Learning for life

How children with unilateral spastic cerebral palsy learn to master bimanual activities

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Cover illustration*: Git & Victor Lidman*

Learning for life - How children with unilateral spastic cerebral palsy learn to master bimanual activities

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To my wonderful son Victor ♥

ABSTRACT

Background: For children with unilateral spastic cerebral palsy (USCP), activities in daily life pose a challenge due to reduced function in one hand.
Aim: To study the development of hand function and occupational performance in children with USCP after intervention with occupational therapy (OT) combined with botulinum neurotoxin A (BoNT-A), and describe learning of bimanual activities in everyday life from a parental perspective and from self-perceived experiences of children and adolescents with USCP.
Methods: Twenty children with USCP (inclusion median age 3y and 1 mo) participated in a randomized controlled trial to evaluate the effects of repeated BoNT-A+OT compared to OT alone over a course of one year. Annual assessments were performed the following three years. Comparisons between the two study groups, and a reference group from a national quality register were made. To capture experiences of learning of bimanual activities in daily living, focus group discussions according to Krueger were conducted with parents of children with USCP, and interviews were conducted with young people with USCP, analysed according to Grounded Theory.
Results: BoNT-A+OT appeared superior to OT alone for bimanual performance ($p<0.03$). Active supination and goal achievement improved in both groups. At final follow-up, the improved bimanual performance in the BoNT-A+OT group was maintained. The OT group increased the bimanual performance during follow-up to the same level as the BoNT-A+OT group. Active supination increased in the total group compared with the reference group ($p<0.001$). The parents described that learning took place in activities that could wake the children´s inner drive, and that children developed their own way to perform an activity, sometimes with support. Other activities were not possible to learn. An overall theme emerged: *'Finding harmony between pleasure and effort is the key to learning*'. In the individual interviews, the learning of bimanual activities was described as a process taking place in interaction with the dynamics of everyday situations, summarized as: *'Managing to learn bimanual activities as life unfolds'*.
Conclusion: Learning of bimanual activities should be viewed from multiple perspectives. The impact of development with age, timing of the right interventions, evaluated in long term, and experiences from parents and people with USCP themselves, need to be considered.
Keywords: hand, bimanual performance, cerebral palsy, children, botulinum toxin.
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SAMMANFATTNING PÅ SVENSKA

Bakgrund: För barn med unilateral spastisk cerebral pares (USCP) utgör aktiviteter i vardagen en utmaning på grund av minskad funktion i en hand.
Syfte: Att studera utvecklingen av handfunktion och aktivitetsförmåga hos barn med USCP efter intervention med arbetsterapi (AT) i kombination med botulinum neurotoxin A (BoNT-A) och beskriva lärande av bimanuella aktiviteter i vardagslivet ur ett föräldraperspektiv och från självupplevda erfarenheter hos unga personer med USCP.
Metoder: Tjugo barn med USCP (inklusionsålder median 3 år och 1 månad) deltog i en randomiserad kontrollerad studie för att utvärdera effekterna av upprepad BoNT-A + AT jämfört med enbart AT under ett år. Årliga bedömningar genomfördes de följande tre åren. Jämförelser mellan de två studiegrupperna och med en referensgrupp från ett nationellt kvalitetsregister gjordes. För att fånga erfarenheter av att lära sig bimanuella aktiviteter i vardagen, genomfördes fokusgruppsdiskussioner enligt Krueger med föräldrar till barn med USCP, och enskilda intervjuer med ungdomar med USCP, analyserade enligt Grounded Theory.
Resultat: BoNT-A + AT verkade ha en bättre effekt än enbart AT för bimanuell förmåga (p<0,03). Aktiv supination och måluppfyllelse förbättrades i båda grupperna. Vid sista uppföljningen kvarstod den förbättrade bimanuella förmågan i BoNT-A + AT-gruppen. AT-gruppen ökade den bimanuell förmågan under uppföljningen och avslutade på samma nivå som BoNT-A + AT-gruppen. Aktiv supination ökade i den totala gruppen jämfört med referensgruppen (p<0,001). Föräldrarna beskrev aktiviteter som kunde väcka barnets inre drivkraft, och att barn utvecklade sitt eget sätt att utföra en aktivitet, ibland med stöd, men det förekom också aktiviteter som inte var möjliga för barnen att lära sig. Ett övergripande tema framkom: *'Att hitta harmoni mellan glädje och ansträngning är nyckeln till lärande'.* I de individuella intervjuerna beskrevs lärandet av bimanuella aktiviteter som en process som sker i samspel med dynamiken i vardagssituationer. Detta sammanfattades som: *"Klara av att lära sig bimanuella aktiviteter medan livet pågår".*
Slutsats: Många faktorer påverkar lärandet av bimanuella aktiviteter. Effekter av utveckling med åldern, tidpunkten för de rätta insatserna, utvärderingar på lång sikt och erfarenheter från föräldrar och personerna själva med USCP måste vägas in.

Nyckelord: hand, bimanuell förmåga, cerebral pares, barn, botulinum toxin.

LIST OF STUDIES

This thesis is based on the following studies, referred to in the text by their Roman numerals.

I. Lidman G, Peny-Dahlstrand M, Nachemson A, Himmelmann K. Botulinum toxin A injections and occupational therapy in children with unilateral spastic cerebral palsy: a randomized controlled trial. *Dev Med & Child Neurol 2015;7:754-61*.

II. Lidman G, Peny-Dahlstrand M, Nachemson A, Himmelmann K. Long-term effects of repeated botulinum toxin A, bimanual training and splinting in young children with cerebral palsy: A four-year follow-up. *Submitted for publication.*

III. Lidman G, Himmelmann K, Gosman-Hedström G, Peny-Dahlstrand M. How children with cerebral palsy master bimanual activities from a parental perspective. *Scand J Occup Ther 2017;9:1-8.*

IV. Lidman G, Himmelmann K, Peny-Dahlstrand M. Managing to learn bimanual activities as life unfolds in unilateral spastic cerebral palsy – a grounded theory approach. *In manuscript.*

CONTENTS

ABBREVIATIONS

AHA	Assisting Hand Assessment
BoNT-A	Botulinum neurotoxin A
CIMT	Constraint-induced Movement Therapy
COPM	Canadian Occupational Performance Measure
CO-OP	Cognitive Orientation to daily Occupational Performance
CP	Cerebral Palsy
CPUP	Cerebral Palsy follow-up program
GT	Grounded Theory
ICF	International Classification of Functioning, Disability and Health
ICF-CY	International Classification of Functioning, Disability and Health for Children and Youth
MACS	Manual Ability Classification System
MOHO	Model of Human Occupation
OT	Occupational Therapist
ROM	Range of movement
RCT	Randomized controlled trial
SDD	Smallest detectable difference
USCP	Unilateral spastic cerebral palsy

THESIS AT A GLANCE

STUDY	AIM	DESIGN-METHOD	RESULTS	CONCLUSION
I	To investigate the effects of repeated BoNT-A injections combined with OT, including a splint, compared with OT alone on hand function in children with USCP.	Randomized controlled trial in 20 children with USCP 10 children received an OT program and 10 BoNT-A + OT program during one year. Outcome measures: AHA, ROM and COPM.	AHA improved in 6/10 in the BoNT-A group compared to 1/10 in the OT group. Active ROM and goals improved in both groups.	Repeated BoNT-A+OT appeared superior to OT alone for bimanual performance in young children with USCP. Active ROM and goals improved.
II	To investigate the long-term development of hand function after repeated BoNT-A injections and OT in children with USCP at a young age compared with a reference group.	Prospective, longitudinal study. 20 children with USCP, from study I, followed during a four years period. The development of AHA, and ROM was investigated and compared with data from a national quality register.	Bimanual performance in the BoNT-A+OT group was maintained, and the OT group improved over time. Active supination increased compared with the reference group.	The increased active supination achieved after intervention improved more compared with the reference group, but no difference was found in bimanual performance.
III	To describe parental reasoning on how children with USCP learn to master the performance of bimanual activities in everyday life.	Qualitative. Interpretive study. Focus Groups discussions, 16 participants, parents of children with USCP. Methodological criteria by Krueger et al.	Overall theme: 'Finding harmony between pleasure and effort is the key to learning'. Followed by four themes and eleven categories.	An activity could wake the child's inner drive to perform. They strived to develop their own way to perform, sometimes with support, but some activities were not possible to learn.
IV	To describe the experiences of children and adolescents with USCP about how they learn and manage bimanual activities.	Qualitative. Interpretive study. Individual interviews 10 participants Grounded Theory method.	Core category: 'Managing to learn bimanual activities as life unfolds' and five categories and 13 sub-categories.	To learn to perform bimanual activities as life unfolds, to achieve a balance between the interacting factors is the key.

1. INTRODUCTION

1.1 HAND FUNCTION AND BIMANUAL PERFORMANCE

Our hands are unique tools in everyday activities and can be used for precision tasks, but also when heavy strength is required. We use them in interaction with other people to strengthen verbal language, show tenderness or to stretch out to greet one another. The hands require a large area of the cortex in the human brain to underpin the heavy load that is required to handle the complex interactions between motor, cognition, perception and emotions occurring when the hands are used to perform everyday activities. Moreover, in all aspects of daily life, we perform activities that require the use of two hands (1).

In bimanual activities, the hands coordinate in a well-adjusted and smooth way. The hands are sometimes used symmetrically, but most often the hands have different tasks: one hand stabilizes and the other performs the manipulative task. The individual must thereby be able to coordinate different forces and adjust the power between stabilizing and the manipulating hand in different ways during the performance of the activity (2-4). This must be done in a well-executed way for the activity to succeed. Hand function develops gradually during childhood and, step by step, the child can carry out activities in order to eventually be independent (5). The association between good hand function and the ability to perform activities in everyday life is evident and a child with a neurological disability involving hand function is thereby additionally challenged. Thus, this supports the importance of research on bimanual hand use in the occupational performance of daily life.

1.2 LEARNING, AND LEARNING OF BIMANUAL ACTIVITIES IN CHILDHOOD

Children learn bimanual activities and develop occupational performance through play and by participating in everyday activities during childhood (6). The development takes place through the child's own active involvement and the active child is a key in learning emphasized in the contemporary theories of development (7, 8). To enable learning activities, it is essential to find activities that stimulate children's own interest and motivation in their different developmental phases (6, 9,10). Children need to perform activities by

themselves and also do activities together with others who are more competent, who act as role models (8, 11). Earlier strategies and abilities can then be used, when learning new activities in upcoming situations (12). Occupational development occurs in an interaction with biopsychosocial factors that involve physical, physiological and social and also cultural conditions (12, 13). During childhood, the child takes more and more responsibility for his or her own performance, with a progressive increase of cognitive skills and strengthened problem-solving, reasoning and thinking abilities, thereby becoming able to perform more complex activities and finally be independent as adults (14, 15). Different learning theories offer explanations for the child's occupational development in different perspectives, as in which human beings are seen as part of their environment, and therefore not distinguished from this (6), or where an important key is associated to the active learning, i.e. learning by doing (8). Other authors describe the specific development of motor learning, based on repetition and practice (16, 17). Motor learning can be described as a learning process in three different hierarchical stages: *the verbal cognitive stage*, in which the child acquires an idea of the task, *the motor stage,* when the child becomes more independent in the performance, solving most strategic problems and practicing on details, and the final stage, *the autonomous stage,* when the motor skill becomes mostly automatic (16).

1.3 CEREBRAL PALSY

Cerebral palsy (CP) is caused by a lesion in the developing brain and affects about two per 1000 live-born children in the Western world (18-20). CP is the most common physical impairment in childhood and is described as a group of motor disorders, accompanied by other associated impairments causing a lifelong disability (21-23). The location, timing and size of the lesion play a role for the future development of the child. There are more boys (~60%) than girls with CP (20, 23). Most children are born at term, but preterm birth and low birth weight are associated with an increased risk of CP (20). Furthermore, maternal infections, multiple births and malformations of the brain are associated with increased risk for CP (24-26). There is also a small group of children who acquire a lesion causing CP after the neonatal period, where the causes are usually trauma, infections or drowning incidents (27).

1.3.1 Definition of cerebral palsy

The latest definition of CP was proposed in 2006 by the International Executive Committee for the Definition of Cerebral Palsy and was the result of a consensus discussion between experts in the field of CP and developmental disorders from around the world:

"Cerebral palsy describes a group of permanent disorders of the development of movement and posture, causing activity limitation that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbance of sensation, perception, cognition, communication, and behavior, by epilepsy, and by secondary musculoskeletal problems." (from Rosenbaum et al. 2007(21))

1.3.2 Classifications of cerebral palsy

Classification is complicated due to the wide variety of symptoms and degree of activity limitation that exists in CP. Subtypes are based on the predominant neurological findings. CP is broadly divided into three subtypes with characteristic patterns of movement and posture: spastic, dyskinetic and ataxic CP (28, 29). Spastic CP affects about 80% of the CP population (20, 30, 31). Spasticity is an abnormally increased velocity-dependent muscle tone (32, 33), also defined as hyper-resistance in the European consensus meeting in 2014 (34). Spastic CP is subdivided into unilateral or bilateral spastic CP, unilateral when one side of the body is affected and bilateral when both sides are involved (28). Dyskinetic CP occurs in approximately 7-15% (20, 30, 35, 36) and is characterized by involuntary, uncontrolled, recurring, occasionally stereotyped movements and, based on the patterns of movement, is described into two subtypes: dystonia and choreoathetosis (37). The less common subtype ataxic CP is characterized by tremor, and disturbed balance and coordination, and occurs in approximately 3-5% (20, 30, 35, 36).

1.3.3 Unilateral spastic CP

In the total population of CP, more than a third have unilateral spastic CP (USCP) (20, 35, 36, 38) and, in the latest report from the Panorama of Cerebral Palsy in Sweden study, USCP comprised 44% (20). USCP, also defined as hemiplegia, is characterized by motor impairment in one side of the body. The brain lesion itself is found on the opposite side, usually only on one side, but bilateral lesions may also occur. In some cases, no lesion can be seen in magnetic resonance imaging (39). The motor impairment may range from very

mild to a significant impact on motor abilities. USCP may be accompanied by attention deficits and cognitive impairment, more frequently when epilepsy is present (23). Deficits in motor planning and executive function are also seen, reflecting the complexity of USCP (40-42). In this thesis, all participants were diagnosed with USCP, and the focus was on their hand function and performance in bimanual activities.

1.4 HAND FUNCTION IN CHILDREN WITH UNILATERAL SPASTIC CEREBRAL PALSY

The lesion causing USCP often affects the children's ability to use their hands (43, 44). The degree of impaired hand function varies from good ability, with some difficulty in high-precision tasks, to sparing use of the hand. Some effect of the bimanual performance in everyday activities is frequent (45, 46). Most of the children will be gradually independent during childhood, but the quality of performance will often be affected. Already at an early age, before six months, children who are later diagnosed with USCP may show a clear hand preference. When the child develops reaching and grasping abilities, the fingers are flexed and the thumb is adducted, instead of an open hand (47). One hand often develops typically while one hand has the appearance of increased muscle tone, weakness, slowness, and mirror movements, along with reduced coordination and sensation (43, 44, 48-50). The affected side is often characterized by poor muscle mass (51), and bony changes may occur (52). Findings indicate that the development of hand function is rapid at a young age and is related to the ability to grasp with the affected hand in early age (53, 54). Following cognitive development, the children can gradually develop strategies to cope with activities they need to learn during childhood growth.

The increased muscle tone, spasticity (33) is a phenomenon of impaired neuromuscular response to passive stretch (34). When the child actively uses the affected side, the tone may increase in several muscles. The shoulder is pulled into flexion, adduction and internal rotation, with the elbow in flexion, the forearm in pronation, the wrist in flexion and ulnar deviation, fingers in flexion and the thumb in the palm (44, 47, 52, 55, 56). The increased muscle tone can lead to limitations in range of motion (ROM) and muscle shortening and eventually contractures (57, 58). In contrast, there is also muscle weakness,

which can be prominent in both the antagonist as well as an underlying weakness of the spastic muscles (56, 59). Hyper mobility at the proximal finger joints, with swan neck deformity as a consequence, may be observed, affecting the ability to grasp (60).

Mirror movements are involuntary movements of one body part that mirror the voluntary movement in the opposite half. The movements are symmetrical and decrease the quality of bimanual performance. The degree of intensity is associated with increasing fatigue or complex activities (61-65). Incomplete maturation of the corpus callosum and ineffective activity caused by the brain lesion are the likely cause of mirror movement (66, 67).

The interpretation of the sensation, stereognosis, often affected in USCP, is needed when objects must be handled without vision. This impairment has been identified in different studies in between 50% - 92% of the children (49, 68, 69). This causes a reduced ability to control the movements in the hand and similarly causes impairment in motor function and precision of the performance (70, 71).

The coordination between the hands is affected in USCP, and more and better skills are developed in the well-functioning hand compared to the affected. An asymmetric hand use is often seen and complicates the performance of bimanual activities. Recent findings indicate that children with USCP with a high manual ability in early age have more rapid and favorable development compared to children with low function (53, 54). Furthermore, a rapidly increased use of the affected hand in early preschool age is described, especially favorable for the children with an early ability to use active grasping (53, 54). The characteristics of the brain lesion were in addition found to affect this limit of development, and children with white matter damage of immaturity developed faster and to a higher level compared with children who suffered from a middle cerebral artery infarction with involvement of basal ganglia and thalamus (72-75). Moreover, other findings indicate a negative effect on the ability to scale the force in the better hand, when the non-efficient hand is active (76).

Altogether, these impairments often lead to a slow and insecure performance and cause difficulties in learning activities that require bimanual ability. Further, automaticity of the movements is disturbed, which in addition results in an increased cognitive load (52, 77). Still, separate hand skills cannot fully explain the use in everyday activities, since daily activities are more complex (48). The level of the impairment and the interaction between different hand skills are

crucial. Furthermore, the cognitive processes involved in complex activities can be another difficulty, besides the feature of the activity and the environmental factors important for the outcome of the performance (42, 78).

1.4.1 Classification system of hand function in cerebral palsy

The Manual Ability Classification System (MACS), the most commonly used classification system, describes how children with CP handle objects in everyday life. It is valid for children of four to 18 years of age with CP and consists of manual ability in five levels (79, 80):

Level I: Handles objects easily and successfully.

Level II: Handles most objects but with somewhat reduced quality and/or speed of achievement.

Level III: Handles objects with difficulty; needs help to prepare and/or modify activities.

Level IV: Handles a limited selection of easily managed objects in adapted situations.

Level V: Does not handle objects and has severely limited ability to perform even simple actions.

In the studies of this thesis, the manual ability of participants corresponds to the MACS levels I-III (79-81).

1.5 INTERVENTIONS FOR IMPROVING HAND FUNCTION

A large amount of research has been conducted in children with USCP, aiming to facilitate the development of hand skills needed during childhood, to prevent future complications and to provide the basis for independent performance later in life (45, 82). These are still preferably studies investigating the effects over a short time, and studies extending over longer periods of time are often seen to be needed (45, 83). There is also an emerging interest in research in very early interventions, further down during the infant period (52, 84).

1.5.1. Current occupational therapy interventions

Interventions for increasing the bimanual ability of children with USCP may be divided into interventions aimed at improving the function in the reduced hand, thereby improving coordination between both hands, and at improving the occupational performance itself, i.e. being able to master bimanual activities in the setting of daily life. In addition, these interventions are often performed in different contexts, at the clinic or in the children's natural environment.

Interventions aimed at improving the affected hand and/or coordination between hands

Hand splints are a frequently used therapy, if increased muscle tone of the hand or arm is identified. One type of hand splint is the "non-functional" splint, preferably used during the night (52, 85). This hand splint provides prolonged stretch with the purpose of preventing loss of range of movement and muscle stiffness or of increasing the length of the muscles. This type of therapy has been evaluated in only a few studies, and the samples have been small (52, 85, 86-88).

The Constraint-induced Movement Therapy (CIMT) for children with USCP aims to improve the capacity of the affected upper limb, through an immobilization of the unaffected hand; thus, it forces exclusive use and intensive training of the affected limb (43, 44, 83, 89). In one of the modified forms for children, the constraint is daily, lasting for two hours at a time and for eight weeks, involving parents and/or preschool teachers conducting a home-based program with unimanual tasks (90, 91). Constraint therapy may already be relevant during the first year of life, and studies in so called baby-CIMT in very early age are currently discussed (84). The CIMT has shown significant improvements in various studies done over a short time and maintained performance in a small long-term study by Nordstrand et al. (83) (90-94). CIMT treatments have also been combined with bimanual training therapies (95).

Bimanual therapy is based on theories of motor learning and evidence shows significant benefit (45, 97, 98). These therapies comprise gross and fine motor activities that are selected to be appropriate for the age and in consideration to the child's affected limb. The persons' self-initiated voluntary movements are encouraged in play and other motivating daily activities. A key in this therapy is the repetition of activities. The training consists of both bilateral symmetrical and asymmetrical movements. With time, the complexity increases and requires

active coordination and manipulation, including the children's own engagement in problem-solving. One of these bimanual therapies is the 'Hand-Arm Intensive Bimanual Therapy' (HABIT) (97, 99).

Interventions aimed to master activities in everyday life

Goal-directed training involves practice in selected goals in everyday activities chosen by the child or adolescent and in some cases the parents. In bimanual training, the goals may be chosen in self-care, play or school-based activities. The training is based on motor learning theory and dynamic systems theory, involving the interaction between the child, the activity itself and the context in which the activity is carried out. The training in everyday situations and transferring the practice in everyday routines are important parts of this intervention and there is strong evidence that goal-directed home programs are effective (45, 78).

The Cognitive Orientation to daily Occupational Performance (CO-OP) is defined as a client-centered, performance-based, problem-solving approach, with possible transfer effects. CO-OP can be used for children with performance difficulties and aims to enable skill acquisition through a process of strategy and guided discovery. The children learn strategies for how to talk themselves through performance problems and practice in activities that are important to them, and may include bimanual activities (100, 101). Recent studies on children with CP show promising results of applying the CO-OP approach (102).

Home programs conducted in the children's natural environment are often used in a family-centered service, involving parents in the treatment (78,103). The "partnership home program" can be used for bimanual therapies and consists of a five-step process as follows: establishing a collaborative relationship with the child’s parent, collaborative goal setting, constructing a home program, supporting the program implementation and evaluating the outcomes (104, 105). The bimanual activities are selected based on the child's age, interests and ability in the affected hand, and the complexity of bimanual coordination is progressively increased in the program. The parent is the one who guides the child to perform the training, following instructions from the occupational therapist and supplemented with regular follow-up sessions (104-106). In a study evaluating this program, the parents described that this way of training was beneficial to their children's progress and was also more time-efficient than

travelling to the clinic (107). However, continuous support to maintain the parents' motivation to continue to implement the home program was still needed.

1.5.2 Botulinum neurotoxin type-A combined with occupational therapy

Occupational therapy can be additional to treatment with botulinum neurotoxin type-A (BoNT-A) to give improved hand function (108, 109).

BoNT-A has been used to reduce spasticity in children with CP for more than two decades (82, 108, 109, 111, 112). BoNT-A is injected in the muscle, often under general anaesthesia, nitrous oxide sedation or other sedation, and analgesia (113, 114). The injections may be guided with neuromuscular electric stimulation or ultrasound. The BoNT-A blocks the presynaptic release of acetylcholine from the motor endplates of the lower motor neuron, decreasing tone by limiting muscle contraction (115). The outcome is influenced by the dosage, intervals of treatment and the following interventions (113). There is a high level of evidence supporting the use of BoNT-A combined with occupational therapy in the short term, to improve the performance of the upper limbs in children with USCP (107). The BoNT-A is injected into selected muscles, which results in reduced spasticity and creates possibilities to increase the volitional control of the muscles (114, 116). The maximum effect of the BoNT-A occurs four to six weeks after the injection, and the effect lasts for three to six months. The window of opportunity exists during this period, where occupational therapy interventions are recommended (108). The injections may need to be repeated to have a long-lasting effect on function (110). When combined with occupational training, BoNT-A is found to have a positive effect on body functions and structures, as well as on bimanual performance (108, 110,116-118).

1.5.3 Hand surgery combined with occupational therapy

Hand surgery in children with USCP is often accompanied by occupational therapy such as functional and bimanual training, manual stretching of selected muscles, treatment with hand splints, and goal-directed and task-oriented training in everyday activities. The surgical procedures in children with USCP may include lengthening of muscles with the purpose of reducing the strength of the spastic muscle, shortening or transfer of muscles to achieve a good balance between muscles agonists and antagonists, as well as stabilization of joints (109,

119-121). Few studies have evaluated function and bimanual performance, but there are findings that indicate improvement in the short term (122, 123).

2. THEORETICAL AND METHODOLOGICAL FRAMEWORK

This thesis includes both quantitative and qualitative studies. This means that several theoretical perspectives have been used based on children and adolescents with CP and their development, performance and learning of bimanual activities. The occupational perspective and the biopsychosocial perspective are included in all studies and is the main theme throughout this thesis. Studies I and II used deductive methods, including the biological and medical perspective, while studies III and IV are inductive and include a learning perspective.

2.1 THE OCCUPATIONAL PERSPECTIVE

The occupational perspective is a way of looking at, and thinking about, human occupation (124). The perspective is based on the assumption that humans are active beings, that occupations form and develop a person, and that humans are social beings that perform activities in interaction with others (125, 126). Occupations are always conducted in a dynamic interaction between the person, the activity and the environment, and the result is influenced by the interaction between these elements, i.e. the occupational performance (6, 127). Performance and participation in different occupations are different for each individual and occupational patterns are created on the basis of the individual's interests, volition and values (126). This means that people are involved in occupations both because they want to and because they need to. Finally, while self-chosen activities define who a person is, how his or her identity is shaped also depends on the way in which participation and performance of the occupation will be during life (128, 129). Occupational performance is also used as a tool for occupational therapy interventions, which implies that these activities meet the meaning and relevance to the person performing them (130).

A definition of the term occupational perspective is given by Njelesani et al. (124 p. 233) as: "an occupational perspective is a way of looking at or thinking about human doing." The authors mean that it describes a statement where occupation is the core, but by weighing the term 'human doing', the definition has been made more understandable and results in a broader use of the

definition. Each individual researcher then has the opportunity to specify his or her own 'occupational perspective' (124).

2.1.1 Definition of occupational perspective and occupational performance in this thesis

In this thesis, the occupational perspective has a starting point in that activity constitutes a synthesis of both doing and being, leading to development in a child (131). Development takes place on many levels, physiologically, psychologically and socially. The performance of an activity is a process that takes place in a context; it has a beginning and an end and includes several steps. All steps, from idea to implementation, are included in the definition; the actual creation is illustrated in a model by Peny-Dahlstrand and Bergqvist (132) (Figure 1). Each activity also has different complexities and is performed in a specific context. In addition, the person's own unique abilities affect the performance of the activity (126, 127). The challenge of children and adolescents with USCP is to find a way to deal with their performance capacity and at the same time master the bimanual activities occurring in different contexts, which will be crucial to their ability to perform the activities they want to, need to, or are expected to, perform in their lives.

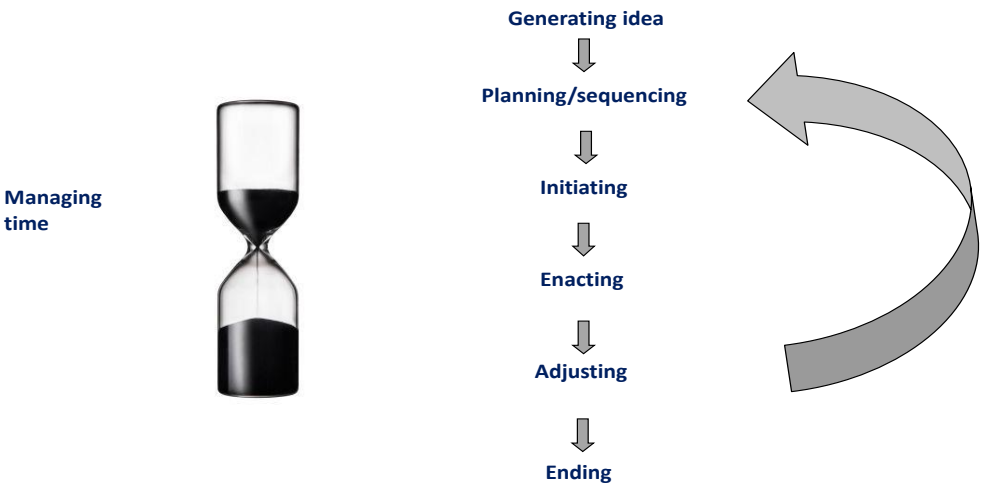

Figure 1: The Model of the process of doing (MPoP), published with permission from the authors (132, 133).

2.1.2 Definition of bimanual performance in occupation in this thesis

This thesis focuses on bimanual activities that children and adolescents with USCP learn during their development in childhood (134). The definition includes the activities that are usually performed with two hands by people with typical hand function, but also how children and adolescents with USCP deal with bimanual activities in daily life. Therefore, the definition also includes how bimanual activities are mastered, including activities performed with only one hand, with assistance from others or abstaining from activities (135, 136).

2.2 BIOLOGICAL AND MEDICAL PERSPECTIVE

This perspective focuses on biological development and the impact of different human systems from cell to major bodily systems. The medical perspective has a biomedical focus and is diagnostic and disease oriented, as well as treatment oriented. The biomechanical attributes during the performance of a task include, for example, the size, force and location of objects (137). From this perspective, biomechanical actions and interaction between physical structures are included. This may well involve the ability of range of movement, muscle strength, spasticity, coordination, sensibility and grip, which are often in focus when measuring bimanual ability in children with USCP.

2.3 BIOPSYCHOSOCIAL PERSPECTIVE

The concept of health is seen as complex interaction between biological, psychological and social factors, which could be defined as the biopsychosocial perspective. The model of The International Classification of Functioning, Disability and Health (ICF) (138) and Model of Human Occupation (MOHO) (139) are conceptual frameworks that address these dynamic systems and focus on the individual's behavior and functioning in everyday situations. This can be exemplified by the learning of bimanual activities, which depends on physical, physiological and social conditions, but also what motivates a person to action, sense of own abilities and values (126).

2.3.1 International Classification of Functioning, Disability and Health - ICF

The complexity of impaired hand function in an individual with USCP requires multi-level approach and interventions in several aspects. The ICF was developed by the World Health Organization (WHO) to apply to different health perspectives and to provide a structure and a uniform terminology to describe how people live with their health condition. Bodily, individual and societal perspectives are described in body functions and structures, activities and participation domains and the ICF also describes environmental and personal factors (138).

The ICF is also available in an edition for children, the International Classification of Functioning, Disability and Health for Children and Youth, ICF-CY (138). This model is designed for a better description of the growth and development perspectives of children and youth and how children function in their everyday environments.

2.3.2 Model of Human Occupation - MOHO

The MOHO is a widely used conceptual practice model in occupational therapy (126, 139). It explains how a person engages in occupations and considers this as a result of the interaction between the four elements of volition, habituation, performance capacity and social and physical environment. This model describes what happens when a person meets difficulties in carrying out daily activities and when the dynamic between the four elements is interrupted.

2.4 PERSPECTIVE ON LEARNING

This perspective defines children's learning processes. In the earliest stage of development children learn simple activities, which is followed by a gradual learning of more complex activities during childhood. Cognitive skills increase and strengthen the ability to solve problems, reasoning and the child's own abilities for thinking (14, 15). Learning takes place through internal motivation, in activities that stimulate the child's own interests and are perceived as meaningful and task-specific, as well as through external motivation through reactions from other people in the environment (10, 140). Moreover, children observe how others do and learn new activities by trying on their own (8).

2.4.1 Definition of learning and learning of bimanual activities in this thesis

In this thesis, the definition of learning includes a process, influenced by physical, physiological, social, physical, and environmental factors, to acquire new abilities or modify existing abilities (6, 15). The learning of bimanual activities in children and adolescents with USCP includes how to learn and how to master bimanual activities at different ages and contexts in development during their childhood (6, 15, 141).

3. AIMS

The overall aim of this thesis was to study the development of hand function and occupational performance in children with USCP after intervention with occupational therapy combined with botulinum neurotoxin A, and describe learning of bimanual activities in everyday life from a parental perspective and from self-perceived experiences of children and adolescents with USCP.

SPECIFIC AIMS

Study I — To evaluate and compare the effectiveness of repeated botulinum toxin A injections plus occupational therapy versus occupational therapy alone on hand function in children with USCP.

Study II — To investigate long-term follow-up of the effectiveness of repeated BoNT-A combined with OT compared with OT alone at young age, and to describe abilities in terms of stereognosis, strength and manual dexterity. The second aim was to compare the development of the children´s hand function and bimanual performance over time with a reference group from a Swedish national quality register.

Study III — To describe what promoted the learning of bimanual activities in children with USCP, from a parental perspective.

Study IV — To explore and describe the experiences of children and adolescents with USCP when it comes to their learning and dealing with activities that require both hands.

4. METHODS AND PARTICIPANTS

4.1 OVERALL STUDY DESIGN

In this thesis, the choice of methods was guided by the specific research questions in each study. Quantitative methods were used in Studies I and II with a prospective, initially experimental, approach, where the participants were followed over time. The impact of interventions was evaluated in Studies I and II, with a randomized controlled design in Study I and a prospective longitudinal design in Study II. Qualitative methods were employed in Studies III and IV: in Study III, the focus group method and, in Study IV, the grounded theory method. The quantitative and qualitative methods complemented each other and give different perspectives of the overall aim of the thesis (Table 1).

Table 1. Overview of methodological approaches considering population, design, data collections and data analysis.

STUDY	STUDY POPULATION	STUDY DESIGN	DATA COLLECTION	DATA ANALYSIS
I	20 participants	Quantitative Randomized Controlled Trial	Longitudinal	N-1 $\chi 2$ test Peksun exact method Wilcoxon's signed rank test
II	20 participants	Quantitative Observational study	Longitudinal	Fisher's exact test Chan and Zheng method Wilcoxon's signed rank test Spearman rank correlation test
III	16 participants	Qualitative Interpretive	Group discussions	Focus group methodological criteria by Krueger (146)
IV	10 participants	Qualitative Interpretive	Individual interviews	Grounded theory inspired by Corbin (149)

4.2 METHODOLOGICAL APPROACHES

4.2.1 Randomized controlled trial and longitudinal trial

In Study I, a randomized controlled trial (RCT) was chosen to evaluate the effects of two different interventions. In quantitative research, RCT is considered to generate a high level of evidence and is conducted in such a way that as many sourses of bias as possible are removed from the process (142). The word *randomized* means that the participant recieves the treatment randomly, *controlled* represents the use of a control group that does not receive the new treatment being tested and *trial* represents the fact that the treatment is under trial and will only be approved for use if the results indicate a good level of effect. Study I was recorded according to the guidelines of the Consolidated Standards of Reporting Trials (CONSORT 2010) (143). These guidelines are intended to maintain a high standard for the reporting of RCT and was developed through a collaboration of and consensus by scientists and editors.

A longitudinal design characterized the long-term follow-up in Study II, which implies that the participants were assessed over a prolonged period of time. A reference group was used that consisted of a comparable sample of children with; comparisons regarding frequency and levels over time were performed (144).

4.2.2 Focus group method

As the purpose of Study III was to generate an explanation for the specific phenomenon, the focus group method was considered to be appropriate (145, 146). The interaction in the group formation distinguishes its form compared to other types of methods. Group interaction provided different aspects and became a tool to capture a current phenomenon that was not always easy to verbalize. The focus group discussions thus enabled the parents of children with USCP to contribute their thoughts, experience and specific expertise. Krueger et al. developed and described explicit methodological criteria and research methods for focus group discussions, where the multiplicity and the composition of the group are important (145, 146). A composition of both homogeneous and heterogeneous groups is sought, in the sense that all participants have experience of the topic discussed; however, equally important, is heterogeneity, that is, to capture a certain variation in aspects of the subject. The analysis of the collected data in the focus group method includes parts of other qualitative research as

well as the complexity of group interaction, which was considered to address the aim of Study III (147).

4.2.3 Grounded Theory

The purpose of Study IV was to describe experiences of a subject not explored earlier in the view of the children and adolescents themselves. Grounded Theory (GT) is an analytical method suitable for theoretical explanations about complex processes and has proven to work well to develop knowledge in subjects not yet explored. It was therefore considered to be appropriate in this study (148). The method makes it possible to identify patterns of action-interaction and emotions seen in the responses of the participants (149). Concerns of external requirements and social norms are also possible.

The GT method was developed by two sociologists, Barney Glaser and Anselm Strauss, in the 1960s. The two had utterly different research traditions, with bases in quantitative and qualitative methods, but their collaborations led to contributions of written guidelines for the implementation of qualitative analyses (150). The founders themselves and some collaborators eventually developed the method in different directions. One of the second-generation researchers, Juliette Corbin, who collaborated with Anselm Strauss, together represented a positivistic GT (149). The GT method used in Study IV was inspired by Corbin et al.

4.3 STUDY POPULATION

Children and adolescents with USCP and parents of children with USCP were included in the four studies of this thesis (Table 2). There was an identical sample of children in Studies I and II and four out of this sample also participated in Study IV. In Study III, all the participants were parents of children who participated in Studies I and II. All participants were recruited from the habilitation centres and the Regional Rehabilitation Centre in the county of Västra Götaland, Sweden.

4.3.1 Study I and Study II

The participants were registered in the CP register of western Sweden, a register that has monitored children with CP in western Sweden since 1954 (20, 151). Consent to participate was given by the parents of 20 children, who were

randomized into two intervention groups. This population-based study represented 20% of all children with USCP in their birth-year cohorts in the county of Västra Götaland.

The inclusion criteria were children with USCP from 18 months to ten years, with spasticity interfering with bimanual activity. The spasticity typically occurred in the pronator muscles, thumb muscles and elbow flexors (47, 56).

The exclusion criteria were upper limb dystonia, previous upper limb surgery and/or BoNT-A injections, intellectual disability interfering with the occupational therapy program, or reduced hand function of a very mild degree not suitable for BoNT-A intervention.

In Study II, the long-term effects were compared between the original two groups and, in addition, compared with data from a reference group to investigate the development over time. The reference group consisted of 641 children with USCP; these were provided by the Cerebral Palsy follow-up program (152). CPUP is a national quality register, where all children in Sweden with CP are regularly assessed. The reference group included all children with USCP of comparable age with available data in the CPUP and was considered to represent comparable reference data on hand function in children with USCP of a similar age as the participants in Studies I and II.

4.3.2 Study III

In this study, 16 parents of children with USCP participated, five men and 11 women. They were the parents of 12 children, as some children were represented by both their parents. Their children had previously participated in Studies I and II. The median age of their children was nine years (range six to 12 years) at the time of the focus groups. The children were classified at MACS levels I-III (79, 80).

4.3.3 Study IV

A sample of ten children and adolescents with USCP participated in this study. They were recruited from the Regional Rehabilitation Centre, where children and adolescents come for assessment and treatment. The inclusion criteria were: an age from ten to 18 years, diagnosis of USCP, living in the county of Västra Götaland, and having the cognitive and communicative ability to participate in the interview procedure. The sample comprised a variation of ages, gender and

degree of disability. Four boys and six girls were included; four of these (two boys and two girls) were previous participants in Studies I and II.

Table 2. Characteristics of the study populations in Studies I-IV.

	Study I	**Study II**	**Study III**	**Study IV**
number of participants	20	20 (641)*	16	10
females	6	6 (257)*	11**	6
males	14	14 (384)*	5**	4
median age at inclusion	3.1	3.1 (3.1)*		13.4

* Participants in the reference group. **The gender of the participating parent.

4.4 DATA COLLECTION AND PROCEDURES

4.4.1 Studies I and II

Two intervention programs were compared in Study I, BoNT-A combined with an occupational therapy program and the occupational therapy program alone during two blocks over the course of one year (Figure 2, Figure 3). Simple randomization was used and the group affiliation was known by the participants. The occupational therapy program involved a home program based on the approach by Novak et al. (105, 107) and contained bimanual training, manual stretching, training in goal-directed activities and use of a static night splint (Figure 4). The primary outcome measure to assess hand function was the Assisting Hand Assessment (AHA) (153). Secondary outcome measures were active and passive range of movement (ROM) (154) and selected goals rated by the parents with the Canadian Occupational Performance Measure (COPM) (127,155,156). These assessments represent the domains of body function/ structure and activity/participation of the International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY) (138). All domains were included, as bimanual performance is considered a complex ability to evaluate (Figure 5).

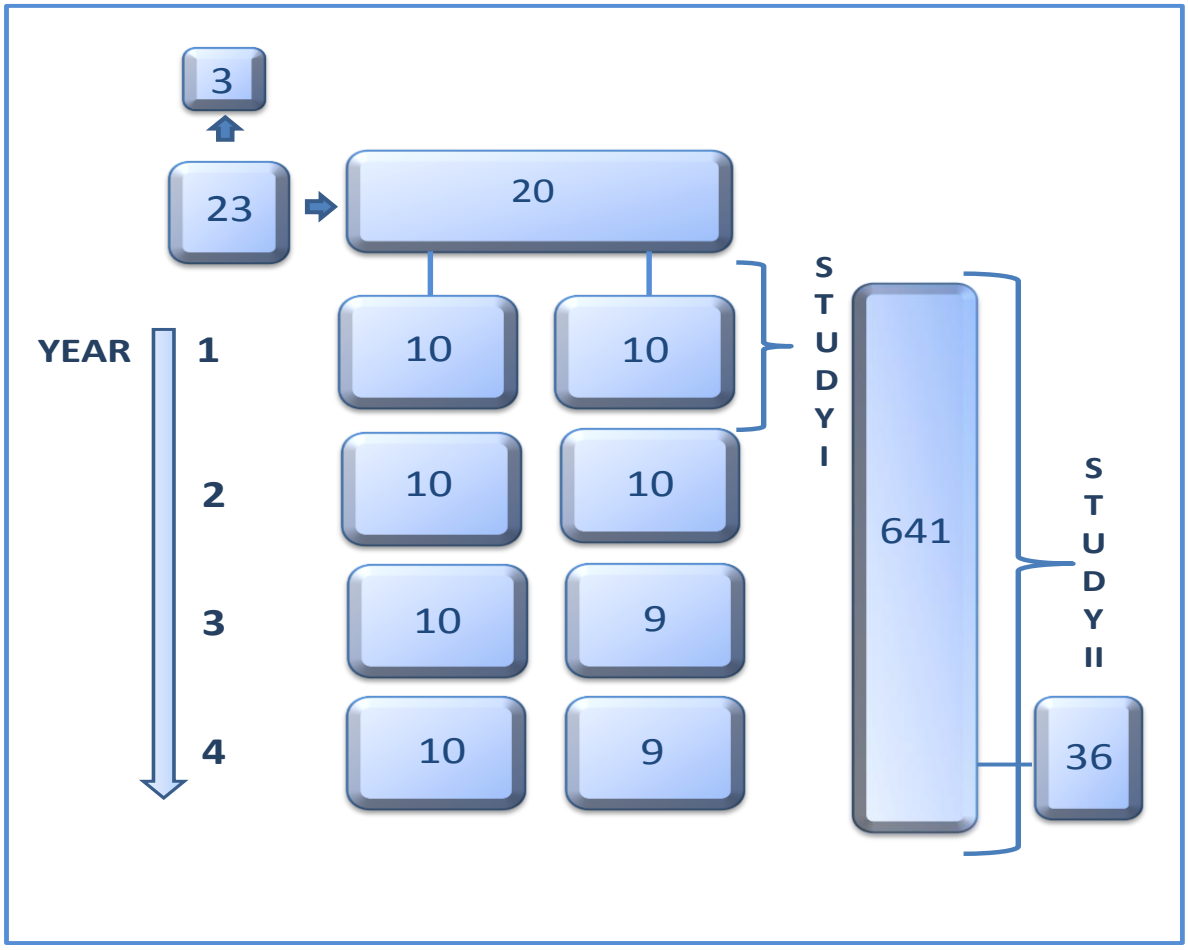

Figure 2: The number of participants in Studies I and II over the four-year period.

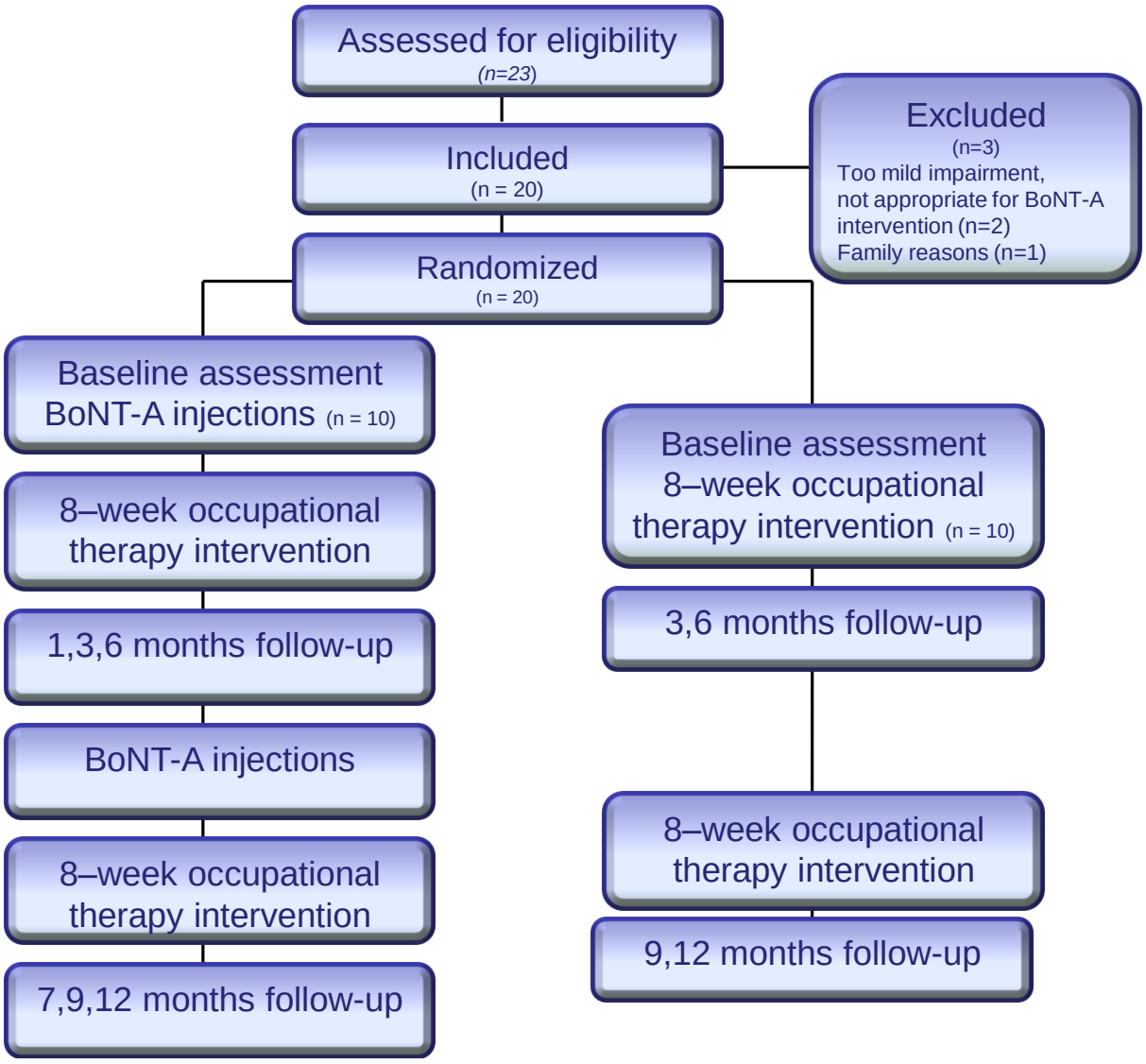

Figure 3: The study flow chart in Study I. Primary outcome was measured at baseline, 3, 6, 9, and 12 months. In the botulinum neurotoxin type-A and occupational therapy (BoNT-A) group and occupational therapy group, additional assessments were performed at 1 and 7 months.

Figure 4: Circular night splint, individually made for each child, with the elbow flexed, the forearm in supination, and the thumb between radial and volar abduction.

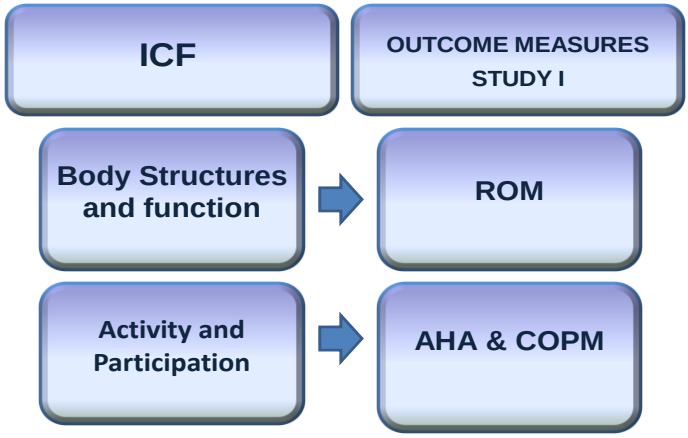

Figure 5: Outcome measures in Study I according to International Classification of Functioning, Disability and Health (ICF) (138).

In Study II, the two intervention groups from Study I were followed for a total period of four years, the first year of interventions included. Annual assessments were performed during the follow-up, in direct connection to the intervention year. The long-term development was investigated and was compared with the data from the reference group. Assessments of stereognosis, grip strength and manual dexterity were conducted at the final follow-up.

Clinical data of the reference group, consisting of children with USCP, were provided from the CPUP data register, including MACS classification levels. Data were collected from children at ages, corresponding to the annual follow-up measurements of the intervention groups. Active supination was available in 641 children (157), and assessments in bimanual use, the Assisting Hand Assessment (AHA) scores (153) were present in 69 of the 641 children.

4.4.1.1 Assisting Hand Assessment – AHA

In Studies I and II the AHA (version 4.1) was used to investigate how effectively the affected hand is used in bimanual activities and how this develops over time. The AHA is a standardized and criterion-referenced test, developed for children who have a unilateral disability in the ages from 18 months to 12 years. The assessment is performed in a play session that is videotaped for later scoring and includes 22 items on a four-point scale. The child's spontaneous and normal way of handling toys is assessed. All toys presented during the assessment usually require bimanual handling (153, 158, 159).

4.4.1.2 Canadian Occupational Performance Measure - COPM

COPM was used in Study I. It is an evidence-based and client-centered outcome measure designed to capture everyday issues and set goals in the areas of self-care, productivity and leisure. Two scores are obtained, for performance and satisfaction with performance, and are rated in a scale from 0 to 10 (155, 156).

4.4.2 Study III

Focus group discussions were carried out in Study III where the participants discussed from their own experience about how their children learned bimanual activities in daily life. Four focus groups, consisting of three to five participants, met on one occasion lasting 1.5 to 2 hours. The composition was homogeneous

in the sense that all participants had children with USCP and heterogeneous according to their children's ages and MACS level (79, 80). As described in the method, the moderator guided the discussion and had a retention role, in order to let the participants express their experiences about the subject as freely as possible (145, 146). A collective understanding of their children's learning of bimanual activities emerged through the discussions. Notes were taken and the discussions were audio recorded and later transcribed verbatim for the further analysis performed by the four authors.

4.4.3 Study IV

Individual interviews with semi-structured questions were conducted in this study. The interviews took place at the participant's home or at the clinic. Three of the participants preferred to have their parents with them, while the remaining participants chose to be interviewed without a parent present. There was a variety of ages and gender as well as how the participants could express themselves and how they could describe their experiences of the subject. The interviews lasted for 30 to 60 minutes and were audio recorded and later transcribed verbatim to be used in the following analysis. Memos were taken during each interview and the interview questions were adapted continuously during the data collection, as described in the GT method (149).

4.5 DATA ANALYSIS

4.5.1 Quantitative analysis - Study I

In this study, statistics were used to compare two groups from a population-based sample, analyzing change over time. The effects of two different interventions were evaluated and compared - repeated BoNT-A injections combined with an occupational therapy program and occupational therapy program alone - on hand function and bimanual performance in children with USCP. The small sample size and the fact that the majority of variables were not normally distributed determined the choice of non-parametric tests.

The AHA, which was the primary outcome measure, was converted into a logit-based score, AHA units (96). The scores were dichotomized based on the the smallest detectable difference (SDD) of the AHA score, 5 or more than 5 AHA units, reflecting an improvement. The SDD, established by the author of the test

takes into account both rater inconsistency and possible variations in children's behaviors (96). The two groups were compared and the proportion of children achieving an AHA score larger than the SDD between baseline and 12 months was identified. The differences in the number of improved proportions were calculated.

Secondary outcome measures, ROM and COPM, were similarly dichotomized and compared between the two groups; in ROM, for active supination, a change of more than 10° was regarded as a significant change and, in the COPM, a score of two points (155-157).

4.5.2 Quantitative analysis - Study II

The original two groups in Study I were followed over a course of four years including the intervention year. Annual data from the three years of follow-up were compared, as well as between baseline and year four. The Wilcoxon's signed rank test (160) was used, appropriate when the data being used for comparison come from scores from the same participants. Changes for each group were calculated, including identification of possible changes in scores from one time point to another. The groups were tested for differences between proportions using Fisher's exact test, owing to the fact that there were few observations (160).

The Total group, comprising the original two groups from Study I, were compared with a reference group. Mixed models for repeated measures with unstructured covariance structure were used to analyze the data, which means that each variance and each covariance are estimated uniquely from the data (161).

At the final follow-up, correlations between AHA (153), active supination (154), stereognosis (71), grip strength (162) and manual dexterity were calculated with Spearman rank correlation statistics (160), measuring the strength and direction of the association between two ranked variables.

4.5.3 Qualitative analysis - Study III

The data from the focus group discussions were analyzed according to the methodology of Krueger (145,146) for Study III. Repeated listening to the audio recordings and reading of the transcript developed a sense of the material, which is the first step in the analysis. All quotes relevant to the research purpose were identified in the raw data and were then sorted into themes through comparing and contrasting the material. This was done separately by the four authors and disagreements in interpretation were resolved by consensus discussions. Thus, trustworthiness was ensured, as the different authors were found to have a high agreement (163). In the next step, systematization of raw data in each theme was made into categories based on condensed meaning by two of the authors. Quotations were chosen from the raw data that illustrated the meaning of each category. In the last step of the analysis, the categorized data were summarized by all of the authors, which was followed by an interpretation phase leading to the overall theme (145,146).

4.5.4 Qualitative analysis - Study IV

A grounded theory (GT) approach (149) was chosen for the analysis of Study IV with the intent to develop a theory explaining the phenomenon of 'the learning of bimanual activities for young people with USCP'. This is a comparative method and was used to describe and analyze the differences in this phenomenon. The data analysis began during the data collection phase. When three interviews were completed, two researchers separately started the reading and reviewing the transcribed interviews and memos. This was followed by an iterative process with a constant comparison of the collected data. In the first analytic step, called the open coding, the data were broken down and coded line by line. A software program (the NVivo 10) (164) was used to assist with handling the material. The codes were labeled and grouped after an inductive approach that allows meaning to emerge from the data. Constant comparison provided the guidance for identification and integration into potential categories, a higher level of concepts. Trustworthiness strategies were integrated during the analysis process, and a third researcher reviewed the interview material and joined the discussions and added alternative interpretation opportunities on three separate occasions (165). When the researchers disagreed, a consensus was reached through discussion and re-reviewing transcripts. The interpretations

were further verified by an adult person with own experience of USCP, engaged before the final step of the analysis. This process led to identification and establishment of the categories and subcategories reflected in the overall interviews, within one unified core category. This directly formed the creation of the overarching theory.

5. ETHICAL CONSIDERATIONS

The four studies received ethical approval by the Regional Ethical Review Board of the University of Gothenburg, Sweden. All children and parents were given verbal and written information about the aims of the studies and signed an informed consent. They were informed that confidentially was assured and that participation was voluntary and that they could withdraw at any time.

Extra attention was paid in Study I to ethical considerations regarding the treatment with botulinum neurotoxin type-A. The children played before and after treatment in a child-friendly environment. The treatment was carried out by a physician and a nurse with specific expertise and experience of treatment in children. The drug was injected into the hand and arm muscles of the children and was done under general anesthesia or nitrogen oxide following an application of local anesthetics.

6. RESULTS

The main findings of Studies I and II are given together and Studies III and IV separately.

6.1 STUDIES I AND II

The results over a four-year period in these studies constitute a comparison of two interventions (Figure 6). Repeated BoNT-A combined with occupational therapy, as well as occupational therapy alone, showed a positive effect on active supination and goal achievement in the short term. Increased bimanual performance was seen only in the group in which injections with BoNT-A were added. Six out of ten improved in this group compared with one out of ten in the group with occupational therapy alone after 12 months ($p< 0.03$). Thus, this combined treatment model resulted in improvements in all ICF domains (Figure 7). The improved bimanual performance was also maintained at the final follow-up at year four. Furthermore, the group of children who only received occupational therapy had increased bimanual performance during this period and reached the same level as the group with the combined treatment model. Both groups increased in active supination during follow-up and at final follow-up; nine of ten participants in the BoNT-A/OT group and seven of ten in the OT group had improved by more than 10^{o}.

However, during the follow-up period of the study, several factors occurred that may have affected the outcome. For ethical reasons, the children not receiving BoNT-A were given the opportunity to be treated during follow-up, if it was considered clinically appropriate. This was of no benefit for the continuation of the study because it confounded the data. The two intervention groups were therefore merged and called the Total group. The Reference group was retrieved from the CPUP register and used for complementary comparison. In bimanual performance, both groups increased with age, but no difference was found in terms of mean development in AHA during the follow-up period.

There was an improvement in active supination in both the Total group and the Reference group, but with a significant difference between the groups, and the Total group increased more at all annual assessments from baseline to the final follow-up ($p<0.001$). However, the Total group had significantly less active supination at baseline ($p<0.001$), compared with the Reference group. The difference was reduced at the final assessments, and the Total group was at the

same level as the Reference group. A mean difference between the groups of 45° (95% CI 30-60) was found at the final assessment.

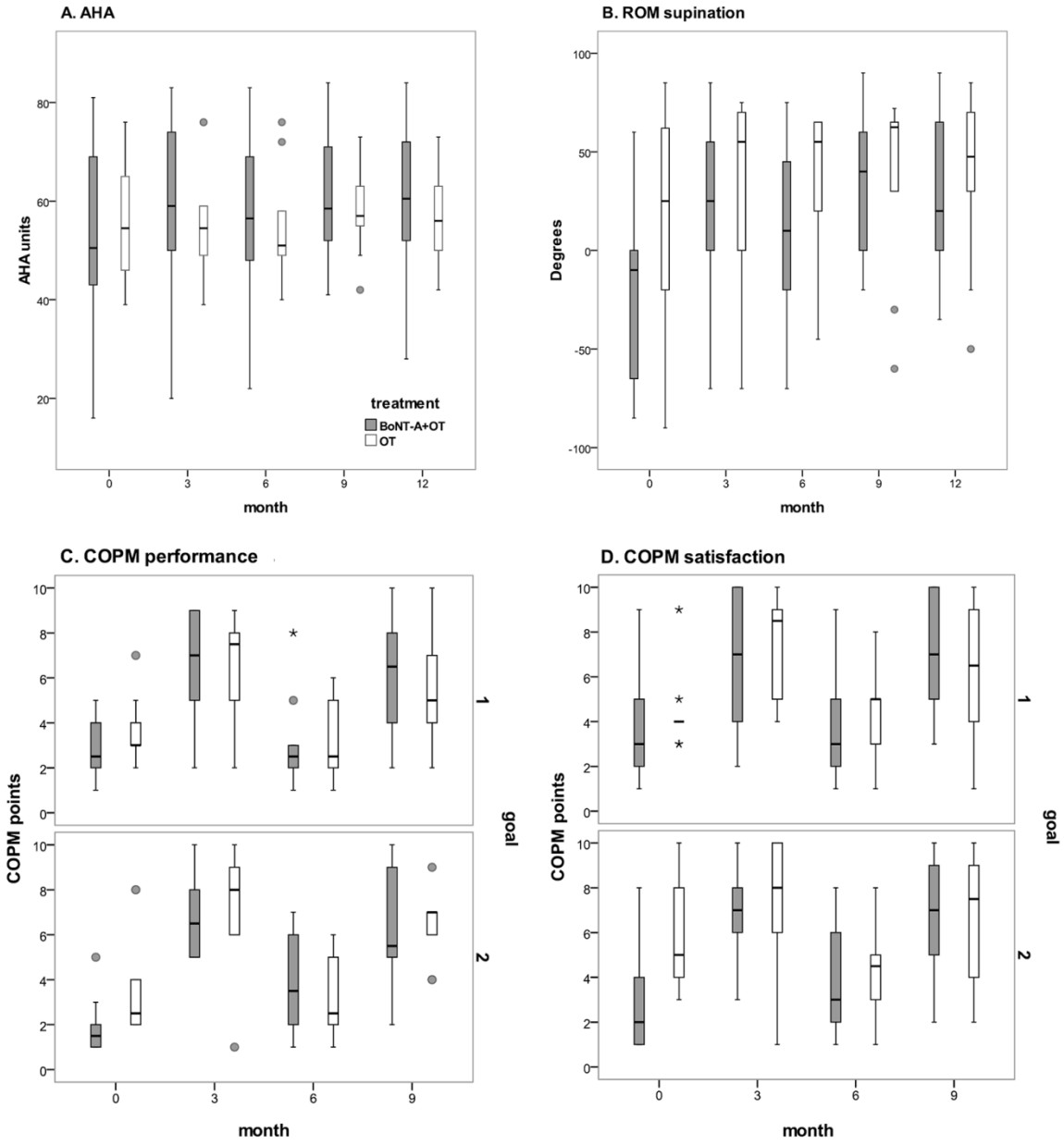

Figure 6. Boxplots illustrating results after repeated interventions in the original groups after 12 months for Assisting Hand Assessment (A), ROM active supination (B), Canadian Occupational Performance Measure (COPM); performance (C) and satisfaction of performance (D).

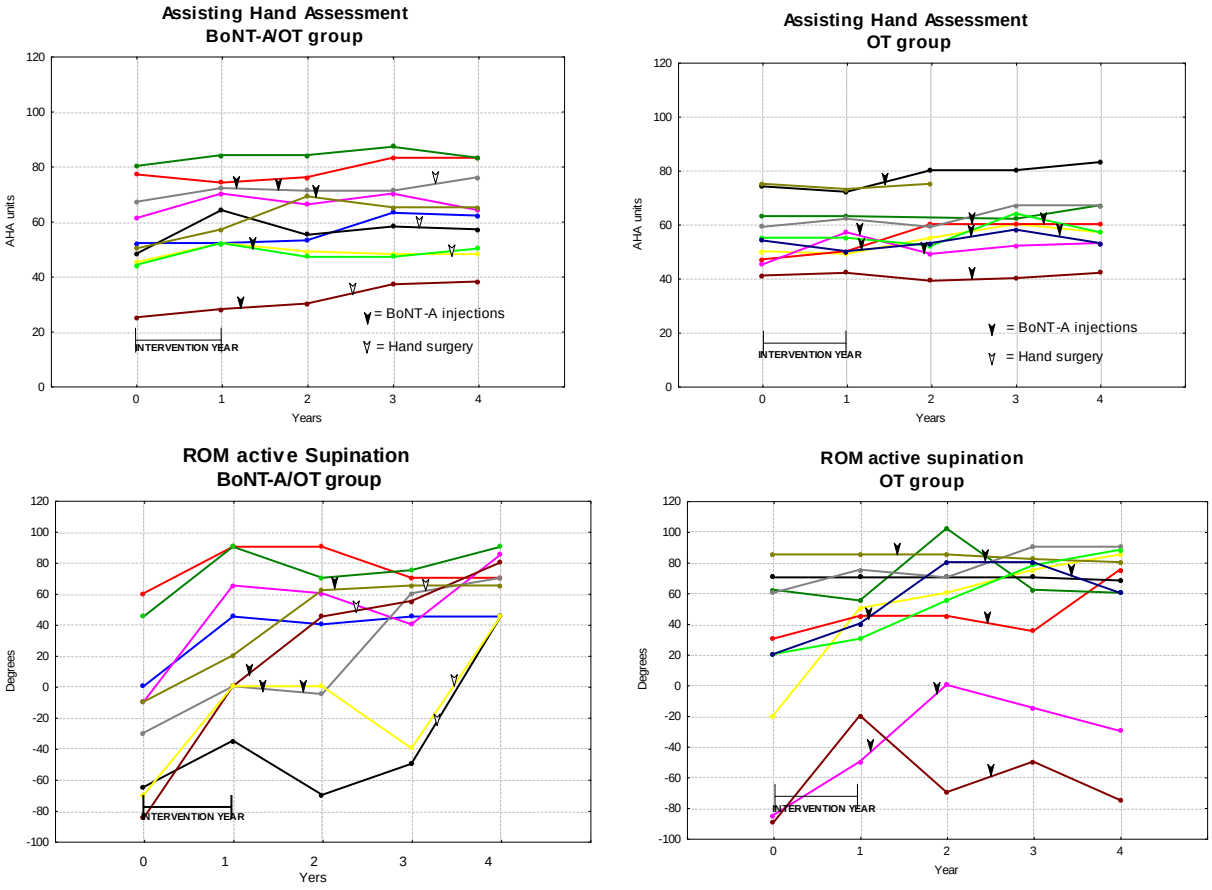

Figure 7: Results of the AHA and active supination in the BoNT-A+OT and OT alone groups for individual cases at baseline and the four-year follow-up assessments.

There was no correlation between AHA score and active supination in the final assessment in any of the groups. In additional assessments, a high score in the AHA was found to be related to preserved stereognosis, increased strength and manual dexterity in all the groups. No variables were associated with active supination.

6.2 STUDY III

This study summarizes how children with USCP do, from a parental perspective, to learn bimanual activities. The analysis of the focus group discussions with the parents of children with USCP resulted in one overall theme: *´Finding harmony between pleasure and effort is the key to learning´*. This points out what can promote the learning of bimanual activities, since the parents explained that their children learned many of these activities. The overall

theme emerged as a synthesis of four themes: 'awakening of the inner drive', 'trying on one's own', 'enabling things to work' and 'it must be worth the effort'. Moreover, each of these themes contained two or three categories, including quotes from the narratives that illustrated key points.
In summary, it was easy for the children to perform when an activity woke their inner drive and they felt joy. They also wanted to develop their own way of performing activities and sometimes may need support from others to succeed. Some activities were not possible to learn or possible to integrate into the child´s everyday life (Figure 8).

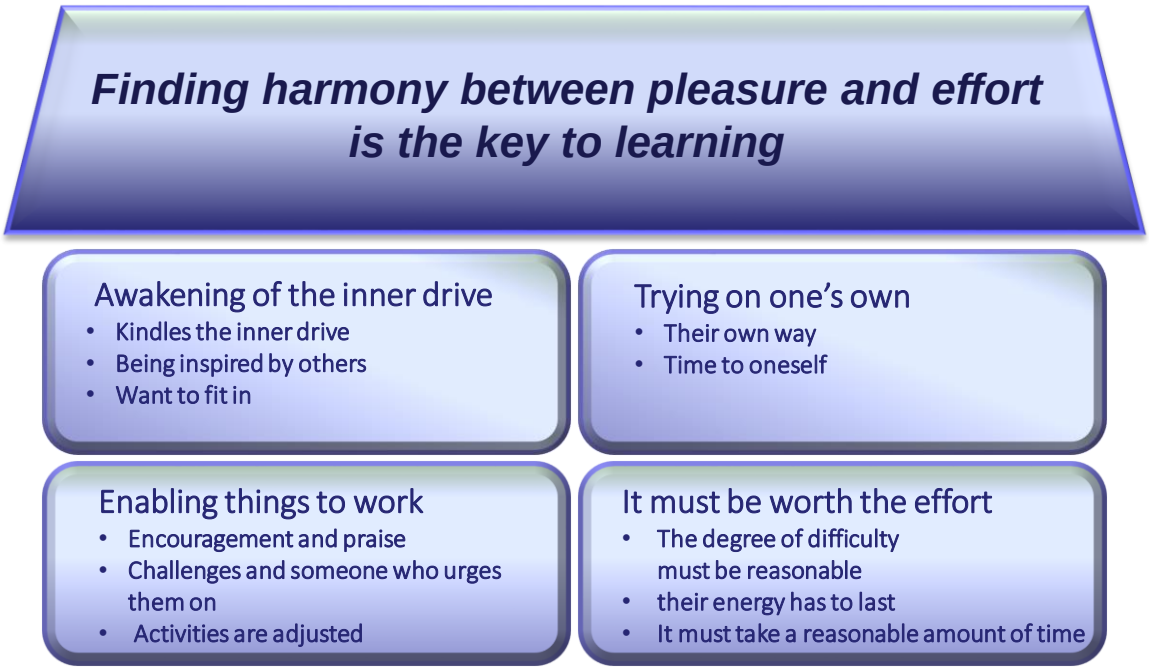

Figure 8: Schematic representation of the overall theme, themes and categories.

6.3 STUDY IV

In this study, the children and adolescents expressed their own views on the learning of bimanual activities, adding an in-depth perspective to this thesis. The core category, "*Managing to learn bimanual activities as life unfolds*", describes that learning of bimanual activities is an ongoing process in life, which must also be adapted to other commitments in their environment. The analysis of the children's and adolescents' narratives was divided into 13 subcategories describing their approach to learning bimanual activities. Furthermore, these subcategories were grouped into five categories interacting with each other and

also related to the core category (Figure 9). The GT approach (149) made it possible to summarize how young people themselves describe how they master learning of bimanual activities into a theory. This may clarify understanding of this process leading to a multi-dimensional theory, aimed for children and adolescents with USCP.

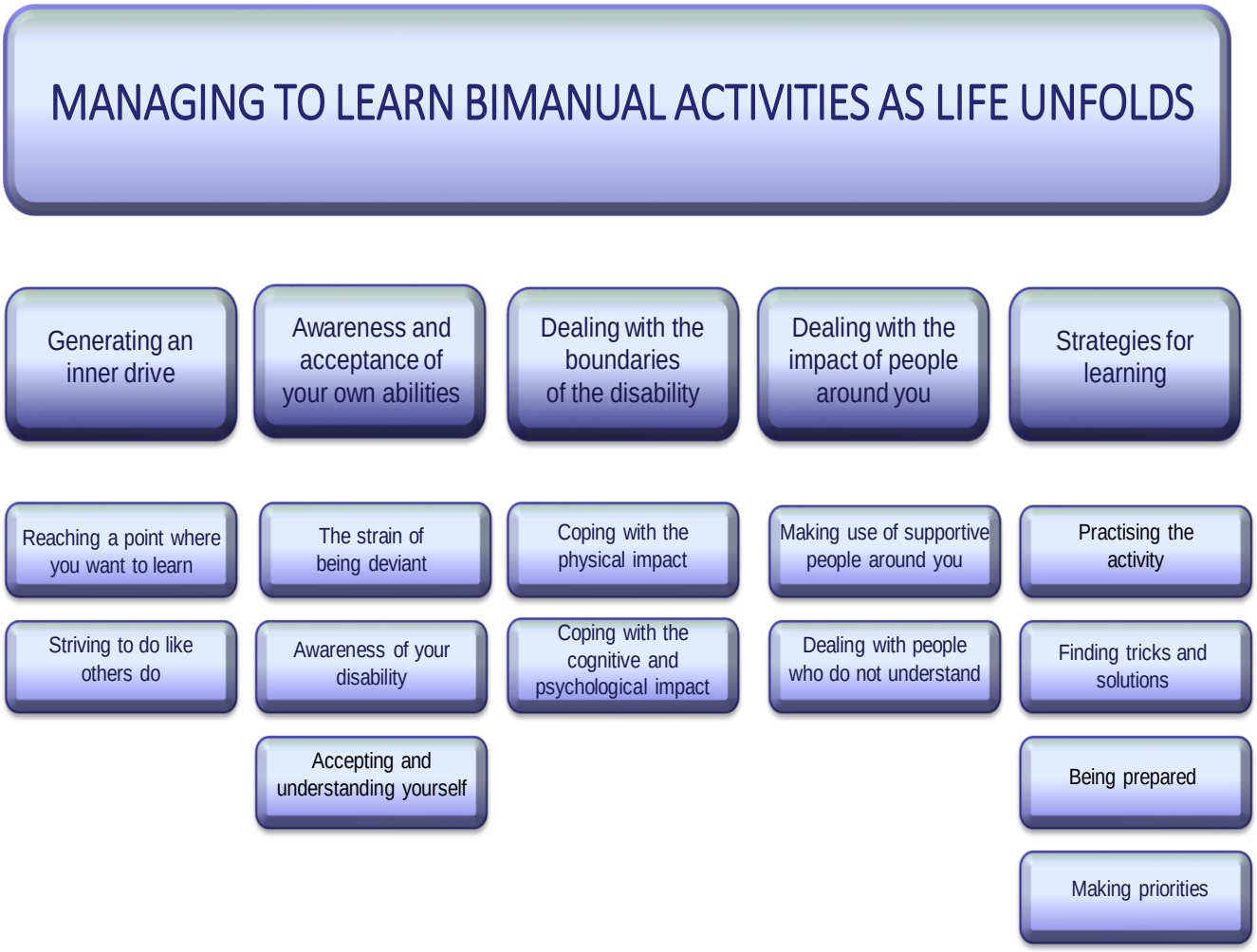

Figure 9: Schematic representation of the main heading, the categories and the sub-categories.

7. DISCUSSION

7.1 DISCUSSIONS ON FINDINGS

This thesis investigates the process of learning bimanual activities in children and adolescents with USCP, using both quantitative and qualitative methods. The purpose is to give a broader understanding of the multiple aspects involved in the learning of bimanual activities, including the impact of development with age.

The thesis comprises evaluations of interventions to improve hand function and bimanual activities, as well as descriptions of experiences of learning of bimanual activities in everyday life. The learning of bimanual activities is described from an occupational and biopsychosocial perspective. This contributes to the knowledge of this complex process, which interacts with the learning and development in childhood among children and adolescents with USCP. This provides an opportunity to approach the learning of bimanual activities from an overall perspective, where all parts are important.

7.1.1 BoNT-A and occupational therapy according to hand function and bimanual activities

The findings in study I, show that repeated BoNT-A in addition to occupational therapy increased bimanual performance in the short term with a superior effect compared to occupational therapy alone. This combination of treatment may therefore be considered when the objective is to improve bimanual ability in young age and provide conditions for learning during development. Moreover, both treatment models were effective in increasing active supination and goal performance and may be appropriate when this is the aim of the treatment. Speth et al. (166) especially demonstrated an increased active supination when conducting treatment with BoNT-A combined with bimanual task-oriented therapy, but also other studies show a high level of evidence when BoNT-A is combined with occupational therapy (108,116, 118, 167, 168). However, comparisons are complicated, as the study designs often differ as regards treatment combinations and studies combining bimanual training and CIMT (95, 108).

Outcome measures in all ICF domains were chosen in study I, to include the complicated process of measuring effects on bimanual performance. This, along

with the use of the SDD (Smallest Detectable Difference) (96, 155-157) in the analysis of the outcome, provided an opportunity to detect a clinically relevant change and give an idea of the possibility of transfer effects. Furthermore, during the intervention year, no other interventions were given, which facilitated the evaluation of effects.

In study II, the same participants were continuously monitored, with the intent to study the effects on a long-term basis. At final assessment, the group receiving BoNT-A in addition to occupational therapy had maintained the increased bimanual performance received after the year of interventions. The group receiving occupational therapy alone, unchanged during the intervention year, successively improved during the follow-up period and caught up to the same level as the group receiving BoNT-A combined with occupational therapy.

The main challenge for the study design was that some of the children that did not receive BoNT-A during the intervention year were subject to BoNT-A treatment based on clinical decisions during the follow-up. Comparisons were therefore made with the Reference group, with data from the CPUP national quality register (152). The comparison with the Reference group showed no differences at final follow-up. However, there were several aggravating circumstances in the long-term follow-up, such as additional interventions that occurred both in the study groups and in the Reference group and that may have affected the findings, a problem previously recognized in long-term studies (54, 75). In addition, there were only few AHA measurements in the Reference group, and these were often associated with other combinations of interventions.

Still, an important finding was that the improved bimanual performance was not temporary but was maintained in the long-term perspective. It can also be speculated that the increased ability in the BoNT-A combined with occupational therapy group provided conditions for the children to reach their peak of bimanual performance earlier in life despite their initial difficulties. Furthermore, it has been suggested that increased ability in young age encourages more use of the affected hand in play and other activities, enhances visual and sensory awareness and lowers the risk for musculoskeletal problems (52).

In active supination, the children involved in the year of interventions, continued to increase their ability of active supinating the forearm with age, according to the annual follow-ups. This result was beneficial in comparison with the

Reference group. One explanation may be an increased use of the nightly splints during follow-up as compared to the Reference group. The splint was aimed to provide a prolonged stretch, elongating and/or keeping the muscles soft, and facilitate the ability to actively supinate the forearm without affecting the ability of pronation. Sacher et al. (169) has demonstrated excessive co-activation in the antagonist muscle, such as musculus pronator teres, explaining reduced active supination of the forearm which may supporting the use of splints. However, there is limited evidence for using this type of splints to provide prolonged stretch in children with CP (52, 85). To evaluate upper-limb splints, a long-term study with a control group including a well-fitted and comfortable splint for long-time use is required (87). These factors put high demands on all involved parties and are complicated to implement, which may be one reason why such studies are lacking. An up-coming study, planned by an Australian research team, may provide indications about the effectiveness of a hand splints supporting the wrist (87).

The lack of correlation between active supination and bimanual performance in the long term was not expected, since the findings in study I revealed an increase in both of these measurements during the intervention year in the group receiving BoNT-A. This does not support earlier findings of active supination as a predictor of upper limb activity (170, 171). Also, hand surgery in children with CP, is often aimed at increasing ability in supination, and has previously shown results indicating improved bimanual performance (120, 121). The importance of supination in ADL activities, is also recognized in studies of upper limb, using 3D kinematics analysis (172, 173). This may suggest that the AHA (153) is not sensitive to all changes in activities depending on increased supination, i.e. a limited change in the score. However, it can also be speculated that there is a limit to active supination, where the forearm position is sufficient for bimanual performance. This may suggest that further increased supination beyond this limit only improves the bimanual performance to a small extent and thereby difficult to assess, but still may be important. This needs further investigation also in relation to the ability and need to pronate the forearm. The entire range of motion may possibly be of interest regarding bimanual performance.

7.1.2 Experiences of learning bimanual activities in a context of daily life

Qualitative methods were used in study III and IV. Important descriptions were highlighted by the parents of children with USCP and in an in-depth perspective, the persons themselves added knowledge about how the learning of bimanual activities were managed in their everyday life.

The overall core category in study IV, describes the learning of bimanual activities in an ongoing everyday life that develops during childhood and was summarized there as: *'Managing to learn bimanual activities as life unfolds'*. The learning sometimes demanded practice, and efforts to find different strategies, which took time and energy and prioritizing between activities was needed for this. In study III, this was described as an overall theme: *'Finding harmony between pleasure and effort is the key to learning*'. This describe a strive to keep a balance in life, and emphasized well-being during the learning of new activities (131). In addition, learning was facilitated when an activity aroused interest and gave the child or adolescent the reward of pleasure from doing it. An awakening of the inner drive, as a force to facilitate the learning, was described in both study III and IV, often appeared in play activities early in life, and later, when personal independence had become more important, in other everyday activities. This may be examples of meaning and value as important aspects of human activities (10, 126), but also as a parallel to the concept of flow, where the individual forget himself, time and space and where the performance and performer come together to form one unit (174). Internal motivation is described in the Self Determination Theory (175), which also includes the importance of persons' possibilities to decide for themselves and to have control over their situation, which was also recognized in the narratives of the children and adolescents in Study IV, in their desire to have control over the activities that they performed. This can be taken a step further to include free will, interest and values, thereby achieving autonomy (175).

Other important aspects of learning were highlighted by the children and adolescents when they described the desire to be like others, for example friends. They expressed the importance of fitting in and participating with others concurrent, in accordance with Sköld et al. (135, 136). The issue of being different or 'deviant' can be difficult to confront. In these situations, the children and adolescents were willing to put greater effort into learning or sometimes avoiding an activity, in order to avoid showing off their difficulties. Achieving

belonging to a group was previously described by Hännikäinen (9) in the term "togetherness." In addition, the occupational performance or the 'doing' leading to participation is recognized by others (176, 177). This is a way to develop as occupational beings (178).

A description of the development of different strategies of learning emerged in Studies III and IV, special methods adapted to specific difficulties. The parents in Study III described these solutions better and differently from the ways they could help their child. It was thus important to create time, space and opportunities for the child to develop these strategies. In addition, priorities were made when some activities were too demanding. Avoiding them could sometimes instead be described as energy and time-saving, and thereby as their not being worth the effort. Hence, both the physical and psychological constraints had an impact on learning. Physical difficulties, such as difficulty controlling movements, caused difficulties in performing activities and therefore required more effort and increased concentration on the performance. Thus, the learning in the individual person may also vary, depending on the degree of disability, the age, the context and the current life situation throughout childhood (10, 126, 179). Consequently, failing many times may affect belief in the ability to perform activities and may lead to excluding oneself from activities. Bandura (140) described the trust in your own ability in terms of ‘self-efficacy belief’ or ‘perceived self-efficacy’ and emphasized how belief can be crucial to performance. In Study IV, the children and adolescents described both strong belief in their ability as well as the opposite in some situations. Adequate support from people around them could help to increase confidence, but negative attitudes towards them could also weaken their belief in their own ability.

An in-depth perspective on the part of the children and adolescents was possible to achieve in Study IV, and the need to understand and accept the limitations of the disability was highlighted. The same was true for dealing with the impact of other people not understanding and/or accepting them. This was a developing process in a transition towards adulthood, how their own maturity affected their thinking about learning and what was needed to find their own identity, similar to what was described in the MOHO as occupational identity (126). Being able to be themselves and be respected for this, without having to worry about other

people's negative reactions, was the most favourable learning situation according to the children.

The learning process can be understood in the light of the conceptual frameworks of ICF (138), which describes the complexity and the association of body functions and structure to activity and participation, while moderated by the context and not least by personal factors. In addition, the MOHO (126) theorizes the involvement of a process of occupational adaptation and identity. The application of interventions in children with USCP needs to involve knowledge of the child's motor, cognitive, psychological and social functions, including recognition of the family's activity patterns in accordance with the MOHO approach (126). To further expand and improve the choices of therapy, it is necessary to collect information about who the children and adolescents are, their habits, interests and the values of their families (139). Only then can accurate interventions be tailored for them.

7.2 INTERVENTIONS AIMED FOR LEARNING BIMANUAL ACTIVITIES

There is an ongoing change in perspective regarding interventions aimed for children with CP, away from a strong focus on addressing underlying functional problems of physical impairments embracing the biopsychosocial perspective. Other aspects, such as independence in daily activities, community participation and environmental factors, are now also considered (180-182). This calls for an approach that is sensitive to timing, and the challenge is to do the right things for and with the right child at the right time. The right timing of the right interventions for the specific child is imperative.

A small child with USCP needs the protection and affection of their parents, and interventions requiring daily treatment are primarily given by the parents, who are those that have the closest relationship. Interventions, including home programs, aiming to stimulate the injured nervous system according to the specific impairment are beneficial at young ages (52, 104). This aspect was found to be effective in the intervention models in Study I and was also described by Novak et al. (106). The best timing of such interventions is not fully clarified. Recent studies discuss the specific development of hand function in young children with USCP, which may provide some guidance for the timing

of interventions (53, 54). An 18-month assessment with the AHA may be used to make a prediction of the future development of bimanual performance (54, 183). Children with high manual ability at an early age have more rapid and favorable development compared to children with low function according to the AHA (153) and the MACS (53, 54). Children at MACS level I-III have been shown to reach 90% of their predicted limit of development in hand function between 33 months and 53 months (54). These different courses of development and the characteristics of the brain lesion may be important in the timing of interventions. In Study I, the children treated with BoNT-A started the intervention probably before reaching their 90% limit, and this timing may have given an increased effect.

When children start preschool or school, other people than the parents spend a lot of time with the child. Education about training and cerebral palsy is therefore a prerequisite for the network around the child. As the child becomes more independent and its cognitive and social skills develop, other types of interventions are essential and the focus often transfers to strategies of problem-solving and goal-directed training (45, 184, 185). Also, ongoing education and information about cerebral palsy was requested by the children and adolescents in Study IV. This may support their process of awareness and acceptance of their abilities, and it may also affect their sense of greater personal control and possibilities for determination and autonomy in their lives (176). The highlighted the importance of social cohesion in their narratives, and participation with friends becomes more important with age. According to the children and adolescents in study IV, requirements and expectations increased in the social framework, especially in school. At this point, the children and adolescents explained that they wanted to be more independent and were therefore willing to make an increased effort to reach this. This motivation comes at a time when physical abilities such as speed and strength seem to increase, which may guide the choice of intervention (83, 186). However, in Studies III and IV, there were descriptions of activities that were not performed because the children and adolescents did not want to expose their shortcomings and did not want to stand out from the crowd. Other activities were not chosen because they took too much time and/or energy, as explained by the parents in Study III. Furthermore, this emphasizes that the children and adolescents require support in prioritizing and finding appropriate solutions, in accordance with the parents in Study III.

Depending on the maturity and development of the child, the intentional focus of interventions should switch from interventions focused on function to person-centered intervention methods aiming to fulfill the child's and adolescent's own goals and intentions (185, 187). Still, the challenge for the therapist is the timing.

8. METHODOLOGICAL CONSIDERATIONS

The limitations of Studies I and II were the small samples and the partially unblinded design, which limits the generalization of the results. In Study I, a non-treated control group could have added a deeper understanding of the results but was considered not to be ethical.

Studies investigating the long-term impact of interventions are scarce, but often desired (108). Such studies are also difficult to carry out because of development with age, accompanying impairments and other current interventions for the child. On the other hand, such difficulties are also described by others (75, 83). This was recognized in Study II, where the main challenge for the study design was that some children that did not receive BoNT-A during the intervention year were subjected to BoNT-A treatment based on clinical decisions during the follow-up. This was of no benefit for the continuation of the study, because it confounded the data. Still, long-term studies are important, when the aim of interventions are to maintain improvements over time and to provide conditions for learning during the development in childhood. A study without these obstructive factors would be hampered by the fact that children with USCP do not live in laboratories. If such a "perfect study" was conducted, the question is whether its results would be applicable for children in the unpredictable everyday life that they, and all of us, live. Nonetheless, Study II in this thesis may give an indication that it was possible to follow the effects during an intervention year, when the treatment was still going on, while longer-term follow-up is accompanied with many uncertain factors, which may put the outcome of the evaluation in question. This is a problem all researchers have to deal with, but the conclusion is that evaluations become more uncertain the longer the study.

In Studies III and IV, qualitative methods were used and a limitation may be the small numbers of participants in the focus groups and individual interviews. The conclusions need to be verified and tested in the clinic. Three of the authors were the same in Studies III and IV and it can be speculated that this affected the analysis of data. Trustworthiness is an important aspect both in the focus group and in the GT methodology and many actions were taken to achieve this, such as separate reading and analysis by all the authors, resulting in a high level of agreement. In Study IV, an adult with USCP was engaged for triangulation purposes.

9. CONCLUSIONS

This thesis demonstrates that learning of bimanual activities can be explained only from multiple perspectives including the impact of development with age in children with USCP. At a young age, the interventions often aim at improving the affected hand and the coordination between the two hands, for example occupational therapy combined with BoNT-A, which was found to increase the bimanual performance in Study I. This may also provide conditions for more complex learning during future development. Later in childhood, the interventions should gradually change into occupational-based treatment, preparing the children to master activities in everyday life. As the children become more independent and their cognitive and social skills develop, interventions aiming at problem-solving and goal-directed training may be introduced. The focus of the interventions should changes and follow the different transition stages and, in the process of maturity, the children's and adolescents' own goals appear as more important. Thus, the interventions need to be person-centered and tailored to suit the specific goals in different life situations. Analyses of multiple aspects and timing of interventions are required from the therapist and the entire team, striving to create the best possible conditions for the children and adolescents to be, and become, what they want to be and give them tools to face the future with self-esteem, prepared to overcome difficulties that arise on the way to their goal.

10. FUTURE RESEARCH

Future studies may investigate whether the multi-dimensional perspective presented in Study IV can be used, i.e. keeping the five categories in balance, to support occupational and other therapy interventions, with the purpose to enable the child to learn bimanual activities in everyday life. In this thesis, learning in children and adolescents with USCP has been illuminated and an interesting future research topic may also be to investigate how individuals with bilateral spastic cerebral palsy learn bimanual activities. This may show differences and/or similarities between the groups. Another subject that needs to be studied is the effectiveness of upper limb orthoses for prolonged stretch and splints aimed at improving task performance. Such studies are both complicated and demanding, but of great importance, as these are frequently prescribed for children with CP.

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