FROM SOUNDS TO SPEECH AND GESTURES

Case studies of linguistic interaction in children with ASC

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LINGUISTICS AND THEORY OF SCIENCE

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Abstract

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Title:	FROM SOUNDS TO SPEECH AND GESTURES Case studies of linguistic interaction in children with ASC
Swedish title:	FRÅN SPRÅKLJUD TILL TAL OCH GESTER - fallstudier om lingvistisk interaktion hos barn med autismspektrumtillstånd
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This thesis investigates the interrelationship between segmental phonology, prosody and gesture, as well as important factors for language development in individuals with autism spectrum condition (ASC), i.e. precursors. Furthermore, the thesis investigates the effects of an intervention given to two Swedish children (boys) with ASC, who were followed longitudinally over a period of 1-1 ½ years. An intervention, where stimuli (minimal pairs) were gradually introduced, was constructed in order to increase awareness of phonemic contrasts and symbolic representations. The hypothesis, which was based on theories of overlapping networks for language and cognition, was that listening to sounds and watching production of sounds, in minimal pairs could lead to development of sound production, in general, and also to more advanced syllable constructions and use of new words. The idea was that cortical areas, including Broca's area and areas for speech perception would be stimulated, which possibly could lead to secondary effects on prosodic and gestural development. The results of the thesis are in support of the existence of a cortical mechanism, for example, mirror neurons, which bridge between perception and production of speech.

The studies were performed during three periods, which laid the ground for three corpora with video recorded materials. The training sessions took place at a special school for children with ASC, where teachers or a speech and language therapist conducted the sessions. Interviews were performed with the school staff and parents. According to the temporal order of language acquisition, phonological contrastive features were gradually introduced. Pairing the sounds with specific objects allowed for opportunity to train to distinguish meaning, which is a part of first-word-acquisition. All the sessions were video recorded, the corpora gathered and annotated.

The first study focused on phonological development, general speech sound production in segments and syllables, phonological contrastive features, feature accuracy and

auditory perceptual skills in one of the boys. Results of the study showed both a quantitative and qualitative development of speech sound production regarding the use of new phonological feature types, new syllable constructions and use of new words during the year. The results were significant, when comparing two periods, which suggests that phonological training can stimulate children with ASC to develop language and speech at 5 to 6 years of age. Thus, perception (and production) of phonological processing may not be rejected as a *precursor* for language development from this study. In this child with ASC, not only was there a delayed speech development but also a deviant one, both concerning segments and syllables, which is in line with previous studies that describe deviant phonological development in ASC.

The second study investigated pitch, pitch range and duration in two boys, over duration of a year. Acoustic data were annotated and analysed. Autistic symptoms, such as increased pitch and increased pitch range decreased for the two boys. It was concluded that prosody developed, despite not being trained. Acoustic analyses of prosody may be useful indicators of language development and tools for diagnosis in ASC. In addition, analysis of threshold range is suggested in future studies in analysing prosody in ASC.

The third study investigated deictic (declarative and imperative), general accompanying, ritualistic, iconic interactional and silent mouth gestures in one boy with ASC (the same boy as in Study I). The results showed a development of gestures, both deictic and general accompanying. The deictic gestures were contrary to expectations, more often declarative than imperative. Declarative gestures increased during the period, while imperative ones decreased. This study also shows how gestures may accompany speech in a very specific manner by the use of various hand shapes, which accompany syllables. Furthermore, results suggest that speech and gestures are interrelated.

In summary, the three studies showed that segmental phonology, prosody and gestures are interrelated. Auditory (visual) perception is suggested to be an important precursor for language development in ASC from this study. Phonological processing is also related to prosody on the word and sentence level, and it may be suggested that training phonology in interaction may improve prosodic development. A finding was that F0 (Fundamental frequency) decreased more than expected in the two children, in relation to the literature on typical F0 development. Another finding was that the gestural development in one of the children showed a very close interrelationship between speech, gestures and the development of indexical functions. Use of both prosody and gestures increased despite not being trained. Furthermore, the two children developed in a similar way during the period of study, and positive development in general suggests that listening to and training with minimal pairs in triadic interaction may be useful for interventions in ASC.

Keywords: perception, speech production, phonology, prosody, gestures, autism spectrum condition

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Sammanfattning (svenska)

Titel: **(Engelsk)**	FROM SOUNDS TO SPEECH AND GESTURES Case studies of linguistic interaction in children with ASC
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Denna sammanläggningsavhandling undersöker relationen mellan segmentell fonologi, prosodi och gester, men också faktorer som är av betydelse för språkutvecklingen vid autismspektrumtillstånd, s k 'precursors', studeras. I avhandlingen undersöks vidare effekter av en intervention som getts till två svenska barn (pojkar) med autismspektrumtillstånd under en tidperiod på 1-1 ½ år. En intervention, där stimuli (minimala par) introduceras gradvis, hade konstruerats i syfte att öka medvetenheten om fonologiska kontraster och symboliska representationer. Hypotesen, som är baserad på teorier om överlappande nätverk för språk och kognition, är att lyssnande och observation av talproduktion, i minimala par, kan leda till utveckling av ljudproduktion generellt, men också till mer avancerade stavelsekonstruktioner och användning av nya ord. Idén är att kortikala områden, som inkluderar Broca's area och areor för talperception stimuleras och även skulle kunna ha effekter på prosodisk utveckling samt gester. Resultaten i avhandlingen ger ett stöd för att det föreligger en neural mekanism, t ex spegelneuron, som överbryggar mellan perception och produktion av tal.

Studierna genomfördes under tre perioder, vilket lade grunden för tre korpusar med talspråksmaterial. Träningssessionerna genomfördes av lärare eller logoped på en specialskola för barn med autismspektrumtillstånd och intervjuer genomfördes med lärare och föräldrar. I enlighet med kronologisk ordning för språkutveckling, introducerades fonologiska särdrag gradvis. Att få tillfälle att para ihop ljud med ett speciellt objekt, möjliggjorde träning i att särskilja betydelse, som är en del av förstaordstillägnande. Alla sessioner videofilmades, korpusar samlades in och annoterades.

Den första studien fokuserar på fonologisk utveckling, generell talproduktion i segment och stavelser, fonologiska särdrag, särdragskorrekthet och auditiv perceptionsförmåga, hos en av pojkarna. Resultatet av studien visade både på en kvantitativ och kvalitativ utveckling av språkljudsproduktion avseende användning av nya fonologiska särdrag,

nya stavelsekonstruktioner och användning av nya ord under året. Resultaten var signifikanta, när två perioder jämfördes, vilket implicerar att fonologisk träning kan stimulera barn med autismspektrumtillstånd att utveckla språk och tal vid den här åldern. Fonologiskt processande i perception och produktion kan sålunda inte avvisas som *igångsättare* för språklig och kognitiv utveckling, i och med den här studien. I studien noterades inte bara en försenad, men också avvikande utveckling hos det aktuella barnet, som är i linje med studier som beskriver avvikande fonologisk utveckling vid autismspektrumtillstånd.

Den andra studien undersöker tonhöjd och tonhöjdsomfång samt duration hos två pojkar med autismspektrumtillstånd under ett års tid. Akustiska mätdata annoterades, och analyserades. Autistiska drag som ökad tonhöjd och ökat omfång sjönk hos de båda pojkarna. En slutsats är att prosodin utvecklades trots att den inte tränades. Akustisk analys av prosodi kan vara en användbar indikator på språkutveckling och ett verktyg för diagnossättning vid autism. Användning av tröskelvärden rekommenderas vid framtida studier av prosodi vid autismspektrumtillstånd.

Den tredje studien undersöker deiktiska (deklarativa och imperativa), generellt ackompanjerande, ritualistiska, ikoniska, interaktionsgester och mungester hos en av pojkarna (samma som studie 1). Resultatet visar på en utveckling av gester, både deiktiska och ackompanjerande, vilket i motsats till vad man kan förvänta sig, oftare var gester för delad uppmärksamhet än gester för begäran om föremål. Gester för delad uppmärksamhet ökade under perioden medan gester för begäran om föremål minskade. Studien visar också hur gester ackompanjerar talet på ett mycket specifikt sätt, genom användning av olika handgester som ackompanjerar stavelserna. Resultaten visar också på en relation mellan tal och gester.

I en sammanfattning av de tre studierna, kan vi notera att det finns en tidsmässig relation mellan segmentell fonologi, prosodi och gester. Vidare visar studien på auditiv (visuell) perception som en betydelsefull igångsättare för språklig utveckling vid autismspektrumtillstånd. Fonologiskt processande är relaterat till prosodi på ord - och meningsnivå och resultaten pekar på att träning av fonologi i interaktion kan påverka prosodisk utveckling positivt. Ett resultat var att grundtonsfrekvensen sjönk mer än förväntat hos båda pojkarna, i jämförelse med typisk utveckling av F0. Andra resultat pekade på ett nära samband mellan tal, gester och indexikalitet hos de två barnen. Både prosodi och gester utvecklades trots att de inte tränades. Vidare utvecklades barnen positivt under interventionsperioden och den positiva utvecklingen i allmänhet antyder att lyssnande och träning med minimala par i triadiska interaktioner kan vara till nytta i interventioner hos barn med autismspektrumtillstånd.

Nyckelord: perception, talproduktion fonologi, prosodi, gester, autismspektrumtillstånd

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Pia Nordgren, Gothenburg, 2016

LIST OF PUBLICATIONS

This thesis is based on the following papers:

1 Nordgren, P.M. (2014), Phonological Development in a Child with Autism Spectrum Condition: Case Study of an Intervention, Journal of Interactional Research in Communications Disorders, 5:3, 2013, 291-317, ISSN 2040-5111 (PRINT), ISSN 2040-512 X (ONLINE). [1]

2 Nordgren, P.M. (2015), F0, F0 range and duration of utterances - Longitudinal single-subject studies of prosody in two Swedish children with ASC, published online in Clinical Linguistics & Phonetics on 8 December 2015, ISSN: 0269-9206 (PRINT) 1464-5076 (ONLINE).[2]

3 Nordgren, P.M. (2015) Precursors of speech and language in ASC: A longitudinal case study of gestures, submitted.

[1] Paper I is reprinted with kind permission from Journal of Interactional Research in Communications Disorders.

[2] Paper 2 is reprinted with kind permission from Clinical Linguistics & Phonetics (Taylor & Francis).

LIST OF APPENDICES

This work was approved by the Regional Ethical Review Board in Gothenburg on the 13th of December 2010.

Preface

This work blossomed as a result of my work as a speech therapist for many years and the experiences in my professional life meeting children with autism spectrum conditions (ASC). The main purpose has been to increase knowledge of ASC through linguistic research, focusing on the three perspectives: segmental phonology, prosody and gesture. In creating neurolinguistic models, we get a deeper understanding of the mechanisms behind the condition, which offers a theoretical standpoint for new, possible, methodological approaches in teaching and therapy, which could make interaction for these children possible. Despite many years of research since Kanner (1944) and a lot of research within medical science, there is still a need for linguistic research within this area.

Gothenburg, 2016 Pia Nordgren

CONTENTS

1 GENERAL INTRODUCTION

Recent advances within neuroscience have led to important insights regarding the human brain, which have changed the way we, as linguists, look upon the relationship between speech perception and production. When we acquire language, factors such as senses, vision, hearing and proprioception are used in order to connect sound patterns in the environment with objects or events. In typical development, this comes naturally, since the child is part of dyadic or triadic interactions from an early age. Children with autism spectrum condition (ASC) may, on the other hand, exhibit great difficulties in integrating the perceptual input, which occurs in human interactions. Listening to speech sounds, whilst focusing on objects, is sometimes an overwhelming experience, which is one of the explanations for the difficulties noted in ASC. Many studies try to find the initiators or precursors of language in typical, but also in deviant development, such as in ASC. If we succeed in finding these precursors, we would know how best to adjust the interventions in ASC.

The field of research on ASC is actively developing. There are many questions in the literature and different opinions about the answers. Is ASC a cognitive condition? Are there subgroups within ASC? How many subgroups are there and what characterises them? Which treatment method is the most effective? Is it possible to find precursors of development? Which treatment method has an impact on behaviour? What and how much treatment is adequate? What are the causes of ASC? Is there a specific neurological mechanism involved, and can it explain the symptoms? How can pedagogical aspects be developed in the field, as new research contributes to factors involved in ASC? This thesis will not answer these specific questions but will relate to some of the topics mentioned, such as precursors of language development. Connections between the three areas: segmental phonology, prosody and gesture are investigated in three different papers. Using brain-based theories, we investigate how various linguistic aspects are interrelated and whether we can detect precursors of language development in ASC. Furthermore, we investigate the effects of an intervention given to two boys with ASC. The question is whether improved perceptual skills have an impact on segmental phonology, prosody and gestures. This means that the scientific purpose has been threefold, in investigating interrelationships between linguistic areas, looking for important factors, i.e. precursors, in language acquisition in ASC and also examining whether interventions have an effect. The thesis frame starts with a theoretical background on topics such as ASC, segmental phonology, perception, speech production, language acquisition and neurological theories. Thereafter, the three studies are presented and discussed.

1.1 Autism spectrum conditions (ASC)

1.1.1. ASC – introduction

Autism spectrum conditions (ASC) are a group of neurodevelopmental conditions, first described by Kanner (1943), which are characterised by deficiencies within the areas of social, cognitive and linguistic functioning (Brook and Bowler, 1992), i.e. impairment in social interaction, verbal and non-verbal communication and behaviour. This includes a preference for stereotyped activities, patterns of behaviours and interests (ICD, 10, Bölte and Hallmayer, 2011). The age of onset is always prior to 36 months (Bölte and Hallmayer, 2011). In epidemiological studies, it is noted that as much as 1 % of the general population exhibit ASC (Bölte and Hallmayer, 2011). Language difficulties in children with ASC vary from a close to normal ability to speak to a complete lack of speech. The condition may affect all aspects of language: phonology, lexicon, syntax, semantics, pragmatics and gestures. Segmental levels, for example, phonemes and syllables, are not often investigated in children with ASC. Despite both prosody and gestures being known to be deviant in children with ASC, they are rarely described in the literature.

1.1.2 Terms – definitions

In the literature, the abbreviation ASC is frequently used for autism spectrum condition. In May 2013, there was a major shift in the definition of the ASC diagnosis, in that the DSM V (fifth edition of the Diagnostic and Statistical Manual, 2013) was released. The major change meant that ASC was now an overall term for various conditions within the spectrum. Asperger syndrome and disintegrative disorders were no longer separate diagnoses and Rett syndrome was removed from the DSM diagnosis manual.

Two main criteria are:

1. Limitations in social communication and interaction
2. Limited, repetitive behaviours, interests and activities

Two additional criteria are:

1. Symptoms must occur during early childhood.
2. Symptoms limit and interrupt the person's everyday function

According to the previous diagnostic system, DSM-IV (1994), the child with ASC was to exhibit delays or abnormal functioning in at least one of the following areas (with onset before the child is three years old): social interaction, language used in social communication or symbolic/imaginative play. According to DSM-IV, the disturbance was not to be described as Rett's disorder[1] or childhood disintegrative disorder[2].

[1] Rett syndrome is a neurodevelopmental disorder, which seems to only affect girls, who at about 6–18 months of age regress in their development.

[2] In disintegrative disorder, the child was to develop normally during the first two years of life, often three years and then exhibit a strong retrogression of skills in several areas.

As the introduction of DSM-V has occurred very recently, many terms from the previous DSM-IV are still prevalent in the literature. Five subtypes of pervasive developmental disorders (PDD) are still distinguished in the field: autistic disorder, Asperger disorder, PDD not otherwise specified (PDD-NOS), childhood disintegrative disorder and Rett syndrome. DSM-IV (APA, 1994) established a distinction between Asperger syndrome and autistic disorder (including HFA, high-functioning autism) based on children's developmental language history and language skills (Lewis, Murdoch, Woodyatt, 2007). According to Gillberg (1990), children with Asperger syndrome exhibit symptoms similar to symptoms seen in autism, but exhibit higher cognitive skills and better expressive language. Pervasive developmental disorders-not otherwise specified, and atypical autism were used interchangeably in the literature. These diagnoses implied that the child did not fulfil the criteria for autistic syndrome. A possible problem with the change in DSM V, regarding criteria for ASC, is that comparisons between previous and future research will be complicated. In this thesis, previous research uses terms as defined by DSM-IV.

1.1.3 ASC and other diagnoses

ASC appears at all levels of cognitive functioning, but deficits in intellectual functioning often co-occur with ASC (Fombonne, 2005). Intellectual functioning includes various mental abilities, such as reasoning, problem solving, planning, abstract thinking, judgment, as well as academic and experiential learning. Mental abilities are measured by IQ tests. A score of approximately two standard deviations below average represents a significant cognitive deficit, typically IQ score 70 or below.

Another diagnosis closely related to and co-occurring with ASC is ADHD (attention deficit hyperactivity disorder, ICD-10). Criteria for ADHD are simultaneous hyperactivity, impulsivity and inattentiveness, which appear prior to 6 years of age. Impairment must be present in more than two settings. Other diagnoses such as depression, anxiety disorders and/or pervasive developmental disorders are excluded. Many children exhibit a combination of diagnoses, such as ASC and ADHD diagnosis as well as intellectual disabilities.

1.1.4 Deficiencies in ASC

The idea that a lack of *theory of mind* (Baron-Cohen, Leslie and Frith, 1985) is a reason for many of the social and communicative disabilities seen in children with ASC is commonly agreed upon. If we have a theory of mind, we are able to understand that other human beings have other beliefs than our own, which in general motivates communication and interaction.[3] Individuals with ASC may lack the ability to form a theory of mind, which leads to difficulties with social interaction (Baron-Cohen, Leslie and Frith, 1985; Grela and McLaughlin, 2006). Many researchers suggest the primary language dysfunction in ASC is related to the pragmatic domain. Children with ASC exhibit deficiencies in belief understanding, emotional processing and voluntary imitation as well as joint attention (Bird, Leighton, Press and Heyes, 2007; Hamilton, 2008).[4]

[3] An example is warning others of danger.

[4] Children with ASC do not show an impairment of automatic imitation, but rather imitation that is voluntary would be impaired. Sometimes, children with ASC show excess mimicry, while in other situations they would fail to mimic at all.

1.1.5 ASC during the past decades

During the last few decades, there has been a tendency towards studying theory of mind and cognitive aspects of ASC more than language. For many years, the predominant view has been that children with ASC mostly have deficiencies in semantic-pragmatic aspects of language, which is supported in the literature. Nevertheless, children with ASC exhibit additional difficulties and experience difficulties in all domains of language. The difficulties involve phonological, morphological, lexical, grammatical, semantic-pragmatic deficiencies including supra-segmental aspects of speech, such as prosody. Some recent research shows that phonological difficulties often occur in ASC and that the speech delay in ASC often includes reduced babbling and unusual speech patterns, thus a deviant phonological development (Bölte and Hallmayer, 2011; Rapin and Dunn, 2009; Wolk and Edwards, 1993; Wolk and Giesen, 2000). Furthermore, recent neuroscientific research suggest that there are good reasons to study the interrelationship between various cortical areas, such as the areas of speech perception and production in ASC.

During the past decades, a specific mechanism impairing speech development in ASC has been suggested, i.e. oral motor dysfunction or dyspraxia of speech [5] (Dziuk, Gidley Larson, Apostu, Mahone, Denckla, Mostofsky, 2007; Rogers, Hayden, Hepburn, Charlifue-Smith, Hall, Hayes, 2006).

1.2 Language in ASC

1.2.1 Segmental phonological patterns in ASC

In recent decades, it has only been possible to find a few articles about segmental phonology[6] in ASC. According to a review article (Goldstein, 2002), there was only one article, Koegel, O´Dell, Dunlap, (1988) during a period of twenty years that focused on segmental phonology in children with ASC. Many articles have focused on sign language in treatment, environmental intervention, relations between behavioural problems and language ability, social interaction and parental support, whilst phonology has been thought to be of minor importance because children with ASC experience problems in many other domains as well. One additional reason for this is the difficulties in speech output seen in children with ASC and consequent difficulties in data collection. The importance of segmental phonology in ASC as well as in typical development is related to the fact that it develops early during infancy. Also, it could be possible that children with ASC have a sense for details and could use segmental phonological skills in interactional learning or learning other domains of language. Thus, children exhibiting ASC may benefit from a training perspective, where each phonological unit is separately taught to the child. It is a difficult task for a child with ASC to sort out the various phonemes in speech, when so much demand is put on integrating stimuli. In study I in the thesis, segmental phonological development is studied in one child with ASC, and the idea was that training in phonology could also affect other domains of language.

[5] Dyspraxia is defined as *impaired performance of skilled gestures* (Dziuk et al., 2007).

[6] Segmental phonology can be defined as analyses of the speech into distinctive (contrastive) units or phonemes.

1.2.2 Prosodic properties of speech in SLI and ASC

Swedish has a complex prosodic pattern, and Swedish children with specific language impairment or SLI often exhibit prosodic difficulties (Samuelsson and Nettelbladt, 2004). Prosodic problems are often also present in the speech of children with ASC, who exhibit perceptual difficulties in integrating sensory input that leads to deficiencies in perception and production of prosodic patterns. Prosody (in production) may also develop later in children with ASC compared to typically developing (TD) children. Several recent studies that have used acoustic analyses claim that children with ASC exhibit an increased mean F0 and mean F0 range compared to TD children. Studies of acoustic analyses of prosody in children with ASC are rare, which is why study II in the thesis contributes to the literature in this subject (Diehl, Watson, Benetto, McDonough and Gunlogson, 2009).

1.2.3 Gestures in ASC

Deficits in gestural communication are one of the criteria for ASC (DSM V, APA 2013). One important area of functioning is the area of deictic gestures (pointing), which have been found to be less frequent than in TD children. The reason for this is not fully understood, but it can be related to deictic gestures being part of joint attention. Speech accompanying or general accompanying gestures are also less frequent in ASC, which can be related to the connection between areas for speech and gesture production (Iverson and Thelen, 1999). Thus, if speech is impaired, gestures could also be impaired. Study III investigates gestural development in one child with ASC during a period of 1 ½ years (same child as in study I).

1.2.4 Semantics and pragmatics in ASC

Children with ASC generally exhibit semantic deficits as well as deficiencies within other linguistic areas. This is observable in several distinct ways concerning comprehension of speech (Dunn and Bates, 2005). Semantic difficulties appear to persist into adolescence and adulthood even in high-functioning individuals, who generally exhibit a decline in the severity of symptoms over time. Children with ASC may have a dysfunction of the auditory association cortex. Dunn and Bates (2005) tested 22 children concerning behavioural measures and ERP.[7] Findings from their study revealed neurophysiological support for the behavioural observations that children with ASC have persistent deficits in the semantic processing of auditorily presented words as they enter pre-adolescence. The lexical development differs from TD children. (Dunn and Bates, 2005). For example, when it comes to accessing category members, children with ASC may show a deficiency regarding prototypic words, which can be explained in terms of weak central coherence.[8] In typical development, this allows the child to create a general understanding of a concept or category as the sum of many parts. A failure to form prototypes is similar to weak central coherence. Children with ASC tend to process information in a 'piecemeal' fashion, seeing only the detail and missing the whole picture, which holds the parts together.

Many studies describe the pragmatic difficulties seen in children with ASC. The difficulties with social interaction lead to pragmatic difficulties, but one can also

[7] Event-Related Potentials

[8] Central coherence is an ability to integrate information to learn the overall meaning of words and may be deficient in ASC.

speculate whether the additional language difficulties per se increase the pragmatic difficulties.

1.3 Critical period

The critical period (Lenneberg, 1967) can be described as a limited time during development when the effect of experience on brain function is particularly strong. Listening to speech, for example, affects certain brain areas (neuronal circuits) and lays the ground for language development. Although learning is possible throughout life, there is no doubt that to start younger is better, and in addition that plasticity of the brain is enhanced during these specific windows of opportunity. Critical periods for higher brain functions such as language is, however, debated. Instead, the term optimal periods is sometimes used because the critical period may not be absolute, and also various aspects of development may exhibit its own optimal period (Werker and Tess, 2005). One could wonder if it could be the case that the critical or optimal period would be delayed if relevant experience were lacking. LeBlanc and Fagiolini (2011) suggest the timing of the critical period circuits in the sensory areas of the human brain are deviant in ASC. This might be the case for the children in the present thesis. Difficulties with integrating perceptual input, i.e. auditory perception could lead to a lack of experience and thus achieving the important foundation for language acquisition.

1.4 Subgroups within ASC

This question has been a focus of research during the past twenty years. Researchers have different suggestions about how to divide children into subgroups. It is possible to identify subgroups within ASC in respect to individuals' ability ranging from above average, average, moderate to severe impairments (Lewis, Murdoch and Woodyatt, 2007). A small group of children with ASC never develop any speech, whilst a third of the children develop some words, but do not use them for communicative purposes (Hadwin, Baron-Cohen, Howlin, Hill, 1997). Rapin and Dunn (2009) found two specific subtypes of ASC, i.e. one subtype with problems regarding phonological skills and syntax and one subtype with semantic-pragmatic difficulties. These findings are interesting in that if these subtypes exist, then different children should receive different treatment.

1.5 ASC and SLI

Traditionally, ASC has been regarded as a condition that should be differentiated from specific developmental disorders, such as SLI (Bishop, Wong, Maley, Hill, Hallmayer, 2004). SLI is diagnosed when a child has selective difficulties in acquiring language, but develops in a typical way in other respects (Bishop, 2000). Some children with SLI experience difficulties in aspects of language structure, but others have communicative impairments, which include pragmatic difficulties. They may, for example, experience problems using language appropriately in a given context. Some professionals regard these difficulties as secondary to the structural linguistic deficiencies, while others see this as an indication that the children exhibit ASC (Bishop 2000). Bishop's conclusion was that there are many children who fall between the diagnostic options of SLI and ASC. A descriptive approach that can detect changes over time has therefore been proposed (Reuterskiöld, Wagner and Nettelbladt, 2005; Bishop, 2000).

1.6 Interventions

1.6.1 A functional approach

Many speech and language therapists, occupational and physical therapists as well as educators work with the individual capacity of children with ASC. However, a developmentally based functional approach is seldom used. A functional approach, not focusing on the condition per se, may change the way we think about the disability. It is, for example, a possibility to look into other studies about perceptual processes and children with ASC. It could be that a child with ASC exhibits language difficulties similar to a child with Down's syndrome, when it comes to motor-planning and visuo-spatial processing (Greenspan and Wieder, 1999).

1.6.2 Intervention strategies in ASC

Theoretical frameworks lay the foundation for various treatment strategies in ASC. An example is the early intensive behavioural intervention methodology, which is a behaviouristic approach (cf Skinner, 1957) and which focuses on modifying children's behaviour with, for example, appraisal. This method is one of the treatment methods currently used in interventions. Another behavioural treatment strategy is PECS (the Picture Exchange Communication System), which is based on behavioural principles regarding prompts and reinforcements. The idea is to induce the child to participate in interactions with the use of pictures.

Another method, which is based on the fact that children with ASC exhibit a strength regarding visual processing and that they benefit from highly structured settings with routines and predictability, is the TEACCH (Treatment and Education of Autistic and related Communication-Handicapped Children) method (Mesibov, Shea and Schopler, 2002). Using this method, the environment is arranged to best suit the child's needs. Matching and sorting skills are trained; typically, the materials are sorted within various boxes. Both early intensive behavioural intervention and TEACCH focus not only on speech and language, but other aspects of learning as well. Other methods include, for example, sign language treatment, parental support, support for teachers and training with picture boards or speech-generating devices (Thunberg, 2007).

A basic distinction in interventions for children with ASC relates to whether the intervention focuses on the child or the environment. Intervention strategies, which are directed towards the child, can be divided into two major approaches: Adult-directed instructions and natural language treatment. In adult-directed instructions, the adult controls the learning environment by selecting activities and materials to induce learning (Grela and McLaughlin, 2006; Rogers, Hayden, Hepburn, Charlifue-Smith, Hall and Hayes, 2006). In natural language treatment, on the other hand, the child´s interests in specific objects or communicative initiatives are the most important. The control of the intervention is then shifted from the adult to the child, in that the child is free to select the learning situations. In a third approach, called focused stimulation, the adult presents target words, but the child does not have to respond. An example of a study that uses this approach and one where toddlers are subjected to intervention is the study by Girolametto, Steig Pearce and Weitzman (1996).

The intervention used in the studies of this thesis is closest to the focused stimulation approach, which can be said to combine adult-directed instructions and natural language treatment. The adult leads the sessions, and all the children's initiatives are met with positive feedback and encouraged, but the child does not have to respond. It deviates from Girolametto et al.'s (1996) study in that the same words were repeated in an on-going manner. The work by Roman Jakobson (1968) laid the foundation for the construction of the feature set (the target words, see chapter 3). The work by Zlatev, Racine, Sinha and Itkonen (2008) has been inspirational for the construction of triads in the studies (child + adult + puppet), where the children were induced to imitate.

1.7 Summary of general introduction

The studies in this thesis focus primarily on the children and not so much on the environment. In relation to the fact that the critical (optimal) period may be delayed in ASC (LeBlanc and Fagiolini, 2011), it is interesting that we focus on school children (6-year-olds) with limited speech output. The thesis will add to the general framework, that is, the idea that auditory (and visual) perception may be an important aspect in language development in ASC. The relative strength regarding perceptual input and a sense for details in ASC may lead to an interest in detecting phonological changes in the surrounding speech at a later age than what is typical. Segmental phonology, prosody and gestures are investigated in three studies where triadic interactions occur.

2 SPECIFIC INTRODUCTION

2.1 The classical literature

2.1.1 Typical language development in children – the classical literature

In the classical literature on child language, researchers have proposed various theoretical approaches to child language acquisition. Empiricists (Bloomfield, 1933; Skinner, 1957) believe that knowledge has its foundation in sensory experience, whilst rationalists (Chomsky and Halle, 1968; Hjelmslev, 1953) assume that our knowledge comes from innate ideas. Then, there are researchers who combine both views. Saussure (De Saussure, 1911-1919), for example, suggests that the language faculty is given to us by nature, but that language has to be acquired in a social context. Socialisation and linguistic development are interrelated, and it is a fact that the social use of language arises as phonological, morphological, lexical, syntactical and semantical abilities improve. Saussure writes: 'Human beings have social needs and language has a role in satisfying these basic needs'. In distinguishing between 'Langue' and 'Parole', he made a distinction between the system and the act of speaking. The signifying (auditory) and the signified (conceptual) elements make up the sign. Bloomfield (1933) was an empiricist, but also a structuralist. He believed that repetition of vocal sounds leads to a response, i.e. imitation, which would lead to development of the lexicon.

The rationalists Chomsky and Halle (1968) introduced the 'Universal grammar', which is a system of conditions that characterise any human language. According to their view, every child is born with the ability to acquire language and the child's competence is not always realised in the performance. Performance is what the speaker or hearer actually does and is based on other factors such as memory, attention and non-linguistic knowledge, while competence is the potential performance. Chomsky views the language faculty as independent of cognition. According to Chomsky and Halle (1968), language acquisition would be impossible without constraints on grammar and the existence of phonological and grammatical rules.

Jakobson (1968) was both an empiricist and rationalist and believed in repetition, but also the child's creativity. In addition, there are interactionists, who view interaction as the most important aspect of cognitive development, such as Vygotsky (Rieber and Wollock, 1997). A meaningful social setting is then needed in order to develop language. Piaget (1959), being an interactionist, believes that cognitive precursors are needed in order to develop language. In order to reach later stages, the child must go through preceding stages. Acquiring new knowledge takes place in steps and the child must adjust to new input and make it his or her own development. This means that the child must, for example, analyse new words before they can be put into their own

system. The first stage of early egocentric speech is, for example, echolalia or repetitions.

In summary, from the nativistic view, the child has innate capabilities (and we are born with an innate capacity to acquire language), but in Chomsky's nativistic work regarding LAD (Language Acquisition Device), neither gestures nor sensory experience are mentioned as important aspects in language acquisition. This means that experience is not seen as important, only the child's own competence. On the other hand, the empiricist Bloomfield (1933), for example, believed in repetition of the vocal sounds, i.e. imitation.

This thesis combines various standpoints, such as the view of the empiricists and the nativistist, but foremost it views language as a biological interactive process in humans, as being part of human development. It is related to perceptual skills and cognitive capacities such as executive functioning and memory, which means that language cannot be separated from cognition. In the thesis, it will be assumed that humans are born with an innate capacity, i.e. specific neural networks (areas), which are used in order to acquire language and other higher cortical skills. However, these skills sometimes exhibit a delayed or deviant development, due to various reasons. The surrounding environment is then of specific importance for children's possibility to learn. In this thesis, Jakobson's structuralistic work has been important for the feature set (target words). The focus is on contrastive features in triadic interactions (Zlatev et al., 2008) where two individuals interact with an object. It will be assumed that linguistic features and other developmental areas interact, because of the interconnectivity between brain areas. Thus, instead of focusing on the deficiency in ASC, we focus on the strength, i.e. the ability to focus on small units of contrastive features (see study I).

2.1.2 Jakobsons's work

In order to study the phonological system in children, child language research requires very careful and exact observations concerning actual linguistic development. Children's speech differs in a systematic way from that of adults. In the present literature on child language development and the acquisition of phonology, Roman Jakobsons's monograph from 1968 is still referred to as a major work in this area, and his influence on the view of child language acquisition is still of great importance. Jakobson (1968) argues that children gradually build up a system of maximal contrasts in a universal, chronological order, where the broad oppositions are acquired first. The optimal contrast is between maximal closure, i.e. a labial stop and a maximally open vowel, for example [pa] or [ma]. The speed of the development may however vary, which means that some children learn the sounds of their language quickly and other children need more time to learn the segments of their language. Jakobson (1968) describes that the first consonantal opposition is that of nasal and oral stop (e.g. mama-papa). This opposition is followed by the distinction between labials and dentals (papa-tata, mama-nana) and form the minimal consonantal system of the languages of the world. The child's vocalic system develops firstly the sounds a-i-u and e.

2.2 Perspectives on ASC

2.2.1 Auditory perception and phonological awareness in ASC

ASC is characterised by deficiencies in social and linguistic development (Constantino et al., 2007). Linguistic aspects are seen as important diagnostic criteria of the condition. On the one hand, the social difficulties seen in children with ASC lead to problems in the linguistic domain (and more specifically in the pragmatic domain). The children exhibit difficulties in the social use of speech. On the other hand, socialisation is also related to linguistic development (Koegel, 2000). Early critical stages of phonological development include the ability to distinguish close-sounding elements and transfer these into single phonemes. Studies, which have shown a relationship between social development and language in ASC, have stimulated new efforts to find early precursors of development. One such candidate is auditory perception, which is related to both early language development and early social development.

Closely related to auditory perception is phonological awareness, which can be defined as 'the ability to perceive the basic units of one´s native language within an acoustically presented speech stream'. The *Native Language Magnet Theory* (Kuhl, Conboy, Padden, Nelson and Pruitt, 2005) argues that early perceptual learning alters development and affects future learning abilities. This has implications for ASC (Kuhl et al., 2005) in that early perceptual learning may not always have occurred. The study by Tsao, Liu and Kuhl (2004) tested 6-month-old infants´ performances on a standard measure of speech perception (the head turn conditioning procedure), using a vowel contrast (the vowels in tea and two). A strong pattern of correlation was found between early speech perception skills and later word comprehension and speech production. Thus, this supports the hypothesis that auditory perception of speech is related to language development. Other evidence for this could be found in children with reading disorders, learning disabilities and specific language impairment (SLI), where children typically show deficits in speech perception and other components of language as well as production (Kuhl, 2005).

2.2.2 Speech and vocalisations in ASC

Speech consists of a stream of sounds produced in the speech production process. Children need to perceive the different phonemes and syllables of speech to be able to distinguish word boundaries. A certain level of performance must be achieved before word production can begin. From the re-duplicated babbling stage, children develop consonant-vowel combinations and CVC combinations (Steinberg and Sciarini, 2006), and then the CVCV tier evolves in, for example, Swedish. Before the developmental level of 1.6 years, children are typically involved in babbling and repetition as well as concatenation of syllabic patterns and attention to acoustic properties of their own production. Levelt, Roelofs and Meyer (1999) discuss a 'protosyllabary', a repository of meaningless speech motor patterns. The child then goes through a phase of 'phonemization', where concatenations of phonological segments are constructed (1.6 to 2.6 years). Children with ASC and no or limited speech output may not have experienced this stage. It is debated whether the lexicon then influences morphology, phonology and articulation (Levelt et al., 1999) or whether an interaction occurs between lexical, morphological, phonological and phonetic processes (Dell and Reich, 1981). In the present thesis, it will be assumed that phonological features are primary for children with ASC (and limited speech output, at this stage of development) in that they

are acquired first during the early babbling stage. Interaction with lexical processes may occur later.

Pre-linguistic vocalisations can be defined as 'children's vocal productions', which may be interpretable by the surrounding environment. Vocalisations may be speech-like or non-speech-like and may, as such, exhibit different functions, namely, communicative functions or self-regulatory functions. They do not necessarily involve segments, but always involve prosody. Vocalisations during the second year of life follow from those of the first year and may vary in choice of consonants (Kent and Bauer, 1985). Studies of vocalisations and speech in children with ASC and limited speech output are rare. The complex task of collecting data in almost non-speaking children may be one reason for the limited research on this matter. Children with ASC may use vocalisations with varying prosody, in order to express emotions. The vocalisations may be intentional or non-intentional, but are often intentional and may be related to various cognitive functions such as shared attention. Atypical vocalisations in ASC have been found in some previous studies (Bartolucci and Pierce, 1977; Cleland, Gibbon, Peppé, O'Hare and Rutherford, 2010; Schoen, Paul and Schawarska, 2011; Wolk and Edwards, 1993; Wolk and Giesen, 2000). Recent theories also discuss the deficiencies in ASC regarding the identification of word boundaries, phonological decoding and motor function in relation to apraxia of speech and central auditory processing (CAP).[9]

2.2.3 Joint attention and ASC

Joint attention, which is an important component in children's development include references to objects and events in the environment, which leads to the emergence of first-word acquisition. Children either respond to another person´s attention or initiate joint attention. It is therefore of great interest to understand the relationship between the impairment in joint attention and linguistic deficiencies seen in children with ASC (Murray, Creaghead, Manning-Courtney, Shear, Bean and Prendeville, 2008). Joint attention seems to precede theory of mind, which is an important cognitive function. The following stages precede joint attention (Kaplan and Hafner, 2006):

1. Mutual Gaze
2. Gaze following
3. Imperative pointing
4. Declarative pointing

Joint attention starts to develop about 3 months of age in dyadic interactions (primary intersubjectivity, compare Zlatev et al., 2008) and is usually fully developed at about 18 months of age. Kaplan and Hafner (2006) define joint attention as follows: 'Joint attention is a coordinated and collaborative coupling between intentional agents where the goal of each agent is to attend to the same aspect of the environment' (secondary intersubjectivity, compare Zlatev et al., 2008). This means that just looking at the same object is not joint attention. Instead, joint attention is present when you interpret the

[9] CAP is a necessary mechanism for the development of language and acoustic stimuli, which need to be processed by the central nervous system (Dekerle, Meunier, N´Guyen, Gillet-Perret, Lassus-Sangosse and Donnadieu, 2013). Cortical auditory development takes place continually during children's growth and involves several anatomical structures, which are involved in perceptual discrimination.[9] Children with ASC may exhibit an increased activity in the areas of the brain, which affect auditory processing (Bölte and Hallmayer, 2011).

intentions of other agents by watching their movements, attention and emotional behaviour (Kaplan and Hafner (2006). In summary, children start to get control of the environment in the form of attention manipulation at 3 - 4 months of age, and at the end of the second year complex social skills develop (Kaplan and Hafner, 2006). This provides a basis for shared experiences, which is necessary for development. One argument for the relationship between joint attention and linguistic skills is the temporal correlation in acquisition. A relationship between joint attention and developing theory of mind in TD children has been found (Charman, Baron-Cohen, Swettenham, Baird, Drew and Cox, 2003). In the present thesis, the children were involved in interaction (including joint attention), where two individuals share a common focus (on an object), i.e. secondary intersubjectivity (Zlatev et al., 2008).

2.2.4 Imitation and ASC

The earliest function of imitation, which involves body movements, vocalisations and facial expressions, provides a sense of connectedness, mutuality and communication. In children about 6 months of age, imitation leads to knowledge about other people´s actions and intentions and is also important in the sharing of emotions. Rogers et al. (2003) write that:

> 'motor imitation may serve as a gateway for experiencing a lifelong sense of connectedness with other people, a foundation for shared experiences of activities, emotions and thought'.

Children with ASC are more impaired than TD children in overall imitation abilities, oro-facial imitation and imitation of actions on objects (Rogers, Hepburn, Stackhouse, Wehner, 2003; Williams, Massaro, Peel, Bosseler and Suddendorf, 2004). Dawson, Webb, Schellenberg, Dager, Friedman, Aylward, Richards and Todd (2002) point out several aspects that are known to be impaired in ASC: joint attention, face processing and motor imitation. Lack of social competence may not account for the poor imitation performance. However, automatic imitation may be improved in children with ASC because of decreased imitation inhibition (Bird, Leighton, Press and Heyes, 2007). This seems to be consistent with general findings regarding the occurrence of echolalia[10] and echopraxia.[11] Imitation impairment could either be due to dysfunction of the mechanism that translates observed actions into executed actions or non-specific factors (Bird et al., 2007). Speech production, gestures and silent mouth gestures (see study III) are studied in the present studies.

2.2.5 Perception and belief understanding in ASC

A critical precursor of belief understanding is perception (Hadwin et al., 1997). Before children can understand that people can have different beliefs about one situation, they have to understand that people can have different perspectives of the same object. Visual and auditory perception of another person naming an object will offer the child both visual and auditory input for word acquisition and at the same time joint attention, which is the first step towards theory of mind. In this sense, perception, word acquisition, and

[10] Involuntary imitation of the speech patterns of others.
[11] Involuntary imitation of observed actions.

theory of mind are connected. Weak central coherence may contribute to the problems seen in people with ASC (Happe´, 1994; Frith, 1989). The weak central coherence theory suggests that people with ASC do not make use of context and attend to parts rather than to wholes. In other words, people with ASC are good at tasks, which can be done by attention to detail (for example, phonological features) while ignoring the big picture. Auditory information processing is also dependent on social experience, i.e. the child's experience of interaction (Constantino et al., 2007). The children in the present thesis have the opportunity of social experience during the course of the studies. In addition, they get to focus on small contrastive features of phonological distinctions, which may be of interest for children with ASC.

2.2.6 The biology of speech and language in ASC

Brain areas involved in social and emotional behaviour, whose deficiencies are important for ASC, are suggested to be the medial prefrontal cortex, parts of the temporal lobe and the amygdala (Bölte and Hallmayer, 2011). During the last few decades, researchers have suggested that so called mirror neurons exist in the prefrontal cortex; these may be involved in understanding the intentions of others, that is, the theory of mind (Lacoboni and Dapretto, 2006; Southgate and Hamilton, 2008). In addition, parts of the temporal lobe may be important (Bölte and Hallmayer, 2011). It is noteworthy that both these regions (the prefrontal cortex and the temporal lobe) exhibit proximity to regions that are important for speech and language, i.e. Broca's[12] and Wernicke's[13] areas. In fact, fMRI studies have shown decreased activation of Broca's area (important for speech production) and increased activation of Wernicke's area (important for speech perception) in individuals with ASC, which could explain some of the difficulties seen in the condition.

Understanding others' intentions while watching their actions is important for social behaviour. When we see someone reaching out for an object, we assume that this person's intention is to have the object (Lacoboni, Molnar-Szakacs, Gallese, Mazziotta, Rizzolatti, 2005). For example, an individual may intend to grasp an object, rather than to throw it away. Mirror neurons have been suggested to be involved in this coding of the motor act, also related to imitation. The hypothesis that dysfunctional mirror neurons might be an explanation for the deficits of ASC has been under active research during the last decade (Agnew, Bhakoo and Puri, 2007; Lacoboni and Dapretto, 2006; Oberman, Hubbard, McCleery, Altschuler, Ramachandran and Pineda, 2005; Rizzolatti and Arbib, 1998). These ideas are, however, hotly debated. Southgate and Hamilton (2008) suggest that several other brain structures and functions are related to imitation, not just mirror neurons. They still believe that mirror neurons have some role in ASC, but suggest that the mirror neuron system (MNS) could be divided into several subsystems. Mirror neurons are not only to be activated during motoric actions, but also during auditory perception as well as visual perception. This contributes to the theory of a link between perception and production of speech (Fadiga, Craighero, Buccino and Rizzolatti, 2002; Lieberman and Mattingly 1985). Can we then expect an intervention involving perception to have implications for production? One question we might ask is whether auditory perception influences speech production in a more direct way than just preceding production. We know that speech muscles are activated when we listen to speech and that we use auditory feedback as we speak. According to Pickering and Garrod (2007), there is direct evidence of an involvement of articulation in speech

[12] Brodmann 44 and 45
[13] Brodmann 22

comprehension. Pickering and Garrod (2007) write: 'Listeners activate the appropriate muscles in the tongue and lips while listening to speech but not during non-speech'. Additionally, increased muscle activity in the lips is associated with increased activity (i.e. blood flow) in Broca's area, which suggests that this area mediates between the comprehension and production systems during speech perception. In ASC, a common symptom is echolalia,[14] which may be caused by a dysfunctional MNS, alternatively impairment in networks including Broca's area. This is related to apraxia, characterised by inability to perform tool-use hand actions and produce verbal commands in daily life (Dawson et al., 2002; Hamilton, 2008). It is also possible that there is a link between linguistic prediction of speech sounds and theory of mind, related to the same prediction system in TD individuals (Pickering and Garrod, 2007) and that this prediction system is deficient in individuals with ASC.

Thus, perception activates the production system and leads to imitation. Some children with ASC are lacking experiences of speech sound imitation during development, which is why it may be important to provide opportunities to imitate speech sounds, syllables and words. In this thesis, it will be investigated whether perception and production are connected and whether speech perception exercises may have an impact on speech production.

2.2.7 Intersubjectivity in ASC

The 1st person perspective involves the proprioceptive system (muscles, etc.), while the 3rd person perspective involves the auditory and visual systems, i.e. when attention is directed towards another individual (Zlatev et al., 2008). Individuals with ASC could exhibit functioning systems for proprioceptive feedback and auditory-visual feedback; however, these systems may not be integrated. This would mean that the so called 1st person perspective and the 3rd person perspective (Zlatev, Racine, Sinha, Itkonen, 2008) are separate and that these functions do not function together. TD children, on the other hand, first develop primary intersubjectivity involving face-to-face interaction and later a secondary intersubjectivity, which is demonstrated by declarative pointing. Children with ASC may exhibit increased perceptual ability, i.e. increased activation of Wernicke's area, and decreased ability to produce speech sounds, i.e. decreased activation of Broca's area or it could be the case that perception and production function separately. The use of gestures may also be less frequent than in TD children. In relation to these theories, the present thesis investigates whether training auditory perception has an impact not only on speech production, but also on prosody and gestures.

2.2.8 Speech perception, gesture recognition and speech production in ASC

When we speak, there is a continuous stream of sounds and facial and gestural movements in face-to-face communication (Williams et al., 2004). Children are originally amodal and grow socially during age 2–6 months, being interested in human facial expressions. Children with ASC may have a poor audio-visual integration (Williams et al., 2004), which can lead to a delay in social development. Social development in this way starts with knowledge of facial expressions and proceeds to understanding intentions, mutual interaction, joint attention and eventually, theory of mind or mental states. Wolf, Gales, Shane and Shane (2001) suggest that sign language should always being taught to children with ASC, because hand movements would

[14] Automatic repetition of vocalisations made by another individual.

contribute to learning the phonetic movements. Gesture recognition is suggested to exist in Broca´s area (Rizzolatti and Arbib, 1998), which implies a link between gesture recognition and speech production. It has been claimed that children with ASC have difficulties both with verbal and non-verbal language, which could be explained by the shared anatomical areas. Nevertheless, vocalisations co-occur with gestures, although this may happen more seldom in ASC, than in TD children.

2.3 Prosody, gestures and silent mouth gestures

2.3.1 Phonological and phonetic prosody

Children continually develop prosodic features, both on a phonological level and on a phonetic level. Babbling patterns of one or two syllables, in conjunction with a language-specific prosodic feature, provide the basis for meaningful utterance. In Swedish, which is a Germanic language, three basic prosodic features that distinguish word meaning occur (Gårding, 1989), i.e. word accent 1 or 2 (intonation patterns on the word level), duration of vowels (long-short) and word stress (varied). There is an on-going discussion whether about accent 1 or 2 is default in Swedish (Bruce, 1977; Lahiri, Wetterlin and Jönsson-Steiner, 2005; Riad, 2014). For the boys in the present study, accent 2 was considered default, since this accent is acquired first in Swedish.

On the phonetic level, the utterances consist of pitch, rhythm, duration and intensity. Typically, mean pitch (F0) decreases during children's growth (see study I). Newborns exhibit an F0 at about 500 Hz, while preschool children of 3 - 4 years of age exhibit an F0 at about 300 Hz. This descent is on-going for children and differs between girls and boys (larger for boys) during adolescence. Furthermore, the F0 range decreases (see study II). The second study in the thesis investigated prosody during an intervention in the two boys in the thesis.

2.3.2 Gestures

Gestures can be classified into manual gestures or silent mouth gestures. Manual gestures are performed with fingers, hands or arms, which show different placement, retraction, protraction, etc. Manual gestures may then be divided into the following subgroups: deictic, general accompanying, ritualistic, interactional and iconic gestures. The action of making deictic gestures can be defined as intentional pointings in order to share attention in non-verbal reference or object requests (Zlatev et al, 2008). Gestures, which are directly connected to speech, i.e. general accompanying gestures, are unintentional motor actions and occur in the same time frame as speech or precede speech. One type of manual gestures that we call interactional are intentional gestures, for instance, the clapping of hands or grabbing another person's hand in a play activity. Manual gestures can also refer to a specific act, such as giving an object to another person, for example, ritualistic gestures. Finally, iconic gestures are intentional, visual representations of referential meaning, i.e. they illustrate words or events and may include use of objects. It means that the code and the referent resemble each other, when we refer to an object. They are related to actions, such as "putting a cup to the mouth".

Gestures are closely connected to speech and language (Bates and Dick, 2002; Iverson and Goldin-Meadow, 2005; Özcaliskan and Goldin-Meadow, 2005; Bikofski and Buccino, 2003). The development of babbling, for example, has been linked to interactional gestures such as hand banging and clapping and word comprehension, and

with the emergence of deictic gestures (pointings). Findings by Özcaliskan and Goldin-Meadow (2005) revealed an increasing amount of speech accompanying gestures, as language (two-word) phrases developed in a group of children. Anatomical closeness in the human brain regarding speech production and hand movements supports the idea that these functions are interconnected. The third study in the thesis investigates gestural development during an intervention focusing on phonological features, in one boy with ASC.

2.3.3 Silent mouth gestures in ASC

Silent mouth gestures are unconscious, unintentional movements of, for example, lips, which are made in preparation of speech. Due to impaired sensory integration and also apraxia of speech,[15] this task is often difficult for children with ASC. Nevertheless, children with ASC may use silent mouth gestures, as a preparation for speech. In the present thesis, silent mouth gestures are mainly referred to when the aim is to describe the preparations, which are made for speech production. Other types of silent mouth gestures are mouth or lip-movements that occur after speech production. Silent mouth gestures are studied in the third study on gestures (study III).

2.4 Purpose of the thesis

The thesis is based on the hypothesis that overlapping cortical networks for language and cognition (including Broca's area and areas for perception) could be stimulated and that listening (auditory perception) and watching production of sounds (visual perception) lead to a development of sound production. Thus, this would provide evidence for perception and production are interrelated. Furthermore, it would indicate that linguistic development and cognitive development are interrelated. In the thesis, the three perspectives: segmental phonology, prosody and gesture were investigated in three papers on this topic and important factors contributing to language development were called precursors (study III).[16] In ASC, precursors of language development may, for example, be: auditory perception, interaction, joint attention, belief understanding and imitation.

More specifically, the purpose of the thesis has been to investigate the relationship between various linguistic variables of importance for the development of language in ASC. This was studied in two boys with ASC, longitudinally during a period of 1 ½ years.

[15] Apraxia of speech can be described as an oral motor speech disorder, which affects a child's ability to translate phonological features into motor actions.

[16] Precursors may be defined as 'an earlier stage that contributes to a later stage'.

3 GENERAL METHOD

3.1 Introduction

The relationship between segmental phonology, prosody and gestures were investigated in three separate papers on this matter. We predicted that auditory (and visual) perception would influence speech production (study I) and that prosody could be influenced by this development, despite not being specifically trained (study II). In addition, we predicted that speech and gestures interact (study III) and thus investigated the development of gestures during the same time period as studies I and II. The overall research questions concerned whether the three perspectives are interrelated, what precursors are important for language development in ASC and whether an intervention given to two boys with ASC showed positive results.

More specifically, the purpose was to investigate phonological (segmental), and gestural development in one boy with ASC and prosodic development in two children with ASC during an intervention that included triadic interaction. The intervention included a puppet game, where the boys listened to phonological contrasts and were induced to produce these sounds in interaction with their teachers and a speech and language therapist (SLT).

3.2 Single - subject - design – methodology

In research on ASC, Single subject designs are frequently used for scientific evaluation of treatment effects (Hegde, 1994). With the single-subject strategy, you compare the same individual's performance both during treatment and outside treatment. The continuous measures result in a better evaluation of the treatment, than using only pre- or post- tests. When several subjects are used, the results are averaged across the individuals, which can sometimes be misleading, given the heterogeneity of symptoms in ASC. In the single-subject design, the participant's results are described separately, and initial baseline measures are made in order to rule out the argument of spontaneous development.

3.3 Participant 1 (Ted)

Participant 1 (whom we called Ted) was involved in all three studies included in the thesis. Ted exhibits ASC and severe intellectual disability and was 5.9 years old, at the onset of the study and 7.2-years-old at the last follow-up. Ted attended a special class for children with ASC, which was integrated in a regular school in Sweden. His vision and

hearing were normal. L1 (for both parents) was a non-Germanic language,[17] while L2 (the language spoken in the family) was Swedish. Both L1 and L2 were spoken at home, together with some English until the boy was 1.6 years old. The parents noticed delayed language development at 1.6 years of age and then changed languages at home to only L1. An investigation of psychomotor development started at 2.5 years of age, and then the parents switched to using L2, as the only language. The Griffith's Test (Griffith, 1954) and the Vineland Adaptive Behaviour Scales (Sparrow and Cicchetti, 1985) showed moderate to severe ASC. An SLT estimated that the boy, at age 2.9, almost totally lacked language and word comprehension, with an expressive language of 4–5 one-syllable utterances. Reynell Language Developmental Scales testing at age 5.6 revealed that the boy was able to point out 8 out of 15 objects (nouns) and to follow a simple instruction. Bilabials, dentals and velars were judged as established in initial and medial positions, in that five objects were named with these sounds. The majority of Ted's utterances consisted of one syllable. Reduplicated babbling was rare, but occurred, such as in [pɛpɛpɛ] for apple. Ted exhibited extremely limited oral speech and communicative skills. Picture boards, pointing and facial expressions were used to some extent in communication. See studies I, II and III.

3.4 Participant 2 (Ben)

Ben was a participant only in the second study, that of prosody.[18] Participant 2 was a 5-year-old boy (at study onset) with ASC, severe intellectual disability (DSM-IV/ICD-10) and ADHD. We called him Ben. Griffith's (Griffith, 1954) and Vineland's tests (Sparrow and Cicchetti, 1985) showed a delayed language development in general, where his skills were equivalent to 1:6 years of age at 3:0 years chronological age. At 4 years of age, hyperactive behaviour occurred, including attention and interactional difficulties.

L1 was Swedish. The boy´s hearing was normal according to brainstem audiometry, while his vision was severely impaired. His mimics and gestures were rare, and utterances were often accompanied by echolalia. The boy's lexicon (at study onset) consisted of about 15 words (examples: *äpple* 'apple', *vatten* 'water', *mamma* 'mummy', *pappa* 'daddy', *åka bil* 'go by car', *mat,* 'food', *byxor* 'trousers', *kaka* 'cake', *läsa bok* 'read a book', *smörgås* 'sandwich', *bada* 'have a bath', *godis* 'sweets' and *knacka* 'knock') in production (nouns and verbs), (estimated by parents and teachers). Phonological, morphological, syntactical (restricted phrase length), comprehensive and pragmatic skills were impaired. According to the teachers, the boy´s voice was monotonic. He used picture boards to enhance communication, which however was of limited value due to his visual impairment. The boy was attending a special class for children with ASC, which was integrated in a regular school. See study II.

3.5 Procedure and Considerations

Several aspects were taken into consideration as the studies were performed. As opposed to most other school assignments, the intervention model was dialogic and presupposed interaction, which was important. In the training, the boys had the possibility of

[17] Ted's family's L1 is not described in more detail in accordance with the requests of the parents.

[18] The reason for not involving both boys in studies I and III was that the two boys were at varying developmental levels, i.e. Ben had more speech than Ted before the study.

matching specific objects (puppets) with sound patterns in the environment. The boys' understanding was facilitated by the presence of objects, which they and the adults could refer to. The puppets were motivating for the boys in that they contained a large amount of detail. We thought it would be important for the intervention to be performed with the boys' ordinary teachers so the boys did not need to connect with a new person (e.g. the researcher). The training can be described as a combination of natural language treatment and adult-directed instructions. The study was performed over a period of 1 (Ben) - 1 ½ years (Ted). The study took place in two periods, each 5 months long (Ben and Ted), and Ted had an additional follow-up period of 6 months.

The studies were designed as *single-subject designs*, with repeated measurements of the dependent variable, which is preferable in investigating children with ASC. Due to Ted's very limited speech output and involvement, study I is better described as a case study. However, the single-subject strategy was a preferable starting point for the study and was also used in the second and third studies.

The weekly video recordings done during the weeks without treatment were called baseline sessions (BL), and the weekly video recordings done during periods of treatment were called probe sessions. Pictures of the puppets in the study were used as stimuli during the baseline and probe sessions, while only puppets were used during the probe sessions. However, as there was virtually no sound production during the first baseline (Ted), we made the decision to use the puppets in addition to pictures during the remaining baseline sessions and the weekly probe sessions.

The children's summer holiday from June to August interrupted the intervention study, which led to a withdrawal of treatment. A second baseline, with video recordings without weekly training was established at the beginning of August. Establishing a baseline (with data of the child's speech before treatment) was, however, difficult because of very limited speech output in Ted's case. See studies I, II and III.

3.6 Stimuli – Materials

The materials used in the study were puppets (see study I) made of different colours and materials such as wood or soft stuffed fabrics, which would be stimulating for different modalities like vision and audition (IAKM, Johansson, 1988 [The International Association for the Karlstad Model]). Different names (CVCV syllables) for the puppets were decided upon beforehand. All the puppets' names exhibited the accent of Swedish (accent 2). In period 1, eight puppets (+ pictures) were used during baseline and probe and in period 2, 13 puppets (+ pictures). Every fourth week (period 2), if the boy participated, we also showed the puppets from period 1. Period 3 included treatment sessions only (and 6-8 puppets per week).

In period 1, four contrastive (or distinctive) feature contrasts were systematically introduced: *place features* (– voice) [p], [t], [k], *place features* (+ voice) [b], [d], [ɡ], *laryngeal features* [p]–[b], [t]–[d], [k]–[ɡ], and *manner features* [m], [p], [b], [n], [t], [d]. Examples of the puppets' names were: [pɒpʊ], [tʊtʊ], [kʊkʊ] and [bʊbʊ]. The feature set was inspired by Jakobson's theories of consonantal opposition. Two puppets per week were used in training sessions. In period 2, labials, dentals and velars were systematically introduced (4-5 puppets per week were used). Vowels were varied in

training between [i] and [a] in period 2 and between [ʊ], [i] and [a] in period 3. In period 1, [ʊ] was the only vowel used. See studies I, II and III.

3.7 Recordings and Transcriptions

All the sessions, 43 in total for Ted and 23 in total for Ben, i.e. 66 sessions (9 hours of data) were video recorded with a Panasonic HDC SD-700.

The sessions began as the boy and the adult were seated. Recordings were made for however long each boy was able to maintain a focus on the activities. Thus, they varied in length and often ended with putting the puppets in a box. The setting was a special room at the boys' school, constructed for working together sessions. Four to five children with ASC had their daily education in the classroom (together with six to seven teachers). Recordings began when the boy and the teacher or SLT entered the room. The length of the recordings varied with consideration taken for the children's participation and attention span. The corpus was transcribed and annotated. Orthographic transcriptions were made for the teacher's or the SLT's speech, and phonetic transcriptions (according to IPA, the International Phonetic Alphabet) were made for the children's speech. The three studies will be described in the next section (Specific method).

4 SPECIFIC METHOD

4.1 Study 1

The first study investigated language development over a duration of one year in a 5-year-old boy (Ted) with ASC. An intervention, where stimuli (minimal pairs) were gradually introduced, was constructed in order to increase awareness of phonemic contrasts and symbolic representations. The method of analysis was both quantitative, regarding, for example, the number of speech productions or feature types and qualitative, concerning, for example, syllable constructions. The transcribed material was analysed and measured for general sound production, phonological features and syllables. One of the researchers interviewed one of the boy's parents twice during the study and took notes from the meetings. During the second interview, the SLT was present. One and a half years after the onset of the study, the parents participated in a written interview. Notes from discussions with teachers were collected on a regular basis during the researcher's visits to the school. Data concerning the SLT's experience rely on the SLT's medical records of the boy. See study I.

4.2 Study 2

Both boys were involved in the second study, where acoustic measurements were taken for F0 variation, analysed in PRAAT (Boersma and Weenink, 2015) and compared with other linguistic aspects, such as syllable constructions, phrase length and accent 2. A corpus of spontaneous child speech utterances[19] was collected, transcribed and analysed for mean F0, F0 range and utterance duration. The presence of accent 2 for Ben's utterances was also noted by two transcribers. Using the data, interobserver-agreement was calculated. Phrase length was annotated for Ben and syllable constructions for Ted. See study II.

4.3 Study 3

In the third study, three speech corpora during 1 ½ years were analysed regarding the development of gestures in the boy included in study I, Ted. Three corpora were collected during the boy's period of first-word acquisition. Questions focused on the development of gestures and also on whether speech and gestures were interrelated. The following gestures were analysed: deictic gestures, general accompanying gestures,

[19] A total of 697 utterances during 23 sessions for participant 1 and 1,078 utterances during 34 sessions for participant 2.

ritualistic gestures, interactional gestures, iconic gestures and silent mouth gestures. See study III.

4.4 General research questions (for all three studies)

1. How are the areas of segmental phonology, prosody and gesture interrelated?

2. Is auditory (and visual) perception important as a precursor of language development in ASC?

3. Did the intervention towards the two boys seem to have an effect?

4.5 Study I – Specific research questions

1. Can the boy in the present study acquire phonological contrasts, more advanced syllable constructions and use of new words following the intervention?

2. Can a deviant phonological development with presence of atypical production of speech in this child with ASC be detected?

4.6 Study II – Specific research questions

1. Did the mean F0 increase or decrease during the intervention?

2. Did the mean F0 range increase or decrease during the intervention?

3. Did the mean utterance duration increase or decrease during the intervention?

4. Were there examples of correctly produced accent 2 present in the segments? Did the production of accent 2 increase?

4.7 Study III – Specific research questions

1. How were the deictic and general accompanying gestures distributed during 1 ½ years?

2. Were imperative gestures more frequent than declarative?

3. Was a temporal agreement between development of deictic gestures and first-word acquisition detected?

4. Did ritualistic, interactional or iconic gestures occur in the speech data?

5. Was there a temporal correlation between speech production and gestures?

6. Silent mouth gestures: When in relation to speech production did these gestures occur?

5 RESULTS OF THE STUDIES

5.1 Study 1 – Segmental phonology

The results of the first study suggested that auditory perceptual stimulation, i.e. listening to sounds in CVCV constructions, influenced speech production. A quantitative and qualitative development of speech was seen in participant 1, Ted, during the year. There was a quantitative development regarding the production of speech sounds and the use of new feature types. The qualitative changes included new phonological contrastive features and syllable types. In addition, feature accuracy increased. We were also able to show some historical data, which showed the same conclusions as the empirical results. The results were significant, comparing two periods, which suggests that phonological training can stimulate children with ASC to develop speech and language at about 6 years of age. The delayed and deviant speech development, both regarding segments, syllables and word boundaries in this child, are in line with studies that describe a deviant phonological development in individuals with ASC (Wolk and Edwards, 1993; Wolk and Giesen, 2000; Peppé et al., 2010). In summary, phonological processing is suggested to be an important precursor of speech and language development. Moreover, auditory perceptual input is suggested to have an impact on oral production, i.e. a link between the brain areas. See study I. Examples of Ted's vocalisations are presented in appendix 1. Appendix 5-12 shows the data of study 1.

5.2 Study 2 – Prosody

The second study showed that increased pitch and increased pitch range were reduced for the two boys in this study. Both boys exhibited mean F0 levels of between 310 to 350 Hz at the beginning of the study. After the intervention a decrease in F0 (about 60 Hz) and an increase in F0 range within intermediate F0 range thresholds (100–300 Hz) were seen for both boys. It is possible that F0 was raised and then attained an F0 level closer to TD children after the period of training. An argument for an effect of the intervention is that F0 decreased more than expected compared to typical development. The boys did not show an increase in mean utterance duration during the year. There was, however, an important increase in mean maximum utterance duration. Ted exhibited reduplicated babbling and vocalisations at the beginning of the year, but then developed syllable constructions and words with a CVCV pattern, which were produced with accent 2, and thus a more varied prosodic pattern. Ben developed an increased phrase length. There were examples of correctly produced words in accent 2 in Ted's speech, which suggests a development in Swedish phonology. Ben had a possible development in accent 2, comparing the two periods of study. One factor possibly contributing to the result, besides the intervention, was the intensive presence of 'motherese' speech on a daily basis. We did not analyse the teachers' or SLT's speech specifically, but got a clear impression from the recordings that 'motherese' speech was

present, which is natural as the teacher and SLT were involved in puppet-play. It is suggested that prosody can be a useful indicator of language development and a tool for diagnosis in ASC. Threshold analysis was suggested as a method for analysis. The results suggest that perceptual training with minimal pairs (exhibiting accent 2) also has an impact on prosody (not being trained specifically). See study II. Examples of Ben's speech production are presented in appendix 3 and an overview of his prosodic development in appendix 4. Appendix 13–21 show the data of study 2.

5.3 Study 3 – Gestures

The results of the third study showed a development of manual gestures, both deictic and general accompanying gestures. General accompanying gestures started to occur during the second period and continued to develop during the third period of study. The deictic gestures were contrary to what was expected, more often declarative than imperative. In addition, declarative gestures increased (period 3), while imperative gestures first increased (period 2) and then decreased (period 3). We found a temporal interrelationship between speech production and gestures, despite gestures not being trained, which was significant. Thus, the gestural development progressed, along with phonological improvement. A possible theoretical explanation for this progress is the shared areas in the human brain for gestures and speech production (Broca's area). There was further evidence of an interrelationship between general accompanying gestures and oral motor function, in that gestures could accompany speech in a very specific manner, by use of various hand shapes that accompanied syllables. Ted, in the present study, performed a specific type of general accompanying gestures, which possibly supported the performance of syllables in his production. This is interesting and may be related to other similar phenomena, such as hand banging (clapping) and the onset of babbling (Bates and Dick, 2002). There were examples of silent mouth gestures present in the data. They were integrated with speech and occurred primarily before speech. See study III. An overview of Ted's results in the three studies is presented in appendix 2. The data of study III are presented in appendix 22–24.

6 SUMMARY OF THE THREE STUDIES

In the present thesis, two boys with ASC have been subjected to interventions, and each followed longitudinally with single-subject-designs.[20] During the intervention period, phonological distinctions (minimal pairs) were gradually introduced for the two boys.[21] The purpose was to increase phonological awareness and ultimately affect phonological segments using objects in the environment, in triadic interactions. In a total of 66 video-recorded sessions (43 for participant 1 and 23 for participant 2), i.e. 9 hours of data, various linguistic analyses were performed. The thesis contains the following three studies:

1. A study of phonological development in participant 1 (Ted).
2. An investigation of F0, F0 range, duration, accent 1 and 2 for the two participants (Ted and Ben).
3. An investigation of gestures and gestural development (participant 1, Ted).

The results (appendix 1–24, studies I–III) showed a positive development for both boys. Ted developed in phonological awareness and production of feature contrasts, syllable constructions and the use of new words during a period of one year. F0 decreased and the number of utterances within F0 range thresholds increased for both participants in the study. This suggested that prosody was affected by the intervention, as F0 decreased more than what was expected in this age group. Co-occurring with development of phonological skills was the development of gestures (study III, Ted). Ted began using an increased amount of deictic and general accompanying gestures (with speech) during the study. In the interaction, particularly declarative (deictic) gestures started to occur and gave rise to the beginning of interaction. We also noted that speech and gestures were interrelated, gestures being rather secondary than primary.

[20] During a period of 1 year (and 1 ½ years), respectively.
[21] According to theories by Jakobson (1968).

7 SUMMARY OF THE PARTICIPANTS' DEVELOPMENT

7.1 Participant 1 (Ted)

Participant 1 (Ted) went through a number of changes during the study period of 1½ years. He developed in segmental phonology, learned the important Swedish syllable structure CVCV and the Swedish accent 2, while F0 levels reached a more typical pattern along with his F0 threshold range. He also increased the number of his deictic gestures, where especially declarative gestures increased. We could also note an increased use of general accompanying gestures. There was a temporal correlation between speech production and gestures. General accompanying gestures and oral motor function seem also to be interrelated.

7.2 Participant 2 (Ben)

Participant 2 (Ben) reached an F0 pattern during the year, which resembled typically developed children. F0 levels decreased and the number of utterances within the intermediate range 100–300 Hz increased. He learned the important Swedish accent 2 and also displayed a tendency towards an increased phrase length during the year.

8 GENERAL DISCUSSION

The overarching purpose of the thesis has been to shed light on the inter-relationship between segmental phonology, prosody and gesture, to look for precursors of language development as well as to study the development of two boys with ASC during an intervention with training in segmental phonology. This has been studied empirically in three papers. The two boys developed positively within several areas of language development. The results lead us to conclude that auditory (visual) perception is an important aspect, i.e. precursor, in development, and that the three main perspectives: segmental phonology, prosody and gesture are interrelated in development, since only one aspect, segmental phonology, was actually trained, but also prosodic and gestural features developed during the course of the study. This is in accordance with what we would expect, since linguistic skills are linked in typical development. However, children with ASC need more time to develop, and the interventions need to be adjusted for each child individually.

We know that word comprehensive skills, auditory perception and phonological awareness precede speech production during children's speech and language development. Recent studies of fMRI images show that several brain areas are involved when we perceive stimuli; both frontal and parietal brain areas light up. Also, we know that injuries to the human brain may cause specific symptoms regarding speech or language, depending on which area is affected (aphasia). From a holistic viewpoint, the most plausible explanation is that perception and production are interrelated. The empirical studies in this thesis also suggest a relationship between perception and production, which support theories about Broca's area being a bridge between the two and also that a mechanism, such as the mirror neuron system is involved. Children with ASC are thought to exhibit a deviant neurological development, which may include impaired networks for speech, language and cognition. By stimulating auditory perception, it may be possible that these networks, including cortical areas for listening and speech production are activated. The connection between the areas of perception and production and the existence of mirror neurons cannot be rejected based on the results of this thesis.

ASC is characterised by difficulties in integrating different sensory perspectives, which we as humans use constantly. The proprioceptive system (feedback from muscles) is foremost involved in one's own perspective, while vision and hearing may be involved when we listen to or read what someone else says or writes. However, in severe ASC, the perspectives may not be integrated, which on the brain level implies that brain areas that are functioning separately, but not in cooperation with other areas. This is very much an explanation for the various difficulties individuals with ASC exhibit. Prosodic and perceptual development evolves initially from vocalisations, which proceed towards word production. As speech develops, it occurs both on the word level and the sentence

level. Children with ASC exhibit deficiencies in integrating perceptual input, which means that the speech stream may be difficult to perceive, in that it includes various properties, such as semantic meaning and prosodic characteristics.

Study I showed a quantitative and qualitative development of sound production, regarding the use of new phonological feature types, new syllable constructions and the use of new words during the year, as perception and phonological awareness (segments) were trained. This is natural since the social use of linguistic skills arises as phonological, syntactical and semantic abilities improve.

In production, children with ASC have previously been thought to exhibit monotonous speech, i.e. restricted F0 and F0 range. Recent acoustic studies, however, show an increased pitch and pitch range in ASC. Study II showed results which are in line with these recent findings, i.e. a restricted number of utterances within intermediate threshold ranges and also that it is possible for children with ASC to develop in prosody. There were progressively reduced symptoms of ASC, such as increased pitch and increased pitch range, thus a pattern similar to typical development, despite prosody not being trained.

There are several links between speech and gestures, which have been described in study III of this thesis. During speech and language development, children acquire speech and gestures simultaneously (Bates and Dick, 2002; Iverson and Goldin-Meadow, 2005; Özcaliskan and Goldin-Meadow, 2005; Bikofski and Buccino, 2003). Deictic gestures, such as pointing are used in order to share a common focus of attention in first-word-learning. Hand banging or clapping has been linked to canonical babbling. As in most other cases, we may here detect a representation on the brain level, related to the fact that areas for gestures and speech production are very close in the human brain. The current study of gestures in one child with ASC showed that deictic (declarative) gestures and general accompanying gestures increased, as speech and language and the first words occurred. It was found that the boy (Ted) used general accompanying gestures, we believe, to support speech production.

The most interesting result in study III was an increase in declarative gestures. Declarative gestures exhibit a cognitive function in that they are directly related to joint attention. This is why the increase in declarative gestures suggests that Ted's use of joint attention increased during the study. In addition, the increased use of declarative gestures also suggests that Ted improved in secondary inter-subjectivity (Zlatev et al., 2008), which is another way of describing the link between linguistic skills and cognition. Perception, joint attention and word acquisition seem to be interrelated, in that when children hear or see another person naming an object, they receive input for semantic representations. In the present studies, there was a possibility of an integration of different sensory perspectives. Furthermore, the relationship was triadic (including the boy, a puppet and an adult), which made joint attention possible. Since joint attention is seen as a step towards theory of mind, one could say that these cognitive skills are related to word acquisition. The phonological structure of the target stimuli represented whole words (puppets' names), and may have been meaningful, especially for the boy (participant 1, Ted), who had not yet attained this level of development. The study used small changes in phonological features as stimuli, as the syllable structure remained the same. These changes may have been interesting for the participants. The non-speaking boy (Ted) may have increased his speech production during the intervention period, which suggests that auditory perception stimulated imitation. Another important aspect

is that visual, auditory and proprioceptive perspectives were integrated during the intervention. The objects per se may have been stimulating, since they appealed to various senses. The children in the study also listened to the same sound combinations repeatedly, in order to become aware of and establish these phonological structures in the production system. This was performed in interaction with objects (puppets) and coloured pictures.

Arguments for auditory perception being an important aspect is the improved syllable constructions and phonological distinctions, but also the changes seen in prosodic aspects. Children with ASC often exhibit an increased ability to pay attention to details, which is described, for example, in the enhanced perceptual functioning theory (Mottron, Dawson, Soulières, Hubert and Burack, 2006). From study III, it may be concluded that verbal and non-verbal speech are interrelated, since gestures increased despite not being trained.

The speech of the two boys included in the study varied with respect to phonological and syllabic patterns, which may be explained by apraxia of speech (Hamilton, 2008) or it may be just typical, but delayed development. Vocalisations vary also in typical development, at about 13 months of age (Kent and Baueer, 1985).

The present study has not aimed to present data on the human brain, but rather to discuss various linguistic aspects in relation to recent neuro-scientific research. Theories on mirror neurons are hotly debated (Lacoboni and Dapretto, 2006; Southgate and Hamilton, 2008), and the existence and the exact location of these neurons are not clear. However, many studies describe Broca's area as an important area for production of speech and gestures. The results of the present thesis (containing three different studies) support the existence of a mechanism bridging between perception and production, such as mirror neurons, because we found that auditory (as well as visual) perception seemed to influence the development of speech production, prosody and gestures. A more network-oriented, holistic, view of the human brain has recently been adopted, instead of the localistic standpoint, which holds certain regions of the brain responsible for various functions. If maturation of the networks is delayed, we may speculate that, it is possible that different brain areas may be functioning separately in ASC, but not together. It involves the integration of perception and production, but also cognitive perspectives, such as the successive development of a secondary intersubjectivity (Zlatev et al., 2008), with presence of a shared focus of attention. The boy in studies I and III showed improvement in phonological segments and syllable structure (i.e. first-word acquisition) as well as declarative gestures, which means that he clearly reached a secondary intersubjectivity, although the primary intersubjectivity appeared not to be fully developed. During the studies, both perspectives were trained. A question for future research concerns whether it is first necessary to acquire a primary intersubjectivity in ASC or if a secondary intersubjectivity is possible directly as various sensory systems integrate.

From the critical period hypothesis, we expect that the optimal period for speech and language development in children with ASC is delayed and as such constitutes an explanation for a delay in linguistic skills in school-aged children. The first period at about 6 months of age (Kuhl et al., 2005) is important for phonological awareness, and attention to one's own voice and the second period, 1.6 - 2.6 years of age is important for the concatenation of phonological segments (Levelt et al., 1999). This thesis suggests

that it is important to continue with interventions during the school years, even after various critical periods in TD children are over.

Within ASC, various subgroups have been discussed, i.e. one subtype which has difficulties with perception and production of phonology and syntax and one subtype having semantic-pragmatic difficulties. The boys in the present study exhibited difficulties of both subtypes, i.e. with all aspects of speech and language. As phonological training of segments (contrastive features) was practiced and we noted improvement in other areas, such as prosody and gestures, we look upon phonological skills as being important at this level of deficiency in ASC. In the literature on speech and language (including gestures) in TD children and children with ASC, several precursors have been discussed, for example, auditory perception, gestures, joint attention and theory of mind. Many precursors, perhaps all, are important, but auditory perception was chosen as a starting point for the present study. Speech perception will lead to speech production, which will correlate with gestural development and drive the development towards joint attention and then theory of mind. Thus, this means that theory of mind is not necessarily primary. It could be the other way around. Also, gestures were rather influenced by auditory perception, rather than being a precursor.

To summarise, in three papers, we have seen important influences on the areas of segmental phonology, prosody and gesture, despite only phonology being trained during the study. This can be explained by the interrelationship between the various abilities and an anatomical closeness in the human brain for speech and gestures. From the empirical studies in this thesis, it is thus suggested that listening, auditory perception and watching the production of speech, visual perception, are all important for development of speech. If we return to one major issue concerning the three categories of difficulties behind ASC: social, cognitive and linguistic deficiencies, we may note from the results in this thesis that one of the boys improved in phonological as well as gestural development. Parents also described an improved interaction. We may, thus, suggest that by treating the linguistic deficiencies, social and cognitive deficiencies may also improve.

The results suggest a relationship between segmental phonology, prosody and gesture, based on empirical research. Moreover, this is also supported by neuroscientific research on the existence of overlapping networks for perception and production.

9 LIMITATIONS OF THE STUDIES

When we conduct research, we aim to make generalisations and to draw conclusions. Empirical research concerning the effectiveness of an independent variable on a dependent variable may be performed on the group level or on the individual level. Group designs use control groups in order to make sure treatment is effective. Since the group of individuals with ASC is a very heterogeneous one, the heterogeneity may cause misleading results on a group level. This may be a reason why single-subject-designs are often used for evaluating treatment effects in ASC. Continuous measures and the use of baselines are made in order to rule out the argument of spontaneous development. Nevertheless, the results of the current thesis are based on just two participants, which is why we have to be careful with generalisations. The results suggest segmental phonology to be an important aspect, which should not be neglected and also that a holistic view is important in interventions of speech and language, since various areas (also represented in the brain) may influence each other.

In the first study (Participant 1), the speech output during the first baseline was lower than during the treatment periods, which suggests an effect of the treatment. However, the boy (Ted) had very few speech productions at the onset of the study, which was a complicating factor. In addition, the results could have been complicated by the change in ADHD medication, which unfortunately co-occurred with the introduction of treatment (study I). Therefore, possible treatment effects occurred later than expected (about week 13). However, as mentioned in the first paper, it is not likely that the change in medication would lead to improvements in phonological features or syllable constructions. Rather, medication should improve the attention span and the possibility to participate. Furthermore, there was great variability in the results, and other complicating factors occurred, such as the use of several languages (participant 1, Ted). Maturation or general development is an important aspect to take into account. This problem was, however, reduced by the use of baselines. We also noted an effect of labials and velars, as they were introduced, which weaken possible arguments for the effects being solely a matter of maturation. Maturation is also weakened as an argument because of the boys' age (about 6 years). The non-speaking boy had a very limited speech production before the study, so it is not likely to expect the development seen in the study due to maturation only. Moreover, in study II, of prosody, both participants significantly decreased in F0 and F0 range more than expected for this age group, which suggests that the change is due to something other than just maturation. Also, in the third study, gestures developed significantly despite not being specifically trained.

One aspect that is important to mention is that the children of the present studies did not only have the opportunity to listen (auditory perception) to the speech sounds, but also the opportunity to view the adult's production of speech sounds

visually, during the interaction. In the present thesis, it is not possible to rule out the influence of also visual perception on speech production. Moreover, they got an increased amount of attention from adults, using motherese speech during the study. Nevertheless, this does not explain the specific development, such as within segmental phonology (using labials or velars, when these were trained or acquiring the CVCV structure as well as the Swedish accent 2).

10 CONTRIBUTION OF THE THESIS

Recent advancements within neuroscientific research have led to new perspectives on the human brain, which renew the interest in segmental phonology in ASC. Knowledge about perception (auditory) and ways that perception is related to language and cognition is an important cornerstone of this thesis. The thesis contains three empirical studies, which investigate the effects of an intervention, focusing on auditory perception and phonological awareness in two children with ASC. Other linguistic areas, such as prosodic features and gestural acts were also investigated as to whether they were influenced by the intervention. From a holistic viewpoint, the results are quite expected. We should expect improvements in other areas, than just the one focused on due to the plasticity of the human brain. The present thesis supports rather than rejects the possible existence of mirror neurons, i.e. some kind of mechanism involved in imitation and which acts as being a bridge between perception and production.

Segmental phonology in children with ASC and limited speech output has not been frequently studied during the last few decades. Instead, a large number of studies have focused on theory of mind and pragmatic aspects. More studies are therefore needed if we are to determine whether training in auditory perception and phonological awareness are important in children with ASC and limited speech output. All the studies in this thesis are in areas that are rarely (if ever) studied. F0 (prosody) may not have been studied longitudinally in ASC before, and threshold analyses have never been used. School-aged children with ASC have not been studied as much as pre-school children, which is natural, given the importance of early interventions. However, this study shows that improvement is possible even in school children who may not yet have fully developed speech and language. In addition, children with limited or no speech output have not been studied as much as speaking children with ASC. They are often excluded from studies because of difficulties in fully quantifying their speech. Participant 1's improvement in phonological segments and syllable structure (study I), the improvement in prosodic features for the two boys in study II (including development of accent 2), as well as gestural development (the boy in study III) could have clinical implications. Further replications of the studies would however be advantageous. The minimal effort (for both child and adult), involved in the kind of training suggested in the thesis, is another important aspect. A training session as short as 5 - 15 minutes would not imply very much effort for children and adults. Furthermore, the benefits seem to be quite large. A short, daily, focused intervention period is here suggested to lead to increase in speech production, auditory perceptual skills, syllable constructions, correctness in phonological features, decreased F0, prosodic patterns, development of declarative gestures, syllabic development, development in grammar and beginning interaction in triads.

With regard to theoretical contributions, the thesis suggests that auditory (visual) perception is an important precursor of language acquisition also in ASC. It is possible for school children at 6 years of age to show important development in language skills, which suggests that the critical (optimal) period is delayed for children with ASC. Also, it can be assumed from the present study, that segmental phonology, prosody and gesture are interrelated. This supports the idea of a mechanism involved (such as mirror neurons or shared networks), which is responsible for the connection.

11 FUTURE WORK

There is lack of studies on increasing speech output in ASC. More specifically, there are practically no studies on school-aged children with ASC and their vocalisations, production of syllables and acquisition of words. Most studies have been carried out on speaking pre-school children with ASC (Cirrin and Gilliam, 2008). Therefore, more studies are needed, which study vocalisations and babbling in other children with ASC. Using the speech apparatus, and listening to one´s own voice, may be more important than previously realised. In addition, integrating the different sensory perspectives, such as vision, hearing and proprioception may in fact be related to the integration of first and second person perspectives. This means that when the child hears his or her own voice, this gives both auditory and proprioceptive feedback and at the same time an opportunity for shared attention. Few studies have investigated the relationship between perception and production in ASC regarding segmental and supra-segmental aspects, which is why future studies are needed in this area.

Furthermore, the search for precursors must be on-going in order to find the best treatment methods for children with ASC. More studies on the interrelationship between segmental phonology, prosody and gesture in relation to pragmatics are also needed.

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SUBJECT INDEX

APPENDIX 1

Syllable types and examples of participant 1's (Ted's) speech during 1 ½ year (43 sessions).

Type	V/VV	CV/VC	CVC/VCV	CVV	CVCV/CVCVCV	Examples
1	V					[y:]
2		VC				[ɛj]
3		CV				[hy:], [ny:], [tɔ:], [bi:], [gʊ]
4		CV				[nʊ], [dʊ]
5		CV			CVCV	[kʊkʊ], [nʊ], [dy]
6	VV		CVC			[hɛn], [vɯ:]
7		CV				[ny:]
8	VV					[ɯ:y:]
9			VCV			[y:hy:]
10						---
11	VV			CVV		[y:ɯ:], [ny:ʊ]
12		CV				[ʏ:œ:a], [gʏ:]
13		CV			CVCV	[papa], [ny:], [dy:], [bʊ]
14		CV	CVC		CVCV	[pa], [mahapa], [mam], [pap], [mam], [pap], [ma], [by:]
15		CV				[nʊ]
16			CVC		CVCV	[mama], [dɛn]
17			CVC	CVV	CVCV	[mama], [papa], [bi:i], [nʏ:] [nʏ:œ:], [naj],
18		CV		CVV	CVCV	[pʊ], [bi:bi:], [ɑ:], [nʏkʏ:œ:], [nɑ:ɯ:], [najɛɑi:], [dʏœ:ha]
19		CV		CVV		[nʊ], [ny:ɯ]
20		CV		CVV		[dʊ], [ny:ɯ]
21		CV	CVC			[nɛ:n], [dɔ:]
22		CV	VCV		CVCV	[ɔp] [dɯ:], ɯ:] [dʏhʏ tɛ:], [atɪ] [ti:] [dɪdɪ]
23			CVC/VCV			[hɛj], [ini:]
24		CV	CVC			[dʊɧ], [gʊ] [dʊ]
25		CV		CVV	CVCV	[na:ʊ], [dœ:] [bi:bi:]
26			CVC		CVCV	[dada], [ndɛ] [gɐgɐkɛ], [œʊj], [kɛk], [dʊθʊ]
27		CV			CVCV	[nɯ], [tata:], [tɯ ɑ ʊ ɑɑ], [gʊgʊ] [da], [ni: mi:]
28		CV			CVCV	[ndʊj], [na hʊ], [dɪdɪ], [nɪmɪ]
29					CVCV	[kɛkɔn], [kɪkɪ], [mɪmɪ], [nɪnɪ], [da] [dɛ:]
30					CVCV	[kaka]
31		CV			CVCV	[kʊkʊ] [ka] [ka], [kakʊkʊ], [gɪgɪ]
32		CV			CVCV	[kɛkɛ] [ka], [gɪgɪ]
33		CV			CVCV	[nʊnʊ], [nɛ: nʊnʊ ja:] [voc] [nɛ: nʊmnʊ ja: na:]
34		CV			CVCV	[pʊpʊ], [pʊ] [ka] [tʊ], [naj] [nɯ:y], [nʊnʊ]
35		CV			CVCV	[nauta], [pupu], [ne nɯ:], [bi:]
36		CV			CVCV	[phi:], [bu ti]
37					CVCV	[dudu], [te:te:], [tutu], [atata]
38			VCV		CVCV	[thithi], [udY]
39		CV			CVCV	[gugu gu], [pupu]
40					CVCV	[kata], [kaka]
41					CVCV	[nalə], [gage]
42					CVCV	[mamama]
43		CV			CVCV	[tYtY], [fo:], [bi:l], [tətɔ], [du:du:], [dududu],

APPENDIX 2

Overview of participant 1's (Ted's) various developmental stages regarding F0 level, F0 threshold range, declarative gestures, imperative gestures, general accompanying gestures and syllable types. BL 1 = Baseline 1, TM 1 = Treatment period 1, BL 2 = Baseline 2, BL 3 = Baseline 3, TM 2 = Treatment period 2, BL 4 = Baseline phase 4, TM 4 = Treatment period 4 (follow-up sessions).

Phase	Mean F0	Max F0	Min F0	Threshold 0-100 Hz	Threshold 100-300 Hz	Threshold 300- Hz	Declara-tive gestures/ minute	Imperative gestures/ minute	General accompanying gestures/ minute	Syllable type
BL 1	351	482	234	31%	25 %	44 %	0.52	0.07	0	V, VC, CV
TM 1	321	447	222	31%	34 %	35 %	0.43	0.20	0.01	CV, VV, CVC, CVCV, VCV
BL 2	331	425	223	30%	42 %	28 %	0.48	0	0	CVC, CVV, CVCV, CV
BL 3	325	410	229	33%	43 %	24 %	0.22	0.34	0.12	CV, CVV. CVC, VCV, CVCV
TM 2	328	426	221	29%	45 %	26 %	0.54	0.39	0.13	CV, CVC, VCV, CVV, CVCV
BL 4	288	419	196	32%	37 %	31 %	0.14	0.07	0	CV, CVCV
FS							0.95	0.03	0.24	CV, VCV, CVCV

APPENDIX 3

Examples of participant 2's (Ben's) speech during the 23 sessions.

1	[bœ:kə], [boʈa], [kʊkʊ], [næ:], [bu:k], [iteka], [kʊmak], [kʊmat], [kəbat], [nalə]
2	[kʊkʊ], [tʊkʊ], [abi:], [ɛla papa bi: bi:l], [nɛj hɑ:], [kʊpa], [ɛtɛ ɛplə]
3	[alɛ kʊkʊ], [vɪlə hɑ:], [tɪtə hɛ:], [jɑ: vɪl], [ɑ: maskə kʊkʊ], [ɪnə hɑ:], [ga a: baba], [a ba ba], [kʊkʊ], [nʊ tɑ: vɪ maskə kɑ:ka], [ha:lə ɛplə], [næ:], [vɪlə hɑ:], [ɛtɛ ɛplə], [bʊgʊ], [mama ɛplə],
5	[œ:tə ɛplə], [ha:lə ɛplə], [kʊkʊ], [gʊgʊ], [gʊwat], [tɪtə hɛ:], [gɣgɣ], [k ɪskə hɑ:], [nœ: hɑ: na ɛplə]
6	[tɪtə han], [papa], [sɔ:va], [kalɑ:s], [gɯ:lə hɑ:], [e ha eple], [tɛkɛ hɑ:], [kʊkʊ] [kʊkɛan mɪnɑ:]
7	[kʊkʊ ska ɛ:ta ɛplə], [ɔ:ka bi:l ɔ:ka], [kʊkʊ], [ɔlə bi:l], [kʊkʊtʊ mɛ:], [tɪtə hɛ:] [gasə mɛ:], [ɔ:lə bi:l]
8	[vɪlahœ:], [ɛplə], [kʊkʊ], [bʊbʊ], [kalɑ:ɧ], [hɛj], [ana], [abli:], [hɑ: ɛplə] [kʊkʊ kɑ: ɛ:ta ɛplə], [a:si:n], [akɛ:ka]
9	[hʊtə hɔɧ], [tɛkət], [lɪgə hœ:], [kʊkʊ], [kʊkʊ ɛ:ta ɛplə], [a kʊkɛas ba] [lɛga tʊkʊ], [tɪkə hɛ:], [kʊ tɪta hɛ:], [ala], [gʊgʊ], [gɛlɑ: ɛtə ɛplə], [kʊkʊ ɛ:ta banɑ:n], [a pɔ:sɛt ɛplə], [lɪgə hɛ:], [mʊmʊ lɪgə hɛ:] [hɛ: kɔ: pɛ:]
10	[papa ɛ:tə gœ:t], [pʊpʊ], [lɪgə hœ:], [kʊkʊ ɛ:tə ɛplə], [ɛɸlɪ], [gʊgʊ] [lʊkʊkɛ:]
11	[nœ:], [kʊkʊ], [gɛlɑ:], [kala:ɧ]
12	[ʊpa paɧ], [pʊkʊ], [bʊkʊ], [hɔpə bɯ:k], [hɑ: masə], [bʊbʊ hɔpə baɧa sɛ] [dʊgʊ], [næ: æ:ta], [basa basa]
13	[ɔ papa bas], [gʊgʊ hɔpə bas], [tʊtʊ], [agʊ ɑ:pa], [atʊ, tʊtʊ, hɛj kʊkʊ], [pʊkʊ]
14	[gɛ:], [ɛ:tɛ tɑ: bələn], [atɛ tɑ: bələn], [tɑ: bələn], [kʊkʊ] [ətəbtɑ: bələn], [əbə masa], [dɛhɛ], [gɛhɛ], [kʊkʊ kɪkə hɛ:] [lɪgə hɛ:], [kɪka hɛ:], [dɛhɛ], [pʊkʊ], [bɑ: tɪta hɛ:], [tɪta mɛ:] [hɛj]
15	[pʊkʊ], [pʊkʊ], [pʊ], [vɪlə hɑ:],[gɛhɑ:], [sɪkə hɛ:],[lɪgə hɛ:], [mama sɪka hɛ:] [bʊkʊ kɪka hɛ:], [alə lʊlʊ], [hɛj hɛj], [pʊkʊ kɪka], [hɛj bʊgʊ], [hɛj pʊkʊ], [næ:] [pʊkʊ kɪka hɛ:], [kɪka hɛ: mʊmʊ], [hɛj ɔpa]
16	[kʊkʊ], [lʊlʊlɛ], [hɛj pʊkʊ], [tɪta bʊbʊ kɪka hɛ:], [gɛhɛ: dɛ:], [bʊbʊ kɪka hɛ:], [gɛdɛ: tapa dɛ:], [kʊku kɪka hɛ: dɛ:], [hɛj bʊlʊ], [hɛ: bala], [gɛhɛj pʊkʊ], [hɛj pʊkʊ] [gɛhɛ: dɛ:], [kalaɧ], [kʊku kɪka məndə]?, [vɪləhɑ:], [hɛlɔ:]
17	[pʊkʊ kIka hɛ:], [gɛhɛ:], [bʊgʊ sɪka hɛ: dɛ:], [ala], [hɛj pʊkʊ], [hɛjhɛj bʊlʊ] [hɛj bʊlʊ], [vɪlə hɑ: dɛn], [alə: lʊlʊ], [mʊmʊ sɪka hɛ: lɛ:], [gɛ: hɛ: dɛ:], [sɪta hɛ:], [ma], [bʊgʊ], [ə sɪɧa hɛ:], [sɪta hɛ:], [tapa], [a basa], [hɔpa], [bala], [pʊkʊ], [hɛj pʊkʊ], [hɛj bʊgʊ] [hɛj bʊlʊ], [bala], [tIta hɛ:], [pʊkʊ sɪka hɛ: lɛ:] [sɪta hɛ:], [dɛn], [tɑ: bɔ: lɪlə], [dansa dɛ:] [jɑ: tapa], [tapa bi:], [atə tapa], [hadə], [halə hɛj pʊkʊ]
18	[balə], [kʊkʊ], [hɛj pʊkʊ], [hɛj kʊkʊ], [kɔmə balə], [bɪ:lə hab], [næ:], [nae: vɪtə hɑ: dɛn] [puku kɪka hɛ:], [nae: hɑ:], [hɑ:], [puku kɪka hɛ: dɛ:], [tɪta hɛ:], [hɛj bʊlʊ], [pakɔ:], [hɛj] [tɪtə han], [ala]
19	[mʊgʊna], [nʊnʊ], [ɛnʊ], [ɛnʊ bʊgʊ dɛ:], [hɛj dɔ: bʊgʊ dæ:], [hɛj gɯ:] [lɛa pʊkʊ dɛ:], [bʊgʊ], [dɛhɛ:], [hɛɔ:], [hɛlɔ: bʊgʊ dæ:], [lalə], [hɛlɔ: bʊgʊ læ:] [hɛj dɔ:], [hɛlɔ: bʊgʊ dæ:]
20	[hɛj kʊkʊ], [hɛj pʊkʊ], [dɛ maŋə kɪkɪ dɛ], [saba kɪkə hɛ:], [nɛbɛa ɧaba], [ka ba ɧa] [bʊka alʊɧ], [bʊkə]
21	[næ:], [lɪgə hɛ:], [hɛlɔ:], [pʊkʊ], [hɛj pʊkʊ], [ɛdə hɛ:], [mama lɪgə hɛ:] [hɛlɔ:], [ɛgɛ:], [ɛgɛ sa pɔ:], [hɛlɔ: pʊkʊ lɛ], [gɛhɛ], [hɛɔ:], [hɛlɔ: pʊkʊ lɛ] [lɛgɛ hɛ:], [næ: mɪn pʊkʊna m]
22	[ɛdɔ:], [gɛ:], [hɛj mɪmɪ], [amaɧɛləka], [hɛj mɪmɪ], [mɛ:mɛ:], [papa], [mɪmɪ]

[hɛj baba], [nɛ:], [mɪmɪ], [hɛj kʊkʊ], [hɛj bɪbɪ], [hɛj pʊkʊ], [bɛ: pɪpɪ], [hɛj pɪpɪ]
[da bʊka], [akahɛɦa], [hɛsa], [kʊkʊ], [hɛj pʊkʊ], [ala], [bʊtə atalas], [papa hɛndɛna],
[klapa ama], [amla], [nalə], [sɪma]

23 [ha hɛkɛ kʊ], [hɛj pɪpɪ], [ɛj aj mɪmɪ], [hɛj pɪpɪ], [ɛj dapa], [la papa], [hɛ bɪbɪ]
[hɛ mɪmɪ], [hɛj nɪnɪ], [hɛj papa], [lɪga hɛ:], [hɛj kʊkʊ], [bɪbɪ], [hɛj ala bɪbɪ]
[nɯhɛ:], [hɛj pɪpɪ], [hɛj alə mɪmɪ], [lɪgə hɛ:], [lɪgə pa:], [inə maskə ma]
[amla], [papa hɛndɛna], [ha ɛdəθa], [bɪbɪ], [mɛmɪ], [mɪmɪ], [papa], [vanə hɛ:],
[mʊmʊ], [ɛta papa intə], [ənsʊma], [ɛhɛ], [mɪbɪ], [mi:mi:mi], [hɛj mimi], [gɛhɛ], [dɪgə hɛ:],
[hɛj bɪbɪ, [kʊkʊ], [hɛj mɪmɪ], [ɪgə hɛ:], [ɛ: pɪpɪ], [matəma], [ʊta mɪma], [hɛj mat], [maɦjtəʊt]
[ta masɦ mat], [nɛ:ta: masɦt], [nɛ:ta: masɦt], [ɛ: tʊmatə], [ka ta: mat], [hɛj], [næ: aka]
[an], [gɛhɛ], [hɛj aŋka], [aka], [ɪɦl], [wadə tʊmatə], [a ta ka tʊ papa matə], [vɪlə ha:]

APPENDIX 4

Overview of participant 2's (Ben's) various developmental stages regarding F0 levels and F0 threshold ranges.
BL 1 = Baseline 1, TM 1 = Treatment period 1, BL 2 = Baseline 2, BL 3 = Baseline 3, TM 2 = Treatment period 2, BL 4 = Baseline 4.

Phase	Mean F0	Max F0	Min F0	Threshold 0-100 Hz	Threshold 100-300 Hz	Threshold 300- Hz
BL 1	310	410	245	41%	44%	15%
TM 1	285	354	205	46%	44%	10%
BL 2	270	402	162	14%	55%	31%
BL 3	256	334	177	28%	63%	9%
TM 2	258	340	170	35%	49%	16%
BL 4	283	360	203	44%	44%	16%

APPENDIX 5

Development of general sound production during the 34 sessions (Ted, study I).

T1	T2	Consensus
0	2	2
1	1	
5	1	
9	9	
1	3	
1	0	
1	2	
1	1	
5	3	
0	0	
1	1	
2	6	
15	19	18
14	13	
10	9	
2	2	
24	21	21
23	17	26
7	9	
9	10	10
6	6	
34		40
8	12	
7		
4	12	
15		
24	34	31
16		
21	22	
19		
19		
6	4	
31		
25	25	

APPENDIX 6

Development of labials (Ted, study I) during the 34 sessions.

T1	T2	Consensus
0	0	0
0	0	
1	1	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
10	8	10
12	12	
2	2	
1	1	
11	7	8
6	4	6
0	0	
1	1	2
1	1	
1		3
1	2	
2		
1	2	
0		
1	0	2
2		
2	5	
0		
0		
0	0	
2		
3	5	

APPENDIX 7

Development of dentals (Ted, study I) during the 34 sessions.

T1	T2	Consensus
0	2	
0	1	
1	0	
7	9	
10	11	
4	4	
1	1	
0	0	
3	1	
0	0	
1	0	
0	4	6
5	7	
2	2	
8	7	
1	1	15
8	10	21
15	12	
2	1	9
8	9	
5	3	26
26		
4	9	
4		
3	5	
12		32
21	28	
8		
7	4	
10		
2		
0	1	
22		
17	13	

APPENDIX 8

Development of velars (Ted, study I) during the 34 sessions.

T1	T2	Consensus
0	0	0
0	0	
0	2	
0	0	
1	1	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
1	1	
0	0	0
0	0	
0	0	
0	0	
0	0	0
0	0	0
0	0	
0	0	
0	1	
0		0
0	0	
1		
0	0	
3		
1	2	2
2		
11	10	
6		
17		
7	5	
0		
1	1	

APPENDIX 9

Development of CVCV syllables (Ted, study I) during the 34 sessions.

T1	T2	Consensus
0	0	0
0	0	
0	0	
1	1	
1	1	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
0	0	
4	6	6
3	3	
0	0	
1	1	
6	4	6
4	6	10
1	2	
1	1	2
0		
6		6
1	2	
0		
1	2	
3		
4	9	5
2		
10	8	
3		
7		
3	3	
3		
5	6	

APPENDIX 10

Development of CV/VC syllables (Ted, study I) during the 34 sessions.

T1	T2	Consensus
0	1	0
1	0	
5	0	
7	6	
10	8	
0	0	
1	1	
1	1	
1	0	
0	0	
0	0	
1	1	
8	5	5
8	6	
8	7	
0	0	
6	5	4
8	4	10
3	5	
6	6	2
3	2	
18		14
5	9	
6		
2	11	
5		
13	13	18
10		
9	11	
13		
10		
3	1	
18		
10	10	

APPENDIX 11

Development of feature points (%) (Ted, study I) during the 34 sessions.

T1	T2	Consensus
0	3	1
0	0	
20	30	
12	12,5	
36	27	
5	5	
8	8	
0	0	
0	0	
0	0	
20	0	
0	0	
45	48	24
8	8	
32	32,5	
0	0	
26	28	10
40	40	28
2	20	
3	32	16
15	15	
38		30
50	50	
36		
25	25	
42,5		
47	47	47
52		
66	64	
42		
85		
70	45	
30,5		
34	34	

APPENDIX 12

Number of prompts for auditory perceptual skills (including accuracy) for period 2 (16 sessions). Period 1, the response was close to zero (Ted, study I).

Prompts	Accuracy
2	0
1	0
2	0
1	0
4	2
0	0
5	2
2	2
3	1
10	3
3	2
3	2
4	1
2	0
1	0
4	2

APPENDIX 13

Development of mean minimum F0, mean maximum F0 and mean F0 (Ted, study II) during the 34 sessions.

Mean minimum F0	Mean maximum F0	Mean F0
289	543	334
210	445	353
205	460	368
189	438	315
183	444	324
207	507	275
236	464	316
258	449	411
262	526	357
175	381	295
233	420	336
217	521	314
207	385	310
242	400	322
239	448	304
233	434	303
226	419	326
220	432	336
261	439	344
247	387	353
198	392	289
210	424	317
226	422	334
236	375	330
191	418	303
217	427	328
216	443	322
215	437	324
235	409	344
231	479	334
229	425	341
205	345	261
207	499	329
177	415	248

APPENDIX 14

Development of mean minimum F0, mean maximum F0 and mean F0 (Ben, study II) during the 23 sessions.

Mean minimum F0	Mean maximum F0	Mean F0
251	399	326
248	364	324
236	468	281
-	-	-
201	388	328
230	407	308
241	402	296
204	364	285
209	359	283
217	349	256
182	288	300
226	372	281
174	312	293
191	361	261
186	345	259
196	307	273
172	417	276
152	387	264
150	353	242
199	309	251
182	340	276
162	318	239
178	362	278
203	360	283

APPENDIX 15

Proportion of utterances within thresholds (Ted, study II) during the 34 sessions.

0-100 Hz	100-300	300 Hz
0,083333333	0,5	0,416666667
0,5	0	0,5
0,333333333	0,259259259	0,407407407
0,3	0,3	0,4
0,285714286	0,178571429	0,535714286
0,176470588	0,294117647	0,529411765
0,111111111	0,666666667	0,222222222
0,4	0,3	0,3
0,125	0,416666667	0,458333333
0,4375	0,3125	0,25
0,25	0,5	0,25
0,264705882	0,147058824	0,588235294
0,375	0,4	0,225
0,5	0,277777778	0,222222222
0,4	0,266666667	0,333333333
0,4	0,4	0,2
0,266666667	0,444444444	0,288888889
0,333333333	0,393939394	0,272727273
0,214285714	0,642857143	0,142857143
0,588235294	0,235294118	0,176470588
0,333333333	0,222222222	0,444444444
0,189655172	0,603448276	0,206896552
0,125	0,75	0,125
0,473684211	0,368421053	0,157894737
0,263157895	0,473684211	0,263157895
0,326923077	0,346153846	0,326923077
0,305882353	0,364705882	0,329411765
0,275862069	0,379310345	0,344827586
0,317073171	0,56097561	0,12195122
0,231707317	0,353658537	0,414634146
0,326923077	0,403846154	0,269230769
0,5	0,416666667	0,083333333
0,195876289	0,268041237	0,536082474
0,261538462	0,415384615	0,323076923

APPENDIX 16

Proportion of utterances within thresholds (Ben, study II)[22] during the 23 sessions.

0-100 Hz	100-300 H	300 Hz
0,541666667	0,416666667	0,041666667
0,5	0,5	0
0,1875	0,40625	0,40625
-	-	-
0,333333333	0,5	0,166666667
0,3	0,5	0,2
0,5	0,416666667	0,083333333
0,333333333	0,555555556	0,111111111
0,431818182	0,5	0,068181818
0,6	0,333333333	0,066666667
0,6	0,4	0
0,4375	0,5	0,0625
0,5	0,4	0,1
0,380952381	0,428571429	0,19047619
0,432432432	0,459459459	0,108108108
0,642857143	0,285714286	0,071428571
0,169811321	0,490566038	0,339622642
0,121212121	0,606060606	0,272727273
0,166666667	0,611111111	0,222222222
0,384615385	0,615384615	0
0,290322581	0,677419355	0,032258065
0,4	0,472727273	0,127272727
0,294117647	0,512605042	0,193277311
0,404494382	0,438202247	0,157303371

22

BL 1	12/70 ≈ 17%	100-200 Hz
	18/70 ≈ 26%	200-300 Hz
Bl 4	24/89 ≈ 27%	100-200 Hz
	15/89 ≈ 17%	200-300 Hz

APPENDIX 17

Mean minimum, mean maximum and mean duration of utterances in seconds (Ted, study II) during the 34 sessions.

Mean min duration	Mean max duration	Mean duration
0,31	1,99	0,96
0,75	1,32	1,04
0,33	5,17	1,61
0,29	1,89	0,96
0,36	5,11	1,77
0,44	2,44	1,05
0,32	1,75	0,84
0,3	1,12	0,66
0,43	2,42	1,2
0,47	2,14	1
0,34	2,32	0,97
0,34	4,16	1,35
0,24	3,69	1
0,26	2,01	0,78
0,32	1,5	0,81
0,57	3,59	0,48
0,18	6,42	1,06
0,2	5,69	1,38
0,43	1,74	0,85
0,37	1,5	0,74
0,3	2,5	1,26
0,38	4,46	1,16
0,46	3,53	1,28
0,37	1,3	0,73
0,31	3,86	1,11
0,22	3,38	0,8
0,2	3,66	0,85
0,24	3,55	0,9
0,34	11,6	1,24
0,22	6,6	0,95
0,28	7,9	1,31
0,25	2,3	0,8
0,25	17,3	1,27
0,14	4,7	1,4

APPENDIX 18

Mean minimum, mean maximum and mean duration of utterances in seconds (Ben, study II) during the 23 sessions.

Mean min duration	Mean max duration	Mean duration
0,26	1,56	0,7
0,14	1,24	0,6
0,46	2,4	1,14
-	-	-
0,37	4,39	0,93
0,41	1,38	0,75
0,28	1,36	0,7
0,28	1,5	0,7
0,36	1,75	0,8
0,3	1,22	0,57
0,28	0,7	0,52
0,26	1,26	0,7
0,4	1,3	0,73
0,2	1,5	0,7
0,2	1,4	0,7
0,2	1,3	0,7
0,18	2,03	0,99
0,38	2,99	0,98
0,3	1,6	0,97
0,4	1,8	0,9
0,4	1,2	0,7
0,2	2	0,6
0,2	2,4	0,8
0,23	2,07	0,9

APPENDIX 19

Proportion of accent 1 (Ben, study II) for the two transcribers (T1 and T2) during the 23 sessions.

T1 Accent 1	T2 Accent 1
0,466666667	0,6
0,166666667	0,833333333
0,583333333	0,583333333
-	-
0,692307692	0,692307692
0,5	0,666666667
0	1
0,363636364	0,454545455
0,545454545	0,787878788
0,5	0,5
1	1
0,333333333	0,555555556
0,142857143	0,428571429
0,181818182	0,181818182
0,111111111	0,333333333
0,294117647	0,705882353
0,142857143	0,285714286
0,095238095	0,238095238
0,083333333	0,5
0,5	0,333333333
0,294117647	0,882352941
0,137931034	0,344827586
0,28125	0,71875
0,321428571	0,428571429

APPENDIX 20

Proportion of accent 2 for the two transcribers (T1 and T2). (Ben, study II) during the 23 sessions.

T1 Accent 2	T2 Accent 2
0,533333333	0,4
0,833333333	0,166666667
0,416666667	0,416666667
-	-
0,307692308	0,307692308
0,5	0,333333333
1	0
0,636363636	0,545454545
0,454545455	0,212121212
0,5	0,5
0	0
0,666666667	0,444444444
0,857142857	0,571428571
0,818181818	0,818181818
0,888888889	0,666666667
0,705882353	0,294117647
0,857142857	0,714285714
0,904761905	0,761904762
0,916666667	0,5
0,5	0,666666667
0,705882353	0,117647059
0,862068966	0,655172414
0,71875	0,28125
0,678571429	0,571428571

APPENDIX 21

Proportion of one-word and two-three word phrases (Ben, study II) during the 23 sessions.

One-word phrases	Two+three word phrases
1	0
0,857142857	0,142857143
0,523809524	0,476190476
-	-
0,823529412	0,176470588
0,727272727	0,272727273
0,533333333	0,4
0,846153846	0,076923077
0,756756757	0,243243243
0,5	0,5
1	0
0,8	0,2
0,5	0,5
0,526315789	0,473684211
0,583333333	0,416666667
0,181818182	0,727272727
0,396226415	0,547169811
0,327272727	0,618181818
0,454545455	0,545454545
0,363636364	0,545454545
0,387096774	0,612903226
0,340425532	0,574468085
0,517241379	0,471264368
0,441558442	0,545454545

APPENDIX 22

Number of declarative, imperative and general accompanying gestures during the study period of 43 sessions (Ted, study III).

Declarative	Imperative	General accompanying
0	0	0
0	0	0
7	1	0
1	4	1
0	0	0
0	1	0
1	5	0
1	1	0
0	0	0
0	0	0
0	0	0
1	0	0
2	0	0
10	0	0
4	0	0
1	0	0
6	0	0
3	0	0
0	5	1
2	3	1
4	0	1
0	0	0
9	4	0
2	2	1
0	0	0
4	9	2
21	11	6
6	3	2
1	1	0
0	0	0
2	0	0
0	0	0
3	4	0
5	0	0
10	2	4
11	0	2
34	0	13

33	1	6
7	0	0
4	1	0
11	0	5
1	1	0
66	1	14

APPENDIX 23

Minutes/session (Ted, study III), and the number of declarative and imperative gestures per minute during the study period of 43 sessions.

Minutes/session	Declarative/minute	Imperative/minute
10,26	0	0
4,58	0	0
7,88	0,888324873	0,126903553
5,59	0,178890877	0,715563506
1,55	0	0
3,48	0	0,287356322
3,55	0,281690141	1,408450704
6,03	0,165837479	0,165837479
4,2	0	0
3,68	0	0
8,38	0	0
3,55	0,281690141	0
3,23	0,619195046	0
3,12	3,205128205	0
5,21	0,767754319	0
5,08	0,196850394	0
9,38	0,639658849	0
10,4	0,288461538	0
6,12	0	0,816993464
8,88	0,225225225	0,337837838
7,31	0,547195622	0
14,52	0	0
6,58	1,384615385	0,615384615
3,54	0,564971751	0,564971751
10,38	0	0
10,38	0,385356455	0,867052023
12,28	1,71009772	0,895765472
21,47	0,279459711	0,139729856
8,13	0,12300123	0,12300123
13,54	0	0
14,52	0,137741047	0
21,13	0	0
19,11	0,156985871	0,209314495
20,08	0,249003984	0
15,25	0,655737705	0,131147541
17,32	0,635103926	0
18,45	1,842818428	0
23	1,434782609	0,043478261
20,54	0,340798442	0

18,2	0,21978022	0,054945055
20,45	0,537897311	0
22,58	0,04428698	0,04428698
23,15	2,850971922	0,043196544

APPENDIX 24

Number of deictic gestures per minute and speech productions per minute during the study period (Ted, study III).

Deictic/minute	Speech/minute
0	0
0	0,218340611
1,015228426	0,76142132
1,073345259	1,431127013
0	6,451612903
0,287356322	0,574712644
1,690140845	0,281690141
0,331674959	0,165837479
0	0,952380952
0	0
0	0,119331742
0,281690141	0,281690141
0,619195046	4,643962848
3,205128205	4,487179487
0,767754319	1,919385797
0,196850394	0,393700787
1,279317697	2,132196162
0,384615385	1,538461538
0,816993464	0,490196079
0,675675676	1,238738739
0,547195623	0,820793434
0,068870523	2,341597796
3,230769231	1,230769231
1,694915254	1,97740113
0,097087379	0,388349515
1,252408478	1,445086705
2,931596091	2,198697068
0,465766185	0,745225897
0,24600246	2,58302583
0	1,403249631
0,137741047	1,308539945
0	0,331282537
0,366300366	1,622187336
0,249003984	1,294820717
0,786885246	1,639344262
0,635103926	2,020785219
1,89701897	2,222222222
1,52173913	1,913043478
0,340798442	0,438169426
0,274725275	0,164835165

0,635696822	0,684596577
0,088573959	1,24003543
2,937365011	4,492440605

FROM SOUNDS TO SPEECH AND GESTURES

Case studies of linguistic interaction in children with ASC

This thesis is based on the idea that auditory (and visual) perception is important for language acquisition. It investigates the relationship between various linguistic areas, such as segmental phonology, prosody and gesture. In three case studies, the longitudinal effects of an intervention given to two children with autism spectrum condition (ASC) are studied. The intervention consisted of stimuli (minimal pairs), which were gradually introduced in order to increase awareness of phonemic contrasts and symbolic representations.

The results of the thesis suggest that auditory (and visual) perception is an important precursor for language development in ASC, and that segmental phonology, prosody and gestures are interrelated. In addition, the results support the existence of a cortical mechanism that acts as a bridge between perception and production. The children, who were subjected to an intervention, developed positively and in a similar way during the course of the study.

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