler, 2004, p. 36). Hollmann and Strüder (2003) suggest that claims of that kind lead to a preservation of spare neurons which can be interconnected via synapse formation, thus implying positive effects on cognitive abilities (p. 266). If individuals are lacking those stimuli in early childhood, the neurons will be lost (Bomholt, Bruhin, Forster, Fugazza, Gehring, Laager, Maier, Scheidegger, Stäheli, Müller & Luder, 2008, p. 6) since there is a metabolic imbalance of dopamine and serotonin. However, both neurotransmitters are substantially involved in the dynamics and functionality of neuronal adjustment processes, which is why an imbalance leads to an inefficient restructuring of neuronal networks, thus having a negative impact on long-term cognitive abilities (Gasse & Dobbelstein, 2003, p. 4). The cerebral integration of motor actions also results in opening up additional information access for cognitive processes, and by that optimises information processing (Popp, Buttkus & Ungerer-Röhrich, 2004, p. 10).

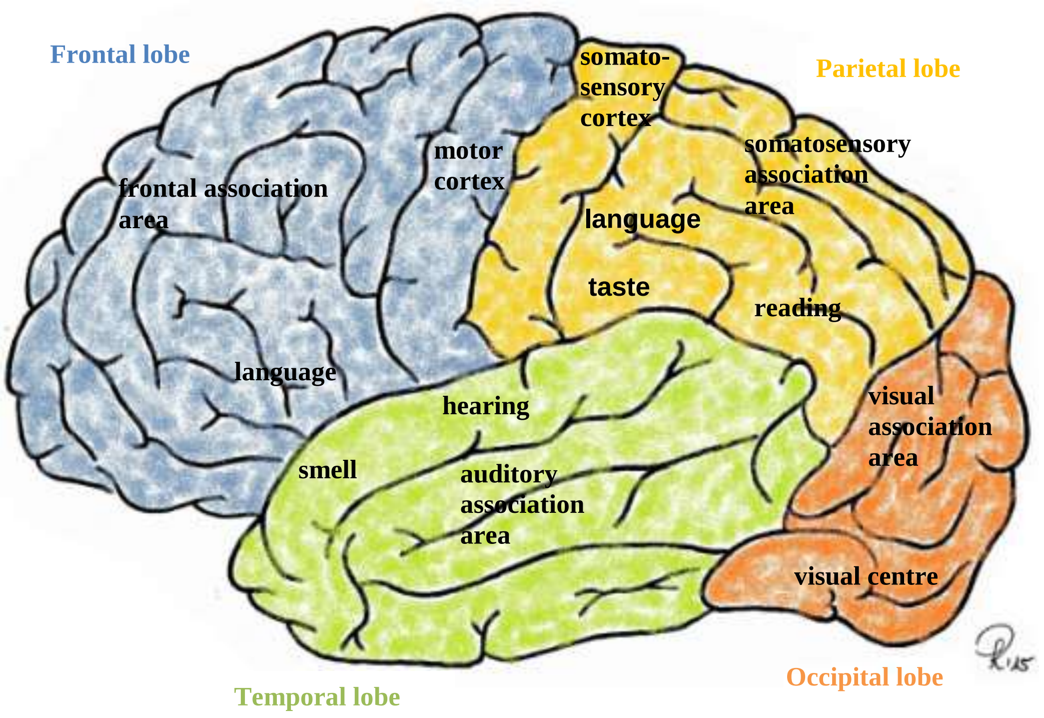

Figure 1. *The cerebrum's composition and functional arrangement*

The hippocampus is of major importance for performing cognitive tasks, such as storing and consolidating information. It is part of the limbic system and is situated below the cerebral cortex and maintains various nervous connections to other parts of the cortex, particularly association areas (Kühner & Vaaler, 2004, p. 35). As a result of movements, sensorimotor routines are integrated via feedback control processes of the limbic system. Hereby the hippocampus, the central structure of the control system, is reached by stimuli from the somatic and motoric cortex (see Figure 1).

From there on, the stimuli are transferred into signals for selective attention and learning. At the same time, the hippocampus sorts out irrelevant stimuli. Due to those selective processes, the neuronal networks of the hippocampus are subject to permanent remodelling. As this also implies the production of new cells, the cognitive performance improves to a great extent (Busche et al., 2006, p. 42). Apart from the enhancement of hippocampal plasticity, physical activity also influences the release of neurotransmitters. Additionally, motoric and sensory stimuli activate the ascending reticular activating system (ARAS) in the brainstem (see Figure 2), which leads to the release of dopamine.

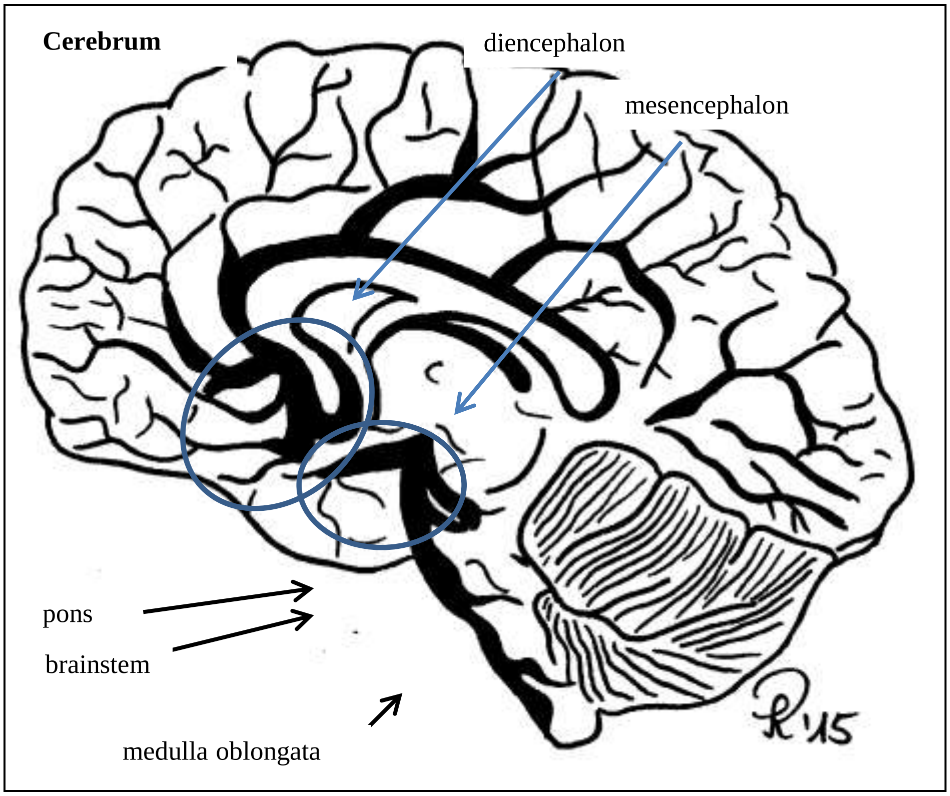

Figure 2. *Illustration of a human brain's main components*

Dopamine wields influence on the frontal lobe’s development by restructuring neuronal networks and synaptic connections. Since the frontal lobe is responsible for the deliberate control of learning processes, an adequate dopamine secretion is crucial for cognitive performance (Busche et al., 2006, p. 43).

As a consequence of long phases of sitting, as students usually experience them throughout a school day, or a general lack of exercise, the level of dopamine decreases. This yields a negative effect on the ability and joy of learning (Weineck, 2007, p. 6). Therefore, physical activity is a suitable way of promoting the release of dopamine and processes connected to that.

What also proves beneficial for the development of cognitive abilities is the purposeful learning of motor sequences. Being accountable for that, continuous feedback systems are executed in the sensory systems and the motor areas in the brain throughout the conduction of the movements that are to be learned. The motor cerebral areas are trained through those feedback processes, which comprises the basal ganglia, the motor cerebral cortex and the cerebellum. Particularly the latter one is heavily involved in cognitive performances (Busche et al., 2006, p. 43).

In order to bring all the previous findings together in the development of the motion sequences with the intention of positively affecting the students’ cognitive abilities, the motion sequences need to be coordinatively challenging. Also, they have to be learned by purpose and should ideally be increased in their efficiency as to initiate learning processes over a longer period of time.

Also physical-medical findings suggest positive effects of physical activity on cognitive performance. Hollmann and Strüder (2003) found that exercising on an ergometer, which resembles an aerobic dynamic endurance performance, leads to a significant enhancement in the circulation of different brain areas (20% on average) once the training load has been increased stepwise by 25 watts. They could also detect an increase in cerebral circulation with accumulative strain. However, this increase does not proceed in a linear way. Rather, the biggest difference of circulation was noticed in the transition from rest to light exercising (Hollmann & Strüdel, 2003, p. 265). Apart from the training’s intensity, circulation is also influenced by the extremities that are affected by the activity. The activation of fingers, for example, means a coordinative strain. Even though the hands only make for roughly 2% of the body mass, they represent nearly 60% of the cerebral cortex. Accordingly, finger movements such as playing the piano can lead to an increase of 20–30% in blood circulation in 60% of the cerebral cortex (Hollmann & Löllgen, 2002, p. 1380).

The heightened brain circulation has favourable effects on brain metabolism. In particular, this implies a better supply with oxygen and nutrients (especially glucose) which results in enhanced alertness. Due to the physical activity, some genes are stimulated and produce more nerve growth factors. Especially BDNF (brain-derived neurotrophic factor) and the corresponding mRNA are increasingly produced in the hippocampus, the cortex and the cerebellum (see Figure 1 and 3).

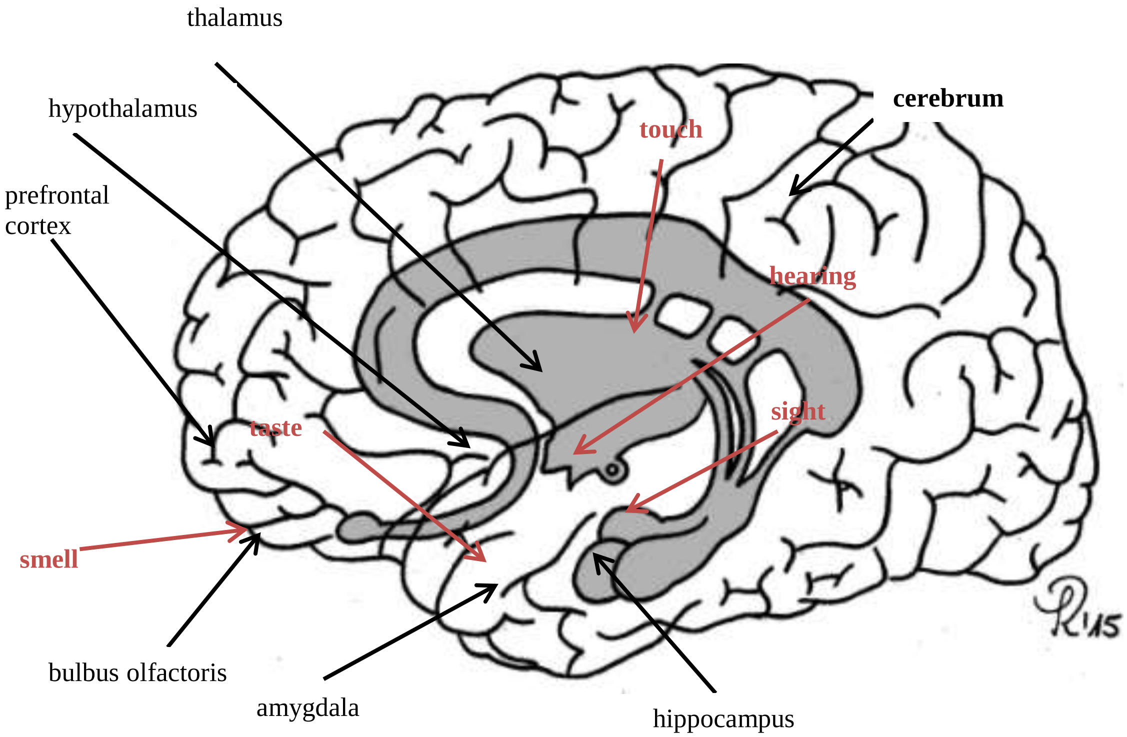

Figure 3. *The limbic system*

This nerve growth factor, a neurotrophin, supports the purposeful development of connections between neurons. The substance is particularly important for the cognitive functions in the hippocampus (Hollmann, Strüder & Tagarakis, 2003, p. 467). Hollmann & Strüber (2003) could also prove that persistent or coordinatively challenging movements stimulate brain activity. This involves an increased spine production, a heightened synapse development and neurogenesis. All those changes are positive since they make neurons more resistive and improve the overall cognitive functions (Hollmann & Strüber, 2003, p. 265).

The effects of physical activity on cognitive abilities mentioned above show that the cerebral blood flow increases mostly when there is a transition from rest to a light degree of strain. For the development of the motion sequences, this means that the intensity does not have to be very high in order to reach the effects aimed at. Also, one has to keep in mind that especially the highly challenging coordinative movements are associated with an increase in blood flow in the cerebral cortex.

The relationship between the ability to concentrate and physical activity

According to Gabler (1993), there is a close relation between attentive abilities and several other cognitive processes (p. 165). Also, there seems to be a connection between those aspects of cognition and the quality of special sportive abilities. This is why Memmert and Weickgenannt (2006) conducted research on sportive activity and the attention abilities of primary school pupils. They found that children who are highly active in any kind of sport show better results regarding their concentration (Memmert & Weickgenannt, 2006, p. 89). In the context of the CHILT project (= Children's Health InterventionaL Trial) this connection was further examined by looking at the attentive and coordinative abilities and the endurance performance via specific test forms (Graf, Koch, Klippel, Büttner, Coburger, Christ, Lehmacher, Bjarnason-Wehrens, Platen, Hollmann, Predel & Dordel, 2003, p. 242). 906 pupils of the ages six and seven participated in this large-scale study, proving that there is indeed a positive connection between the children's coordinative and attentive abilities. Those children who scored best in the test for attentive abilities (both qualitatively and quantitatively) also got the highest scores in the coordination test. However, this result could not be transferred to the relation of the endurance performance and attentive abilities. The authors concluded that there is only a positive correlation between concentrative and coordinative abilities (Graf et al., 2003, p. 245). Due to the results of the CHILT-project that have been presented before, it becomes obvious that the motion sequences for this study have to be designed in a coordinatively challenging way in order to achieve positive effects in terms of attentive abilities.

Those concentration abilities, however, are also influenced by other factors that are predominant on a school day. There are fluctuations to be observed that are attributed to circadian rhythms. According to Wamser and Leyk (2003), this is particularly accompanied by a decline in performance in the last few lessons of a school day (p. 111). Also, the pupils' age is an important factor regarding the quality of attentive abilities. Breithecker (2001) found that five to seven year olds are able to focus for approximately 15 minutes, whereas this number increases for another five minutes in seven to ten year olds. Pupils aged ten to thirteen are even able to hold their attention for 25 minutes (Breithecker, 2001, as cited in Popp et al., 2004, p. 10). If the common

45 - or 90 - minutes lessons at school are kept in mind, the necessity for a measure that counteracts the decline of attention becomes obvious. The motion sequences that shall serve this purpose will be presented next.

Deduction and description of motion sequences

Apart from the theoretical background and assumptions on the development of motion sequences, there will be highlighted the organizational aspects that have to be considered when implementing this measure into schools.

Theoretical background of the intervention's conception

The motion sequences that have been developed in the context of this study are thought to be integrated in school lessons in the form of a movement break. A movement break is a planned break during a lesson in which physical exercises are carried out (Müller & Baumberger, 2004, as cited in Bomholt et al., 2008, p. 4). This break interrupts the learning process and rhythmises it. The break can be understood as a preparation for the following cognitive phase and aims at exploring the pupils' full potential. Müller and Baumberger (2004) suggest three ways of integrating the movement breaks into a lesson (as cited in Bomholt et al., 2008, p. 4). The breaks that were planned for this study are to be done with the whole class, with the teacher prescribing the motion sequences and the pupils carrying them out afterwards. Throughout the movement break, different priorities can be set, such as 'stabilising joints', 'activating muscles', 'supporting well-being' or 'promoting concentration' (Müller & Baumberger, 2008, p. 18). Due to the study's research question, it was focused on exercises that help increasing attentive abilities. However, the motion sequences should not only foster the cognitive area, but also have a positive influence on other aspects. The theoretical background of the motion sequence is modelled on the guidelines of Lesniak (2005, p. 1). She suggests starting off a movement break with an activation phase which is followed by a phase of more coordinatively challenging exercises. The break is supposed to end in a sequence where the pupils calm down again.

The activation phase in this study is intended to start with the motion sequence 'Moving numbers'. This exercise aims at activating the cardio-vascular system by which the cerebral blood flow is increased and the pupils' alertness is heightened. It has to be kept in mind that already at the transition from rest to light physical activity a clear increase of cerebral blood flow can be observed. Also, this exercise will train the pupils' balance which is an important component of coordinative abilities (Meinel & Schnabel, 1998, p. 217).

The second phase sees four coordinative exercises to be carried out. They are ‘Standing on one’s heels and balls of the foot’, ‘Lying 8’, ‘Opposing shoulder rotation’ and ‘Finger-tipping’. The choice of exercises is based on the fact that they all foster balancing abilities. According to Birbaumer and Schmidt (1999), it is particularly proprioceptive stimuli like they occur during balance-challenging tasks that activate the ascending reticular activating system (ARAS) (as cited in Dordel & Breithecker, 2003, p. 8). If those exercises are carried out regularly, the attentive ability and the learning performance will increase (Dordel & Breithecker, 2003, p. 8). The ‘Lying 8’ also fosters the connection of the right and left brain hemisphere, which might resolve learning blockage and optimise learning outcomes (Dennison & Dennison, 2002, p. 12). The phase is finished off with a partner exercise called ‘Finger-tipping’. Not only does this task pose a high demand on one’s coordination, it also results in an increase of cerebral blood flow due to the fingers having a great motoric share in this exercise. The end of the movement break sees several sequences which make the pupils come to rest again, such as the relaxation exercises ‘Estimating time and progressive muscle relaxation’ and ‘Thinking cap’ which then facilitates the beginning of the following cognitive phase.

After depicting the basics about the compilation of motion sequences, the focus is now on organisational conditions which have to be considered when implementing the sequences into schools. The exercises have to be designed in a way that they can easily be integrated into the lessons. In this study, they were introduced into a double period, where it seems ideal to conduct the motion sequences after the first lesson or after a comparatively long cognitive phase as the ability to concentrate decreases rapidly. It has also to be kept in mind that the performance should not take too much time, which is why in this study the number and duration of motion sequences is adapted to an overall time of five to eight minutes (Böing, 2005, p. 7). In order to make use of motion sequences in a quick and uncomplicated way, the exercises should not require too big a logistic and material effort. Therefore, the exercises in this study manage without any desks being moved or additional material being required.

A crucial aspect for the success of the motion sequences is the pupils’ participation. They should be informed about the sense and purpose of the undertaking. Further, it can be helpful to name the exercises so that time on explanations is saved and the pupils find it easier to orientate themselves. Attention should also be paid to the fact that the level of difficulty of the exercises has to be constantly increased in order to maintain a high coordinative demand.

The motion sequences used in movement breaks

The motion sequences will be presented in the order of implementation in the lesson.

a) Activation exercise:

Moving numbers

In the beginning, certain numbers are assigned to certain positions.

1: moving the right knee to the left elbow until they meet

2: moving the left knee to the right elbow until they meet

3: standing on the balls of the foot and lifting the arms upwards

4: shifting the bodyweight to the heels so that the tips of the toes are clearly raised from the floor

Starting with the basic position, the pupils are dynamically walking on the spot. Once the teacher calls one of the numbers, the pupils have to change to that particular position as quickly as possible and remain there until the teacher tells them to walk on the spot again.

Variation possibilities:

- The exercises are conducted with the eyes closed.
- Each position is assigned a colour apart from the number.

b) Exercises for improving coordination:

Standing on one’s heels and balls of the foot

On the teacher’s command, the pupils lift the tips of the toes of their right foot while standing on the ball of their left foot at the same time. The pupils hold this position until the teacher indicates a change.

Variation possibilities:

- The exercise is conducted with the eyes closed.

Lying 8

While standing, the pupils move their right stretched arm forward at eye level. Also, the index finger is stretched. Starting from this position, they draw a lying eight with an anti-clockwise movement. The eyes follow the movement of the index finger.

Variation possibilities:

- The exercise is conducted with the left arm.

- The size of the lying 8 is changed.

- The pupils carry out the exercise while standing on one leg.

Opposing shoulder rotation

From a shoulder-wide starting position, the pupils abduct their stretched arms at shoulder height. One arm now rotates forward, whereas the other arm rotates backward.

Variation possibilities:

- The arms change the rotation direction.

- The pupils carry out the exercise while standing on one leg.

Finger-tipping

This exercise is conducted with two pupils sitting next to each other. One of them closes the eyes and puts the right hand on the desk. The other pupil tips consecutively on two of the other's fingers with his index finger. Now the pupil with eyes closed has to raise the two fingers that perceived the tactile stimulus. After five rounds the pupils switch their task. The pupil responding correctly to most of the stimuli is the winner.

Variation possibilities:

- Both hands are on the desk.

- The arms are crossed in front of the body before the hands are put on the desk.

c) Relaxation exercises

Estimating time and progressive muscle relaxation

The pupils stand in front of their chairs with eyes closed. They lift the elbows to shoulder height and close their hands. From this position, they move the shoulders backwards as far as possible and try to pull their elbows outwards. After a start signal (teacher looks at the watch!) they try to hold the position for exactly 30 seconds. When the time is over according to the pupils' estimate, they sit down on their chairs silently. The pupil who is closest to the real 30 seconds is the winner.

Thinking cap

Sitting on their chairs, the pupils close their eyes and massage their earlobes for 30 seconds. The teacher sets the time.

After the presentation of the motion sequences, the next part focuses on the research question and the hypothesis of this study.

Research methodology

First, the time course and the subject group will be presented. A second focus will be on the design of the biology lessons, where the motion sequences were implemented. Also, the evaluation instruments for the quantitative data analysis will be looked at.

Hypothesis

Due to the disappointing results in the PISA study, this study aims at developing measures for a heightened learning performance in school. Since there is a direct connection between school performance and the ability to concentrate, a method for enhancing attentive abilities during lessons is to be found. For attentive abilities belonging to cognitive abilities which can be positively influenced by physical activity, the question arose whether conducting motion sequences in school can increase attentive abilities and thus lead to a better cognitive performance.

This undertaking was implemented for a four week test phase at a secondary school in Bielefeld, Germany, where the self-designed motion sequences were deployed in 6th-grade Biology classes. In the context of the study, the following hypothesis was to be tested: *The conduction of motion sequences during the lesson will have positive effects on the pupils' concentrative abilities.*

Participants

The overall amount of participating pupils was 55. The treatment class consisted of 27 pupils (10 girls and 17 boys) with the average age of 11.96 (+/- 0.518) years. 28 pupils (15 girls and 13 boys) visited the control class and were of the age 11.75 (+/- 0.441) years.

Time course

As can be seen from Table 1, the intervention stretched over four weeks. A 6th grade class with pupils aged 11 to 13 was the subject of the study, with their Biology lessons lasting from 2.15 p.m. to 3.45 p.m. once a week. In order to create as authentic a teaching situation as possible, the Biology lessons were taken over completely by the author of the study for the time period of four weeks.

Table 1: Time course of the study

Date	***Activity***
03/06/09	***TREATMENT CLASS*** *First double lesson of the intervention (topic: amphibians)* *Conduction of d2 test* *Implementation of motion sequences*
10/06/09	***TREATMENT CLASS*** *Second double lesson of the intervention (topic: amphibians)* *Implementation of motion sequences*
16/06/09	***CONTROL CLASS*** *Conduction of d2 test*
17/06/09	***TREATMENT CLASS*** *Third double lesson of the intervention (topic: reptiles)* *Implementation of motion sequences*
24/06/09	***TREATMENT CLASS*** *Fourth double lesson of the intervention (topic: reptiles)* *Conduction of d2 test (retest)*
30/06/09	***CONTROL CLASS*** *Conduction of d2 test (retest)*

The four double periods available for the study were divided into two lessons dealing with amphibians and the other two dealing with reptiles. The motion sequences were carried out in every double period after a cognitive phase, approximately after 40 to 50 minutes of teaching. After having done the exercises together, the lesson continued with the respective topic. As homework the pupils were asked to practice the motion sequences individually.

In order to check the motion sequences' effect on the ability to concentrate in the treatment class, the pupils conducted the *d2 test of attention*, a concentration endurance test, in the first and the last double period. The first test was implemented after 50 minutes, right after a considerably long cognitive phase. The test was followed by the motion sequences in this lesson. As opposed to this, the retest was done 30 seconds after finishing the motion sequences. To obtain further quantitative data about the intervention and the pupils' perception of it, the children had to fill in a questionnaire in the last double period.

For enhancing the validity of the data gathered in the concentration test, the test was also carried out twice in a control class, each time after a cognitive phase.

Evaluation instruments

In order to check this study's hypothesis, the concentration endurance *test d2 test of attention* was carried out. Further, questionnaires were used to obtain quantitative data. Both instruments and the statistical methods are presented in this chapter.

Description of the d2 test of attention

In order to make assumptions about the pupils' ability to concentrate, which is a prerequisite for a high performance level, the *d2 test of attention* by Brickenkamp (2002) was conducted (p. 6). According to Schorr (1991), this test is the most commonly used in that context (as cited in Wamser & Leyk, 2003, p. 109). An advantage is the great span regarding the age group which can be covered with the test, meaning that people between the ages of nine and 59 in various fields of work can be tested. The testing procedure is also suitable for diagnosing the pupils' concentration performance in school (Dordel & Breithecker, 2003, p. 8). First, the test design will be described, and secondly, there will be verified the three main quality criteria, namely objectivity, reliability and validity. Also, the suitability for school purposes will be evaluated.

Test design

The *d2 test of attention* belongs to the category of general performance tests, which means that no special abilities or skills are expected. It is a cancellation test consisting of 14 test lines with 47 symbols each. There is a total of 16 different symbols which are all the result of a different combination of the letters 'd' and 'p' and one, two, three or four dashes. The task is to cross out as many 'd's with two dashes per line as possible in 20 seconds. The 'd's with two dashes are called 'relevant stimuli' whereas the others are irrelevant. The frequency of occurrence of relevant to irrelevant stimuli is 1 : 1.2 (Brickenkamp, 2002, p. 15). Thus, the test measures the ability to focus on relevant stimuli while shielding irrelevant stimuli. It requires a concentrative focus on external visual stimuli, which is realised due to the individual coordination of incentive and control function. While the incentive function is measured by the quantity of the processed material in the predefined time, hence the work pace, the control function is equate with the quality of work, meaning the accuracy and the number of mistakes (Brickenkamp, 2002, p. 6).

For the analysis of the test, the following variables were surveyed (Dordel & Breithecker, 2003, p. 9):

- TN = Total number of symbols processed

  This value is considered the work pace. For the determination of the TN value, all symbols are counted, regardless if relevant or irrelevant.

- E = Total number of errors

  This value is composed of the sum of omission errors (E1) and confusion errors (E2). The former means relevant symbols that were not crossed out, whereas the latter concerns irrelevant symbols that were crossed out by accident. The total number of errors is employed for making statements on the precision with which the test was conducted.

- OP = Overall performance

  The overall performance describes the number of symbols processed after subtracting the errors. It is used for evaluating the quantitative performance aspect.

- CP = Concentration Performance

  This value arises when subtracting the number of confusion errors (E2) from all the relevant symbols that were crossed out correctly. The value is used for the evaluation of the qualitative performance.

When analysing the test the variables mentioned before are collected for every line before they are added up so that there is a total result for every variable. This value can be compared to the results of class mates, or else be transferred into a special standard table which allows the comparison of test results and certain variables with values of an age-matched sample.

Description of the main quality criteria

Regarding objectivity, the test is equipped with clear instructions and stencils for test evaluation. Various samples are provided for the comparison and interpretation of results. This study relates its results to the sample of 3251 subjects of the ages nine to 60. The division into age-group specific standard tables allows for the comparison of the group tested in this study (average age of 11.96 and 11.75 years) with the values of the age group 11 to 12.11 years (Brickenkamp, 2002, p. 60). The sample consists of 404 subjects who attended any kind of secondary school (Brickenkamp, 2002, p. 93) and provides an objective reference.

Various authors have already conducted reliability checks for the *d2 test*. Regardless of the sample size the reliability coefficient r was always higher than 0.90 (Brickenkamp, 2002, p. 29). The reliability coefficient for the variables TN, OP and CP was particularly high. The variables “total number of errors” (E) and “relative number of errors” (E %) generated good reliability. All the parameters displayed a high stability in retests so that also multiple application of the test will obtain comparable data (Brickenkamp, 2002, p. 28). Thus, the *d2 test* also fulfils the second main quality criteria.

The test’s validity constitutes itself primarily through self-observation by the test subjects. Test persons distinctly stated that the test requires a high degree of concentration (Brickenkamp, 2002, p. 30). Also, the basic pattern of the test is consistent with basic patterns of many other (vocational) activities. The ability of selective attention and concentration is of utmost importance for excellent performance at school. Several studies have investigated the test's construct validity by examining the correlation between the variables of the *d2 test* and construct convergent tests with the value for validity arising from the degree of compliance. According to Brickenkamp (2002), there is a significant correlation of up to 90% between *d2*-variables and those of other concentration tests (p. 34).

Suitability for school purposes

The *d2 test* is adequate for usage at school for various reasons. On the one hand, there is a standard table for tested pupils, which makes the values comparable. On the other hand, the test is very economical, requiring only the test paper, a pencil and a stop watch. It is thus practicable in about ten minutes, including first-time standardised instruction while the actual test time amounts to 4:40 minutes. The whole class can conduct the test at the same time without using up too much teaching time. What is another big advantage of this test is the possibility to use it for retests since there is no training-dependency detectable (Dordel & Breithecker, 2002, p. 13).

Questionnaire design

Apart from the *d2 test of attention*, there was a questionnaire developed for obtaining more pupil-relevant data. It was filled in by the treatment class in the last lesson. Since the questionnaire was self-developed, there was no reliability check conducted. The questions focused on subjective assessment of attentive and concentrative abilities and the intervention's efficacy. Further, the pupils were to assess the motion sequences so as to learn about which exercises have been carried out willingly.

Results

In the following, the previously formulated hypothesis will be examined and the questionnaire for the pupils will be analysed.

Description of the results for the review of the hypothesis

The following hypothesis was the basis for the context of this study: *The conduction of motion sequences during the lesson will have positive effects on the pupils' concentration abilities*.

Firstly, the mean scores of the *d2 test* for both classes at the first test event will be described. For that purpose, the data has been classified age-specifically by comparing the values with those of the age-matched sample. Also, the relevant variables amongst treatment and control class will be compared. With the help of a t-test, the significance of the results will be tested. A two-way analysis of variance (ANOVA) is used for determining whether the attentive abilities have changed over time in one class only and when comparing both classes.

The mean scores of the variables OP (overall performance) and CP (concentration performance) for testing point of time t_1 are also compared to the age-matched sample.

Table 2. *Classification of the raw values (RV) for overall performance (OP) and concentration performance (CP) in percentile ranks (PR) and standard values (SV) on the basis of age-matched pupils from the norm table* (Brickenkamp, 2002, p. 93).

	Treatment class			**Control class**		
number	n = 27			n = 28		
Variable	RV	PR	SV	RV	PR	SV
OP	376,72	77,93	109,96	349,79	69,32	106,54
CP	150,15	78,26	109,89	137,5	68,5	106

It becomes apparent that both classes scored above average for OP and CP when compared to the age-matched sample. Just about 22% of the test pupils of the norm sample achieved higher scores than the treatment class on average. Also the control class pupils attained above average results. Their mean value of overall performance is higher than for 69.32 % of the age-matched sample. With regard to concentration performance they scored better than 68.5 % of their age-equivalent.

The raw data (RV) can also be compared to the standard values (SV), which proves the tested pupils' middle position compared to the age-matched sample. The average value of the standard value was 100, with a standard deviation of 10. Table 2 shows that both classes also scored above average for this category. Pupils of the treatment class achieved almost 110 for both variables whereas the control class achieved 106.

When comparing both classes at test point t_1, pupils of the treatment class obtain slightly better scores for all variables than the pupils of the control class. In order to check whether those results are random or not, a t-test for independent samples was conducted. On average, pupils in the treatment class processed more signs in the given time (TN; p = .072) and made less errors (E; p = .604). The difference in those variables may have emerged randomly.

By subtracting the errors from the total number of symbols processed, the overall performance becomes apparent. This value allows for a statement about the incentive of doing the test.

Table 3. *Comparison of the mean values (MV) of the raw values for the tested variables of both classes at test point t_1*

	Treatment class		**Control class**	
Number	n = 27		n = 28	
Variables	MV	SD	MV	SD
TN	393,59	56,28	365,04	59,02
E	16,89	13,18	18,82	14,27
OP	376,72	54,18	349,79	50,04
CP	150,15	23,22	137,5	19,46

Table 3 suggests that pupils from the treatment class have processed 27 more symbols on average than pupils of the control class. This difference, however, is not significant ($p = .061$).

Focusing on the average CP-value, both classes differ. Pupils in the treatment class crossed out more relevant symbols (d with two dashes) and made less confusion errors (E2), meaning that they conducted the test with more accuracy. A t-test proves the significance of this difference between the classes ($p = .033$).

Now, possible differences between the two classes at the time of the examinations will be analysed. This will be carried out separately for both the attention and concentration abilities. When comparing the mean values of the OP-scores, the greatest effect is that those values were significantly increased at the second time of measurement regardless of class affiliation ($F_{1,53}= 373{,}94$; $p< .001$; $\eta^2= .876$) as can be seen from Figure 4.

Looking at the development of both classes at the different times of measurement, it is always the treatment class that has higher scores at both times for the quantitative aspect (OP) (see Figure 5). Yet, the control class could further achieve better results in the second phase. There are slight differences to be detected for the development over time between the two classes. The treatment class was able to correctly process 70 symbols more on average at t_2 compared to t_1. It could be found that the control class crossed out another three additional symbols compared to the treatment class at t_2, which, however, does not make a significant difference (tests on within-subject effects → time of measurement * class, $F_{1,53}= 0{,}179$; $p= .674$; $\eta^2= .003$).

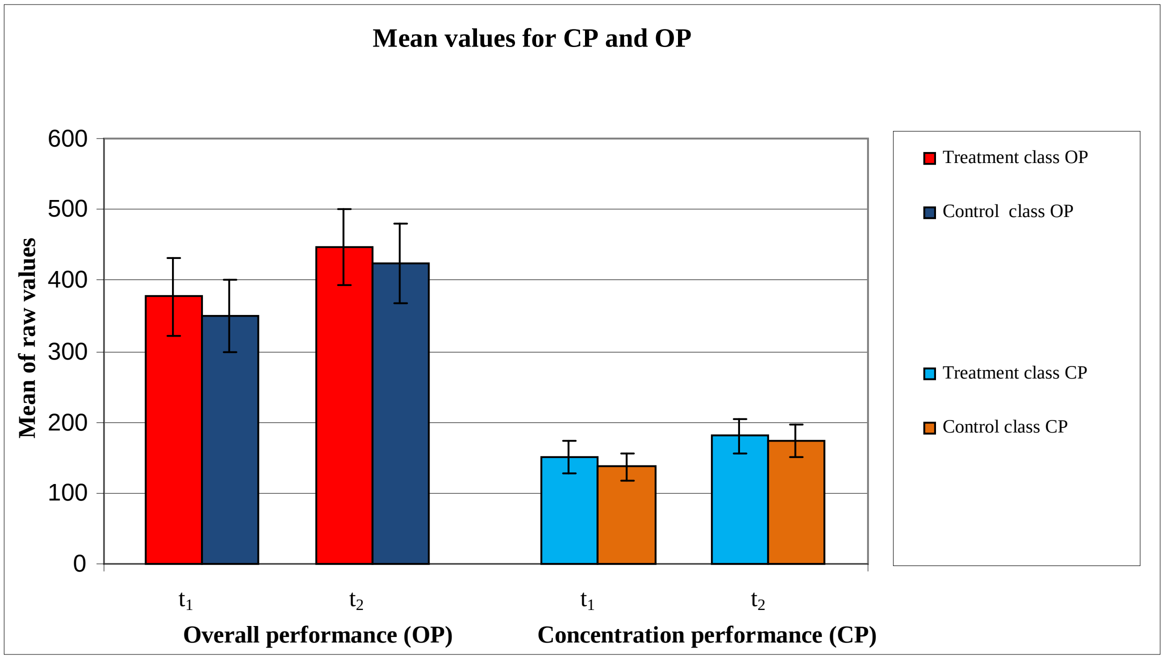

Figure 4. *Representation of the mean values for the quantitative (OP) and qualitative (CP) aspect of the attention and concentration performance in both classes at both measurement times. The abscissa shows the different measurement times for both variables, whereas the ordinate states the mean of the raw values for both classes.*

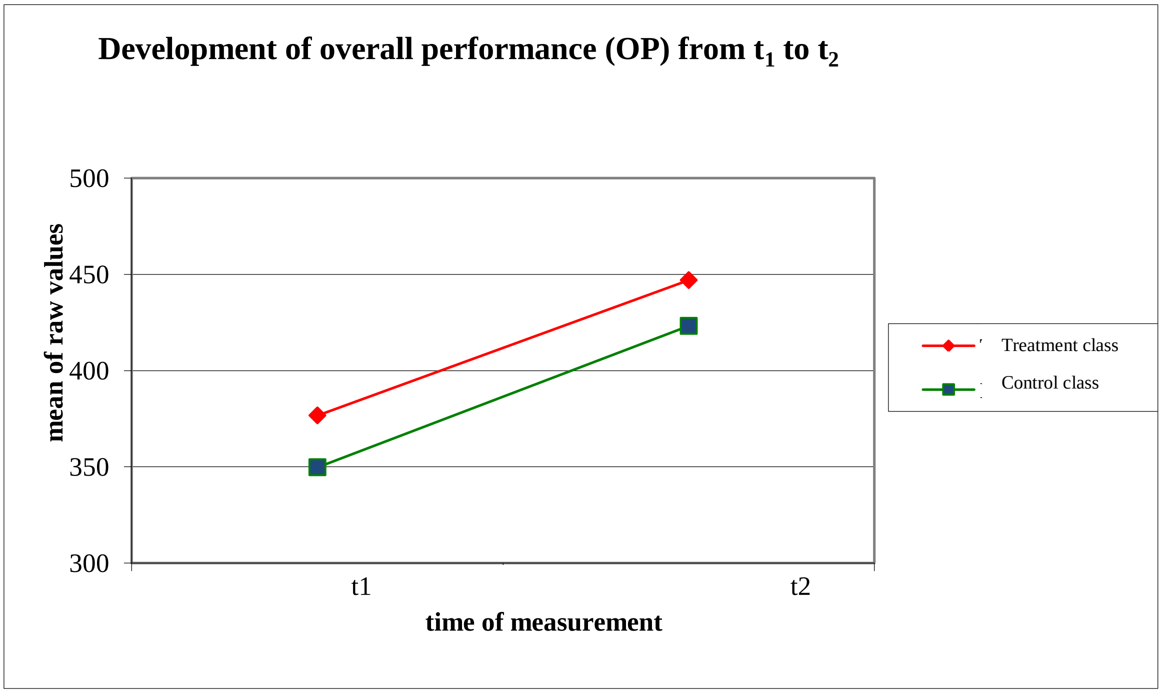

Figure 5. *Depiction of the development of the overall performance (OP) of both classes over the two measurement times. The abscissa shows the points of time of measurement and the ordinate the mean of the raw values of all test subjects.*

If the focus is on the overall performance itself, regardless of the time of measurement, it becomes apparent that there are differences between the two classes. The treatment class' pupils processed a mean of 824 symbols correctly when both measurements are added, whereas pupils of the control class crossed out a mean of 773 d's. However, this difference is not significant (tests on between-subject effects, $F_{1,53}$= 3,303; p= .075; η^2= .059).

Similar results can be detected when looking at the qualitative aspect, namely the concentration performance (CP) (see Figure 6). The raw value increases significantly towards the second measurement independent of class affiliation (tests on within-subject effects → time of measurement, $F_{1,53}$= 300,50; p< .001; η^2= .850).

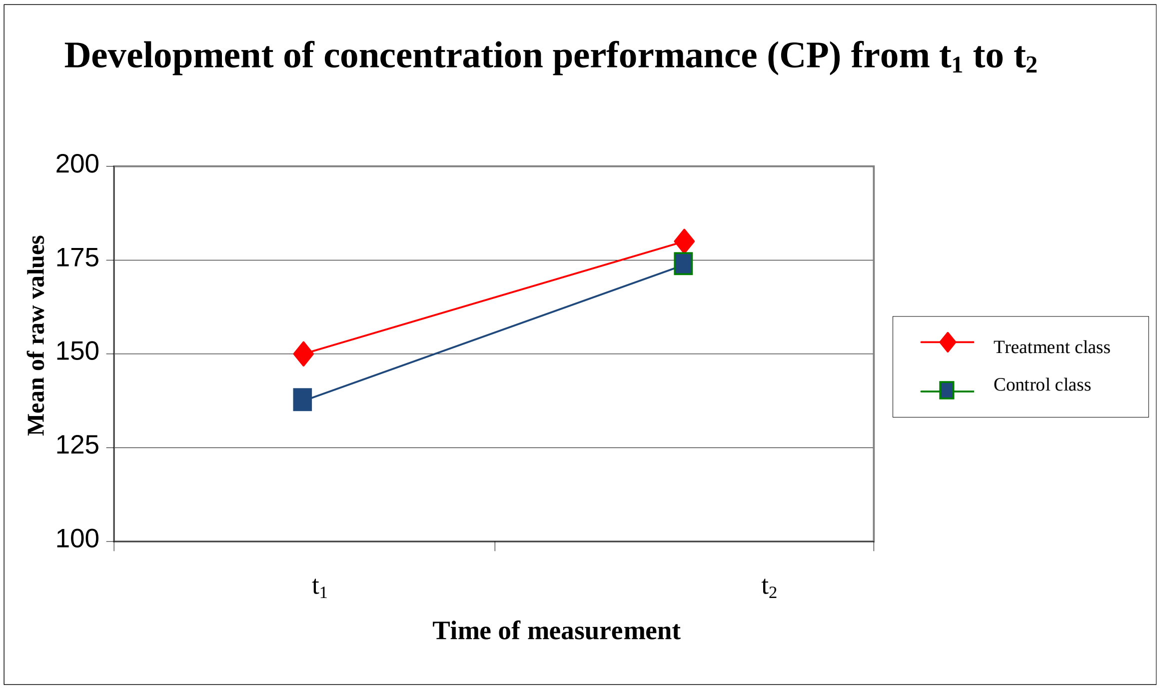

Figure 6. *Depiction of the development of both the classes' concentration performance (CP) over the two measurement times. The abscissa shows the points of time of measurement and the ordinate the mean of the raw values of all test subjects.*

When analysing the interaction of time of measurement and school class, the concentration performance score for the treatment class stands out. It is located at a generally higher level than for the control class, but the latter undergoes a greater change from measurement t_1 to t_2.

After subtracting the confusion errors (E2) at the time of measurement t_2, the treatment class crossed out 30 relevant symbols, whereas the control class achieved a score of 36 relevant symbols being crossed out correctly. Comparing the development of the variable CP from t_1 to t_2 between the two classes, no significant difference can be detected (tests on within-subject effects → time of measurement * class, $F_{1,53}$= 2,39; p= .128; η^2= .043). If further considering the CP-values irrespective of class affiliation, the treatment class arrived at a score of 330 crossed-out symbols compared to the control class with a mean of 311 symbols, after subtracting confusion errors, which again does not make a significant difference (tests on between-subject effects → $F_{1,53}$= 2,93; p= .093; η^2= .052).

Taken all together, the two classes show no significant differences in the attention and concentration scores up to t_2 which is why the previously stated hypothesis has to be discarded. This might be due to several disturbance variables which will be discussed in more detail later.

Results of the pupils' questionnaire

This paragraph focuses on the subjective views of the pupils on the intervention. The answers for question 1 suggest that the treatment class considers it necessary to execute means of raising the attention and concentration performance, with 88.5 % of the pupils stating that they have focus-related problems during teaching phases, sometimes or even often. A prevailing number of pupils is thus convinced that the motion sequences had positive effects on their concentration. After having completed the exercises, 69.23% of the pupils felt more capable of participating in the Biology lessons and 92.3% actually enjoyed doing the motion sequences in their lessons. The positive response can be construed from the fact that 80.77% of the pupils desire the continuation of the motion sequences. They were also asked to give feedback on the individual exercises.

Table 4. *Depiction of the answers on how the pupils liked the single motion sequences expressed as a percentage*

No.	Motion Sequence	very good	good	alright	not at all
1.	Moving numbers	12%	64%	20%	4%
2.	Standing on one's heels and balls of the foot	40%	28%	32%	
3.	Lying 8	16%	32%	48%	4%
4.	Opposing shoulder rotation	32%	28%	28%	12%
5.	Finger-tipping	52%	32%	16%	
6.	Estimating time and progressive muscle relaxation	48%	40%	12%	
7.	Thinking cap	44%	24%	20%	12%

Each time, the motion break was commenced with the exercise ‘Moving numbers’ which serves as an activation of the cardiovascular system. Not only had the pupils to perform the exercise, but they also had to take up a certain position depending on the number. 76 % of the pupils rated this task as very good or good. The following three motion sequences were thought to help coordination. First, ‘Standing on one’s heels and balls of the foot’ was carried out, which 68 % of the pupils liked (answered with ‘very good’ or ‘good’). As the second exercise for coordination, the ‘Lying 8’, was not evaluated as positive as the tasks before. Roughly 50% of the pupils rated this exercise very good or good. The other half considered it acceptable (‘alright’). The third exercise of this block was ‘Opposing shoulder rotation’, which again gained 60 % positive remarks (‘very good’ or ‘good’), whereas 28 % assessed it as acceptable (‘alright’) and 12 % did not like it.

To end the motion break, three relaxation exercises were carried out. ‘Finger-tipping’ was very popular among the pupils (84 % rated it ‘very good’ or ‘good’). Similarly popular was the task ‘Estimating time and progressive muscle relaxation’ with 88% of the pupils rating it ‘very good’ or ‘good’. Still 68% of the pupils liked the final exercise ‘Thinking cap’.

To come to a conclusion, one can say that the subjective perception of the exercises was predominantly positive. They brought joy and a welcome change to the regular school day. Further, the pupils acknowledged being more focused after performing the exercises.

Discussion

It should be noticed that the subject group of 55 pupils and only 27 subjects in the treatment class is rather small, meaning that the interpretation of the results thus has to be considered with great care. For the comparison of the *d2 test*-results with the age-specific sample, it was found that both classes achieved results above average. This might be explained by the fact that the age-specific sample was more heterogeneous since children from all the different German school types (three-tier school system) were represented there, whereas the classes investigated for this study were at a grammar school.

If associating the results for the different variables of concentration performance at t1 and t2, it became apparent that, on average, the treatment class achieved better results than the control class. However, the close analysis with a t-test yielded that those differences could also have been of random cause. This would imply pupils in the treatment class having a generally higher attention ability or alike. It might also be possible that the test results were influenced by external factors since the testing conditions at measurement point t1 were different for both classes. As the *d2 test* was planned to be conducted after a longer cognitive phase, this coincided with the topic of ‘sexual education’ in the control class, which seemed quite restless at measurement t1. This vibrant behaviour could also be observed throughout the testing phase and might have contributed to the control class’ poor results in the first test.

Significant differences between the two classes could be attested to the accuracy with which the test was performed, represented by the variable concentration performance (CP). Still, it has to be kept in mind that this variable was possibly influenced by the aforementioned conditions, making for very different base levels of the two classes.

In order to verify or falsify the hypothesis, a two-way analysis of variance for the variables overall performance (OP) and concentration performance (CP) was conducted. Since it could be found that the test results for OP and CP significantly increased regardless of the class affiliation, it can be assumed that learning effects emerged at measurement point t_2, even though those are not foreseen (Dordel & Breithecker, 2003). When looking at the test results subject to the class, both increased their performance for both variables towards t_2. Further, there were no significant differences between the two classes and their concentration performance regardless of the point of time of measurement. This result might be a surprise as it was not expected that the concentration performance in the control class would develop as positively as in the treatment class. Possible test learning effects and the testing conditions at measurement point t_2, however, may explain this result. It was initially planned to compare the results from t_2 of the treatment class (gathered 30 seconds after finishing the motion sequences) with the results of the control class after a considerably long cognitive phase. Unfortunately, the retest could not be conducted at the agreed date due to a school event. The alternative option for the retest was at the beginning of a sports lesson, which implied that the pupils had been physically more active prior to the test than pupils of the treatment class. Also, they did the test after a short break between the lessons, thus not directly after a cognitive phase. These circumstances may have contributed to the fact that the test results are quite similar for measurement point t_2. Therefore a comparison of the retest data is irrelevant so that the hypothesis can neither be rejected nor verified by our study. Anyhow, the data can be interpreted as being an indicator for a heightened concentration performance once physical activity is integrated into the lessons. A possible explanation for that might be the increase of cerebral blood flow being stimulated by the motoric activity.

Findings like this have already been proven by several other international studies. Wamser and Leyk (2003), for example, found that a four-minute aerobic programme integrated in their lessons resulted in an instant enhancement of attention and concentration abilities (p. 110). Another pilot study by Dordel and Breithecker (2003) could prove that third grade pupils who participated in a ‘moving school day’ (including motion sequences) on a regular basis achieved better results for concentration and attention than other third graders (Dordel & Breithecker, 2003, p. 13). Both studies were carried out over a short time only, but also used the *d2 test of attention* by Brickenkamp. A study by Müller and Petzhold (2006), on the other hand, followed middle school pupils over a longer period of time, with 155 of them conducting movement exercises regularly. Their attention and concentration performance was then compared to 128 control pupils. In order to assess the motion sequences’ influence on the development of the attention and concentration abilities over a time span of five years, the pupils conducted the *d2 test* once a year. Müller and Petzhold (2006) found that those pupils who were regularly engaged in the motion sequences throughout the lessons achieved the highest scores for their concentration performance. They concluded that physical activity throughout the school day also has long-term effects on the increase of attention and concentration abilities (Müller & Petzhold, 2006, p. 118).

These positive findings, however, should be treated cautiously since just recently the provisional results of a large-scale study have been published (Fessler, 2006, p. 234). That particular study was oriented towards the conception of Dordel and Breithecker’s study (2003), but has been extended by a few additional factors. Consequently, a greater sample of test subjects was used, a real control group was initiated and the authors made use of a test-retest design, resulting in a test group of 900 pupils of different ages. The interim findings do not suggest any connection between motor activity and cognitive performance since the differences between control and treatment class were not significant.

Considering the latest results and findings from other studies, one can say that there is quite heterogeneous data to find neither verifying nor falsifying the correlation of physical activity and the rise of attention abilities.

Returning to the study presented in this paper, the questionnaire used to obtain personal feedback from the pupils proves that the intervention was perceived very positively on different levels. Almost 70% of the pupils stated they found it easier to concentrate in Biology lessons after having conducted the motion sequences. An overwhelming majority of the pupils also immensely enjoyed the exercises and 80 % stated they would appreciate a continuation of the motion breaks. Even though the data obtained via the *d2 test* could not prove the intervention’s effectiveness, the pupils’ remarks emphasise the necessity of having movement breaks in regular school settings nevertheless.

Other studies also underline the positive effects that occur due to motoric activity in school lessons. Eggert, Schuck and Wieland (1975) claim a positive correlation between targeted promotion of motor activities in the lessons and an improvement of school performance. The authors explain this by a motor-induced relatively higher contentment with school life. Also, with a bigger proportion of physical activity, self-esteem and frustration tolerance rise (Eggert, Schuck & Wieland, 1975, as cited in Dordel & Breithecker, 2003, p. 6). Moreover, aggressive behaviour can be reduced when children are offered possibilities to be on the move on a daily basis, which again increases their motivation to go to school. Another considerable effect of the additional movement time is the improvement of the social climate outside the classroom (Bös, 2001, as cited in Gasse & Dobbelstein, 2003, p. 3).

Outlook

If the research question of this paper should be further picked up, some criteria have to be considered that could not be realised in this study. It is inevitable to base the investigation on a greater number of test subjects over a longer period of time. It is recommended to research this issue for at least three to four months, throughout which the motion sequences should be carried out on a daily basis (Illi, Breithecker & Mundinger, 1998, p. 99). It would further be interesting to measure the effects across various school years and ages. Thus, the frequency of the conduction of motion sequences should be increased. Another factor to pay attention to is equal test conditions for the different test groups, also taking into account the exact time of day since concentration performance is subject to circadian rhythms. Results may also differ if another evaluation instrument is used as with the *d2 test*, the learning effects would be recognised. If it were possible to test the pupils individually and over a longer testing period, the vigilance test could be a valid alternative. It is a computer-based test with a bright flashing point on a circular path, jumping one step further, and sometimes doing double-jumps which have to be noticed by the test subject. Depending on the sample size, this test can last between 30 and 70 minutes, so that the attention abilities over a considerably longer period of time, compared to the *d2 test*, are measured (Amelang & Schmidt-Atzert, 2006, p. 186).

Taking all these modifications into account, the research question could be discussed again with more significant data in the near future. A last practical remark should be made on the applicability of motion sequences in schools. Before implementing the exercises in the lessons, the pupils have to be informed about the intention of this intervention so that they can engage in the correct conduction of the motion sequences in a motivated way. In the common school routine, the exercises should be carried out once a day, preferably after a cognitive phase, for rhythmisising learning phases or in the preparation of a class test. In general, the choice of the moment of implementing the exercises depends on the state of learning, motivation and concentration in a particular class (Böing, 2005, p. 7). While carrying out the sequences, the windows of the classroom should be opened so that the higher oxygen content might positively influence the exercises' effectiveness.

Introducing the exercises can take a while, but the actual conduction of them should not take more than five to eight minutes. With increasing practice, naturally more exercises can be carried out in one lesson. If all the tasks are fully mastered by the pupils, they should be modified in order to keep setting adequate stimuli. For the pupils to engage in the intervention with the right level of motivation, it is important that the teacher also shows a positive attitude towards this measure. The motion breaks should never be regarded as an interruption of the lesson, but as a meaningful way of positively influencing the learning ability.

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