Sensorimotor Therapy: Assessing Quantitative and Qualitative Expressions of Physiological and Psychological Development in Children

Mats Niklasson

Faculty of Arts and Social Sciences

Psychology

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This licentiate thesis is dedicated to all persistent children and their brave parents who made these studies possible. It is also dedicated to Emma who made it possible for Irene and me to develop Vestibularis.

Licentiate thesis: Sensorimotor therapy: Assessing quantitative and qualitative expressions of physiological and psychological development in children.

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Abstract

The first purpose of this thesis was to examine whether sensorimotor therapy utilizing the training program "*Retraining for Balance*" might be an appropriate technique for sensorimotor proficiency. The second purpose was to gain increased understanding of the effects of sensorimotor therapy on the physical and psychological development of children and youth. A third purpose was to put sensorimotor therapy in a wider perspective through a somewhat novel extension of the theoretical framework. Two naturalistic studies were conducted. **Paper I** was quantitative and comprised 232 children (181 boys and 51 girls) divided into three groups (**1**) a younger group (7 years or younger, *n*=65), (**2**) a middle group (8 to 10 years old, *n*=91) and, (**3**) an older group (11 years old or older, *n*=76). The participants presented attentional and motor difficulties before starting therapy. The treatment period was in average close to 3 years. Results indicated significant improvements concerning sensorimotor skills in all age groups. **Paper II** was a qualitative study, which included the records of 8 children (7 boys and 1 girl) randomly selected from the cohort of 232 children. The analysis used the EPP-method and yielded 3 overarching themes, which together formed *"the kinesthetic-vestibular developmental model"*. The model illustrated how *Introductions* of sensorimotor exercises pushed the therapy process forward due to periods of *Regression* and *Transformation.* The results were generalized to the remaining 224 children in the cohort by comparing each participant's records with "*the kinesthetic-vestibular developmental model"*. The tentative conclusion was that sensorimotor therapy according to the method *"Retraining for Balance"* might constitute a complement to treatment of ADHD, DCD and LD but controlled studies are necessary before more decisive conclusions can be drawn.

Keywords: Developmental Coordination Disorder, Learning Disorder, Attention Deficit Hyperactivity Disorder, Primary reflexes, Vestibular stimulation, Psychological development, Regression, Retraining for Balance.

Licentiatsuppsats: Sensomotorisk terapi: Värdering av kvantitativa och kvalitativa yttringar av barns fysiologiska och psykologiska utveckling.

Mats Niklasson, avdelningen för psykologi, Karlstads universitet, Sverige.

Sammanfattning

Denna licentiatuppsats första syfte var att undersöka om sensomotorisk terapi enligt metoden *"Retraining for Balance"* utvecklar sensomotoriska färdigheter. Andra syftet var att nå ökad förståelse för hur sensomotorisk terapi påverkar barn och ungdomar. Ett tredje syfte var att sätta in sensomotorisk terapi i ett större och delvis nytt teoretiskt perspektiv. Två naturalistiska studier genomfördes. **Paper I** var en kvantitativ studie med 232 barn (181 pojkar och 51 flickor) vilka delades in i tre grupper (**1**) en yngre grupp (7 år eller yngre, n=65), (**2**) en mellangrupp (8 till 10 år, n=91) och (**3**) en äldre grupp (11 år och äldre, n=76). Samtliga deltagare hade före träningens start uppmärksamhetsproblem och motoriska svårigheter. Träningstiden var i genomsnitt ungefär tre år. Resultaten indikerade signifikanta sensomotoriska förbättringar i samtliga tre grupper. **Paper II** var kvalitativ och inbegrep anteckningar från åtta barn (7 pojkar och 1 flicka) som slumpats ur den större gruppen av 232 barn. Analysen gjordes med EPP-metoden och resulterade i tre teman som tillsammans bildade *'den kinestetisk-vestibulära utvecklingsmodellen'*. Modellen illustrerade hur *Introduktion* av sensomoriska övningar gav fart åt en terapeutisk process med såväl *Regression* som *Transformation*. Studiens resultat kunde generaliseras till de resterande 224 barnen i gruppen med avseende på modellanpassning. Denna uppsats tentativa slutsats blev att sensomotorisk terapi enligt metoden *"Retraining for Balance"* skulle kunna utgöra ett komplement till redan befintlig behandling av såväl ADHD som DCD och inlärningssvårigheter men kontrollerade studier är nödvändiga innan avgörande slutsatser kan dras.

Nyckelord: Developmental Coordination Disorder, Inlärningssvårigheter, Attention Deficit Hyperactivity Disorder, Primära reflexer, Vestibulär stimulering, Psykologisk utveckling, Regression, Retraining for Balance.

This thesis is based on the following two papers, which will be referred to in the text by their Roman numerals:

I Niklasson, M., Niklasson, I., & Norlander T. (2009). Sensorimotor therapy: Using stereotypic movements and vestibular stimulation to increase sensorimotor proficiency of children with attentional and motor difficulties. *Perceptual and Motor Skills*, *108*, 643-669.

II Niklasson, M., Niklasson, I., & Norlander T. (2010). Sensorimotor therapy: Physical and psychological regressions contribute to an improved kinesthetic and vestibular capacity in children and adolescents with motor difficulties and concentration problems. *Social Behavior and Personality*, ***38***(3), 327-346.

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Paper I

Paper II

1. Introduction

1.1 Background

1.1.1 Introduction

It was through the concern to meet the needs of the intelligent but underachieving child that the 'modern' field of learning disabilities was born. That said, we must keep in mind that it also started with a deep concern for the mentally retarded and a hopeful vision and conviction that fulfillment of the human potential was possible.

1.1.2 Learning disabilities in a historical perspective

The written history of learning disabilities may be said to have started (Strauss & Lehtinen, 1947) in 1799 with the physician and educator Jean-Marc Gastard Itard (1775-1838). Living in France, Itard discovered the 'wild boy' Victor. Although diagnosed as 'idiot' and considered incurable by the father of scientific psychiatry, Philippe Pinel (Flugel, 1933), Itard was convinced that the boy could be educated into 'an acceptable human being'. As a man of his time, Itard was shaped by the spirit of the French Revolution and by the philosophy of an inherent limitless possibility of human development. Being a physician for the deaf he used the same sensory training for Victor as he used for speech training with his patients. Although Victor's social behavior improved, his intelligence and ability to comprehend remained below expectation. Itard felt his experiment was a failure but published the training and the teaching in a book, 'The wild boy of Aveyron' (1801; 1806; 1932). All of the teaching and training carried out has become of great significance (Flugel, 1933) because it was the first systematic attempt to train someone 'feeble-minded'. His work was successfully continued by one of his medical students, Edouard Séguin (1812-1880). Influenced by the utopian socialist Count de Saint-Simon, Séguin believed that educating the mentally disabled was a step toward a better society (www.newworldencyclopedia.org). Already about 1828, a special institute for the

education of the mentally disabled had been established in Paris and in 1842 Séguin became its director. Like his teacher, Séguin rejected the notion (Anastasi & Urbina, 2007) that mental retardation was incurable and practiced sense training and muscle training for the benefit of his patients. At the time (Strauss & Lehtinen, 1947), his work was in line with medical science, which proposed specific training of those senses impaired as a way to improve the function of the nervous system. Already in 1846 Séguin claimed that a child's sensory system must be mature before he/she could be taught to read and write (B. Holle, personal communication February 28,1990) and still today (Anastasi & Urbina, 2007), the methods used for training mentally disabled children in sensory discrimination and motor control have their origin in Séguin's work and in no small way Maria Montessori's work was also influenced by him.

Simon and Binet

By the mid 19th century (Strauss & Lehtinen, 1947), the first institutes created according to the French model were established in USA and in Great Britain. However, by the end of the century, due to effective laws regulating the compulsory education of children, educators in the US were troubled with a new problem. For a couple of months each year (Ravitch, 2000), 95 % of the children aged five to thirteen attended schools. Among these children were those who showed various degrees of retarded intellectual development, a decreased ability to understand and to learn, but who still were too capable to be institutionalized. As a consequence of the need to separate the mentally deficient student from the normal, Binet and Simon developed an intelligence test. The first scale presented in 1905 (Anastasi & Urbina, 2007), included sensory and perceptual skills but as Binet held reasoning, judgment and comprehension as essential for intelligence, the test stressed the verbal content.

However useful, the test, or more correctly the concepts used failed to fully distinguish mentally deficient children from the mentally retarded. Binet and Simon (Strauss and Lehtinen, 1947) suggested a division of all 'abnormals' into three groups (1) the mentally defective (2) the ill-balanced and (3) a mixed type with features of both the ill-balanced and the mentally defective.

While the ill-balanced is mainly 'undisciplined' and shows an abnormal character the mentally defective does not, but instead seems to benefit little from school teaching. Simon and Binet seem to have roughly defined both the slow learner and the restless child but in the years to come the concepts would be further differentiated and refined.

Organic drivenness

Doll, Phelps and Melcher (1932) postulated that mental retardation seen in children with cerebral palsy was not a direct effect of brain injury but rather due to the lack of ability to move and to explore. An important step was taken (Strauss & Lehtinen, 1947) when science was able to distinguish between syndromes of endogeneity and exogeneity in mental deficiency. Larsen (1931) exemplified (in Strauss and Lehtinen, 1947, p.16) encephalitis, birth-injury and meningitis as being exogenous meaning that there are acquired neurological symptoms, which are originally organic.

Kahn and Cohen (1934) described what they labeled 'Organic drivenness' as a consequence for some children surviving encephalitis epidemica. The primary symptom was hyperkinesis but the child also showed an inability to keep quiet, as well as clumsiness and abruptness in the performance of movements. Silver (1951) included in his review of the 'organic child' the hypokinetic child. This child often displayed lags in language development and in motor abilities. He was extremely rigid, clung to a parent and avoided or expressed anxiety in 'anti-gravity' play. Silver suggested that both the hyperkinetic and the hypokinetic child should be tested for primitive – and postural reflexes. The concept 'organic' was used to describe structural or 'real' diseases/disorders, of known metabolic, structural or chemical origin, in the domain of the neurologist as opposed to functional disorders, for example psychosomatic diseases/disorders, mainly treated by psychiatrists (Berkow, 1989; Bloom & Lazerson,1988; Havard, 1990). Body image (Schilder, 1964), for example, was based on physiological data and on the structural organization of the organism, but the final synthesis came from the personality. However, as Bloom and Lazerson (1988) claimed, the organic nature of a brain

problem might be diagnosed as functional, whilst not being totally functional, due to an inability to measure the appropriate index. Mabel Todd, a contemporary of Larsen, Kahn and Cohen, defined proprioceptive sensations as organic (Todd, 1937) and grouped them into three types according to their origin (1) Kinesthesia, the feeling of movement. (2) Vestibular sensations, the feeling of position in space. (3) Visceral sensations, impressions from internal organs. Already in 1870, Ewald Hering (Finger, 1994) used the term somewhat differently, in connection with memory, suggesting that 'organic memory' was more than just a part of the higher nervous system although his extension of these ideas was, and still is, very questionable.

Minimal Brain Dysfunction

In the 1940s (Silver, 1986), as a result of an increased effort to differentiate children with educational difficulties, it was found that those with a history of nervous system damage either perinatal or later had more evident behavior problems. They were abnormally rigid, more emotionally labile, hyperactive, impulsive, easy to distract and disordered. These were the children who came to be labeled as having 'Minimal Brain Damage'. Over time more children and adolescents with these problems were recognized but less evidence of brain damage was to be found. Instead research suggested more subtle disturbances. The new findings lead to a shift from damage to a possible immature or dysfunctional nervous system and further to the label 'Minimal Brain Dysfunction'. The term (Blythe, 2009) was coined by Clements (1966) and referred to children of near average or above average intelligence with mild to severe behavior problems or learning disabilities. Deviations could be manifested as combinations of impairment in perception, memory, language, conceptualization, and in control of impulse, attention or motor function. The expression 'Minimal' was criticized by Hagberg (1975) who meant that the term implied incorrect associations. After all, these problems cannot be considered to be minimal either from the child's perspective or from the family's perspective. Use of concept MBD was gradually dropped during the early 1980s (Gillberg, 2003) not the least because of influential criticism from Rutter (1981; 1982).

Dyspraxia

In the mid 1930s, Orton made the suggestion (Ahonen, Kooistra, Viholainen, & Cantell, 2004) that 'dyspraxia' or abnormal clumsiness was a developmental disorder to be found among dyslexic children. Not only were these children late in learning to walk and run, they were also late in visuomotor and manual tasks. In his book 'Reading, writing and speech problems in children' (1937), Orton developed the idea that clumsy children could have difficulties both in learning more complex body movements and in learning movements which are necessary for speech and writing:

"Such children are often somewhat delayed in learning even the simpler movements such as walking and running, and have great difficulty in learning to use their hands and to copy motions showed to them. They are slow in learning to dress themselves and are clumsy in their attempts to button their clothes, tie their shoes, handle a spoon, and in other simple tasks" (Orton, 1937, p.121).

Clumsy children

Annell (1949) described a group of children with motor dysfunction. In a cohort of 600 children aged 6 to 17 years, either in the ward or out-patients of the Department of Child Psychiatry in Uppsala, Sweden, 78 children (61 boys and 17 girls) or 13% had motor dysfunctions. Of these children, 57 (47 boys and 10 girls) had an average or above average I.Q. Besides having difficulties in ordinary life activities (things such as threading needles, eating without spilling and doing up buttons) they often had a history of late speech development. Children described in her paper and exemplified in this vignette are recognizable even today: *Briefly, this 8-year old boy had the physical development of an 8-year-old, the speech development of a 14-year-old and the motor development of a 5-year-old. In his class at school he is in some respects far ahead of his classmates, but as regards motor activities he is far behind them and has no normal contact with them. He tries, when such subjects are studied in school in which his motor retardation is apparent, to compensate his weakness by clowning or by distracting interest from the work he is to do"* (pp.906-907).

Under the heading 'Clumsy Children', an editorial in British Medical Journal (1962) did a follow up on Annell's article. The editor compared her observations with more recent research and concluded that clumsy children are not uncommon and as this is a physical handicap we must not do things worse by calling them naughty.

Reading and writing difficulties

A.E Tansley (1967) claimed that possible damage to the nervous system existed among children with reading and writing difficulties and emphasized the importance of reading readiness. Teachers, he argued, are often too anxious about getting a child to read and might push him before he is ready. It is therefore important that teachers and parents are trained to see signs of readiness. The child should have a readiness in (1) language development, (2) physical and sensory development and in (3) emotional and social development. He outlined a 'remedial' treatment of a child's inability and used the concept 'remedial' because the treatment given was psychological, educational, social and medical relating to a scientific diagnosis of the reading disability.

Toward a science of learning disabilities

As the field of learning disabilities slowly grew, Ozer (1968) found it necessary to put forward the need for a more accurate neurological examination of the child with learning disabilities. This examination did not only focus on motor function, but also compared the child's brain function to its learning capacity. Still in the 1970s, when the first generation of youngsters diagnosed as learning disabled grew up (Orenstein, 2000), a true science of learning disorders seemed unreachable (Pennington, 2009). Chruickshank (1981) suggested a novel perspective for teacher training and proposed the 'Neuroeducator'. The requirements were (1) an understanding of human anatomy, (2) a solid understanding of human neurology and neurophysiology, (3) a basic understanding of intelligence, (4) a basic understanding of perception and the psychology of learning, (5) an understanding of movement education and an understanding of (6) speech communication. He also required from the student the ability

to communicate the child's problem accurately to its parents. Mycklebust (1983) added that the evolving definition would come to include references to both verbal and nonverbal learning and concluded; *"A science of learning disabilities is forthcoming"*.

1.1.3 Learning disorders – the present situation

The vignettes above show that the sensorimotor and concentration problems we face today among children and adolescents are far from new. It is obvious that sensorimotor difficulties have been a documented companion to mental retardation as well as to learning disorders throughout the last century.

Today, different kinds of learning disabilities constitute a serious, worldwide problem. About 10% of all school-age children are affected (Levin, 2003) and Orenstein (2000) estimates that as many as 20% of adults suffer from different kinds of Undiagnosed Learning Disabilities (ULD). In addition, according to Levin (2003), 10% of adult psychiatric patients suffer from learning disabilities. As adolescents they evince social, emotional, and academic difficulties to a greater extent than others and they run a higher risk of starting to use alcohol (Rasmussen & Gillberg, 2000). Using the broader term 'learning disorders' (Pennington, 2009) to connote *"any neurodevelopmental disorder that interferes with the learning of academic and/or social skills"* (p.3), Pennington reviewed Dyslexia, Speech and Language Disorders, Autism Spectrum Disorder, Attention Deficit Hyperactivity Disorder (ADHD), Intellectual Disability, Developmental Coordination Disorder (DCD), Mathematics Disorder and Nonverbal Learning Disorder.

<u>Attention Deficit Hyperactivity Disorder</u>

ADHD is recognized as a functional deficit that affects approximately 5% of the population globally (Polanczyk, de Lima, Horta, Biederman & Rohde, 2007) and many children diagnosed with ADHD are described as awkward or clumsy. They exhibit motor-perceptual difficulties (Yochman, Ornoy & Parusch, 2006) and match the criteria of DCD (Feng, Cheng & Wang,

2007; APA, 1994). A Swedish study (Kadesjö & Gillberg, 1998) showed that almost 50% of the children matching the full criteria for ADHD (DSM-III-R) also matched the criteria for DCD, a result confirmed in later studies (Pitcher, Piek, & Hay, 2003; Watemberg, Waiserberg, Zuk, & Lerman-Sagie, 2007). Recently Gillberg (2010) pointed at a coexistence of disorders is rule rather than exception.

Developmental Coordination Disorder

DCD, the term coined at a consensus meeting at the University of Western Ontario, London, Canada in 1994, is a chronic and usually permanent condition (Ahonen, Kooistra, Viholainen & Cantell, 2004) largely equivalent to what was previously called 'Clumsy Child Syndrome' referring to children whose motor development is delayed regardless of age, intellect or whether neurological causes are evident. Between 5 and 9 % of all school children are affected (Cairney, Hay, Wade, Faught, & Flouris, 2006). What is now labeled DCD (Pennington, 2000) was previously recognized under different names such as 'motor deficiency', 'congenital maladroitness', and 'Minimal Brain Dysfunction'. As a motor skills disorder (American Psychiatric Association, 1994) the main features for DCD in younger children are besides clumsiness, delays in crawling, sitting, walking buttoning shirts, zipping pants and tying shoelaces. Manifestations among older children are difficulties in printing or writing, playing ball assembling puzzles and building models. "*The diagnosis is made only if this impairment significantly interferes with academic achievement or activities of daily life"* and *"if the coordination difficulties are not due to a general medical condition"* (p.55). Although DCD (Gillberg, 2003) has a most specific and common comorbidity in ADHD it remains 'the black sheep' and is seldom mentioned in intervention and assessment manuals.

Deficits in Attention, Motor control and Perception

The concept DAMP (Gillberg, 2003), an acronym for deficits in attention, motor control and perception, was developed in Scandinavia in the 1970s as an attempt to make the less precise term MBD more workable. The concept came to be used within clinical practice especially in

Sweden and Denmark. Today DAMP can be regarded as almost equivalent to a combination of ADHD and DCD (P. Rasmussen, personal communication, March 19, 2013)

1.1.4 'Reflexes', a perspective

Semantics and concepts

Among psychologists, the concept 'reflex' is recognized as a basic aspect of physiological psychology (Clarke, & Jacyna, 1987) and given a certain historical status. Although the papillary reflex (Flugel, 1933) was observed by Galen (A.D 129-199) and the word 'reflex' was used by Jean Astruc (1684-1766) the concept did not reach widespread recognition until the substantive 'the reflex' (Clarke, & Jacyna, 1987) was coined by Marshall Hall in 1833 and used in a biological and purely mechanical sense. Through his research on decapitated animals (Flugel, 1933) Marshall Hall had observed that by proper stimulation certain kinds of bodily movements were elicited with the help of the spinal cord and the peripheral nerves. These movements were independent of the brain and therefore had another character compared to voluntary and conscious movements. One of the first to document the development of infant reflexes from birth and beyond (1882), through experience and learning, was W. Preyer (1841-1897) a physiologist and a pioneer in the science of child psychology.

As neonates (Illingworth, 1987) we were all equipped with about 70 brainstem mediated primitive (primary) reflexes, some of which were closely connected to the vestibular system. To begin with these reflexes were like a 'survival kit' and easy to elicit. During the first year of life (Capute, & Accardo, 1991) as the nervous system matured and voluntary motor activity emerged they became more difficult to elicit. As primitive reflexes are inhibited during the first year of life, postural (bodyrighting) reactions (Morrison, 1985; Capute, & Accardo, 1991) as well as gross motor milestones such as rolling, creeping (locomotion in prone), and crawling (quadrupedal locomotion) appear. Gross motor milestones generally emerge during the 6th to 12th month. This is also one of the intervals when the vestibular system is most sensitive and receptive to stimulation (Ornitz, 1983). During the period when the child is creeping and

crawling (Maurer & Maurer, 1989) it is also very likely that a more mature sense of balance develops.

These early reflexes (Chrutchfield, & Barnes, 1993) are traditionally called 'primitive' either because they are thought not to persist throughout life or *"because the infant's brain is considered to be a primitive underdeveloped, incompetent, deficient- edition of the adult brain"* (Touwen, 1984 p.115). There are, however, controversies surrounding the concept. First, Touwen (1984) argued that neither the concept 'primitive' nor the concept 'reflex' are appropriate because neither is the infant's brain primitive nor does pure stereotyped reflexes occur. McPhillips, Hepper, and Mulhem (2000) prefer to use the concept 'primary reflexes' while French authors such as Mehler and Dupoux (1994) use the concept 'archaic'. Second, there is a controversy as to whether,' the reflexes' persist throughout life or not. Paulsen and Gottlieb (1968) state: *"The initial background from which the primitive reflex arose apparently still remains, and any foetal reflex responses may reappear whenever higher controls are weakened"* (p.50) a view shared by Teitelbaum (1967) for whom it was obvious that the reflexes remain within the nervous system. Ayres (1973) concluded that the degree of mastery over the reflexes is a reflection of the maturity of the nervous system.

A possible regression to lower level brain activity when higher levels are impaired, resulting in primitive motor behavior, is suggested by Bergström (1963). Jacobs and Gossman (1980) investigated certain primitive reflexes and found them active in healthy adults. So did van Boxtel, Bosma, Jolles, and Vreeling (2006) who found their prevalence increasing with age, but there was no support regarding their presence as markers of cognitive recession in individuals ageing normally. Touwen (1984) on the other hand, considered the morphological difference between the adult's brain and the infant's brain. Emphasizing their different functions, he argued that the adult's ageing brain and the infant's healthy brain cannot possibly display identical mechanisms.

The term 'Neurological soft signs' (NSS) (Ayd jr, 2000) is used to describe neurological aberrations not believed to constitute well-defined neurological disturbances. NSS are difficult to localize, they might sometimes be considered as reflecting a diffuse brain dysfunction, but are nonetheless frequent among youths with hyperactivity and emotional disorders. The use of 'Soft signs' as both a concept and a diagnostic tool, was dismissed by Ingram (1973) as 'soft thinking'. According to Mitchell (2003), NSS are of importance because they are rarely present in healthy controls. There is no standard list of NSS but the concept includes retained primitive reflexes (grasp, snout and sucking), a deficit in sensory integration and subtle deficits in sequencing of complex motor functions and in motor coordination. Children diagnosed with DCD (Polatajko, 1999) don't show any clear-cut evidence of neuropathology or neurological 'hard' signs but might show 'soft' neurological signs.

1.1.5 The vestibular system

Appearing nine weeks after conception, the vestibular nuclei are functional by the eleventh week (Humphrey, 1965). At about the 21st week (Robbins, 1977; Larsen, 1993), aside from the interoceptive sensory receptors (sensory receptors in the walls of the thoracic, abdominal, and pelvic viscera), the vestibular system is the only sensory system that is mature. Although developed this early, some authors (Windle, 1971; Prechtl, 1984) believe that the system is inhibited during prenatal life. Others like Odent (1986) and Restak (1979) claim that the fetus, floating, is constantly stimulated by the mother's movements and registers its first perceptions through the vestibular system. It is because of this early maturation that the vestibular system is so important for brain development and *"a disturbance of its function by any factor will be reflected in the formation of the whole nervous system"* (Klosovskii, 1963, p. 116). In favor of the proposition that the fetus reacts to the gravitational force (Hubbard, & Wright, 1984, Eliot, 2000) is the turning of its head into the head-down position weeks or days before birth.

The vestibular system can easily be seen purely anatomically, as just what it is, a part of the inner ear, physiologically responsible for balance, the detection of movement and closely connected to

hearing but not recognized as one of our basic senses. It is, however, different from other senses not least because experiences after stimulation are not specifically located, which they are with other senses. One of the first to study its psychological implications was Paul Schilder who observed (1971) that organic changes in the vestibular system did not only affect body attitudes. Changes were also reflected in psychic structures influencing perception and consciousness. *"These general considerations make it possible that the study of the vestibular apparatus may have great importance for the understanding of psychotic and neurotic states"* (p.85).

Common sensibles

Even before Aristotle (ca. 384-322 B.C), Greek philosophers discussed and described perception, much of which was collected by Theophrastus (ca. 370-286 B.C.) (Stratton, 1917). The senses, as analyzed by Aristotle, (Heller-Roazen, 2007) were sight, hearing, smell, taste and touch of which he considered touch to be primary. To each sense he added a corresponding proper object, characteristic medium and particular organ and wrote (Berthoz, 2000) that although we see things as parts they are perceived as a whole. In 'De Anima', 'On the soul', (Aristotle, 1992) book II and III, Aristotle discussed the senses and concluded that there could not be more than five. Yet, he argued, each sense is not enough to explain the totality of sensory experience and proposed the perceptual phenomena 'common sensibles'. *"'Common sensibles' are movement, rest, number, figure, magnitude; these are at any rate certain kinds of movement which are perceptible by touch and by sight"* (book II, ch.6). Throughout history the term *"Common sensibles"* has been used and discussed within Greek, Arabic and Latin scholastic traditions. Thomas Aquinas wrote in 'Commentaria in Aristotelem' (Heller-Roazen, 2007) that it is through the common sense we can feel that we are living. Another man of church, Jean d'Arckel (1314-1378), is ascribed to have said that the 'common sense', located either in the heart or in the brain where the five senses meet, is the source of all individual senses and of life. An expression from Leonard da Vinci (Cozolino, 2010) was that the 'common sense' judges that which is given to it by other senses.

Jiri Procháska (1749-1820), most famous for his publications about 'the reflex', was also interested in 'sensorium commune' (Clarke & Jacyna, 1987), which for him was the place where the sensory impression turned into a motor message, which activated the muscle. He proposed 'sensorium commune' to be located in the brain stem, spinal cord, cerebellum and thalamus. Consulting 'The Oxford Companion to the Mind' (Gregory, 2004) for an up to date definition of 'common sense' it said, *"The original meaning is a 'common centre' or neural pool, into which all the five senses were supposed to contribute to give coherent perceptions, though the various senses are so very different"* (p.193).

The late 18th and early 19th centuries were very active and fruitful years for physiological research (Finger, 1994, Wade, 2009). Observations gave empirical support for a separation of a muscle sense from touch. The British neurologist Henry Charlton Bastian (1837-1915) believed that information, necessary for the brain's coordination of motor acts, were provided by the muscles. In 1880 he coined the term 'kinaesthetic' a concept replaced in 1906 by Sherrington's term 'proprioceptive'. Although giddiness and vertigo (Wade, 2009) had been well known phenomena described mostly in medical terms since ancient times it took a long time for science to connect the sensations to the vestibular system. By 1765, Robert Whytt included vertigo among the symptoms caused by nervous diseases. In 1803, Bell discussed diseases of the inner ear documenting that an inflammation around the auditory nerve also gave an increased sensitivity for vertigo and concluded that little was known about diseases of the labyrinth. The gross anatomy of the labyrinth was known but its function was not understood. Through the interest in vertigo, the vestibular system was obviously investigated indirectly. William Charles Wells (1757-1817) who carried out research on post rotational vertigo and nystagmus was later to be recognized as the first who suggested a connection between the vestibular sense and behavior. Theoretically, he also understood that some neurological system must register the body's position in relation to gravity but he never came up with an answer. The answer was provided in the 20th century when the electron microscope was invented and scientists were able to identify hair cells in the cochlea and later in the vestibular system. By habit or tradition

the senses had been studied separately and it was not until the 1960s (Berthoz, 2000) that physiologists realized the importance of studying the combining of sensations.

The gravitational force

Gravity (Gribbin, 2010) is " *A force exerted by any object with mass on any other object with mass*" (p.211). In a strict physical and semantic meaning (G.Vitiello, personal communication, December 24, 2001) the use of the concept 'gravitational force' is preferable to the use of 'gravity' because a force is measurable unlike 'pure gravity', which is not. However, in everyday life 'gravity' can be used as a short for 'the gravitational force'. Gravitation (Rees, 2000) is the most perplexing of the basic forces of nature and still today it is a mystery. The force is so fundamental that if we should start anew with intelligent life on another planet we would have to start with gravitation. As gravitation is always an attraction it is the organizing force for the cosmos. In a recent paper Verlinde (2011), a string theorist, argued that gravity emerges from something more basic as a consequence of the laws of thermodynamics. Therefore (Overbye, 2010) the force has hitherto been viewed in a wrong way by science. Although Isaac Newton's most celebrated scientific achievement was the discovery of universal gravitation (Torretti, 1999) even he had difficulties understanding what gravitation really is. Just the scientific, mechanical explanation did not seem to satisfy him. In General Scholium, an appendix to the second edition of 'Principia' (1726), he communicated his spiritual side and wrote that God is omnipresent forever, constituting space and time by existing everywhere and always. It is also said that Newton regarded Pythagoras´ (569-475 BC) concept 'music of the spheres' as a metaphor for the law of gravitation.

As healthy humans we take an upright position for granted although defying the gravitational force is a life long struggle. Very soon after birth the infant starts to lift his head up against gravitation. According to Paul Schilder (Hubbard & Wright, 1984) it will take the growing child about 15 years to master the force. At the beginning of the 20th century, Joel E. Goldthwait (Goldthwait, Brown, Swaim, & Kuhns, 1937; Oschman, 2000) and his colleagues

at Harvard Medical School were trying to attract scientific attention to their research on patients with various chronic disorders all of which were due to faulty 'Body Mechanics'. Goldthwaith stressed the importance of people paying attention to how they moved and held their bodies in relation to gravitation. If posture was correct more energy would be left for use in daily activities and less strain would be put on different body parts and joints. An incorrect posture would also be likely to have unhealthy effects on the viscera of both the thorax and the abdomen. Once again we can hear history speaking to us but the trace left from Goldthwait is not to be found within traditional science but has been picked up by different movement therapies and by modern bodywork. The first scientific evidence that the early development of the vestibular system is dependent upon gravitational stimulus was provided by a study (Ronca, & Alberts, 2000) on pregnant rats flown on the Space Shuttle. The rats, developed in space, had a limited sense of balance after delivery on earth. The study showed that the vestibular system needs the gravitational force to mature correctly.

Meanwhile the British journal 'New Scientist' (MacKenzie, 2000) reported on a study, which had used a chemical reaction and the gravitational force. Initially, physicists insisted that the research was not worth doing because the force of gravitation on molecules was presumed to be too weak to affect chemical reactions, as compared to other forces. However, the study (Papaseit, Pochon, & Tabony, 2000) was completed and results showed how gravitation had indeed influenced chemical reactions on the cellular level. The scientists studied microtubules, fibers made of a protein called tubulin. When cold solutions of mammalian tubulin mixed with GTP (an energy releasing compound) were adjusted to body temperature for a certain time, distinct bands of microtubules were formed at right angles to gravity. When the procedure was repeated in microgravity the bands pointed in all directions. This spontaneous generation of patterns in a chemical reaction, due to tiny environmental asymmetries, was the first experimental model of biological self-organization. The result had previously been predicted, in the 1950s, by the biophysicist Ilya Prigogine and by Alan Turing.

1.2 Theoretical perspectives

1.2.1 Introduction

During the last centuries, focus on cognition, teaching, information and instruction has increased. The importance of early learning is a mantra within both politics and science, and parents are instructed how to begin to teach their children as early as possible. The concept 'learning' as defined by Ayd Jr (2000) is a process that depends on sensory input and by which new information is obtained. The process requires reinforcement and involves practice. According to Levin (2009), 'learning' is essentially an emotional phenomenon, which satisfies vital needs while Hydén (1969) refers to 'learning' as a systems capacity to react, as a result of experience, in a modified or a new way. Although coherent research is scarce, more children seem to be less mobile and less time seem to be spent playing spontaneously (Ridgers, Carter, Stratton, & McKenzie, 2011; Verloigne et al., 2012; Gleave, & Cole-Hamilton, 2012). Despite increased focus on educational quality, the number of children and adolescents who fail at school remain high (Enkvist, 2003; Olofsson, 2010; Sahlberg, 2011; Svensson, 2013). Among those labeled 'failing students' (Sahlberg, 2011) used to be those who had personality- as well as behavior-problems. Educational failure is also linked to unpromising attitudes towards learning and further education and to a person's role in society. There are well-known comorbidities between various disorders (Pennington, 2009; Gillberg, 2010) but possible connections between learning disorders and sensorimotor immaturity has so far been neglected or disputed (Kavale, & Mattson,1983; Pennigton, 2009; Hattie, 2009; Billard, de Villèle, Sallée, & Deltei-Pinton, 2013). The results in Kavale's and Mattson's meta-study were later questioned by Nolan (2004) due to failure in study design.

In contrast to Pennigton's definition of learning disorders, as of **1.1.3,** Tannok and Brown (2009) emphasized that despite a noticeable learning capacity the child has unexpected difficulties to develop age-appropriate skills or abilities. Their description does not include

behavioral symptoms such as inattention, hyperactivity and/or impulsivity. One reason why a possible connection has been refuted might be the fact that no method, so far, has proved to be effective enough. Several longitudinal studies of DCD (Polatajko, 1999) show that motor problems persist and that other parts of the child's development are affected.

Meanwhile a lot of research concerning diagnoses and conceptual issues has been published while few, if any, (Polatajko, Rodger, Dhillon, & Hirji, 2004) cohesive training methods have been developed, evaluated and used. One hitherto underestimated reason why some children and adolescents are unable to meet the demands of the school system might as well be sensorimotor immaturity. If so, they are at risk to continue to fail in the classroom unless their situation is rethought. To keep on doing the same thing and expecting different results (Sahlberg, 2011) seems to fail in the long run. According to Kegan (1994) the word *education* is etymologically derived from the Latin word e-duco meaning 'bring out' and suggests a sort of transformation. On the other hand the focus of *information* is to change what is known, to accumulate and leaving the form as it is. This might be close to what Watzlawick, Weakland, and Fish (1974), Ahrenfelt (2001) and Wrangsjö (2011) define as *a first-order change* as opposed to a second-order change. A first-order change (Watzlawick et al., 1974) follows a 'more of the same' strategy based on common sense. It will be a 'renewal' of what is already there (Ahrenfelt, 2001). *A second-order change* on the other hand is unexpected, doesn't follow common sense and the process is somewhat paradoxical (Watzlawick et al., 1974) and there is a change of the whole system (Ahrenfelt, 2001).

Choosing the approach of *education* and *a second-order change* rather than Information and a first order change a different, but still complementary, approach to conquering learning disorders is introduced here. The purpose of the current licentiate thesis was threefold. (1) To compile data collected at the Vestibularis clinic, concerning the use of the method '*Retraining for Balance*', in order to evaluate if a further controlled study could be of interest. If so, investigate if the method is suitable as a complement to regular treatment of DCD, Learning

Disorders (LD) and ADHD. (2) To gain increased understanding of the effects of sensorimotor therapy on the physical and psychological development of children and youth when using RB. (3) To put sensorimotor therapy in a wider perspective through a somewhat novel extension of the theoretical framework.

1.2.2 Different approaches to sensorimotor training

Techniques used in formalized sensorimotor training differ both from a theoretical and a methodological perspective. Pless (2001) makes a distinction between General Abilities Approach (GAA), Sensory Integration Approach (SIA) and Special Skills Approach (SSA). The GAA proposes that age-appropriate reflexes, postural reactions, and perceptuomotor proficiency form the basis of functional motor ability and the development of thought processes. The SIA stresses vestibular stimulation and suggests that sensory integration might be the basis for language, motor and intellectual development. According to the SSA, finally, more sophisticated motor skills are formed by specific motor learning.

Specific Skills Approach

Specific Skills Approach is typically used within traditional physical education (PE) where functional skills (Pless, 2001) are practiced with guidance and repetition. A recently published 9-year intervention study (Ericsson and Karlsson, 2012), with the aim to examine if increased PE could have long-term effects on school performance and on motor skills, found improvements regarding both motor skills and school performance. The authors concluded that daily PE and also adapted training of motor skills for those in need of extra training are to be recommended during compulsory school years. A recommendation well in line with Schilder's who in the 1940:s suggested (Hubbard & Wright, 1984) that it will take a child 15 years to develop motor skills and coordination despite the gravitational force.

General Abilities Approach

Peter Blythe and Sally Goddard Blythe at the Institute for Neuro-Physiological Psychology

(INPP) in Chester, Great Britain have for more than 20 years successfully spread their work and today a lot of practitioners are using their method globally. As a Senior Lecturer in Applied Psychology/Education (Blythe, 1990, Goddard Blythe, 2009) in the late 60:s, Blythe found himself unable to explain possible causes to spelling, reading, writing and mathematical problems to his students. Reading Tansley's book 'Reading and Remedial Reading' (1967) Blythe understood that there could be physical causes to educational problems. Together with one of his students, David McGlown, he started to investigate which physical developmental factors were playing a significant role in specific learning difficulties. They came up with three factors, one of which was a continued presence of the asymmetrical tonic reflex (ATNR). The other two factors were ambiguity of laterality and a marked problem regarding visual perception. With the aim of informing teachers that underachieving children with average or above average intelligence in fact might have a cluster of minor physical dysfunction they coined the concept 'Organic Brain Dysfunction' (OBD) in 1971. A few years later, in their book ' An Organic Basis for Neuroses and Educational Difficulties - A new look at the old Minimal Brain Dysfunction Syndrome' (1979) the authors held 'Minimal Brain Dysfunction' (MBD) to be a too diffuse and unclearly cut diagnosis and introduced OBD as a complement, arguing for the necessity of assessing the prevalence of certain primitive reflexes as well as the absence of transformed reflex patterns. In Sweden OBD was met with suspicion and heavy resistance among physicians (Hagberg, Hansson, Lundberg, Carlström, Gillberg, Norrsell, & Rasmussen, 1981; Hellström & Jalling, 1981; Arvidsson, 1981). As an answer to the critique Blythe and McGlown wrote (1981) that OBD was never presented as a universal answer. It was just an intention to more clearly define MBD and thereby giving it a place within a strict and acceptable framework.

The use of the concept OBD (Blythe 2009) became invalid as Blythe in 1984 realized that retention of the ATNR would prevent the child from crawling. Likewise a persistent symmetrical tonic neck reflex (STNR) would prevent a child from creeping on hands and knees. Because the persistence of reflexes was symptoms of delayed neurological maturation,

using inability to crawl and creep as diagnostic criteria was no longer valid. For a while the definition 'Central Nervous Dysfunction' seemed more appropriate but since 1987 the concept 'Neuro-Developmental Delay' (NDD) is used. NDD was described as (Goddard Blythe, 2009) a continued presence of primitive reflexes beyond the age of six months in connection with underdeveloped or absent postural reflexes above the age of 3.5 years.

Theory and practice behind the present training at INPP (Goddard, 1990) follows a concept of replication, (1) as each reflex has a purpose to fulfill it will not be suppressed until its work is done (2) the suppression of reflexes follows a certain sequence and pattern (3) which are due to stereotyped movements (Thelen, 1979) performed by all human babies during their first year of life. On one hand these movements promote the inhibition of a primitive reflex while releasing a subsequent postural reflex on the other hand. This inhibition, modification and transformation of a primitive reflex are an innate and mechanistic process, which is observable and can be used at any age to rehabilitate impairment. According to Blythe and Goddard Blythe (Blythe, 2009; Goddard Blythe, 2009) it is possible to give the nervous system a second chance to mature.

Sensory Integration Approach and the vestibular system

Although Blythe stresses the importance of vestibular stimulation (Vose, 1986), it was the groundbreaking work of Jean Ayres (1973), which was to be regarded as foremost within the SIA approach. Ayres defined sensory integration (Fisher & Murray, 1991) as "*the neurological process that organizes sensation from one's own body and from the environment and makes it possible to use the body effectively within the environment*". A central theoretical and practical position in the SIA is held by the vestibular system (Ayres, 1973). Paul Schilder, a pioneer in the field of vestibular investigations, described (1933) the vestibular apparatus as a coordinating system for sensory functions. An opinion also held by Ayres (1973) who emphasized the importance of the functional integration of the senses. Vestibular receptors are tonically active which means that even when the head is at rest they send a continuous stream of neural impulses to the brain.

Hubbard (1971) wrote about the second 'language' of the vestibulum, which he labeled as a crypto-vestibular speech. This chronic and subliminal 'language' is almost only sensed through other organs. Could it be that Aristotle, the scholars and even the physiologists of the 18th century were intuitive forerunners to the discovery of the function of the vestibular system? Although Aristotle declared firmly that there was no sixth sense, he stated that all form a unity through incidental perception (book III, ch.1). Over the centuries there have been slight movements from his original writing towards the essence of the vestibular system as it is understood today, especially with its closeness to proprioception and to the reticular formation. It is not unlikely that they, in their time, were closer to nature than we are today. However, none seems to have come up with a suggestion as to what makes the 'common sense' able to combine different perceptions in to a coherent one. The vestibular system together with the reticular formation (Guyton, 1991) and the proprioceptive system (Brodal, 1960, 2004; Robbins, 1977) appear to be good candidates for an integrating system as impulses from the five senses and from muscle joints are directly and indirectly received by vestibular nuclei. But which factor might be the integrating factor?

1.2.3 The gravitational force

Turning to Bergström (1997) the answer is the gravitational force. He described how the proprioceptors are driven by this force and how this is a precondition for a proper brain stem function and for consciousness. Also Hydén (1961), who rotated experimental animals and found an increased production of RNA in the big vestibular cells, the Deiter's cells, wrote about gravitation as a non-adaptive, ever present and unchanging force and continued that for increased neural activity, gravitation is the most important energy source. However, Hasnulin, Hasnulina and Sevostyanova (2004) went one step further and declared that gravitation connects all material in the universe.

Primary reflexes, the vestibular system and the gravitational force

There is no consensus (Piontelli, 1992) as to whether the vestibular system is active in utero or

not. Nevertheless, the study of fetal movements is of interest. Life in utero is a preparation for life to come. All fetal movements observed (Prechtl, 1993) have also been observed in the newborn. As early as 1885, Preyer was convinced that the fetus moved its legs and arms before the 16th week. He also considered that movements performed by the newborn (Thelen, 2000), were the same as those developed in utero. However right he was, it took almost 100 years to confirm fetal movements during the first trimester (Reinold, 1976). Regarding the movements of the neonate, De Vries, Visser and Prechtl (1984) wrote, *"The similarity between prenatal and postnatal patterns of movement is also striking. The only differences are in quality of movement, probably because of the increased influence of gravity after birth"* (p.62).

Metaphorically, birth is a transition from one 'planet' to another, from water into air. For nine months the fetus has been held and contained in a restricted and rather secure universe. Being born is said to be the most stressful and dramatic event ever to be experienced, a preparation for life to come. During delivery through the birth canal primary reflexes such as the asymmetric tonic neck reflex (ATNR) and spinal Galant are set to work and the intense squeezing of the body activates the hormone system. The newborn's first cry comes after contact with air (Casaer, 1993; Prechtl, 1993) and it is likely that the increase in oxygen tension switches on the vestibular system, which increases muscle tone. For survival it is of importance that sensory trigger-mechanisms such as sucking and rooting are activated soon after birth. Common to all infants are also the palmar grasp, plantar and Moro reflexes. These reflexes are old adaptations of the clinging to the mother. Retention of the Moro reflex (Goddard Blythe, 2009) is associated with an increased sensitivity to vestibular stimulation and might affect both emotional behavior and physiological processes. Because the Moro reflex is ontogenetically very old its retention will hinder (ontogenetically) younger primary reflexes from fulfilling their work as it, practically, will keep these contained. The importance of the Moro reflex acting as a gateway was shown in a paper (Taylor, Houghton, & Chapman, 2004), aimed at studying the overlap of ADHD and the retention of four primary reflexes, the Asymmetrical Tonic Neck Reflex (ATNR), the Symmetrical Tonic Neck Reflex (STNR), the Tonic Neck Reflex (TLR) and the Moro reflex.

The study indicated an overlap between ADHD symptomatology and the retention of the four reflexes as well.

In a randomized, double-blind, controlled study McPhilips et al. (2000) used stereotypical neonatal movements similar to those developed by INPP, but no vestibular stimulation, on children with specific reading difficulties. After training, the experiment group showed significant results both regarding reflex inhibition and reading improvements. A recent study by Brookes, Tinkler, Nicholson, and Fawcett (2010) found that balance problems were very common among children and adults with dyslexia even without a comorbidity of attention deficit. Comparing underachieving children with well performing children, Franco and Panhoca (2008) found a statistically significant relationship between vestibular disorder and learning impairment.

Essentially, the Moro reflex is purely vestibular and, as such, also fundamental when it comes to the baby's relationship to the earth. At birth, the newborn is almost insensitive to external stimuli but a common fear for all infants is the fear of falling (Hubbard, 1971; Feldenkrais, 1988). Hubbard (1971) stated that the fear of falling is so basic that it might as well *"serve as a paradigm for all subsequent fears"*. Schilder (1964) also stressed the problem and proposed that the child should be given 'motor help'. By this he meant that not only should parents be taught how to carry and handle their child they should also have to be in an emotional inner balance themselves. Gravitational security (Ayres, 1979) is a prerequisite for a good relationship, not only to one self, but also to other people and not the least to the parents. The child's attempt to overcome the gravitational force is a primal struggle during the first years of life but it will take about another fifteen years (Hubbard & Wright, 1984) for the child to fully master movements in relation to the force. Despite this effort, once achieved, gravitational security is not a given.

Retraining for Balance

The method *'Retraining for Balance'* (RB) could be considered mainly as a mixture between

GAA and SIA with a slight touch of SSA. The concepts of primary reflexes and postural reactions were borrowed from GAA while the theoretical foundation of vestibular stimulation was borrowed from SIA. Exercises from SSA were used in therapy as a 'rounding up'. The basic GAA perspective, theoretically and practically, used in RB were developed by Peter Blythe (Goddard Blythe, 2009) at INPP. In the early 1990s, the INPP- guidelines for how to carry out assessments (Goddard, 1990) and use exercises were strictly mechanical and linear. The meaning being, that when through assessment certain immaturities were identified certain exercises were supposed to be used in a 'goal directed' way. This meant that some children went through training using just a few exercises while others had to use more exercises and the duration and content became rather different from child to child. Vestibularis, a private practice in Sweden, was not satisfied with the results achieved whilst working in this way. It had noticed that some exercises seemed more powerful than others and this inspired the attempt to create a harmonious totality of the different movements (Niklasson, Niklasson, & Bergström, 1999, 2007). Vestibularis had identified a need to bring coherence and continuity to the different exercises. One reason for this was that different physiological and psychological regressions emerged when certain exercises and vestibular stimulation were used. Kris (1952) had distinguished a 'regression in the service of the ego', a regression where the ego itself is in charge, a phenomenon not mentioned by Blythe. When an exercise was used long enough the regressions faded and physiological and/or psychological behavior seemed to be transformed to a more mature level. Regression and progression (Werner, 1957; Loewald, 1981) are complementary and of great importance concerning organization both on the psychological level and of physical development (McGraw, 1995). Instead of breaking the apparent 'flow' by being too mechanical, Vestibularis aimed at creating a smooth succession of exercises, thereby achieving a maximal 'squeeze' from each one. Vestibularis came to understand the significance of regressions (Bergström, 1964) from a developmental point of view. Another reason for the modification undertaken by Vestibularis was that vestibular stimulation seemed to be effective with all clients when used as a complement to fetal and neonatal movements. This view was not shared by INPP as Goddard (1990) wrote that vestibular stimulation could be used when

nothing else worked. Vestibularis' modification or rather re-construction was named '*Retraining for Balance*' and aimed at forming a method with a common start and end and with a sense of cohesion between exercises.

2. The present investigation

2.1 Introduction

In this section the aims, designs, instruments, procedures, statistics and results of the two papers contained in this thesis will be discussed. All data collected and analyzed in **Paper I** and **Paper II** originate from files obtained at the Movement School Vestibularis including 232 children and adolescents, 181 boys and 51 girls, all of whom had completed therapy in accord with principles of the method *'Retraining for Balance'*. The current study was made possible because the Quality Management System according to SS-EN ISO 9001:2000 (West, Cianfrani, & Tsiakals, 2000) is used at the Vestibularis clinic. Within the standards of the quality system, training according to the method as well as how files are archived is controlled.

2.2 Paper I. Sensorimotor Therapy: Using Stereotypic Movements and Vestibular Stimulation to Increase Sensorimotor Proficiency of Children with Attentional and Motor Difficulties

2.2.1 Aim

The purpose of this naturalistic study was to analyze previously collected data to investigate whether future controlled studies would be of interest.

2.2.2 Design

The participants completed the '*Retraining for Balance*' program, which had seven parts: (a) fetal movements and infant movements, (b) vestibular stimulation, (c) auditory perceptual stimulation, (d) tactile stimulation, (e) gross motor basic movements or milestones, (f) sports-related gross motor skills, and (g) complementary play exercises. The treatment period was close

to 3 years on average, and the children practiced about 15 min. per day while supervised by their parents. Throughout therapy, training was checked by visits to Vestibularis at intervals of 8 weeks.

Analyses were done using a repeated-measures design. Therapy began and ended with a test battery consisting of teacher and parent ratings and psychophysiological tests providing the basis for the within-subjects factor of the study (before, after). To make comparisons of children at different ages, the children were divided into three groups, in accord with Piaget, based on their age at the start of the project: a younger group (the preoperational stage) with 65 children, 51 boys and 14 girls, 7 years or younger (M = 6.2, SD = 2.0); a middle group (the concrete operational stage) of 91 children, 73 boys and 18 girls, 8 to 10 years of age (M = 9.0, SD = 0.8); and a group of 76 somewhat older children (the abstract operational stage), 57 boys and 19 girls, 11 years old or older (M = 12.3, SD = 1.7). In this way, one of the between-subjects factors, Age group (younger, middle, older), was constructed. The second between-subjects factor was Sex (boys, girls).

2.2.3 Instruments

Retraining for Balance - Physiological test (RB-P)

This test (Niklasson & Niklasson, 1999a, 2007a) was developed to assess sensorimotor (physiological) proficiency in terms of primary reflexes, postural responses, gross motor milestones, and vestibular ability. RB-P consists of 41 different subtests which are divided into six dimensions: (a) Primary reflexes-vestibular stimulation (13 items), (b) Primary reflexes-tactile stimulation (3 items), (c) Postural reactions (11 items), (d) Gross motor milestones (4 items), (e) Eye movements (6 items), (f) Sports-related gross motor skills (4 items).

The scores were rated on a quantitative 5-point scale from 0 to 4 (Field & Blythe, 1989; Niklasson & Niklasson, 1999a, 2007a): 0: No deviation, 1: Small remainder of a primary reflex or Minor difficulty completing a specific feature, 2: Remainder of a primary reflex or Partial

absence of a postural response or Difficulty completing an item, 3: Almost intact primary reflex or Almost a total absence of a postural response or A marked difficulty completing a particular item, and 4: Intact primary reflex or A total absence of a postural response or An inability to complete or execute a specific item. An index was computed for each dimension by multiplying the mean by 10, yielding a scale with anchors of 0: No deviation and 40: Significant deviation from normal performance.

A Cronbach alpha performed with the six dimensions of RB-P gave for the present study an estimate of 0.72. Also in the present study some indications of concurrent validity were given since ratings of RB-P were significantly correlated with scores on RB-O (r = 0.51, p < 0.001), RB-A (r = -0.25, p < 0.001) and the Keystone Visual Skills test (r = -0.27, p < 0.001).

Retraining for Balance - Orientation and balance test (RB-O)

The test (Field & Blythe, 1989; Niklasson & Niklasson, 1999b, 2007b) consisted of 5 subtests: (a, b) The Romberg test, standing balance assessment, eyes open and eyes closed (Rodnitzky, 1988; Cherng, Chen, & Su, 2001; Geuze, 2005), (c) Rotating on a chair, a vestibular test (Vose, 1986; Guyton, 1991; Niklasson, Niklasson, & Bergström, 1999, 2007), two tests of orientation, (d) Body-space perception and (e) Time perception.

Each test was responded to with either, 0: “no deviation from normal age-appropriate behavior” or 1: ”deviation from normal age-appropriate behavior”. In this study a mean was computed for the results in each category then the categories were summed. Although test scales were not ideal for analyses of homogeneity Cronbach alpha was 0.61. Also in the current study RB-O scores correlated significantly with both RB-P (r = 0.51, p < 0.001), RB-A (r = -0.19, p < 0.02) and with the Keystone Visual Skills test (r = -0.18, p < 0.02).

Retraining for Balance - Audiometric Test (RB-A)

The RB-A was based on a technique developed by Johansen (1993) and used a clinical diagnostic audiometer, DA 74 (Danaplex, Copenhagen, Denmark). The test was performed twice. Once at the participant's second visit and once by the end of therapy. The current study focused on the part of the test that measuredb auditory preference in binaural pure tone audiometry (Carpenter, 1990). Two added measures were the one at 20 dB, considered the threshold between normal and deviant hearing, and the one perceived at the softest sound volume. The measurements showed, together and singularly, whether the participant had a right or a left ear preference or whether dominance was lacking. Right dominance facilitates a more rapid processing of speech sounds (Singer & Cone-Wesson, 2004). The scale spanned 0-200, on which values below 100 indicate a left-side dominance. The test's rationale for importance of right-ear dominance was validated by Tallal, Miller, and Holly Fitch (1993) and by Okamoto, Stracke, Ross, Kakigi, & Pantev (2007).

Teacher Rating Scale (TRS)

Conners' test for teachers (Conners, 1969; Goyette, Conners, & Ulrich, 1978) was used in its shortened version (Conners, 1990; Janols & von Knorring, 1991; J.O. Janols, personal communication, May 3 and 16, 2007). The Swedish version comprised 27 statements and yielded a summary measure and four subscales, (a) Behavioral Problems, (b) Impulsivity or Hyperactivity, (c) Problems of Concentration, and (d) Inattention (A.L von Knorring, personal communication, June 23, 2002). Each statement was checked by teachers at the start of therapy and on completion on a 4-point scale: 0: Not at all true, 1: Somewhat true, 2: Quite true, 3: Definitely true. 0 indicates no problem and 3 a very major problem. To make comparisons among the subscales and the composite value possible, means were computed from 0 to 3 points of the subscales and the composite score.

Parent Symptom Questionnaire (PSQ)

A shortened, Swedish version (C. Gillberg, personal communication, December 6,1990 and April 4, 2007), (Gillberg, 1991) of Conners' test for parents of children with attentional problems was used (Conners, 1970, 1973; Goyette *et al.,*1978). The questionnaire comprised 10 statements with a special focus on *attentional* variables, which might indicate whether the child has problems in the area of ADHD (Gillberg, 1991), and yielded a composite measure and three subscales, (a) Behavioral Problems, (b) Impulsivity or Hyperactivity, and (c) Inattention. Each statement was checked by a parent on a similar 4-point scale as the Teacher Rating Scale at the beginning and at the completion of therapy.

Reasons for Training (RT)

A questionnaire (Bergström, Niklasson, & Niklasson, 1999), which assessed parents' satisfaction after completion of therapy. On 5 lines, parents indicated the child's problems in order of severity at the start of therapy and why they thought the child needed sensorimotor training. They listed as many problems as appropriate. At the end of therapy, the parents rated on a 4-point scale with anchors of 0 how much they thought each problem had changed. 0: No positive change, 1: Little positive change, 2: Quite some positive change, 3: Great positive change.

Keystone Visual Skills Test (KVST)

This was a vision test related to vestibular functions (Burman, 1977). The test had 14 subtests assigned to 15 test cards measuring simultaneous perception, eye coordination, stereovision, colorvision, as well as the effective acuity during resting accommodation at a distance (comparable to a distance of 4 m) and close up (reading distance of 40 cm). The test cards were shown to participants who stated what they saw. Responses were recorded, yielding a maximum of 66 points. Given that vision and vestibular function are considered related (Wenzel, 1978), and since visual acuity decreases with hypofunction in the vestibular system (Braswell & Rine, 2006), the test was given both at the beginning of therapy (the third visit) and at one of the last

visits. In the present study, the test was used for concurrent validation of other sensorimotor tests administered.

2.2.4 Procedure

The children were brought to the Vestibularis clinic for therapy by their parents. Typically, they had heard about the therapy from other parents, preschool or school advisors, or from School Health Care. Before deciding to start therapy an introductory call was always made on telephone. The parents were informed about the layout and the cost of the training, which they had to pay themselves and that participation was voluntary. They were also informed that they did not have to sign up for the whole program. A decision to either continue or to stop was to be taken at each visit. The parents were told about the importance of the training being performed by the parents and children, for about 15 minutes daily, at home.

Prior to the first visit parents were sent a simple questionnaire about their child's level of development and maturity, the questionnaire Reasons for Training, and a contract of mutual agreement. In the contract between Vestibularis and the parents, it was stated what the parents must do for the therapy to be as effective as possible. In order to avoid confounding data the contract also stated that there was to be no medication during the program without notification to the staff of Vestibularis. Therapy could be resumed after medication or when the effects of the medication had been assessed. The contract was signed by the parents and by the staff of Vestibularis, and each part received a copy. Only children who did not receive medication were included in the current study.

At the first visit the children and their parents were shown the facilities of the clinic. To give the child an easy start there was time for play prior to the sensorimotor test. Usually initial tests were done in the morning when the child would be rested. Travelling families were advised to spend the night before visit, on site. Once in the assessment room, the child and his parents were informed about the tests. The child was told that a break could be taken during testing and

he/she could even quit without giving a reason. Similarly the child and parents were informed that they could discontinue their participation without providing a reason. Completion of RB-P and RB-O required about 1.5 hour. Scores were recorded and the child and parents were informed of the results. Then a decision on further training was made. Instructions for the home training were given. All participants began with the same exercises. Later, different exercises were done in accord with each child's progress, as indicated in the manual.

A copy of Conners' Parent Symptom Questionnaire and Teacher Rating Scale were given to the parents to be returned completed at the second visit. A telephone appointment in 2 weeks preceded the next visit. Visits of 1.5 hours were then scheduled every 8:th week for testing relevant motor and sensory performance.

At the second visit the first Audiometric Test was done. Based on the results an audiocassette or a CD was recorded with especially composed music. The item was provided at the third visit along with an instruction on how and when to listen 10 minutes per day. Retesting occurred on completion of therapy. The subsequent visits followed the same pattern. Appropriate sensorimotor testing was performed and the child and parents described how training was done at home. A new program was then introduced. At the second to last visit, Conners' Teacher Rating Scale and Parent Symptom Questionnaire were given to the parents for completion on return for the last visit, during which RB-P an RB-O also were completed and the parents filled out the Reasons for Training.

2.2.5 Statistics

Teacher Rating Scale

A three-way mixed Pillais' MANOVA was conducted with Treatment (before-after) as within–subjects factor and Age group (younger, middle, older) and Sex (boys, girls) as between-subjects factors. The dependent variables were the total score plus scores on subscales of Behavior, Hyperactivity, Concentration and Inattention.

Parent Symptom Questionnaire

A three-way mixed Pillais' MANOVA was conducted with Treatment (before-after) as within–subjects factor and Age group (younger, middle, older) and Sex (boys, girls) as between-subjects factors. The dependent variables comprised scores on the subscales of Behavior, Inattention and Impulsivity.

Reasons for Training

A one-way ANOVA was conducted with three parent groups who had indicated positive changes (large, some, small) as the independent variable and the Parent Symptom Questionnaire total score after treatment as the dependent variable.

Retraining for Balance - Physiological test

A three-way mixed Pillais' MANOVA was conducted with Treatment (before-after) as within–subjects factor and Age group (younger, middle, older) and Sex (boys, girls) as between-subjects factors. The dependent variables were the total score and subscale scores of Primary reflexes-vestibular stimulation, Primary reflexes-tactile stimulation, Postural reactions, Gross motor milestones, Eye movements and Sports-related motor skills.

Retraining for Balance - Orientation and balance test

A three-way mixed MANOVA was conducted with Treatment (before-after) as within–subjects factor and Age group (younger, middle, older) and Sex (boys, girls) as between-subjects factors. The dependent variables were scores on the Orientation and balance test.

Retraining for Balance - Audiometric test

Before therapy 131 of the children (valid = 63%) had right dominant hearing and after treatment 190 did have (valid = 90.5%). To examine the rated improvements a three-way mixed MANOVA was conducted with Treatment (before-after) as within-subjects factor and Age

group (younger, middle, older) and Sex (boys, girls) as between-subjects factors. The dependent variable was the RB-A.

2.2.6 Results

The results of the current naturalistic study showed significant improvements on various sensorimotor tasks in all age groups as indicated by the RB-P, RB-O and RB-A tests. In addition to improved sensorimotor proficiency on the *'Retraining for Balance'*, there was also a proficiency effect of biological development, which was evident in older children performing better than the middle and younger groups on the RB-P and RB-O, but not evident on RB-A. Furthermore, scores on the Teacher Rating Scale and the Parent Symptom Questionnaire indicated that the children in all age groups displayed significant improvement following treatment. Older children were rated as less hyperactive but more inattentive on the Teacher Rating Scale. Sex differences were found only in three instances on the RB-P. Boys performed better on the Gross motor milestones, whereas girls did better on Eye movements and Sports-related gross motor skills.

2.3 Paper II. Sensorimotor Therapy: Physical and Psychological Regressions Contribute to an Improved Kinesthetic and Vestibular Capacity in Children and Adolescent with Motor Difficulties and Concentration Problems

2.3.1 Aim

The aim of this qualitative study was to gain increased understanding of the effects of sensorimotor therapy on the physical and psychological development of children and young people when using the method *'Retraining for Balance'*.

2.3.2 Design

A cohort of 232 children and adolescents completed therapy in accordance with the method *'Retraining for Balance'* (see **Paper I**). At each visit children and their parents reported on the results of the home program and meticulous notes were kept. In this way, records were created with personal flow charts describing the experiences of the training of each participant as well as the perception of the training by the parents.

2.3.3 Procedure

In order to gain a more thorough understanding of the effective mechanisms of the treatment 8 cases from the cohort were randomly selected. The empirical data consisted of the records containing the flow charts and the notes from each return visit. The parents' reports were of significance because the children sometimes found it difficult to verbalize their experiences. In traditional phenomenological methodology the experiences of the clients themselves constitute the basis. In the current study experiences in the third person are thus also included. Dennett (1991, 2003) referred to that procedure as hetero-phenomenology. Gallagher (1997) argued that there is no difference between third person reports and phenomenology in a traditional sense.

2.3.4 Processing the Data

The Empirical Phenomenological Psychological Method (EPP-method) devised by Karlsson (1995) was used in processing the data. The method consisted of a multi-stage analysis, including techniques for dividing texts into smaller, so called, "meaning units" (MU). This division was not based on grammatical rules, but entirely on content which the researcher discovered and where there was a suitable shift of meaning. Thereafter the units were transformed so that the psychological and contextual implications were stressed, making it possible to analyze the units when dealt with outside their original context. The analysis yielded 1.019 transformed meaning units that in turn generated 29 categories. Each category illustrated a special perspective of the phenomena studied and was described in a synopsis. To control for the reliability of the results of the study, the *Norlander Credibility Test* (NCT) (Edebol, Bood, & Norlander, 2008) designed for phenomenological analysis, was used. Two assessors had the task of independently assigning 50 transformed MUs to 10 of the categories. The assessment of one of the assessors corresponded to 84%, while that of the other reached 82%, yielding a mean of 83%. An additional NCT was done with two other independent assessors given the same data but with the instruction to place 5 MUs into each synopsis. The outcome was 80% for one of them and 88% for the other one, yielding a mean of 84%. Both of the results were in line with previously published results (Edebol *et al.,* 2008). Finally, the material was transformed from "situated structures" into general themes or typological structures. This was done through a procedure whereby the three authors independently organized the synopses into general themes, then jointly compared their solutions (which were noticeably similar), and finally agreed on the themes.

2.3.5 Results

As the analyses proceeded three themes emerged, each of which consisted several categories: (a) The Introduction of various sensorimotor exercises, (b) Regressions in terms of a return to earlier behavior, (c) Transformations in terms of positive development and change. The three themes emerged regularly throughout the entire study, and together they formed what was

termed as "the kinesthetic-vestibular developmental model". The process involved in '*Retraining for Balance*' might be described as a flow in which 16 Introductions, 3 periods of Regression, and 4 periods of Transformations jointly pushed the individual toward an increased physical and psychological maturity.

In order to examine whether the results of the present study could be generalized to a larger group of children, the records of the 8 participants were compared to the records of the remaining 224 children and adolescents from the earlier study of sensorimotor therapy. Two of the authors independently rated all records vis-á-vis the "kinesthetic-vestibular model of development" in terms of either "very good adjustment", "good adjustment", or "doubtful or poor adjustment". The results, which were noticeably alike, were then compared and agreed on. In order to meet the criteria for a "very good adjustment", the records were required to clearly show the 3 regression periods and the 4 periods of transformation. A "good adjustment" allowed for the omission of one of the regression periods, although the main tendency of the developmental curve had to be present. A "doubtful or poor adjustment" involved the presence of only one regression period and few transformations. The results indicated that 63% of the children and adolescents exhibited a "very good adjustment" to the kinesthetic model whereas 32% of the records were judged to show a "good adjustment" to the model. Only 5% of the records were judged to show a "doubtful or poor adjustment" to the model. It is worth noting that the distribution above was obtained as early as when a third of the records had been assessed, suggesting that saturation had been reached.

3. General discussion

3.1 Introduction

The aims of the present thesis were (1) to examine whether sensorimotor therapy utilizing the training program "*Retraining for Balance*" might be an appropriate technique for sensorimotor proficiency, (2) to gain increased understanding of the effects of sensorimotor therapy on the physical and psychological development of children and youth when using '*Retraining for Balance*' and finally (3) to put sensorimotor therapy in a wider perspective through a somewhat novel extension of the theoretical framework.

Clinical implications of clumsiness have been underrated in child psychiatry (Gillberg, 1995). Clumsiness in early childhood is one marker for neurodevelopmental delay and/or deviance and for later neuropsychiatric problems. However difficult to define in terms of workable criteria one of the more important characteristics is a lack of movement coordination. Better understanding of the sensorimotor phenomena will hopefully contribute to improved psychological adjustment for those children and adolescents affected.

3.2 Addressing the problem

3.2.1 A lack of consensus

Although sensorimotor problems have been known and described for over one hundred years and several longitudinal studies (Polatajko, 1999) have shown that motor problems persist, and that other parts of the child's development are affected, there is still a lack of appropriate methods. The first meta-analysis on DCD since 1998 was recently published (Wilson,

Ruddock, Smits-Engelsman, Polatajko, & Blank, 2013). The aim was to describe the main cognitive and motor-control deficits that are most effective in discriminating children with DCD from those without. The study suggested that the ability to develop steady coordination together with an anticipated control of action might be basic disturbances. Regardless, no single method has, so far, been proved to be effective enough. What might be the reasons?

One reason might be that problems viewed as organic in nature are diagnosed as functional and vice versa (Gillberg, & Kadesjö, 2009; Muyselaar-Jellema, & Severijnen, 2011). An example given by Gillberg and Kadesjö (2009) is Attention Deficit Disorder (ADD) and DCD. Traditionally, DCD is considered to belong within the territory of a child neurologist or a developmental pediatrician while ADD, including ADHD, typically falls within the domain of child psychiatry and psychology: "*This 'split' may explain the fact that few psychiatrists are aware of the implications of the motor and perceptual problems that are so often comorbid with childhood ADHD. Conversely, child neurologists often fail to appreciate the effect of attention deficits on the lives of the clumsy children whom they see for diagnosis and workup*" (Gillberg and Kadesjö, 2009, p.305). In a previous report, discussing the comorbidity of ADHD and DCD (Gillberg, Gillberg, Rasmusen, Kadesjö, Söderström, Råstam, Johnson, Rothenberger, & Niklasson, 2004), it was concluded that, in the long run, the DCD part was often as important as the ADHD part. Consequently, training in neuropsychiatry would be needed for all working with children, adolescents and adults with ADHD.

Another reason might be that intervention methods remain controversial (Polatajko *et al.,* 2004) not the least because, as yet, there is no best approach for any given disorder. For example, according to Pennington (2009), SIA was found to be unsuitable for DCD and vestibular stimulation (Polatajko, 1985) proved to have no effect on children with learning disabilities. These results are quite the opposite of results shown in **Paper I-II.** Vestibular stimulation is considered vital within SIA and was used as a part of *'Retraining for Balance'* in both studies. Results in **Paper I** showed significant improvements regarding sensorimotor

abilities in all three age groups while results in **Paper II** pointed at improved academic proficiency among participants. Because vestibular stimulation was given in combination with different stereotyped movements it was not clear what caused the effects. However, though even the stereotyped movements are essentially vestibular it was suggested that vestibular stimulation per se is of importance.

A third reason, for the circumstance that no single method has, so far, been proved to be effective enough, might be medical concepts having been mixed up with educational wishes (Hagberg et al., 1981; Hellström & Jalling, 1981; Arvidsson, 1981; Pennington, 2009; Blythe & Goddard Blythe, 2012) clouding the methodology with validation difficulties as a result. Using the selling saying 'one size fits all', transferred to methods for sensorimotor training, has so far proven to be just a wish and might so remain. A challenge for further research will be to more thoroughly investigate whether a consensus is possible to reach or not.

3.3 Toward a Dynamic Systems Approach to motor development

3.3.1 Introduction

The therapy '*Retraining for Balance*' uses primary reflex inhibition as well as vestibular stimulation, which make it neither a pure GAA nor a pure SIA (Pless, 2001). Rather, the method is a mixture of both. Results in **Paper II** showed connections between physiological achievements and psychological reactions. These reactions could be strong, unexpected and even paradoxical. Very much like second order changes as described by Watslawick et al (1974), Ahrenfelt (2001) and Wrangsjö (2011). '*Retraining for Balance*' is not a pure SSA (Pless, 2001) either but uses training at the functional level, in erect position, as a final part of therapy. Although the SSA is used only at a later stage of therapy special motor skills, as for example running and playing football, improved early in therapy as reported in **Paper II**. None of the

approaches suggested by Pless (2001) is fully suitable for '*Retraining for Balance*' so another framework ought to be found.

3.3.2 Dynamic Systems perspectives

Following a tradition of systems thinking in psychology and biology, Dynamic Systems (Kelso, 1995; Thelen & Smith, 2006) is a rather new approach. This way to study development is connected to an understanding of nonlinear and complex systems in mathematics and physics. The basic meaning of the term is "*systems of elements that change over time"* (Thelen & Smith, 2006, p.258). The Adolescent Dynamics Lab at Queens University (2013) in Kingston, Ontario in Canada, summarizes the main perspective of a Dynamic Systems Approach to include:

- *Self-organization***,** which means that there is a spontaneous emergence of new forms due to interactions at the systems lower level. The state of the system is neither a product of external causes nor is it pre-determined.
- *Hierarchical organization of nested structure* means that elements of lower-order form the next higher level which then in turn forms the next higher level through self-organization.
- *Reciprocal and circular cause* means causations both within each level and between levels.
- *Non-linear dynamics* is about how small impacts can result in large effects, a process of interplay between positive and negative feedback. Processes of negative feedback are self-stabilizing while positive feedback amplifies lower-order variations that create instability, necessary for the emergence of new forms.
- *Perturbation reveals the nature of the system* means that different systems react similar or differently to the same perturbation.
- *System change occurs through the process of a phase of transition* means that there is a period of variability and instability when a stable structure breaks down and a new structure emerges.

The explicit focus of Dynamic Systems Approach is change (Fogel, 2011) and its theoretical framework has been applied to both motor and cognitive development by amongst others Thelen and Smith (2002; 2006). Their research has given novel insights into the development of motor skills where one basic notion is motivation (Santrock, 2011). An infant is goal directed so if motivation is high a new motor behavior might be created. However, this process is also dependent on the developmental level of the nervous system as well as of body constitution and environmental support. According to this branch of dynamic systems theory gross motor milestones such as crawling and walking are learned through a process of adaption. Thereby motor development becomes an active process in which the infant and environment work together as a part of a system in perpetual change. The dynamic perspective to motor development (Goldfield & Wolff, 2004) (here after '*motor development*') depart somewhat from other perspectives on development in that it tries to show how more complex organizational patterns occur when biological systems use physical laws. Laws included are both those governing far-from equilibrium systems (Prigogine, 1980; Prigogine & Stengers, 1984) and the laws of Newtonian mechanics. These perspectives stand apart because (a) they describe how self-organization works together with selective processes in order to bring about new patterns of movement. This selective process is viewed as the result of the infant's exploratory activity. (b) The perspective describes how parts of a system, without an external agent, interact to create changes in the whole. (c) In accordance with Thelen (2000) the nervous system is viewed "*as part of an embodied system*", where the brain is seen as the medium where enforced physical laws bring forth patterns of coordination through its coupling to the structured environment.

3.3.3 Micro-genetic design as a tool to capture change

Dynamic Systems Approach focus on change and change should be observed when it is occurring (Spencer, Corbetta, Buchanan, Clearfield, Ulrich, & Schöner, 2006). A clear view of change is given when a 'micro-genetic method' is used (Flynn, Pine & Lewis, 2006; Fogel, 2011). In the 1950:s the concept 'microgenesis' was used by Werner to describe measurement of repeated presentations to the same participants. He considered (Werner & Kaplan, 1963) the

unfolding, inner dynamic activity to be genetic, a 'micro-genetic process'. The 'micro-genetic method' (Flynn, Pine & Lewis, 2006) brings forward information about individuals during time of transition and is watching for regressions and sudden jumps. While a cross-sectional design yields broader out-lines this design yields in-depth information. One advantage (Fogel, 2011) is the possibility to trace changes within one and the same system over time while it is happening. Another advantage might be the possibility to uncover principles of change that may lead an understanding how to promote desired changes and how to avoid those undesired. As such, the method (Flynn, Pine & Lewis, 2006) would be a useful diagnostic tool for clinicians. Studies (Fogel, 2011) might use both quantitative and qualitative approaches. Quantitative method can be used to describe developmental trajectories while qualitative method could be useful when describing developmental transformation. According to Flynn, Pine and Lewis (2006) the understanding of change is a cornerstone within psychological research and using a 'micro-genetic method' could be rewarding. Although neither **Paper I**, nor **Paper II** aimed at using a 'micro-genetic method', **both Papers** have captured both change and transitions. As the same cohort was used for both studies the results can be considered complementary. The results in **Paper I**, a quantitative study, described developmental trajectories by showing how balance improved when primary reflexes were suppressed and gross motor milestones emerged. The exercises used by '*Retraining for Balance*' constituted a combination of neonatal movements and vestibular stimulation. The suppression of primary reflexes followed a certain sequence due to stereotyped movements (Thelen, 1979), which all human babies are supposed to have performed during their first year of life (Goddard, 1990). According to Goddard this process is innate and mechanistic and can be observed. By imitating the process it is possible to give the nervous system a second chance to mature. Movements, which are 'natural' for infants became exercises for children in therapy. **Paper I** described how exercises promoted primary reflex suppression thus releasing postural reactions while gross motor milestones such as creeping and crawling emerged. The processes of change was observed and described at re-assessments every 8:th week.

Other processes of change were described in **Paper II**, a qualitative study. The analysis showed how a number of physiological and psychological phenomena emerged, after introduction of exercises, during periods of regression and transformation. These phenomena were observed by the parents at home, by teachers at school and further described and discussed at re-assessments. Both **Paper I** and **Paper II** described processes very similar to those, which are to be found within the framework of a Dynamic Systems Approach. When it came to '*self-organization*' spontaneous emergence of new forms were observed but if the unfolding were independent of external causes or not will be discussed below. The emergence of postural reactions and gross motor milestones as primary reflexes were suppressed were likely to be similar to a '*hierarchical organization of nested structures*' and to a '*reciprocal and circular cause*'. During therapy it became obvious that very simple exercises, sometimes, could cause significant effects as described by '*non-linear dynamics*'. Although the overall reactions to exercises were similar, individuality were observed which was in line with how '*perturbation reveals the nature of the system*'. A typical example of how a '*system change occurs through the process of a phase transition*' was the difficulty of creeping on hands and knees during the short period when crawling emerged. Although the participant previously had been able to creep coordinated, for a while this ability was interrupted. However, when the period of transition was over a correct creeping on hands and knees re-emerged. Periods of transitions were also described in **Paper II** where '*the kinesthetic-vestibular developmental model*' showed how both Regressions and Transformations gradually unfolded.

3.3.4 Motivation as a driving force in 'motor development'

The theory of '*motor development*' describes (Goldfield &Wolff, 2004) how, without an external agent, parts of a system interact to create changes in the whole. According to the theory the driving force (Thelen & Smith, 2006; Santrock, 2011) is considered to be motivation. Through perception and action the infant will learn how to adapt and to modulate movement patterns. On the other hand, Goldfield and Wolff (2004) mentioned how biological systems use physical laws and such laws ought to be examples of external agents.

An explanation is given in an early article, examining the theory (Kamm, Thelen and Jensen, 1990), in which the authors repeatedly came back to the gravitational force. Expressing that gravitation mostly is treated as a constant and that an infant, as all other people, both experiences and produces its movements within the context of the gravitational field. Their view was, however, that only when movements are produced and evolved and when the nervous system can counteract, gravitation makes a difference. As an example the authors described a sitting infant who, in order to progress, had to try out the limits of the posture. The child has to have a motivation to explore the dynamics of its own movement in order to advance even if it risks falling over. Otherwise it might risk to get stuck. In motor development, in general, motivation and adaption might be important aspects as well, but what is igniting motivation? A similar question was addressed by Smith and Thelen (2003) when they rhetorically wrote, "*What are infants doing every day that improves their location memory?"* Their hypothetical answer was that it might be either self-locomotion since crawling seems to enhance spatial memories or manipulation activities due to improved fine motor skills. Then again, these answers require the questions, what then causes self-locomotion and/or better fine motor skills?

In **Paper I,** a study (Zheng, Horii, Appleton, Darlington, and Smith, 2001) suggested a connection between hippocampus, the vestibular system, spatial maps and spatial memory. Information from the vestibular system was used by hippocampus in order to build up maps of space, which could be used when spatial memories were developed during learning. Recent studies (Smith, Brandt, Strupp, Darlington, & Zheng, 2009; Smith, Darlington, Zheng, 2010) confirmed a connection by suggesting that, since the vestibular system provides self-motion information, vestibular loss might lead to hippocampal atrophy, cognitive deficits especially connected to spatial memory. In an earlier study (Smith, Zheng, Horii, & Darlington, 2005) the authors suggested that persons with vestibular disorders, not necessarily connected to dizziness or vertigo, are at risk of encountering cognitive problems. They also speculated that these problems might be connected to anxiety disorders and depression as observed in patients with vestibular deficits. In line with these studies, an answer to the question above, from Smith

and Thelen (2003) could be that the infant, among other things, activates the vestibular system through self-locomotion.

Empirical experiences from therapy as described in **Paper II** showed that some children's curiosity and courage increased when vestibular stimulation was introduced. These were children who since infancy had been stuck in immature movement- and behavior patterns and some of whom, despite prior external stimulation, had remained stuck. Prior to start of therapy, but not included in the studies, parents were informally asked to describe how they had experienced their child during infancy and early childhood. Some parents reported that their child had been passive and remained so despite different efforts of activation. Examples of activation had been training of skills that the child wasn't good at, i.e., more of the same. These were often exercises on the functional level very much like those described in **Paper I** as belonging to Special Skills Approach. In contrast, it was suggested in **Paper I** that training below the functional level in combination with vestibular stimulation enhanced balance. Further, **Paper II** described how children showed a much greater interest in physical activity when they felt more in control of their body. In line with these suggestions it was proposed elsewhere (Niklasson, 2012) that sensorimotor therapy according to '*Retraining for Balance*' is a *second-order change* (Watzlawick et al., 1974; Ahrenfelt, 2001; Wrangsjö, 2011), a change of the whole system.

Vestibular stimulation was a theme within therapy as described in **Paper I-II**. The vestibular apparatus is regarded as the system for detection of gravitation but there are receptors also in the trunk (Mittelstaedt, 1992) and studies (Albrecht-Buehler, 1991; Tairbekov, 2004) have even recognized gravitational reception at cellular level. Although the graviton, the gravitational particle, is yet to be found and although no consensus is reached whether the gravitational force acts on a micro-level or not, when vestibular stimulation was used as if the force makes a difference, both physiological and psychological reactions occurred. This thesis suggests that a well-functioning and adapted vestibular system (Klosovskii, 1963; Shepard, 1990) is of

importance for the ignition of both motivation and motor development. As stated by D. and K. Stanley-Jones (1960); *"The force of gravity is the most unchanging, and therefore the most reliable physical fact on the surface of the earth, whether by sea or on land or air. It is therefore on the gravity-receptors, with their unchanging response to an unchanging stimulus, that the nervous system has come to depend on for an unceasing and therefore reliable source of energy, without which it is unable to perform any part of its function"* (p.60).

3.3.5 Gravitation and vestibular stimulation as a possible driving force

Contrary to what could be expected '*Retraining for Balance*' uses slow (Guyton, 1991) vestibular movements and rotations. **Paper I and II** both described how the use of vestibular stimulation might have activated a child's response to gravitation. Further research should study not only if this suggestion is correct but also if the stimulus is needed just to ignite the system to self-organization or if continuous stimulation is needed for further organization. Other questions for further research to ask are when, and even if, vestibular stimulation is needed? A double-blind controlled study by McPhillips *et.al.* (2000), did not use vestibular stimulation, just stereotypical infant-movements, and received good results. However, empirical experiences not included in the current papers show that uninterrupted stimulation is to be preferred. **Paper II** suggested that vestibular stimulation could contribute to an improved learning capacity in children and similar results concerning learning in general were reported by Medeiros, Bittar, Pedalini, Formigoni and Bento (2005). **Paper I** showed significant improvements in all age groups on the *Retraining for Balance - Orientation and Balance Test* but the older group performed best which might be explained by enhanced biological development. Results also indicated that paying attention as well as the ability to concentrate in academic activities had improved significantly in all three age groups after therapy. It was suggested that problems of attention and concentration should be viewed as connected to sensorimotor difficulties. A recent study by Shum and Pang (2009) confirmed that children with ADHD have impaired balance function while early studies, however small (Kantner & Tocco, 1980; Arnold, Clark, Sachs, Jakim, & Smithies, 1985) showed positive effect on hyperactivity by vestibular

stimulation. In all, results in **Paper I** suggest that further studies ought to include a thorough look at a possible connection between inattention, balance problems and vestibular stimulation.

3.3.6 Gravitation and vestibular stimulation as a possible driving force in motor development

The method '*Retraining for Balance*', developed from empiricism without any aim to connect to any theory, was experienced as more effective when vestibular stimulation was introduced as a corner stone in therapy. Several studies, mainly within the frame of the Sensory Integration Approach, have over the years investigated connections between vestibular stimulation, motor development and DCD but as Pennington (2009) pointed out, they lack empirical validation. Nonetheless, in a review article Ottenbacher (1983) stated that controlled vestibular stimulation had a positive effect on both motor development and on reflex inhibition, which was also suggested in **Paper I.** The *Retraining for Balance – Physiological Test* (RB-P) was used to identify and further assess neurological soft signs such as primary reflexes as well as the strength of postural reactions and the level of gross motor milestones. During therapy regular re-assessments every 8:th week evaluated the interaction between the three components (**Paper I**). Motor development (Capute & Accardo, 1991, p.21) follows a sequence where postural reactions and gross motor milestones appear as the primary reflexes are suppressed. This reflex-based and maturationist view which goes back to McGraw (1989) and Gesell (1988) requires, according to the theory of '*motor development*' (Kamm et al., 1990), a hierarchical view of the nervous system where, when cortex increases its control, the subcortical primary reflexes are either suppressed or forming a base for more functional movements. Although the theory finds it possible that primary reflexes are suppressed as the cortex matures it does not fully recognize such a hierarchical view. As a complement it proposes that a competing motor behavior can challenge a stable behavior, as for example a determination to go against one primary reflex, will interfere with the behavior's stability, which might result in a perturbation, transition and novel movement behavior. This is the nonlinearity of a dynamic system, out of small causes might large effects come. The system self-organizes as old forms lose their stability and new forms emerges. In this way development is looked at as series of phase shifts where stability and

instability are interacting.

Another stable behavior is crawling (Smith & Thelen, 2003) which in **Paper I** is mentioned among gross motor milestones. Crawling will, according to Smith and Thelen, appear when the infant has enough strength and coordination to balance on hands and knees. Not all children creep before they crawl (Goldfield & Wolff, 2004). Some skip creeping and some creep after crawling. Crawling, according to Smith & Thelen (2003), is not hard-wired in the nervous system neither is it programmed in the genes. It is a self-organized behavior, a solution to a problem, soon to be replaced by another behavior. Results in **Paper I** support the 'Accardo, Capute sequence'. Significant effects were yielded for treatment with both primary reflexes and postural reactions as well as for treatment and gross motor milestones. As a consequence Smith's and Thelen's statement above is questioned. The unfolding of gross motor milestones with children who never had neither crept nor been crawling as infants might speak in favor of milestones being 'hard wired' in the nervous system. To investigate whether they are or not, is suggested to be an issue for further investigations. However, if they should continue to appear as being 'hard-wired' they ought to be regarded as 'girders' (Niklasson, 2005) in the nervous system and could as such be of help to quicker recovery after, for example, head injuries just as vestibular stimulation is suggested to be (Niklasson, Rasmussen, & Norlander, 2010; Edner, 2012). These presumed 'girders' are also suggested to enhance balance in healthy people, just like girders in a building are stabilizing the whole construction.

Without dismissing the theory of '*motor development*', rather include it as a complement, it is well worth asking whether the increased vestibular responsiveness (Ornitz, 1983) between the 6 – 12 months after birth is a biological coincidence or not? It is namely during these months that the infant is supposed to develop creeping and crawling to be able to walk at around 12 months. Without specification, as to whether it is rolling, creeping etc., Table 3 (**Paper I**) shows that gross motor miles stones were generally undeveloped when therapy started but to a significantly greater extent developed after therapy. All 232 participants in the study had

retained primitive reflexes for reasons unknown. What is known is that participants during therapy more or less suppressed the reflexes, as was shown in Table 3. The method used was aimed to give the nervous system a second chance to mature through repetition of stereotypical fetal and infant movements. This second chance is made possible because that which was fully matured at birth (Feldenkrais, 1988) remains localized in both organs and in the nervous system and can be reactivated through proper activation (M. Bergström, personal communication). As already suggested, a well-functioning vestibular system seems to be of importance and might be a part of the activation.

3.3.7 Maturation in motor development

In a study Lin, Woolacott and Jensen (2004) showed that postural control among elderly people was not only linked to age but correlated with functional balance as well. Another study (Carpenter, Adkin, Brawley, & Frank, 2006) examined how young adults and older adults with balance problems reacted when balance demands increased. In both groups, increased demands affected blood pressure, anxiety, as well as the capacity to handle the body. As balance problems are main features in DCD those suffering (Faught, Hay, Cairney, & Flouris, 2005) are more at risk for coronary and vascular diseases. As shown in follow-up studies (Losse, Henderson, Elliman, Hall, Knight, & Jongmans, 1991; Cantell, Smyth, & Ahonen, 2003) motor difficulties do not disappear but could become less obvious due to maturation (Teicher, 1941; Peters, Romine, & Dykman, 1975; Cherng, Chen, & Su, 2001). The results in **Paper I** showed significant improvements on various sensorimotor tasks in all age groups. In addition there was a proficiency effect of biological development, evident in older children who performed better than the middle and younger groups on the '*Retraining for Balance – Physiological Test*' and the '*Retraining for Balance – Orientation and Balance Test*'. This was, however, not evident on the '*Audiometric Test*'.

In a qualitative study, including more than 200 children aged 4 to 13 years, with the aim to investigate development of motility, Teicher (1941) was able to describe a progression of

maturation. Three tests were used in the study (1) Schilder's test (2) getting up from a lying down position and (3) a test of laterality. The results showed that around onset of puberty movement-patterns approaches those seen in adults. It was also concluded that the difference in patterns between the very young and the older children are sharp but very subtle between closely related age groups. The study found no differences between boys and girls. A study on children with 'Minimal Brain Dysfunction' (Peters, *et. al.,*1975) found more soft neurological signs in the intervention group than in the controls but signs became less distinct around the age of 11. Therefore, they concluded, the older intervention-group children were more alike those in the control-group.

Even though **Paper I** is a naturalistic study an effort to distinguish maturation from effect of intervention was made by splitting the cohort of 232 children and adolescents, 181 boys and 51 girls, into three groups according to Piaget (Crain, 1992) based on their age at the start of training. The groups were (1) a younger group (*the preoperational stage*) with 65 children, 51 boys and 14 girls, 7 years or younger (M=6.2, SD=2.0), (2) a middle group (*the concrete operational stage*) including 91 children, 73 boys and 18 girls, 8 to 10 years of age (M=9.0, SD=0.8) and finally (3) a group of 76 somewhat older children (*the abstract operational stage*), 57 boys and 19 girls, 11 years old or older (M=12.3, SD=1.7). As shown in Table 3 in **Paper I** the tendencies of accumulated scores before training, Tot1, is similar to those reported by Teicher (1941) and by Peters *et.al.* (1975). The older group performed significantly better on the RB-P test before training as compared to both younger and middle groups. According to Teicher (1941), although maturation progressed, not even at the age of 15 all children had reached an adult level of motility. This is similar to what was reported by Ornitz (1983) and by Cherng *et.al.* (2001), regarding the continuity of vestibular maturation. After therapy, as shown in **Paper I**, Table 3 (Tot2), the tendency of a larger difference between the younger and the older groups remained. However, both the older- and the middle groups performed better than the younger group. Even though accumulated scores after therapy are significantly better in all three groups the larger difference between the younger and the older groups could be explained by

maturation. There were only a few differences between boys and girls. Girls performed better on 'Sports-related gross motor skills' and 'Eye-movements' while boys did better on 'Gross motor milestones'.

Not only motor problems are considered threats to the coronary-vascular system, so is also a noisy environment. Norlander, Moås and Archer (2005) showed in their study that it was possible to reduce the noise-level in classrooms by training pupils to relax. After intervention, not only was the noise level reduced, the teachers rating of the children's concentration capacity had also increased. Another way for pupils to reduce self-perceived stress could be to train the right ear and since atypical primary reflexes and auditory perception have shown to be related (Korpilahti, Zachau, Heinänen, Ervast, & Rytky, 2006) **Paper I** used '*Retraining for Balance-Audiometric Test'* (RB-A) to investigate ear dominance (Tallal *et.al.,*1993). Right-ear dominance is preferable because right ear connects directly to the left hemisphere and to the speech center. In a study Okamoto *et.al*, 2007 found that left hemispheric dominance made it easier to process sound in a noisy environment. Results in **Paper I,** Table 4, did not show evident results. Although right-ear scores improved significantly during therapy, for some left- ear dominance or zero dominance remained. Not the least from the viewpoint of laterality The *Audiometric Test* is recommended to be further investigated in a controlled study. In his study, Teicher (1941) examined laterality in terms of preferred hand and foot and found a positive correlation between dominance of reflexes and laterality. A similar correlation between atypical auditory perception and retained primary reflexes were suggested by Korpilahti *et.al.* (2006). Taken together, laterality regarding auditory perception as well as hand - foot preference may hold additional information well worth to investigate further.

3.3.8 Hindrances for maturation

It was proposed (Prechtl, 1993) that the vestibular system is activated at birth due to the onset of lung ventilation. The influence of the vestibular system increases the infant's muscle tone and will make it possible to elicit the Moro reflex, a reflex of significant interest. Although it is

supposed to be suppressed by the fourth to sixth month after birth it remains retained with most of the clients who start therapy at Vestibularis. Because the Moro reflex (Taylor, et al., 2004) is first to emerge it can be considered to contain those reflexes emerging later, which means that the latter will be stuck until the Moro reflex is suppressed. Further research is advised to investigate if a retained Moro reflex could be a more fundamental reason for sensorimotor immaturity.

Although not consistent (Roberts, Burchinal, & Clarke-Klein, 1995), Otitis Media might constitute another threat during infancy and childhood (Hagerman, Falkenstein, 1987; Adesman, Altshuler, Lipkin, & Walco, 1990; Golz, Netzer, Westerman, Gilbert, Joachims, & Goldenberg, 2005; Padolsky, 2008; Goddard Blythe, 2009), not the least because the closeness of the hearing organ and the vestibular system (Canalis, 1996). As mentioned previously, already in 1803, Bell (Wade, 2009) discussed diseases of the inner ear and suggested that an inflammation around the auditory nerve also gave an increased sensitivity for vertigo. Although medical consensus is lacking today quite a few restless children have experienced ear problems. A study by Nadi and Luxon (2008) suggested pediatric and vestibular assessments for children with a combination of vestibular- and balance problems and hearing impairment as well as with developmental disorders. In an Editorial (Gillberg, & Rasmussen, 2003) the authors strongly argued for the need of a thorough physical, neurological and neurodevelopmental examination of children with behavioral- and/or learning problems. Issues for further research should be to establish normalization for the prevalence of primary reflexes within a larger population of children and adolescents and to further investigate possible correlations between Otitis Media and sensorimotor problems.

3.3.9 Movements as a key to the psyche

The aim of **Paper II** was to gain increased understanding of both the psychological and the physiological processes of sensorimotor therapy. During the analysis three themes emerged (1) Introduction of exercises (2) Regressions in terms of a return to earlier behavior and (3)

Transformations in terms of positive development and change. The three themes came to form '*the kinesthetic-vestibular development model'*. In **Paper I** it was argued that sensorimotor exercises enhanced physiological development and the results in **Paper II** was able to describe psychological development as well. This complementary view brought a new perspective to the field of what is traditionally called sensorimotor training. Because the psychological aspects of regression became apparent in the process, the training was transformed into a therapy. The psychological development seems to follow a similar pattern as was described in **Paper I** regarding physiological development. 'New' behavior emerged as older ones faded away. The term 'new' seems, however, not quiet right in these circumstances. The behaviors that unfolded during therapy and were labeled regressions were regarded to be 'below' or older than the participant's chronological age. A common trait for the different behaviors unfolding was a strong emotion. More emotional reactivity together with higher alertness to all sensory stimulus and more motoric activity are traits connected to a 'generalized arousal' as described by Pfaff (2006). He regarded this to be *'the most fundamental force in the nervous system'* (p.5). These notions are in line with suggestions made in **Paper II**.

Anecdotally, parents could tell that they felt that their child was getting in better contact with itself (**Paper II**). After a period of regression a more stable level was reached often escorted by a sensed feeling of development. Individual development was described by Loewald (1978) as an ascending spiral in which basic themes are experienced over and over again on different levels of mentation. Coming from psychotherapy, experiences similar to those reported in **Paper II** were described by Levin and Gunther (2003). They wrote that regressions are usually an escape to some developmental level that previously was not fully mastered. This level feels less stressful and more comfortable to operate from. After a while the regression will give way to a *"progressive swing"* and the person is able to demonstrate competencies in various ways. *"When we describe regression and progression in terms of movement along a line of development we are simply stating that mental capacities disappear or (re) appear; these changes are usually in relation to the experiences of stressful events"* (Levin and Gunther, 2003 p.206).

Since regressions appeared during sensorimotor therapy (**Paper II**) it could be possible, hypothetically, that participants where mentally challenged by the exercises, but how can movements be 'threatening'? Could it be a connection to the 'generalized arousal' (Pfaff, 2006) as described above? For now there are no factual answers, only speculations. However, in a discussion about memory, Hydén (1973) argued that there are a lot of information that have been laid down in the brain before and after birth, which is not used until a situation triggers and releases the function. A similar view proposed by Grosjean (2005) was that infants learn at a non-conscious level and the mechanisms for learning intervene at both a cognitive and a motor level. As mentioned in **Paper II** participants had often difficulties to verbally express feelings and thoughts. That's why a hetero-phenomenological approach was used. For example, when younger participants in general were asked how they felt a usual answer was, 'good'. During therapy verbal ability often improved which became obvious since sentences and utterances were richer. Referring to a psychotherapeutic setting, Grosjean (2005) wrote that the process of verbal and non-verbal interactions acts on "*primitive emotional reflexes*", which activates neocortical structures. A possible connection between sensorimotor therapy and language development ought to be an urgent issue for further research. Results from such studies might shed light on vestibular function and language development as proposed by Ayres (1973). It might also extend the knowledge about when and how to use first person or third person methodology respectively (Piccinini, 2010).

Therapy continued (**Paper I–II**), in average, for about 36 months and most of the time exercises were done without too much complaint. Not included in the studies but evaluated regularly, according to the *Quality Management System SS-EN ISO 9001:2008* (European committee for standardization, 2008), is participant's completion rate. During the last 14 years the rate is in average 75% (www.vestibularis.se/results). Although '*Retraining for Balance*' uses some joy-full exercises, the average exercises are rather boring and sometimes demanding. Never the less most children and adolescents starting are keeping up to later finish therapy. There must be a reason and the answer might be found on a pre-verbal level. Further research is advised to ask the

question. In contrast to the theory of '*motor development*' the results in **Paper I** could suggest that gross motor milestones are 'hard-wired' in the nervous system. **Paper II** identified three periods of regression and four periods of transformation as summarized in '*the kinesthetic-vestibular development model*'. Further analysis indicated that 63 % of participants had a '*very good*' adjustment to the model while 32 % were regarded to have a '*good*' adjustment and 5 % had a '*doubtful or poor*' adjustment. An interpretation in line with Levin and Gunther (2003) could suggest that a majority of participants had three areas of psychological development, which were to be more fully filled. Is it possibly so, that **Paper II** have identified three, hitherto, overseen psychological development stages, windows of opportunity, which are closely connected to physiological development? A further controlled study is advised to investigate this issue more thoroughly. If both gross motor milestones and these three psychological milestones continue to appear as being 'hard-wired' it might lead to a better understanding of infant development as a possible presumption for good health and for lifelong learning.

3.4 Toward a Dynamic Systems Approach to sensorimotor development

3.4.1 Open systems and Self-organization

According to Woollacott (1993), the development of motility and balance can be considered as emergent properties. Both **Papers I** and **II** have identified an unfolding or emergence of novel behavior and movements and a possible connection and explanation can be found within the theory of the Dynamic Systems Approach. The concept emergence (Konopka, 2007) aims at an apparently spontaneous unfolding of new properties, which can't be explained or predicted by the parts of the complex system alone. This happens in humans (Scrimali, 2008) because they are open, very complex and organized systems, which perpetually exchange energy, information and matter with the outside world. A thermodynamically open system (Schrödinger, 1992; von Bertalanffy, 1993) is not in equilibrium. Instead it tends actively towards a higher state of order

by reducing the entropy (disorder), which by necessity is produced as a consequence of life. The striving of an open system is to reach further and further from equilibrium. The gravitational force (Nicholis, 1993; Prigogine, 2003) is the basic organizing factor, which mediates the passage from equilibrium to non-equilibrium. When the system is able to import more negentropy (ordered information) than the entropy it dissipates the complexity increases. In a transferred sense this might be what is experienced when participants during or after therapy are more able to sit still and concentrate as reported in **Papers I** and **II.** Also in open systems far from equilibrium, small effects will be magnified and this is possibly what has been described, in **Paper I** and **II**, concerning therapy. Mainzer (1994) argues that genes alone cannot fully determine an organism. Self-organization of some kind is involved in each stage of brain development and it is necessary for ontogeny to use the self-organization of neural systems in order to handle their complexity. With reference to Hydén (see *1.2.3*), Pribram (1999) wrote that a striking fact regarding neurons is that they produce more RNA than any other cells when stimulated. Commenting on his own results, on the developing nervous system, Hydén (1961) noted that a continuous input of equilibrium-changes and gravitation is of importance for the support of the metabolic and synthetic process in the vestibular brain centers. Many other motor- and sensory areas within the nervous system are also activated through these processes, especially the reticular activating system, which is important for the activating of the cortex. Discussing early childhood experience, Hydén (1969) argued that functional, structural and biochemical differentiation occurs in the brain through activation of genes when a child receives critical stimulation during the right period of life. This brings forward a discussion about epigenetics that might be properly applied to **Papers I** and **II.** A question to ask in further research is, how does the environment affect the outcome of therapy? Which influence brings positive parenting? As stated in **Paper I,** a suggested advantage of *'Retraining for Balance'* is the total involvement of parents, but are the differences between parents personalities and their way to handle the training of importance? In **Paper II** the concept *'regression in the service of the ego'* was introduced. Influenced by Schilder's view that parents need an emotional inner balance (see *1.2.3*) to be able to guide their child, Kestenberg (1984) used the expression *'regression in service*

of parenting' meaning that especially mothers regress with their children in each phase of parenthood, which makes it possible for them to reorganize their psyche. Such process of reorganization might ameliorate parental clashes with younger as well as older children and during therapy '*Playfulness*' (Kroebner, 1963) were considered one way to cope and to gain motivation. A parent's ability is a sensitive issue but nonetheless of importance for further studies when outcome of therapy is to be evaluated.

Another question for further research to investigate is whether or not long schooldays and homework affect the outcome of therapy. According to Bergström (1989) a too information-centered education of children could be counterproductive in the long run since it will risk undermining the brain's emotional capacity. The anatomical frame in Bergström's model is MacLean's '*triune* brain' (1990), a concept that has been criticized by Ingvar (1995) as obsolete, and by LeDoux (2004) as a too broad package of the emotional brain and its evolutionary history. However, the model was considered (Panksepp, 1998, 2005) as both a beneficial oversight of how the mammalian brain organizes above the lower brain stem and as help to understand different parts of the limbic system, also called the 'emotional brain'. In line with Bergström's model of brain-function it is suggested to investigate whether a less information-centered approach from the school-system is preferable during therapy. A further controlled study is also advised to decrease the time span of therapy in order to control other possible environmental impacts.

3.4.2 Sensorimotor therapy and learning disorders

As described in **Paper I** parents filled in a form, *Reasons for Training* (Bergström *et.al.*,1999), ahead of therapy. Parents indicated what they regarded as their child's main problem or difficulty followed by what they considered as being the second to the fifth problem. Although '*Retraining for Balance*' was introduced as a method for 'motor-training', 32.3% of parents considered '*attention-difficulties*' as the most critical problem while only 18.5% had identified '*motor problems or clumsiness*' as the primary issue. '*Reading difficulties*' was 9.1%, '*mood swings*',

'*aggression*' 6.9%, 'other learning problems' 6.9% and '*writing difficulties*' was 6.5%. These parental opinions mirrored the wide variety of difficulties associated with motor problems.

Learning disorders have hitherto been labeled mostly as a cognitive problem and, accordingly, special education seems to have aimed at teaching children strategies to overcome their problems, which seems to have been beneficial for some. However, much of the remedial education offered, as reported by parents but not mentioned in the current papers, seems to have been based on the principle of 'more of the same', a first order change, i.e., if you can't read, read more. For some children though difficulties more or less remained despite remedial efforts. Since children with Learning Disorders grow up to be adults with LD it was estimated, by Levin and Gunther (2003), that about 20% of a general population suffer from LD. This is because most LD are never neither diagnosed nor properly treated which in turn leads to significant emotional problems.

The results in **Papers I-II** showed that not only sensorimotor functions but also cognitive abilities improved during therapy. In line with these results it was suggested that therapy according to '*Retraining for Balance*' could provide a second order change (Watslawick et al., 1974; Ahrenfelt, 2001; Wrangsjö (2011) and might as such be helpful for those not helped by traditional remedial education. This must, however, be further investigated.

3.4.3 A Dynamic Systems approach to sensorimotor development

It might be possible, as it seems, to fit sensorimotor therapy according to '*Retraining for Balance*' (RB) into the general model of Dynamic Systems Approach as described in ***3.3.2.*** However, when it comes to the theory of a '*Dynamical Systems Approach to motor development*', there are three issues to discuss which are crucial for the model RB. The first is the criteria of self-organization without an external agent. Both **Papers I** and **II** described how vestibular stimulation was considered to be essential for therapy and this stimulation is not possible without the gravitational force as an external factor. The force was indeed recognized by the

theory of *'motor development'* but only as a factor of resistance for a system in function. Could it be that the theory of '*motor development*' presupposes a well-functioning nervous system and thereby oversees problems as addressed in **Papers I** and **II**?

The second issue, which has to be further evaluated and discussed, connects to the first and deals with the concept of motivation in motor development. The theory of '*motor development*' holds that motivation, as such, is a driving force for a child while '*Retraining for Balance*' suggests that motivation is held back, more or less, due to an insufficient vestibular system. It further suggests that as the function of the vestibular system improves, its enhanced capacity will be essential for further physiological development, as described in **Paper I,** and for psychological development as described in **Paper II**. Based on these suggestions and on Maslow's hierarchy of needs (Passer *et. al.,* 2009) it might be possible to consider '*motor development*' as more of a cortical and cognitive approach to development while '*Retraining for Balance*' could be considered as a more subcortical and sensory approach. Maslow's pyramid includes seven steps going from basic physiological needs at the bottom to self-actualization at the top. It is also divided into two parts, deficiency needs and growth needs. The lower area of deficiency needs includes the step for 'psychological safety and security' while the basic step of the upper area is 'cognitive needs, knowledge and understanding'. '*Motor development*' proposes that a child, as described by Thelen and Smith (2006), has reached the upper area and is more able to use its 'cognitive motivation' i.e. *thinking and aiming – daring to do and being able – doing*.

On the other hand, according to '*Retraining for Balance*' as described in **Paper I** and **II**, some children were held back on the lower level, still insecure both physiologically and psychologically and not fully able to use its 'cognitive motivation i.e. *thinking and aiming – not daring and unable – not doing*. Compared from this point of view '*motor development*' and '*Retraining for Balance*' are not the same and it is therefore suggested that it would be more appropriate to view sensorimotor therapy according to '*Retraining for Balance*' as a '*Dynamic Systems Approach to sensorimotor development*'. By adding 'sensori' to 'motor' it is argued that a

basic sensory input, vestibular sensation, might have been taken for granted within the theory of '*motor development*'. **Paper I** and **Paper II** are proposed to have described how motivation, in terms of inter alia curiosity and activity, developed when vestibular stimulation was introduced. In the perspective of 'learning', results in **Paper I** pointed towards Piaget's view (Thelen, 2000a) that higher cognitive functions are enhanced by sensorimotor experiences an opinion also held by Frick (1982). This mind-body-world interconnection regarded as important also by Thelen (2000b) who discussed it in terms of 'action, perception and cognition'. However, according to Santrock (2011) Piaget's view of sensorimotor development is partly disputed and in need of modification.

The third issue concerns the hierarchical view. Theory of '*motor development*' does not accept a reflex-based and maturationist view on development. Instead it proposes a competition between different motor-behavior as for example a determination to go against a reflex. As argued above such a view presupposes a well-functioning nervous system and may well hold for a majority of the population. **Paper I** and **II**, however, target a minority of children in need of help to develop better neurophysiological functions. As an overarching model for how the nervous system works in such circumstances the 'triune brain' (MacLean,1990) was suggested as a useable tool. Discussing memory formation within the frame of thermodynamically open systems, Hydén (1973), proposed that a theory of '*dynamic hierarchic order*' would be needed. Since the concept embraces both '*dynamic*' and '*hierarchic*' this is in accordance with the suggested processes described in **Papers I** and **II.** As far as is known the concept is not in use, maybe because it is somewhat contradictory to the Dynamic Systems Approach. If it will fit into a proposed theory of 'sensorimotor development' is a matter for future discussion and research.

3.4.4 Sensorimotor therapy, emotion and learning

'*Learning*', according to Levin (2009), is basically an emotional phenomenon. **Paper II** showed how different kinds of emotions emerged during therapy and a proposed interpretation is that

participants also came to be more in touch with their emotional repertoire. Results also showed that schoolwork improved. Since there are more connections (Brendtro, & Longhurst, 2005) from the brain's limbic system to cortex than from cortex to the limbic system, it is suggested that a more developed emotional system could enhance learning. In line with Levin (2009) a further speculation is that increased emotional ability also enhances cognitive development. Emotion and learning is also tied together during therapy (F.M Levin, personal communication, August 21, 2010) through interaction between therapist and client. During sessions there are always new insights following various transitions. In this sense the '*Introductions*', as described in **Paper II** gain a higher value than being just a meeting with assessments and new exercises. Could one reason to the relatively high completion rate at Vestibularis be successful '*Introductions*'? If so, how important is the setting and the therapist for outcome of therapy? A further controlled study is recommended to include these questions.

3.4.5 Examples of other efforts for wellbeing

'Retraining for Balance' is one method and one approach among others aiming at enhancing physiological and/or psychological wellbeing but as declared above, its effectiveness has to be further evaluated. Physical activity as such belongs to the Specific Skills Approach and the positive effect on health is undisputed. A meta-analysis (Josefsson, Lindwall, & Archer, 2013) with the aim to investigate effects of exercise on the reduction of depressions symptom, concluded that as long as people with moderate depression are healthy enough and also motivated, exercise is recommended. In a randomized controlled intervention trial (Duberg, Hagberg, Sunvisson, & Möller, 2012) with the aim to study if dance could influence self-rated health in a group of adolescent girls with internalizing problems, a positive correlation was found. An important aspect ought to be that the group took part in 'free dance', which is noncompetitive and, as the authors stresses, such joyful social activity can influence health.

Another study (Sandlund & Norlander, 2000) aimed at reviewing studies regarding how Tai Chi, as a possible stress reducer, could be linked to relaxation and exercise in a perspective of psychological and physiological wellbeing. It was found that Tai Chi might increase

psychological wellness and may as well affect mood but it was not apparent whether the effects were due to only its relaxation part, as stress reduction also occurs when activities are experienced as pleasurable. A novel commercial entertainment is the home video game console Wii Fit. A pilot study (Hammond, Jones, Hill, & Male, 2013) aimed at investigating if Wii Fit, used by children with movement difficulties, could improve motor and psychological outcomes. Preliminary results show that Wii Fit might be a useable tool to support both motor- and psychosocial development but further research was regarded as needed.

3.4.6 Final remarks

Altogether the results in **Paper I** and **II** indicated that sensorimotor therapy in accordance with the method '*Retraining for Balance*' might constitute a suitable complement to existing methods for treatment of ADHD, DCD and LD but further studies are as argued needed. If the method should prove efficient it is suggested to be of importance with an appropriate labeling since different approaches to sensorimotor training are in existence (Blythe, Goodard Blythe, 2012). An intension in the current licentiate theses was to distinguish '*Retraining for Balance*' from other methods by setting the therapy in a broader theoretical perspective. Suggested direction for future research is a more thorough synthesis of first/third person account, measurement and neuroscience. Boyle (2008) proposed "*a three-tiered inter-theoretic model of explanation*" with an explanatory coherence across the three levels of phenomenology, psychology and neuroscience. Such a triangulation could make it possible to better understand what happens in the brain during '*Retraining for Balance*' and during other kinds of therapy.

4. Conclusions

In this licentiate thesis one naturalistic study examined whether sensorimotor therapy in accordance with the method Retraining for Balance could be an appropriate technique for sensorimotor proficiency. **Paper I** concluded that Retraining for Balance might constitute a complement to regular treatment of Developmental Coordination Disorder, Learning Disorders and Attention Deficit Hyperactivity Disorder but controlled studies are necessary before more decisive conclusions can be drawn.

Following the first study, another naturalistic study aimed at gaining an increased understanding of the effects of sensorimotor therapy using the method Retraining for Balance on the physiological and psychological development of children and young people. Three themes emerged regularly throughout the entire study, Introductions, Regressions and Transformations. Together they formed what was to be called '*the kinesthetic-vestibular development model*'. The results in **Paper II** were generalized to larger group of children and it was concluded that sensorimotor therapy based on '*the kinesthetic-vestibular development model*' might thus constitute a therapeutic complement to other types of treatment such as educational efforts, medication, and cognitive behavior therapy.

A theoretical framework was also included in this thesis. The aims were partly to put sensorimotor training in accordance with the method Retraining for Balance in a wider perspective and partly to try to distinguish the method from other methods.

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