

Studies from the Swedish Institute for Disability Research No. 23

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Sounds of silence

Phonological awareness and
written language in children
with and without speech

Janna Ferreira

The Swedish Institute for Disability Research

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Linköping University



Linköping University,

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After all, I have finished this work. This is the worst thing I have ever done. In spite of odd self-confidence, bad self discipline and tempting distraction attractions this work is finally to its end. Not even kamikaze bunnies write doctoral dissertations... But still, what a victory to manage.

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With love,

Janna

List of papers

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

I.

Gustafson, S., Ferreira, J. & Rönnerberg, J. (2007). Phonological or orthographic training for children with phonological or orthographic decoding deficits.

Dyslexia, 13, 211-229.

II.

Ferreira, J., Rönnerberg, J., Gustafson, S., & Wengelin, Å. (in press). Reading, why not? Literacy skills in children with motor and speech impairments. Accepted for publication in *Communication Disorders Quarterly*.

III.

Ferreira, J., Rönnerberg, J., Gustafson, S., & Wengelin, Å. *Phonological awareness training to teach children with impairments in reading or speech*. Manuscript submitted for publication.

IV.

Ferreira, J. *The spelling of silence - Spelling error analysis of an anarthric Bliss user*. Manuscript submitted for publication.

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*“And the vision that was
planted in my brain
still remains
within the sound of silence”*

- Simon & Garfunkle

Introduction

Is it written language and the cognitive traces of phonological awareness that Simon and Garfunkle had in mind when writing their song? Probably not, but the lyrics catch the process of reading very well; visual stimuli that are perceived in our brain need to be processed and stored not only in a visual form but in a silent version of sounds, as phonological entities.

This thesis explores phonological awareness and written language in the presence and absence of speech. Two main groups have been included in the thesis to explore this field: typically speaking children with reading impairments and children with motor speech impairments. The inclusion of these two groups allows comparisons of two different impairments. It allows comparisons of speech perception and production, their contributions to the development of phonological representations, the development of phonological awareness and the effect that training phonological awareness has on improving written language reception and production.

The outline of the thesis

In the background section the studies will be set in a disability research context followed by a linguistic background for the understanding of communication systems. Relevant theories of spoken and written languages and their relation, including phonological processing, are presented followed by a section on augmentative and alternative communication. Finally, groups interesting for theoretical comparison within the area of written language are presented.

The next part of the thesis includes the general aims and methods followed by a brief report of the research studies (Papers I-IV), additional analyses and a final summary of the findings.

The discussion section includes a general part based on the research findings and one part discussing the methodological problems in disability research and in the present thesis, along with ethical issues.

The discussion section is followed by a presentation of clinical implications, including the presentation of a model. At the end of the thesis, final conclusions are drawn and suggestions for further research are proposed.

Background

In understanding the field of written language and phonological awareness a disability research approach comparing groups with different impairments in relation to written language is fruitful. This background section will put the research topic into a disability research context and introduce a line of reasoning about spoken, written and alternative languages and their relation. Relevant groups of impairments will be presented.

Disability Research

Research on disabilities is traditionally of great importance in the development of our knowledge about normal function (Damasio & Damasio, 1989). Pioneering scientists like Paul Broca (1824-1880), Alexander Luria (1902-1977) and Oliver Sacks (1933-) all studied lesions and impairments to develop theories of normal cognitive function. Even with important technological advances that make it possible to study the working brain, e.g., fMRI (Jezzard, Matthews & Smith, 2002), impairments still offer a rich opportunity to further understand typical developments, functions and systems. Disability research seizes this opportunity.

Rönnerberg and Melinder (2007) stressed two types of knowledge integration as important contributions of disability research to the development of theories. The knowledge integration involves focus on concepts, skills or difficulties; either studied horizontally (e.g., comparisons of a particular skill in people with different impairments) or vertically (e.g., a particular skill is studied at several different levels, e.g., the biological, psychological and sociological levels). The argument is that these processes integrate knowledge about a concept which contributes more to the full picture of the concept than many traditional studies do. This thesis will attempt to take a horizontal, and to some extent also a vertical, approach to the concepts of phonological awareness and written language skills.

Moreover, disability research is valuable to bring knowledge to practitioners, parents and people with impairments, to develop an understanding for the disability at hand. Disability research can also provide knowledge to facilitate

everyday life, evaluate interventions and find compensatory strategies, which also are issues that will be addressed in this thesis.

Language models

Language is the complex system that connects concepts with labels and vice versa. Ferdinand de Saussure (de Saussure, 1986) called the concepts of our world “le signifié” (the signified) and the label of the concept was referred to as “le signifiant” (the signifier). Concepts are described as abstract entities that we fill with meaning and associations, e.g the concept of a “pen” as a thing you write with. We refer to these concepts by a more or less arbitrary name, e.g., by the sound pattern /pen/ in oral language, by the orthographic shapes /pen/ in written language, by a writing hand movement in sign language or with an ideographic pen shape picture in Blissymbolics.

Thus, the labels we use to signify concepts with can differ in modalities and they can also differ in their iconicity (Schlosser & Sigafos, 2002). The levels of iconicity can be described as the degree of relationship between the signifier (e.g., the label) and the signified (e.g., the concept). The iconicity degrees are usually referred to as icon, index or symbol, based on the categorisation made by Pierce (Stanford Encyclopedia of Philosophy, 2006). The icon resembles the concept it refers to, i.e., it has a “likeness” to the concept. The index on the other hand has no direct resemblance to the concept but has another kind of relationship with the concept it refers to. Finally, the symbol has a purely arbitrary, conventional relation to the concept it refers to. Essentially these categories can also be reduced to two types of symbol structures (McNaughton, 1993): (A) Type One structure, symbols with representation related to their referents by visual/physical resemblance (i.e., solely icons and visually related indices) and (B) Type Two structure, symbols related to their referents by aspects such as semantics or phonology (i.e., semantically related indices and arbitrary symbols). The different experiences of these two types of symbol systems will have different impact on the “speed, accuracy, and effortlessness with which processing is accomplished by the orthographic, phonologic, context and meaning processors” (McNaughton & Lindsay, 1995, p. 219) involved in reading and writing.

In the framework suggested by Bloom and Lahey (Lahey, 1988) the signifying part of the sign, the symbol, is represented by FORM in the framework figure (see a simplified version in Figure 1), the signified part of the sign, the meaning, is represented by CONTENT and the framework is supplemented with USE for the usage of the signs.

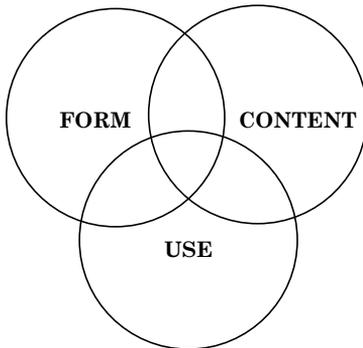


Figure 1. Simplified version of the framework by Bloom and Lahey (Lahey, 1988).

Cognitively, the child must be able to separate form from content to be able to understand the concept of the alphabetic system (Johnsen & Jennische, 1991). Communication systems that do not provide the user with features that separates form and meaning are unlikely to provide the child with knowledge to manage the task of reading and writing (McNaughton & Lindsay, 1995).

Spoken language

Human interaction is based on multimodality (Loncke, Campbell, England & Haley, 2006). Speech is the expressive form of spoken language. Typically, we use speech for communication, based on articulation, transferred acoustically and perceived auditorily. Spoken language is under optimal circumstances the fastest way to create messages to represent thoughts. Spoken language is fast in its nature and the speech signal stays just a short moment for the listener to perceive it. Speech has an important social dimension in how it affects the impressions we make on other people (Burroughs & Tomblin, 1990). Speech is also used covertly in higher cognitive operations, such as planning, and the solving of mathematical problems (Ackermann, Mathiak & Ivry, 2004). Listening

is the receptive form of spoken language, used from the beginning of infancy to receive information and response from our environment and ourselves but also to develop our phonological production (Oller & Eilers, 1988). The auditory modality provides us with the important building blocks that constitute human language: phonemes, syllables, morphemes and words (Adams, 1990). The expressive power of human language is based on its *duality*, the fact that it is built upon phonological entities that do not carry meaning as well as syntactical entities that do carry meaning (Lindblom, 1990). The combinatorial power of these entities gives opportunities to an infinite amount of messages. This way, humans can express thoughts that no one else has ever expressed. Our language also allows us to speak about abstract things and on decontextualised topics (i.e., beyond here and now) (Lundberg, 2006).

But as a supplement to the auditory modality we also use the visual modality to receive additional information from nonverbal communication (Loncke, et al., 2006). Mimics, gestures, eye contact, etc. add information to our messages that we intend, or might not intend, to send.

Written language

While spoken language has been used by humans to communicate for at least 40.000 years, written language has only been around for approximately 4.000-5.000 years (Lieberman, 1998; Melin, 2000). Spoken language is found in all human cultures while written language is not (Street, 1993). Spoken language is basic and written language is an artefact which is developed to represent spoken language (Perfetti & Sandak, 2000).

Reading is the receptive form of written language. Reading includes two components: word decoding and linguistic comprehension that together form the ability of reading comprehension (Hoover & Gough, 1990). Word decoding is the technical aspect of reading (Gustafson, 2000). In alphabetic scripts, word decoding is based on recognition of graphemes and the process to activate phonological representations with the input of graphemes, to transform written words to corresponding sounds. For speed in the reading process, visual recognition of syllables and words as holistic entities (i.e., sight words) are also necessary skills (Adams, 1990).

Linguistic comprehension refers to the ability to access semantic word information and based on this make interpretations of sentences and larger bodies of linguistic material (Hoover & Gough, 1990). Thus, reading comprehension involves linguistic comprehension derived from information decoded from orthographic representations.

It is fascinating that this auditorily based communication form of spoken language can be transcribed into a highly visual modality (Liberman, 1998) as is the case for written language. Written language is based on print, transferred in visual shapes and perceived visually. Despite being visual in its form, written language is intimately related to spoken language. Perfetti and Sandak (2000) state for example that “reading is not merely ‘language by eye’”. Reading is built upon spoken language and the phonological entities that are the basis of spoken language.

The visual and auditory information processed in written language constitute a multimodality that is stressed in all reading models. Most reading models describe process routes based on either visual or auditory information. The connectionist models (e.g., Plaut, 1999), or one-route models, stress the interconnections and parallel use of the different parts of the system, while dual route models (e.g., Ellis & Young, 1988) stress that different routes are used in different tasks and different stages of the reading acquisition (Høien & Lundberg, 1988). The differences and similarities has been described and a combined model proposed by Bjaalid, Høien & Lundberg (1997). However, the present thesis was not designed to in depth test these reading models, but rather stress the multimodality of the models.

The multimodality of the process of transforming print to meaning is well captured by Seidenberg and McClelland, (1989) and adapted by Adams (1990) to the model presented in Figure 2.

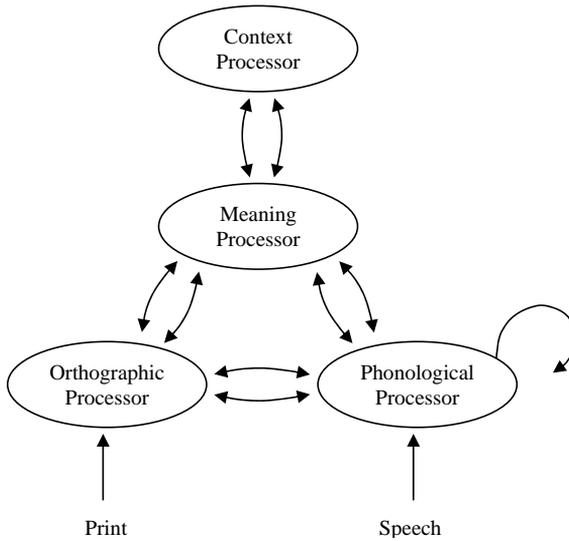


Figure 2. The process of reading (Adams, 1990).

One direct process route goes from the decoding of orthographic representations in the orthographic processor to the matching of the written string to meaning in the meaning processor. The other, indirect process route goes from the decoding of graphemes in the orthographic processor through the conversion of graphemes to phonemes in the phonological processor and then matching the string to meaning in the meaning processor.

In addition to the orthographic and phonological decoding and recoding, the model includes the process of transforming written language into stored semantic entities in the meaning processor, i.e comprehension of text. This is done by matching the written string to semantic entities in the meaning processor, but also through the check of contextual relevance made by the context processor. Thus, written language processing is truly multimodal, since it requires both phonological and orthographic processing. The studies included in this thesis give us opportunities to discuss interesting links between visual input handled by the orthographic processor, phonological representations handled by the phonological processor and linguistic competence handled by the meaning processor.

From a compensatory perspective it is interesting to consider the dual route model with different routes as alternatives to each other. The orthographic route

could compensate for deficits in the phonological route and vice versa. In describing deficits in reading and spelling development, stage models, closely connected to the dual route theories are also applicable.

Stage theories acknowledge the developmental differences in reading approach that children show during their reading acquisition. The essence of these stage theories can be conglomerated into three stages (Frith, 1985): (A) the logographic stage, (B) the alphabetic stage, and (C) the orthographic stage.

At the first, logographic stage, reading is based on words as holistic entities, as “sight words”. The reader has not yet developed the knowledge of grapheme-phoneme-correspondence. At the next, alphabetic stage, the readers crack the alphabetic code and reading is based on grapheme-phoneme conversion. At the last, orthographic stage, reading is automatic and based on recognition of lexical and sublexical, morphological and visual entities. The stage theories stress that the strategies used at earlier stages might very well be used in later stages, but then as back-up strategies rather than the dominant strategy (Høien & Lundberg, 1988). It is fully compatible with the stage theories to apply them to older children and adults with reading impairments in order to understand their written language processing.

Writing is the expressive form of written language. In this thesis, spelling will be the feature of written language that is in focus. Studies of spelling are unique in the sense that they overtly explore the nature of the speller's internal representation of the word (Simon, 1976). More exactly, the dictation of words, not free writing is focused in the thesis. The spelling of dictated words or non-words is a part of the writing process that does not necessarily involve the lexicon and is therefore a more strict variable for the examination of phonological processing.

Computers have reduced the dependency on fine motor skills to produce letters and text, but writing still demands the knowledge of letters; the knowledge of phoneme-grapheme-correspondence to match phonological entities to memorised visual forms of graphemes; an ability to segment, be aware of and remember the order of sublexical units (Adams, 1990; Lundberg & Høien 1989;

Treiman, 1993) and the ability to, if necessary, match these strings to meaningful semantic entities.

The relationship between spoken and written language is further stressed in the term “Matthew effect” (Stanovich, 1986). This term is used to describe the reciprocal relationship between spoken and written language, and the effect of “the rich get richer” whereas “the poor get poorer”. Stanovich describes for example the importance of well developed spoken language skills to develop written language skills and further development of spoken language skills on the basis of good written language skills. High word decoding abilities have a general long-term effect (ibid) in that good readers for example develop their vocabulary (Krashen, 1989) and sense for grammatical features, and thereby also develop their spoken language more than will those who do not have access to the written language.

As written language is based on spoken language it would be particularly interesting to study written language in the context of reduced function of spoken language. The present thesis is an attempt to study this topic.

Phonological processing

To understand the complex relation between spoken and written language we need to focus on phonological processing, which is an important aspect of language, needed in both spoken and written language. Four fields of phonological processing are relevant here: phonological representation, phonological production, phonological working memory and phonological awareness.

Phonological representations. Phonological representations are cognitive manifestations of speech sounds. Reading and writing has been suggested to be affected by an indistinctness of phonological representations (Elbro, 1998; Elbro & Jensen, 2005; Rack, Snowling & Olson, 1992) and by a less accurate phoneme discrimination (Adlard & Hazan, 1998; Masterson, Hazan & Vijayatilake, 1995; Mody, 2003). Less distinct phoneme boundaries (Fowler, 1991) and problems segmenting phonemes (Nation & Hulme, 1997) has also been suggested to affect reading and spelling performance.

Phonological production. Phonological production is the ability to produce words correctly, manifested according to the phonological system of the present language. Phonological production has been described as a relevant factor for reading success. An early ability to pronounce words without phonological errors can predict reading outcome (Scarborough, 1990). Studies of children with isolated phonological impairments confirm the higher risk for these children to develop reading disabilities (Snowling, Bishop & Stothard, 2000).

Phonological working memory. Phonological working memory includes the temporary storage of verbal and phonological information, and the subvocal rehearsal component (the phonological loop) that deals with manipulation and processing of acoustic and phonological information (Baddeley, 2003). Phonological working memory has been emphasised in the reading and spelling process (Gathercole, Willis & Baddeley, 1991; Hansen & Bowey, 1994; Wagner & Torgesen, 1987). The phonological loop is handling the processes where the sound structure of linguistic material is an important feature. Phonology is a tool for rehearsal (Baddeley, 1995) and serves as a working memory support during the reading and spelling process so that the system has time to blend the letters into words and match these to meaningful semantic content (Adams, 1990; Gathercole et al. 1991; Wagner & Torgesen, 1987). The importance of phonology in the working memory process of dysarthric people has also been stressed and the cognitive features of the phonological loop instead of physical articulation have been emphasised (Baddeley & Wilson, 1985; Blischak, 1994; Dahlgren Sandberg, 2006).

Phonological awareness. Finally, phonological awareness is the ability to be aware of and manipulate phonological units such as words, syllables, rhyme and phonemes (Adams, 1990). Phonological awareness is a well documented skill with high predictive value when it comes to reading and spelling development (Carroll, Snowling, Hulme & Stevenson, 2003; Goswami & Bryant, 1990; Mody, 2003; Plaza & Cohen, 2003; Shankweiler & Fowler, 2004; Wagner & Torgesen, 1987). Phonological awareness has also been explored in relation to children with severe speech impairments (Berninger & Gans, 1986; Card & Dodd, 2006; Dahlgren Sandberg, 2006; Denne, Langdown, Pring & Roy, 2005; Larsson, 2006;

Moriarty & Gillon, 2006). Working memory and phonological awareness are two skills that work by accessing phonological representations (Snowling & Hulme, 1994).

Related to phonological processing is also the so called phonological recoding, but this skill is dependent on both phonology and orthography. The phonological recoding, or the grapheme-phoneme conversion is the ability to translate print to sound (Tunmer & Chapman, 2005). It is the process where phonological representations are activated with the input of visual graphemic shapes. It requires rapid access to distinct phonological representations as well as knowledge of orthographic rules for grapheme-phoneme matching also of pairs that do not have an one-to-one-relationship.

Orthographic processing

Orthographic processing skills include rapid and automatic visual recognition of the graphic forms of letters and letter combinations (Adams, 1990). Visual analysis of the written word is not limited to a holistic identification of a visual whole word pattern, but includes analysis of graphemes, syllables and morphemes (Prinzmetal, Treiman & Rho, 1986). In written language there are certain rules for the combination of graphemes that can be learnt and used to speed up recognition (Treiman & Bourassa, 2000). The orthographic skill is not a simple recognition of whole word gestalts, but an active analytic skill that recognises length and visual salience of letters and letter combinations, together with information about position (Seymour & Elder, 1986). In the reading and spelling process, the working memory subsystem called the visuospatial sketchpad supports the phonological loop with orthographic, visual information to be recoded. It has been suggested that there is a special working memory system for graphemic representations called the graphemic buffer (Caramazza & Miceli, 1990). The graphemic buffer keeps graphemic units in memory while we cluster new graphemic information, convert graphemes to phonological representations in phonological recoding or match them to semantic entities.

An interactive model of literacy proposes that children will use both orthographic and phonological processes combined with semantic and contextual information in skilled reading and spelling (Lennox & Siegel, 1998; Stanovich,

1980). Stanovich (ibid) also suggests that if any of these processing skills are impaired, skills at other levels of the system will try to compensate for the loss.

General language and context

Adams' model of the process of reading (1990) also includes a meaning and a context processor. Children with the ability to rapidly check their lexicon and long term memory for contextual relevance of the word, sentence or text just read will have an advantage not only in reading comprehension but also in reading speed (Adams, 1990; Tunmer & Chapman, 1998). Reading and spelling is highly dependent on general language skills (Cain, Oakhill & Bryant, 2004), e.g., within the areas of morphology, vocabulary, and syntax (Dixon, LeFevre & Twilley, 1988; Kelly, 1996). Well developed general language skills also contribute to improved metalinguistic skills (Cooper, Roth, Speece & Schatschneider, 2002).

Augmentative and alternative communication

For some children, production or reception of spoken language is not feasible. Deficits in the abilities to speak, perceive or understand spoken language can be reasons for introducing an augmentative or alternative communication system (AAC). Three main groups in need of AAC have been recognised (Martinsen & von Tetzchner, 1996):

(A) In the *expressive language group*, children need AAC as an alternative mode for expressing themselves. However, the auditory channel is still used for the reception of language. The group is often exemplified by children with severe motor impairment and anarthria.

(B) In the *supportive language group*, children need AAC as a complement to a speech that might be hard to understand in certain contexts or during certain periods. However, the auditory channel is still used for the reception of language. The group is often exemplified by children with dysarthria. It can also be exemplified by children who temporarily need AAC because of a delayed speech development but who are predicted to develop speech later on.

(C) Finally, in the *alternative language group*, children need AAC as an alternative for both expressive and receptive language. This group can be

exemplified by children with autism and severe mental retardation who will need AAC for both expressive and receptive aspects of communication.

Included in this thesis are participants with motor speech impairments belonging to either of the two first groups, but also children mainly relying on a distorted speech. Participants from the last group were not included in the thesis because of their poor reception of spoken language.

With AAC as the main expressive communication form, the auditory modality is often exchanged for a visual one, and the importance of the visual modality in language is highly increased (McNaughton & Lindsay, 1995).

Manual signs can be used as AAC together with speech to highlight words and give children with speech impairments opportunities to elucidate speech with low intelligibility. Sign languages used by people with severe hearing impairments are not described as AAC. Sign languages have a linguistic complexity that beats other AAC-systems by far, but the principle of exchanging the spoken language with a visual modality (Rönnberg, Rudner & Foo, in press) is the same.

Bliss communication is one of the most complex AAC systems available. Blissymbolics were developed by Charles Bliss as a “logical writing for an illogical world” (Bliss, 1965, p. 2), an ideographic communication system created for international communication. Bliss himself called his work “semantography” (ibid). Theoretically, the Bliss system has the linguistic features of a language, i.e., it is created by smaller units that can be combined in infinite ways. Blissymbolics came to be adapted for use in children with speech and motor disabilities in Canada during the 70’s. Since then, it has been widely spread over the nations, within the area of special education. The child who communicates with Bliss has a limited access to symbols, since these must be physically stored. But the system allows the user to learn that combination of symbols can create meaning (Hetzroni, 2004). Grammatical functions, such as tense, plural and genitive are available and the symbols are colour coded to signal lexical categories like noun, adjectives and verbs.

For the children who use AAC, it is strongly beneficial to vocabulary and morphology (Bruno & Trembath, 2006; Hooper, Connell & Flett, 1987). The

presence of an expressive language gives opportunities to practice grammatical rules, develop morphology, syntax and semantics (Sturm & Clendon, 2004), and to enhance language also receptively (Foley, 1993). This is beneficial to reading comprehension (Rankin, Harwood & Mirenda, 1994).

There are several visual alternatives to speech (von Tetzchner & Jensen, 1996) that makes it possible for children with severe motor speech impairments to express themselves. However, visual communication systems do not support the auditory aspects of language. To be able to express aspects of auditory phonological entities, voice output has to be included in the AAC system.

Voice output

Speech generating devices provides children without speech with voice output. The significance of this artificial alternative to self-produced speech is poorly investigated (Smith, 2005). The main benefits of voice output can be hypothesised to be the following three: (A) the voice output generally increases the motivation to express things verbally (Smith, 2005), (B) the voice output can give the child without speech the ability to speak with younger people, peers or others that are unable or too impatient to read or interpret visual communication symbols (Cosbey & Johnston, 2006), (C) the voice output can provide the child without speech with opportunities for self-initiated phonological feedback (Dahlgren Sandberg, 2006; Elbro, Rasmussen & Spelling, 1996; Foley & Pollatsek, 1999).

Horizontal integration

Children with motor speech impairments and children with reading impairments are included in the thesis for horizontal comparisons on the basis of different access to speech. In addition to these two groups, children with hearing impairments will be included in the comparisons theoretically, since they provide an interesting contrast to the children with motor speech impairments, in their access to articulation but not to auditory reception.

Reading impairments

The most obvious target group for studies of written language is the children with specific reading impairments. Scientifically, this group can give us information about the concepts of reading and writing since they have specific problems with these skills. In research this group is often referred to as “children with specific reading impairments”, but the actual existence of impairments limited to the receptive input of written language is very rare. In trauma literature, alexia without agraphia is described (Tamhankar, Coslett, Fisher, Sutton & Grant, 2004) but there is no common congenital impairment that exemplifies the absence of writing in presence of reading, or vice versa.

Although Bishop and Snowling (2004) states that most children with specific reading impairments also show oral difficulties, studies of this group can give us information about phonological processing and phonological awareness in the presence of spoken language but deficits in written language.

Bishop and Snowling (2004) presented a two-dimensional model in order to show the relationship between specific reading impairment and specific language impairment.

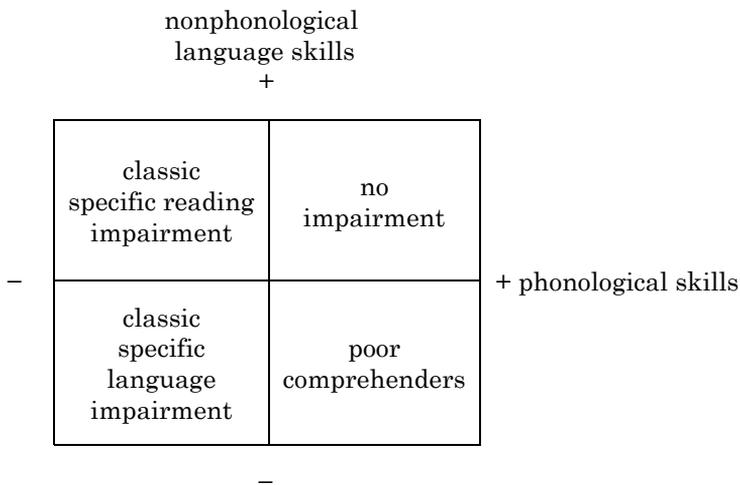


Figure. 3. Relationship between specific reading impairment and specific language impairment (adapted from Bishop & Snowling, 2004)

In this model, the issues of phonological skills, as well as nonphonological language skills, to understand the linguistic deficits of reading impairments are stressed (see Figure 3). Nonphonological language skills are the skills related to larger linguistic units, such as morphemes, words and the syntactic combination of these units.

In normal development of written language, reading and writing development are two parallel processes, but Bryant and Bradley (1994) discuss differences between the processes. Both children and adults sometimes fail to spell words they have no problems reading. There are also examples when children fail to read items they have spelled. Bryant and Bradley (*ibid*) argue that producing language is harder than recognising it, and that children use their articulation to identify the constituent sounds when spelling. In reading, on the other hand, children seem to depend more on "chunking" strategies. Thus, the difference between reading and free spelling is a specific case of recognition and free recall, as described in the field of memory research (Tulving & Watkins, 1973).

Reading impairments can be classified in numerous ways, but for the purpose of this thesis it is especially interesting to study the two types of reading and writing impairments referred to as the phonological and orthographic subtypes (Gustafson, 2000; Vellutino & Fletcher, 2005). Children with the phonological subtype have specific problems using the phonological route of the dual-route system and children with the orthographic subtype have difficulties using the orthographic route (Castles & Coltheart, 1993).

Phonological recoding involves the matching of graphemes to phonemes and skills in this area have been suggested to be highly dependent on phonological awareness. Phonological processing in general and phonological awareness specifically are widely accepted as strong predictors of reading development (Carroll et al, 2003; Mody, 2003; Plaza & Cohen, 2003; Richardson, Thomson, Scott & Goswami, 2004; Shankweiler & Fowler, 2004). Interventions targeting phonological awareness have been found to be effective (Ehri et al., 2001; Elbro & Petersen, 2004; Hatcher, Hulme & Ellis, 1994; Torgesen et al., 2001; Wise, Ring, & Olson, 1999).

However, the most effective interventions for children with reading impairments are not the strictly phonological interventions but the ones that aim to develop explicit links between phonemes and graphemes (Ehri et al 2001; Castles & Coltheart, 2004), i.e., promote phonological and orthographic skills in combination.

In the end, most children with reading and writing impairments crack the alphabetic code. Many people who experience reading and writing deficits at a young age will still encounter problems with written language in adult life, especially with phonological and morpho-phonological aspects (Moats, 1996). They may not be fast or always accurate in their reading or spelling, but at the least they will have a basic knowledge of decoding.

Motor speech impairments

The other group included in this thesis is the children with motor speech impairments. Children with motor speech impairments form a very heterogeneous group. Their diagnoses differ in origin as well as levels and types of physical impairments, sensory/perceptual impairments (visual and hearing), cognitive impairments and communication impairments (language and speech) (Smith, 2005). The children with severe motor impairments and dysarthria and children with anarthria allow us to theoretically and practically explore the importance of expressive language skills in relation to reading and writing.

The acquisition of phonological awareness has been found to be possible without any access to speech (Baddeley & Wilson, 1985; Foley, 1993), but the levels of the developed skills and the ability to use these skills properly in the reading and spelling process are more unclear (Dahlgren Sandberg, 2001; Denne, et al., 2005; Moriarty & Gillon, 2006; Vandervelden & Siegel, 1999).

There are studies that have explored the possibilities of visual compensation within the field of AAC (Bishop, Rankin & Mirenda, 1994; McNaughton & Lindsay, 1995). Through the visual features of many AAC systems reading direction can be taught and the visual mode also provides the child with a more direct feedback on the relation between symbol and meaning, which can be used in order to develop print awareness (Hetzroni, 2004). Many systems also provide the user with printed words along with their visual symbols. It is suggested,

however that children seldom manage to spontaneously use this written information unless formal instructions in the area of written language has been offered (Bishop et al., 1994).

The most important clinical finding of this group is that in spite of primarily normal levels of intelligence, many of these children do not learn how to read and write and will never crack the alphabetic code (Denne, et al., 2005; Smith, 2005). This separates these children from those with other kinds of impairments that will be presented and discussed in this thesis.

For horizontal integration of knowledge it is relevant to consider other types of impairments that can give theoretically relevant information to the discussion on phonological awareness, reading and writing. Children with hearing impairments are not included as participants in the studies but are considered relevant in the theoretical discussion of phonological awareness and written language. They provide an interesting comparison to the children with motor speech impairments, in their access to articulation but not to auditory reception.

Hearing impairments

People with hearing impairments might look like a less obvious target group for studies of written language. However, the absence of hearing, a skill fundamental in relation to phonological processing, makes it theoretically relevant to see how this impairment affects reading and writing skills.

Hearing is not necessary in order to develop phonological representations (Rönnerberg, et al., 1998). There are basically three ways to obtain phonological representations in the absence of hearing: visual information through lipreading (Lidestam, 2003), motor information through articulation or alphabetic information through graphemes or finger spelling (Leybaert, 2005). However, the phonological representations acquired by these modalities are less precise than the representations received auditorily. Research shows that written language is affected by hearing impairments (Goldin-Meadow & Mayberry, 2001; Perfetti & Sandak, 2000; Roos, 2004, Sutcliffe, et al., 1999).

Besides phonological errors, many deaf people make errors in written language that originates from the fact that the written language is a second language (Sutcliffe, Dowker & Campbell, 1999; Wengelin, 2002) and not their

native language, i.e., sign language. The problems with reading and writing encountered by deaf children can not only be explained by phonology and the second language theory though, the importance of early language acquisition is also stressed in the literature. Perfetti and Sandak (2000) reported that deaf children of deaf parents tended to read better than deaf children of hearing parents. The reasons suggested for these findings include world knowledge, vocabulary and morphology. The fact that these children tend to get earlier input from their parents about the things they experience and the earlier linguistic development gives them advantages in the area of reading comprehension (Leybaert, 2005). However, the sign language, perfect for compensating for auditory language deficits and strengthening the overall language skills of the signer, does not give support for the phonology, syntax or morphology of the spoken language (Musselman, 2000; Perfetti & Sandak, 2000).

Following education even profoundly deaf children crack the alphabetic code, and some of them will even become proficient readers. There are different theories dealing with deaf people's acquisition of written language. For the comparison with children with motor speech impairment and children with reading and writing impairments it is specifically interesting to consider the theories of acquisition through articulation (Chincotta & Chincotta, 1996) and orthography (Padden, 1993) which could offer compensatory routes for processing written language for the children included in this thesis.

General aims

The general aim of this thesis is to explore phonological awareness and written language in the presence and absence of speech in children with reading impairments and children with motor speech impairments.

The inclusion of these two groups allowed comparisons of two different impairments. Comparisons of speech perception and production, their contributions to the development of phonological representations, the development of phonological awareness and the effect that training of phonological awareness has on improving written language reception and production was explored.

In Paper I written language and phonological awareness was studied in an intervention study with children with reading disabilities. Phonological awareness training was contrasted to orthographic training and conducted for children with phonological or orthographic decoding deficits. The aims of this study was to examine the effectiveness of the two training programs and the design allowed us to explore whether the children would benefit most from training focused on their relative strength or weakness in word decoding.

In Paper II phonological awareness was focused in relation to motor speech impairments. The aim of this study was to explore relative strengths and weaknesses in reading in relation to other cognitive and linguistic functions.

In Paper III the effects of phonological awareness intervention on written language was further studied in an intervention study including children with motor speech impairments and children with reading impairments.

In the final paper, Paper IV, a case study was conducted to further explore spelling skills which were found to be amenable to practice for children with speech impairments in Paper III.

General methodological design

The general methodological selection made for this thesis includes a triangulation of data and methods. The children in focus for the studies were taken from two different populations. The two populations were (A) typically speaking children in the age of 8-10 years with reading impairments reported from their local school, and (B) children with congenital motor speech impairments in the age of 8-15. The selections of methodological designs were dependent on the size and heterogeneity of the populations, along with accessibility to participants. The selection of participants was based on contacts with nearby schools and inclusion of participants from volunteering schools.

Paper I was conducted with eighty children with reading impairments (a relatively large population) which allowed a 2 x 2 x 2 split plot design with type of training (phonological / orthographical) and type of decoding problem (phonological / orthographical) as between-subjects variables and test session (pretest / posttest) as within-subject variable. The study was designed as an intervention study with typical reading controls and controls receiving ordinary special education. Parametric statistics were used to analyse intervention effects.

Paper II was designed as an explorative multiple case study conducted with children with motor speech impairments (a relatively small population). The sample included children with dysarthria in different degrees, anarthric children and children with apraxia. The range was large also for other variables. This allowed a rich exploration of the sample, but with a low generalisation power. Non-parametric statistics were used and the sample was explored in two subgroups based on a median split of their reading skills.

Paper III was an intervention study with children from both the populations. Control groups were created by selecting low performing typical reading children and children receiving ordinary special education from Paper I. Group matching of initial skills facilitated a parametric testing of intervention effects. Within-groups explorations of effect size were also conducted.

Finally, the methodological design was supplemented with a case study in Paper IV, where an explorative error analysis on spelling errors was conducted.

Summary of the papers

Paper I

Purpose

The purpose of Paper I was to explore the effects of orthographic or phonological intervention for normal speaking children with mainly orthographic or phonological types of reading impairments. The main research question was if children benefit most from training their relative strength or their relative weakness in word decoding.

Method

In an intervention study, eighty normal speaking children with reading disabilities, aged 8-10, received either a phonological ($n = 41$) or an orthographic ($n = 39$) training program. The children were divided into the two training groups on the basis of their relative results, transformed into z-scores, on a phonological and an orthographic word decoding test. Half of each training group demonstrated a relative strength in orthographic word decoding and half of each training group had a relative strength in phonological word decoding.

Both intervention programs were computerised and intervention took place in ordinary school settings with special instruction teachers. Two comparison groups were also included in the study, one with children with reading impairment that received ordinary special education, and one with normal readers.

Results and discussion

Results showed strong average training effects on text reading and general word decoding for both phonological and orthographic training, but not significantly higher improvements than for the comparison groups. However, this was expected since the special instruction teachers in the comparison conditions had the possibility to adapt the training to each individual pupil.

The main research finding was a double dissociation: children with pronounced phonological decoding deficits improved their general word decoding skill more from phonological than from orthographic training, while children

with orthographic decoding deficits improved their general word decoding skill more from orthographic than phonological training. This result was statistically significant for children who showed a large discrepancy between their phonological and orthographic word decoding skills.

However, children with phonological word decoding problems improved their general word decoding skills more than did children with orthographic word decoding problems. It is suggested that the training programs used in the study were more adequate for children with phonological decoding problems.

The effect sizes on text reading showed a similar pattern as general word decoding, with larger effects when children trained on their relative weak decoding skill. However, the interaction was not statistically significant. Text reading was not the focus of this intervention and the findings suggest that other factors should be considered in the area of text reading ability, e.g., vocabulary and reception of grammar.

Effect sizes on phonological awareness were moderate to large for all groups. It is notable that orthographic training also improved phonological awareness and an explanation for this might be that the orthographic program also provided phonological information through links between letters, words and sounds.

Effects on spelling were modest in all groups and both training groups showed less improvement on arithmetic than on the reading measures, indicating a training effect specifically related to the content of the intervention rather than general, motivational factors.

The results were discussed in relation to the resistance against training that is common in intervention studies within the area of reading and spelling. The study suggests that in children with reading impairments who are in an early stage of their reading development, training should focus on the children's relative weakness rather than their relative strength in word decoding.

Paper II

Purpose

The purpose of Paper II was to explore the cognitive and linguistic components that contribute to reading in children with congenital motor and speech impairments.

Method

In an explorative study, designed as a multiple case study, twelve children with various levels of motor and speech impairments were tested to explore their reading skills in relation to letter knowledge, speech level, auditory discrimination, phonological awareness, language skills, digit span and nonverbal IQ. The sample was divided a posteriori into two subgroups, based on a median split of reading performance.

Results and discussion

Results showed that compared to the high level readers in the sample, the low level readers had a general tendency to perform low on most variables tested, but not on the digit span test. Significant group differences were found for auditory phoneme discrimination skills and general language skills.

The results are discussed in the light of an integrated reading model for basic reading, not only for skilled reading. This discussion includes low-level, bottom-up skills, i.e., discrimination between speech units, both at the phoneme level and at the syllable level as highly needed in the reading process. In addition to this, high-level, top-down skills like general language skills have been identified as required skills in the reading process.

The study also provided results that showed significant group differences but no rank correlation or vice versa. These results were theoretically interesting and generated new hypotheses.

Speech for example, is a factor that showed significant group differences, but no rank correlations were observed. High level readers had significantly better speech than low level readers. The two anarthric children were graded as low level readers. However, there were participants in the sample that read well but

still had severe problems with articulation. A hypothesis was proposed concerning the effect of using impaired articulation actively when reading compared to not using the impaired speech actively when reading.

Letter knowledge was highly rank correlated with reading in this study. Many teachers seemed to “spare” the children who struggled with reading from the “strange” letters in Swedish, such as Z, Q and W.

Phonological awareness was rank correlated to reading as has been seen in earlier studies. Phonological awareness has been found highly teachable in the children with typical speech, and improved phonological awareness has been found to have a positive effect on reading ability. Therefore, a phonological awareness intervention for children with motor speech impairments was suggested.

Nonverbal IQ was rank correlated with reading in the study. However, the study did not support the importance of high nonverbal IQ for children with speech and motor impairment. The nonverbal intelligence in the sample was low. A hypothesis was proposed concerning a threshold involving nonverbal IQ to reach higher levels of reading.

Paper III

Purpose

The purpose of Paper III was to further evaluate the effects of phonological awareness intervention on reading and spelling ability, in children with reading or motor speech impairments. The study tested two *disability specific* hypotheses: (A) children with *motor speech* impairments benefit from computerised phonological awareness training and improve their reading and spelling skills. (B) children with *reading* impairments benefit from computerised phonological awareness training and improve their reading and spelling skills. The study also tested two intervention specific hypotheses: (A) The computerised phonological awareness training has a greater effect than ordinary special instruction in improving childrens' reading and spelling skills. (B) The computerised phonological awareness training can decrease the differences in reading and spelling between controls with typical reading and speech and children in the training groups.

Method

In an intervention study two training groups with different disabilities, motor speech impairment (n = 9) and reading impairment (n = 10), participated in a phonological awareness intervention. The intervention included phonological awareness training through computerised exercises. Two comparison groups were included: children with typical reading and speech and children with reading impairments receiving ordinary special instruction. Sentence reading, word spelling and non-word spelling were assessed in all groups and phonological awareness was further studied in the group with speech impairment.

Results and discussion

Results showed statistically significant improvements in sentence reading skills for all groups except for the group with motor speech impairments. Intervention effects were found for both training groups on word spelling. Non-word spelling did not improve. Post intervention, the group with motor speech impairment showed a qualitative improvement in the phonological awareness

tasks rhyme, phoneme synthesis and compound words, but not in subtraction of syllables.

Thus, the disability specific hypotheses of this study found support for improvements following intervention for both the training groups. The intervention specific hypothesis of this study also found support. The computerised phonological awareness training led to statistically significant improvements in word spelling for both the training groups but not for the control groups. However, there were no statistically significant group differences on any measure in favour of the training groups.

The results are discussed in the light of transfer effects of phonological awareness skills to reading. The results are also discussed in relation to auditory discrimination and indistinct phonological representations. Auditory discrimination was further discussed in relation to intelligibility and the contributions of speech for the group with motor speech impairment. The access to speech, be it ever so dysarthric, is suggested to play a role in reading and spelling acquisition for children with motor speech impairments. Furthermore, the importance of general language skills was stressed. Differences in training time between the groups were acknowledged and discussed.

Paper IV

Purpose

The aim of Paper IV was to further scrutinise spelling skills which were found to be teachable to children with speech impairments in Paper III. The purpose was to analyse the spelling errors of an anarthric girl with Cerebral Palsy. On the basis of the features of the bliss communication system used by the girl, it was hypothesised that there would be more phonological than visual errors in her spelling.

Method

In a case study the spelling skills of an anarthric girl was studied with focus on spelling errors. A non-word list of 65 items was used. The non-words had thirteen different initial consonants and word lengths differing between 2-7 letters. The words had cv(cvcvc)-structure. The spelling errors were analysed and related to case history, speech and cognitive and linguistic background variables.

Results and discussion

The results on non-word spelling perfectly matched the classic graphemic buffer deficit with more spelling errors on longer words (a word length effect), a bow-shaped letter position curve implying a higher proportion of spelling errors in medial letter positions (a letter position effect) and certain error types (primarily omissions). Preliminary data also suggested a similar spelling pattern for real words. The written product was clinically graded as exceptional considering that the girl studied was anarthric and only had low level phonological awareness skills to support her written language skills. Furthermore, the girl had good reception of grammar and an extensive alternative communication system. She had good auditory discrimination skills.

The results were discussed in relation to impairments in (A) *segmentation of spoken words* and (B) *working memory deficits* for orthographic as well as auditory units. The results were further discussed in relation to sonority, and the effect of prosodic stress on error patterns were suggested as an interesting focus for further research.

Additional analysis

Paper I focused on reading impairments and suitable interventions for children with either pronounced phonological or orthographical problems.

Language data was also collected from this sample and an additional analysis of those data shows differences on reception of grammar between normal readers and the children with the most pronounced reading problems (orthographical or phonological) ($F(86,2) = 5.10, p < .05$). No differences in general language abilities (vocabulary, reception of grammar, complex reception of narratives) were found between children with phonological or orthographical problems.

In Paper III the discrepancy between performances in auditory discrimination and in speech output are mentioned. This result will be further stressed in the following discussion. The additional analysis, computed for the 9 participants with speech impairment who took part in all tests revealed a significant correlation ($p = .01$) between auditory discrimination and sentence reading, post intervention, as well as between auditory discrimination and word spelling, post intervention. For intelligibility in output speech and graded speech quality on the other hand, significant correlations ($p = .01$) were only found for complex reception of narratives.

Summary of the findings

The four studies have explored phonological awareness and written language in the presence and absence of speech in children with motor speech impairments and children with reading impairments. These are the primary findings of the four papers:

- (1) Generally, the studies confirmed a relationship between phonological awareness and reading and spelling.
- (2) Interventions targeting reading and spelling in typical speaking children with reading impairments should focus on the relative weakness rather than the relative strength in word decoding in children with reading impairments who are in an early stage of reading development (Paper I).
- (3) For children with reading impairments, phonological as well as orthographic intervention had effects on reading and spelling (Paper I). The children with the lowest reading performance also showed effects of phonological intervention (Paper III).
- (4) Significant differences were shown between low level readers and high level readers in the areas of auditory phoneme discrimination skills and general language skills in children with motor speech impairments (Paper II).
- (5) Phonological intervention had effect on word spelling skills but not on reading skills, in children with motor speech impairments (Paper III).
- (6) In an analysis of non-word spelling errors of an anarthric case, more spelling errors were found on longer words, and a higher proportion of spelling errors were found in medial letter positions, implying deficit in segmentation of spoken words and working memory (Paper IV).

General discussion

The main findings will initially be discussed in relation to phonological processing and the four fields of this process, i.e., phonological representations, phonological production, phonological memory and phonological awareness. This will be followed by a section on the findings related to orthographic training. Specific findings of different intervention effects related to weak and strong decoding skills, as well as different intervention effects on reading and spelling will be discussed. The general discussion ends with a section on the findings related to general language processing.

Phonological representations

Phonological representations are cognitive manifestations of speech sounds. In optimal circumstances these representations are developed on the basis of auditory speech input and on articulation of speech output (Joanisse & Seidenberg, 1998, Snowling & Hulme, 1994).

The studies of this thesis clearly show the presence of phonological representations in children with reading impairments as well as in children with speech impairments. Both groups produce spellings indicating phonological processing. Both groups can reflect upon speech entities and manipulate speech sounds in phonological awareness tasks conducted in all the studies included in this thesis. These are expected findings. In dealing with spoken language, if yet only receptively, we all have to deal with phonological units and create phonological representations. With hearing impairments and motor speech impairments as example populations it seems possible to create these representations without auditory information as well as with distorted motor information. Some kind of more abstract phonological system may be the key explanation (Rönnerberg, et al., 1998).

It is also evident that these phonological representations are accessed in the reading and spelling process by the children with reading impairments as well as by the children with motor speech impairments studied in this thesis. The studies suggest two hypotheses regarding the participating children's phonological representations. They were either:

- (1) less well developed, and/or
- (2) less well manipulated.

It can be argued that the paths to phonological representations, through sensory, motor, and perceptual information, are interchangeable and that they will all compensate for each other (e.g., if you lack auditory sensory information you can form your representations by sensory information through articulation). However, it seems more likely that the phonological representations will be slightly less distinct for each part of information that is lost. In the case of the children with motor speech impairments the first hypothesis has to be taken into account. Phonological representations were operationalised as auditory discrimination of phonemes and well developed auditory discrimination was significantly correlated with reading in Paper II.

The group differences on the phonological awareness tests between children with reading impairments and typical readers presented in Paper I, along with the low levels of phonological awareness presented in Paper II give support for the second hypothesis.

In sum, the studies gave support for both hypotheses. Phonological representations, operationalised as auditory discrimination of phonemes, are (1) less well developed in many of the children with motor speech impairments included in this thesis. Phonological representations are also (2) less well manipulated in phonological awareness tasks, by the children with as well as by the children without speech in the studies.

Phonological production

In Paper II, speech could not be ruled out as an important variable for reading and writing. At mean level the high level readers and the low level readers in the sample differ from each other in speech level, however the results were not conclusive. The two anarthric participants perform as low level readers and the three children without cerebral palsy perform as high level readers. Phonological representations are facilitated by articulation feedback and speech could serve as rehearsal and auditory feedback (Gathercole, Willis & Baddeley, 1991). Even so, the relation between speech intelligibility and reading and spelling is not linear. Paper II showed that severely distorted dysarthric speech

was sufficient for developing good reading skills. This is also suggested by the results of Paper III; when the anarthric participants in Paper II are not included in the intervention conducted in Paper III, the contributions of articulation seem to vanish. Findings in Papers II and III show that auditory phoneme discrimination was significantly better for children reading at a higher level, an indication that phonological representations indeed varied in distinctness in the group with speech impairment. However, auditory phoneme discrimination was not related to speech intelligibility when examined in Paper III. In fact no inter-correlations were found for graded quality of speech or word intelligibility, neither for phonological awareness nor auditory discrimination, so the loss of a greater part of the motor information does not seem to affect the phonological representations to any higher degree than the loss of a smaller part. In order to create phonological representations, normal speech seems far from necessary. For example, no difficulties with simple auditory phoneme discrimination were found in the anarthric girl studied in Paper IV. However, articulation can assist as a rehearsal tool, used in memory processing.

In a theoretical comparison between children with motor speech impairments and children with hearing impairment it seems reasonable that articulation can help to create phonological representations. Children with hearing impairments constitute a theoretically intriguing comparison group to children with motor speech impairments in this aspect. Several hypotheses can be made in relation to the children with hearing impairments. The reading and spelling skills of children with hearing impairments are supported mainly by (A) actual oral articulation, (B) lipreading, (C) early expressive language skills. These hypotheses have different outcomes applied to the children with motor speech impairments. The first hypothesis would imply that reading and spelling skills could be predicted by the level of oral skills. This is not the case for children with hearing impairments or for children with motor speech impairments. The second hypothesis addresses lipreading, an ability that should be equally available to both groups. However, children with hearing impairments have generally much better reading and spelling skills than children with motor speech impairments. In this case it would be interesting to investigate the lipreading skills in the both

groups to see if they in some way can be related to the performance levels in reading and spelling. The last hypothesis is based on the fact that deaf children of deaf parents develop better reading and spelling skills than other children with hearing impairments. These deaf children with deaf parents share early exposure to receptive language with children with motor speech impairments. Motor speech impairments do not prevent the child from accessing spoken language from their parents. However, the children with severe motor speech impairment do not get early hands on experiences of general expression of language, e.g., they do not get to use and manipulate language themselves in an early age. This would be interesting to further investigate. Would this early expressive language need any special linguistic features, e.g., consist of Type Two symbols where form and content are separated (McNaughton, 1993) or provide the user with general skills of segmenting sublexical units, insensitive to modality?

In sum, phonological production, operationalised as intelligibility of speech has an impact on reading and spelling, but speech can be severely distorted and still support written language skills. Lipreading and early expressive skills of languages supporting segmentation of sublexical units are alternative hypotheses to pure oral articulation in how to develop reading and spelling.

Phonological memory

Rudner and Rönnberg (in press) have presented a model that deals with working memory processes in suboptimum conditions. When the language signal is poorly specified, as in sensory loss of hearing, or as in our case: poor auditory discrimination a mismatch with phonological or general language representations in long-term memory takes place which demands an explicit use of working memory to solve the task (Rönnberg, Rudner & Foo (in press)). In earlier research, reduced capacity in working memory has been suggested for the children without speech (Dahlgren Sandberg, 1996; Larsson, 2006; Smith, 2005) as well as for children with reading impairments (McCallum, et al., 2006). The combination of reduced working memory skills and the mismatch situation that place higher demands on working memory affect reading and spelling performance. The findings in the case study in Paper IV strengthen this

hypothesis. The spelling pattern gave clear evidence of position related indistinctness. Primacy and recency effects were the primary findings in the non-word spellings of this case study, replicating findings in the normal speaking population (Wing & Baddeley, 1980) and in people with acquired brain lesions (Caramazza & Miceli, 1990). In the case of transparent languages where spelling is closely related to phonology, specially developed stimuli material is needed to say whether this indistinctness is related solely to phonological representations, or to orthographic representations as suggested by Caramazza and Miceli (1990). In the study presented in Paper IV the spelling deficits were present in spite of well developed auditory phoneme discrimination, but in the presence of deficits in high level phonological awareness skills. Difficulties in segmentation of phonological strings, as well as deficits in working memory processing seem to be affecting the case study participant's performance in spelling.

However, this issue has not been fully explored in the studies. In Paper I, no assessment of working memory was included. In Paper II, no differences were found in measures of probed digit span between low level readers and high level readers. The digit span test in the format used in Paper II is non-sensitive to temporal order, a feature which was considered as an important aspect in the spelling of the girl in the case study conducted in Paper IV. Thus, piecing together the findings of this thesis it can be inferred that working memory may play a role in reading and spelling in children with motor speech impairment, and that temporal order may be an essential factor in this process.

In sum, phonological memory deficits in combination with poor segmentation skills affect spelling in the case study of this thesis. Phonological memory has not been fully explored in the studies.

Phonological awareness

Phonological awareness has a double function. First, phonological awareness is a manipulation of speech units that functions as a direct cognitive feedback to strengthen the phonological and morphological representations. Secondly, phonological awareness functions as an ability to manipulate speech units for further usage in other cognitive tasks, e.g., the synthesis of phonemes and

syllables in a word to be able to read it, or the segmenting of phonemes in a word to be able to know what units to spell.

The results of this thesis are in line with earlier research that has shown relationships between phonological awareness and reading and spelling (Carroll, et al., 2003; Mody, 2003; Shankweiler & Fowler, 2004). In Paper I typical readers had better performance on phonological awareness than all the training groups with reading impairments. In Paper II, phonological awareness was rank correlated with reading in the children with motor speech impairments. Several of the low level readers could not complete any of the more complex phonological awareness tasks, such as subtraction of segments.

The most important finding, however, is that the manipulation of phonological representations (i.e., phonological awareness) can be trained (Ehri, et al., 2001, Lundberg, Frost & Petersen, 1988). This has been done in Paper I and Paper III. The studies showed improvement in phonological awareness for speaking children with phonological decoding deficits, for speaking children with low reading performance, and for children with motor speech impairments.

The phonological awareness intervention conducted in Paper III offered data on the relation between phonological awareness and reading and spelling in children with and without fully functional speech. Following intervention the children with reading impairments improved their reading and word spelling and the children with motor speech impairment improved their word spelling. When further examined, the group with motor speech impairment showed improvements in basic levels of phonological awareness, e.g., rhyme, but not sophisticated levels, e.g., syllable subtraction. This is in line with other recent findings (Hesketh, Dima & Nelson, 2007). Thus, phonological awareness could be trained and developed in children with reading impairments and trained and developed at more basic levels in the children with motor speech impairments.

In Paper I, phonological awareness was explicitly trained with a phonological training program which improved reading as well as spelling in children with pronounced phonological problems. This indicates a direct impact from phonological awareness to written language (Bradley & Bryant, 1983; Carroll, et al., 2003; Mody, 2003; Plaza & Cohen, 2003). However, the children with

pronounced orthographic problems did not improve significantly after phonological awareness intervention but showed improvements from orthographic training. This suggests that there are subgroups that benefit well from phonological training and children who need a more orthographic focus in the intervention. These findings can bring some light to the discussion on treatment resisters (Torgesen, 2000) and the importance of individually adapted interventions.

In sum, phonological awareness was related to reading and spelling within the group of children with motor speech impairments and between the groups of children with reading impairments and typical readers. Phonological awareness could be trained and developed in children with reading impairments and trained and developed at more basic levels in the children with motor speech impairments. Speaking children with pronounced orthographic decoding deficits did not benefit from phonological training.

Orthographic training

The orthographic training conducted in Paper I had positive effects on reading primarily in speaking children with pronounced orthographic decoding deficits, but also on speaking children with phonological deficits. Thus, increased orthographic skills serves as a route to better reading and spelling performance, as indicated by Paper I. The impact of orthographic processing on reading and spelling has been acknowledged in earlier research (Berninger, et al., 2002; Ehri, 1987; Hammill, 2004). However, the studies included in this thesis do not give any examples of cases where orthographic decoding has fully compensated for phonological decoding deficits. The orthographic decoding is yet a source for misreading and misspelling among the children with reading impairments as well as among the children with motor speech impairments. In Paper IV, the girl showed deficits in segmentation of phonological units and working memory processing. She had not developed orthographic strategies to compensate for her phonological deficits. However, an intervention targeting sublexical orthographic units (e.g., syllables and morphological units) could have the potential to increase her orthographic knowledge in order to release cognitive capacity for her

phonological processing, i.e., orthographic strategies would not compensate for phonological strategies but the routes would supplement each other.

In sum, orthographic training had positive effects in reading on speaking children with orthographic decoding deficits but also in speaking children with phonological decoding deficits. Orthographic strategies were not found to compensate for phonological strategies but orthographic strategies were suggested as a supplement to release cognitive capacity for phonological processing.

Different intervention effects related to weak and strong decoding skills

It would be reasonable to think that children would benefit from interventions that tapped into their relative strengths. The use of better developed skills would serve as a strategy compensating for the relatively weak skills. However, the study in Paper I examined phonological and orthographic interventions for children with either pronounced phonological or orthographic decoding deficits. The study gave evidence for an alternative hypothesis, that we should train the relative decoding weakness of the child. The children with reading impairments primarily affecting phonological decoding, benefited more from phonological intervention, and children with primarily orthographic decoding deficits benefited more from orthographic intervention. This demands an elaboration. The children in Paper I are children with reading impairments who are in an early stage of their reading development. For these children, the alternative hypothesis seems applicable. The weak decoding skills at an early age seem to have the potential for improvement. Later in their reading development, the children develop word decoding strategies and preferences and the training of non-preferred strategies does not seem to be effective (Gustafson, Samuelsson & Rönnerberg, 2000). Note that skill in using a word decoding strategy (Paper I) does not automatically imply strategy preference (Gustafson et al, 2000).

It is possible that children with motor speech impairments also would benefit from early training of weak skills with potential of improvement. Later on, focus could be set on strengthening compensatory strategies. This, however, demands further research to be ascertained.

The findings must also be elucidated by stage theories (Frith, 1985). According to these, alphabetical, phonemic (Høien & Lundberg, 1988) reading is developed earlier than orthographic reading. Many studies show that phonological approaches in interventions are effective at early stages of reading development. The phonological awareness intervention conducted in Paper I improved the reading and spelling skills of the children with pronounced phonological decoding deficits. Phonological awareness training conducted in Paper III also had effect on the lowest performing children with reading impairments, in spite of the fact that half of this group had mixed problems with slightly more orthographic decoding deficits. Thus, phonological awareness training seems suitable at early reading development stages.

In sum, children with primarily phonological decoding deficits benefited more from phonological intervention, and children with primarily orthographic decoding deficits benefited more from orthographic intervention. The thesis therefore suggests training of weak decoding skills rather than strong decoding skills at early stages of reading development.

Different intervention effects on reading and spelling

The transfer effects of phonological training on reading and spelling are complex. Training of phonological awareness had a transfer effect on reading in the children with reading impairments and on word spelling in both the children with reading impairments and the participants with motor speech impairments. Reading and spelling puts different demands on the child. Phonology and orthography plays crucial roles in these demands as has been described by Bryant and Bradley (1994). They found that poor readers often showed more discrepancy between their reading and spelling skills than did good readers, and they referred this to the phonological and orthographic strategies used to solve the tasks of reading and spelling. Emergent reading takes its starting point in orthography and emergent spelling in phonology (Bryant & Bradley, 1994).

In the studies conducted within this thesis, there were discrepancies in improvement for reading versus spelling in children with and without speech impairments. The general pattern in Paper I is that for speaking children with reading impairments the effects of phonological awareness training were

statistically significant for reading skills but effects on spelling were more modest. In Paper III phonological awareness training had a higher effect size on reading skills than on spelling skills in speaking children with reading impairments but in children with speech impairment the training did not improve reading skills at all, but had an effect on spelling skills. Thus, it seems like the interventions somehow had opposite effects on children with reading impairments compared to children with motor speech impairments.

These findings can partly be explained by the reasoning of Bryant and Bradley (1994). In Paper I, the phonological awareness intervention seems to encourage the children to use more phonology in the reading task and thereby solve the reading task better. In the spelling task the room for phonological improvement was smaller and orthographic knowledge was needed to perform higher. However, spelling did improve, and the orthographic intervention did not improve spelling more than the phonological awareness intervention.

For the children with motor speech impairments the phonological awareness training did not improve reading, but had an effect on spelling. Since the emergent spelling is based on phonology, it is fully plausible that the phonological awareness intervention had an effect on spelling. It is the lack of improvement in the area of reading that needs additional attention. I want to suggest a recognition-recall explanation for these findings. The task of reading and the task of dictation spelling involve different demands on recognition and recall of phonology versus orthography.

(A). Reading involves the recognition of orthographic units and supposedly also the recall of phonological units.

(B). Dictation spelling involves the recognition of phonological units and the recall of orthographic units.

The word reading task does not demand the activation of phonological units as a necessary component. The task can be solved orthographically. The tentative explanation of the findings in Paper III is that the children with motor speech impairments do try to access the phonological representations. This makes the reading task hard to accomplish for the children with speech impairments who have weak phonological representations. The problems in accessing cognitive

representations of phonology has been described by Dahlgren Sandberg (1996). She reported that the spelling of words was easier for non-speaking children if they were provided with an orally presented word than if they had to recall the word themselves when prompted with a picture. Recall of phonological representations is more difficult than recognition (Cleary, 2004). The spelling task with dictated words on the other hand, involves recognition of phonological units which the children with speech impairments manage better than recall of phonological units as in the reading task. There have been suggestions that spelling should be taught as a recognition process as well as a production process (Scott & Brown, 2001). It seems like the phonological awareness intervention does indeed improve the awareness of phonological units, realised as recognition, but it does not improve phonological representations per se, as the recall function is still not improved.

In sum, the data suggest opposite effects on reading and spelling for the two research groups. The general patterns is that children with reading impairments improve reading more than spelling. Children with motor speech impairments improve spelling but not reading. Dictation spelling involves a recognition of phonological representations that seems easier for children with motor speech impairments than the recall of phonological representations that may be what is needed in reading.

General language processing

The results of the studies conducted in Papers I and III show that phonological awareness can develop in both children with motor speech impairments and in children with reading impairments, following intervention. It seems that these two groups reach different levels of phonological awareness, and they also seem to have different capacity to use this awareness, depending on other skills they possess, such as auditory phoneme discrimination and general language skills.

General language skills, as manifested in the reception of language are closely related to reading and writing performance. This is shown in the additional analysis of Paper I, where general language ability of the normal speaking children was analysed. The results showed that normal readers had a

significantly better reception of grammar than the children with the most pronounced reading difficulties. This stresses the general importance of language skills for the development of reading and spelling, as described by Hirsch (2003) in relation to knowledge of words and the world and by Adams (1990) in the context and meaning processor. However, the additional analysis also showed that the language skills did not seem to support any decoding skills (i.e., phonological or orthographic) more than the other.

In Paper II the children with the best reading abilities also performed significantly better on tests of general language ability than the children with low reading performance. In Paper III the two training groups, with impairments in either reading or motor speech, differed in vocabulary; and the group with motor speech impairment also differed from the group with speech and normal reading when it came to reception of grammar. Note that this was in comparison with the lowest performing readers in the normal reading sample from Paper I. In Paper IV the case study participant had an extraordinary bliss-based communication system which gave her access to a wide vocabulary and which allowed her to make grammatical inflections. She performed well on reception of grammar but a test of vocabulary showed that her vocabulary was limited in many domains. As a representative for the anarthric group, her general language ability is well developed, when clinically viewed (cf. Schulerud, 2002). However, in spite of well developed general language skills, the spelling of the girl in the case study presented in Paper IV is far from age adequate. Thus, general language skills are not sufficient to develop high abilities in processing written language.

In sum, general language processing skills are necessary but not sufficient skills for developing reading and spelling in children with reading impairments as well as in children with motor speech impairments.

“Norm referenced criteria do not have any real relevance, because it’s not normal to be normal, if you’re not normal”.

- Granlund (1995, p. 32)

Methodological discussion

This quotation by Granlund (1995) catches two of the most important methodological discussion issues in disability research:

1. Is it valid to compare people with impairments with people without impairments?
2. Is it ethical to compare people with impairments with people without impairments?

Both these issues will be addressed in the methodological discussion.

Methodological issues in disability research

Validity. Validity is a concept to describe the accuracy of a measurement (Vogt, 1999). We want the measure to be free from systematic errors, i.e., we want it to measure what it is supposed to measure and not something else.

It is a really delicate issue to construct tests suitable for measuring the skills of people with impairments. The first considerations that have to be made are the ones related to validity. Does the test measure the same thing for people with impairments as it does for people without impairments? For example, if intelligence is measured by letting the participants answer questions and build things with bricks, what is measured with that test if the test participants have severe speech and motor impairments? To secure validity, changes in test procedures, instructions, presentations, modalities, reply modes, etc. may have to

be made. Test items may have to be adjusted to fit another type or level of performance. However, the validity issue is still of relevance after reconstructing the way of measuring. The reconstructed test now may possess internal validity, i.e., the variable measured is the same for the two groups and we can hereby understand the causal effect of one variable on the other variables in comparing the both groups. But maybe now the construct validity of the test is lost, i.e., the test is no longer measuring the constructs of interest. This shows how unreflected routine comparison between people with impairments and people without impairments can lead to collections of non-valid data.

The validity issue is certainly important in the area of assessment of children with speech and motor impairment. In this thesis, adjustments of test material have been made to assure internal validity. However, one area of specific interest in relation to validity in this thesis is the assessment of working memory in the presence of speech and motor impairments, as has been addressed in Paper II and in other studies (Dahlgren Sandberg 1996; Larsson, 2006). It is evident that the construct validity was affected in selection of a probed digit recall test in Paper II, which has been discussed in the paper. Working memory in every day life is a cognitive function that gives access to several complex human behaviours. It would be interesting to investigate whether it is possible to study the influence of working memory without explicitly addressing it and demanding responses that can not be executed by children with motor impairment. This is yet to be done.

For validity it is also important to consider the inclusion of a sufficient amount of items. It is a delicate balance, however, to choose the correct number of items so that the participants will have the stamina to perform at their true level of capacity, while we still get sufficient amount of data for research (cf. Truxler & O'Keefe, 2007). Sometimes more items can actually reduce the test validity (Burisch, 1998). In this thesis, the low number of items in some of the tests used in the studies was chosen in ethical consideration of the children with speech motor impairments. This assured a decent degree of validity in the results that were collected since fatigue and concentration deficits were less probable to affect the findings.

Another validity problem with the assessment is to find tests that truly measure improvement that occurs. In comparisons between the children with motor speech impairments, the children with reading impairments and the children with typical speech, it would have been valuable to be able to use the same assessment of phonological awareness, since this was the variable in focus for intervention. However, floor and ceiling effects in test sessions prevented us from finding such a measurement.

Yet another threat against validity is the presence of confounding variables, variables other than the ones of interest. Confounding variables are likely to be found in heterogeneous samples. The heterogeneity of particularly the group with motor speech impairments is high. Different diagnoses, different localisation of lesions, different degrees of mobility and use of different AAC-systems could all contribute to the findings as confounding variables. The risk for confounding variables in the presented studies was partly addressed by matching groups on some of the variables considered important. Methodological triangulation was also used to get data of different kinds from different samples, allowing a more complex picture of literacy to be presented, with the purpose of horizontal integration of knowledge. The heterogeneity also raised several important hypotheses that would be interesting to further investigate. The development of literacy is complex and there are still variables that can be, and indeed are, important to literacy besides those addressed in this thesis, for example a vertical integration of knowledge from the social level.

Generality. The ability to make generalisations from research findings is dependent on the methodological design of the studies. In Paper I, the access to participants from a relatively large population allowed a quasi-experimental design. The findings of this study are therefore more suitable for making generalisations that can apply to the whole population (Troia, 1999). However, in disability research, the sample sizes, or even the populations themselves, available for studies are often quite small. The triangulation of methods and types of populations used within this thesis is a way to collect data also in a smaller and more heterogeneous population. This makes it possible to collect data of different types to explore the complex picture of phonological awareness

and written language. In Paper IV a case study was conducted which was valuable to generate new hypotheses and to be able to make an in-depth study of the phenomenon of spelling errors produced by a person with anarthria and severe motor impairment. This study has low generalisation power but is replicating findings in case studies with other types of participants (Caramazza & Miceli, 1990). The horizontal integration of knowledge aimed at in disability research allows us to acknowledge similar phenomenon across different disability groups. Thus, an interesting finding in a case study can add to a deeper understanding of the phenomenon.

Ethics in disability research

In line with the reasoning of Granlund (1995) one can argue that it is unethical to compare people with impairments with people without impairments. The norm is beyond reach for the person with an impairment and comparisons with the norm might only lead to stating the obvious, e.g., people with severe rheumatism might not be able to reach the cookie jar on the fridge while people with normal hand function can (i.e., “No hands, no cookies!” (Hedlund, 1997)). It might be completely irrelevant to compare to the norm, when other ways of exploring the construct might be much more interesting and relevant, e.g., observing which compensating strategy the person with rheumatism will use to get the cookie (which in fact will have its ethical limits too).

So, even if certain comparisons between people with impairments and people without impairments cannot be described as unethical, there may be other comparisons that can give us more interesting and relevant information. This is the strength of the horizontal integration of knowledge which is carried out in this thesis.

“Teaching reading IS rocket science”

- American Federation of Teachers, (1999).

Clinical implications

Reading and writing are skills of great importance in modern life. Through reading, children acquire knowledge that contribute to their cognitive development; they can receive information and take part in a cultural context that in many aspects is based on written language in the world of today. Through writing, children can express their own thoughts and for children without speech and with severe motor impairments writing is the single possibility for independent expression (Dowden, 1999). For these reasons it follows that it is essential for the individual child that teachers and clinicians know the “rocket science” of teaching literacy (cf. American Federation of Teachers, 1999).

The main clinical implications of this thesis can be found within the area of intervention. The intervention studies included the development of a software with focus on phonological awareness and this thesis demonstrates that intervention targeting phonological awareness has an effect on reading and spelling. Phonological awareness can be trained and developed in children with reading impairments and trained and developed at more basic levels in the children with motor speech impairments. Speaking children with pronounced orthographic decoding deficits did not benefit from phonological training. Orthographic training had positive effects on reading in speaking children with orthographic decoding deficits but also in speaking children with phonological decoding deficits. For speaking children with reading impairments, the findings suggest training of weak decoding skills rather than of strong decoding skills at

early stages of their reading development. For children with motor speech impairments the thesis reports intervention effects on spelling but not reading. Reading is considered a more difficult task than spelling on dictation.

Besides orthographic and phonological decoding skills and phonological awareness, that have been the focus for intervention in this thesis, the studies provide some other findings of clinical interest, presented below.

The findings suggest that general language abilities (i.e., vocabulary, morphology and syntax) are necessary for developing reading and spelling, to both children with reading impairments and children with motor speech impairments. Thus, it seems important to address general language abilities in relation to the teaching of reading and spelling. For children with severe dysarthria and anarthria, these language abilities also include alternative communication, as seen in the case study in Paper IV.

The general nonverbal intelligence of the children with motor speech impairments included in this thesis is below their age level. Many of the children had knowledge in reading and spelling, but nonverbal intelligence was correlated with reading performance in the sample. However, without longitudinal data of the instructions and support given to the children during their earlier reading and spelling development, it is, impossible to know the causal relationship behind these findings. Earlier research has demonstrated low expectations and priorities of parents and teachers of children with severe motor and speech impairments (Light & McNaughton, 1993). It is a clinically important issue to consider whether we provide these children with enough opportunities and support to develop reading and spelling.

Final conclusions

This thesis demonstrates progress in reading and spelling following both a phonological awareness intervention and an intervention focused on orthography. Speaking children with pronounced orthographic decoding deficits did not benefit from phonological training, but showed significant improvements from an intervention with orthographic focus. The findings suggest training of weak decoding skills rather than strong decoding skills at early stages of reading development. The findings were discussed in relation to phonological processing and the four subfields of this process, i.e., phonological representations, phonological production, phonological memory and phonological awareness.

The overall pattern for children with reading impairments was that they improved more in reading than in spelling while children with motor speech impairments only improved in spelling. These differences are discussed in relation to the recall and recognition demands of the tasks.

In addition to orthographic and phonological decoding skills it is suggested that general language processing skills is necessary for developing reading and spelling in both children with reading impairments and children with motor speech impairments.

The thesis included children with and without speech to explore phonological awareness and written language in the presence and absence of speech. The contributions of speech to reading and spelling are complex. In children with dysarthria, levels of speech intelligibility per se did not seem to predict reading and spelling performance. It seems that also a severely distorted speech can serve as a phonological feedback. However, for the children with anarthria, speech *does* seem to play a role. More research is needed to understand the role of speech in the creation of phonological representations and the access of these representations in phonological working memory and phonological awareness tasks.

The present thesis has a disability research approach and is a contribution to the overall understanding of phonological awareness and written language. Many of the findings are directly applicable to the clinical context.

Further research

The ultimate challenge in the research area of motor speech impairments is to create methodologically well-designed studies. There are still numerous topics to explore to understand the group in order to provide the children with motor speech impairments with tools for independent communication through written language. The findings in this thesis raise many new questions and hypotheses, for example:

1. Orthographic intervention was found effective in children with reading impairments. Could orthographic training have good effect also in children with motor speech impairments? What units should such an intervention target?

2. Training of relative decoding weaknesses was found effective in children with reading impairments. Should decoding training in children with motor speech impairments also target weak skills or stronger, compensatory skills?

3. Spelling errors were a fascinating source to inner representations of phonology in the case study with the anarthric participant in Paper IV. It would be theoretically motivated to conduct a larger study with more children and with a broader spectrum of spelling tasks.

4. A longitudinal case study with very early AAC-intervention of expressive language should be conducted to see the impact on reading and spelling skills in an anarthric child.

5. Comparisons of anarthria and severe dysarthria have to be carried out in a more controlled study with communication mode and use held constant.

6. The lipreading skills of deaf children and of children with motor speech impairments should be explored, followed by an intervention teaching lipreading skills and exploring its effect on reading and spelling skills in the two groups.

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