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# There's more to the picture than meets the ear

Gaze behavior during communication in children with  
hearing impairment

Olof Sandgren



**LUND**  
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DOCTORAL DISSERTATION

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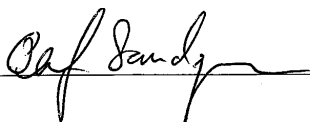
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Abstract  Many children and adolescents with hearing impairment struggle to meet school demands. The difficulties can be traced to the characteristics of the hearing impairment, and to adverse consequences on language development, often overlooked in diagnostics and intervention. This thesis investigates the communicative ability of children and adolescents with bilateral sensorineural hearing impairment by studying verbal and nonverbal interactions with normal hearing peers. The study uses a referential communication task requiring the speaker to make relevant descriptions, and the listener to use verbal and nonverbal means to resolve uncertainties. Analyses focus on verbal questions and answers (paper 1), nonverbal gaze behavior in relation to the verbal production (paper 2 and 3), and the cognitive and linguistic factors influencing the gaze behavior (paper 4). The results yielded that: <ul style="list-style-type: none"> <li>- The structured and predictive conversational setting enables speakers to include unrequested information without compromising the partner's understanding (paper 1).</li> <li>- Gaze behavior is related to the production of verbal utterances, as shown by a higher probability of gaze to the conversational partner's face when asking questions than making statements (paper 2).</li> <li>- Participants with hearing impairment consistently exhibit higher probability of gaze-to-partner than peers with normal hearing (paper 3).</li> <li>- Participants with hearing impairment and reduced phonological short term memory capacity show a doubled probability of gaze-to-partner, compared to peers with normal hearing (paper 4).</li> </ul> <p>The findings express the multimodality of communication, and the need for multidisciplinary assessment and therapy. Implications include pedagogical adaptations to an increased use of nonverbal cues in children and adolescents with hearing impairment. The results highlight areas of phonology and conversational strategies to target for speech-language services, and call for an evaluation of nonword repetition as a clinical marker allowing earlier identification of children with hearing impairment at risk for persistent language impairment.</p>		
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# Introduction

## Preface

This thesis concludes four years of doctoral studies on the communicative ability of children and adolescents with hearing impairment. Finalized during a summer like no other, the thesis addresses research questions grounded in speech-language pathology, cross-fertilized within the interdisciplinary research collaboration Cognition, Communication, and Learning to include novel techniques of data collection and analysis. The thesis consists of four original research papers investigating aspects of the linguistic interaction between children with hearing impairment and peers with normal hearing – from the verbal question and answer strategies used in communication, to the nonverbal gaze behaviors accompanying the spoken message. While demonstrating the multimodality of communication, the answers provided in the thesis are greatly outnumbered by the questions raised for future research. Clearly, four years of work has only scratched the surface of this topic.

After a presentation of the titles of the papers you will find a Swedish summary of the thesis. Chapters 2-6 present some of the basic concepts necessary for understanding the field of cognitive hearing science and the experimental paradigm used in the studies. The chapters describe sensorineural hearing impairment (SNHI), language development in children with SNHI, how verbal and nonverbal means are integrated in communication, how this ability can be tested experimentally, and how gaze behavior contributes to the ability. Chapter 7 describes the Present investigation and how the individual papers connect with each other. Finally, in chapter 8, I discuss what can be learned from the thesis, and how the findings can be used in clinical and pedagogical work, as well as in future research studies. All details on our methods and findings are found in the original papers, appended at the end of the thesis.

Enjoy the reading,

Olof Sandgren



## List of papers included in the thesis

1. Sandgren, O., Ibertsson, T., Andersson, R., Hansson, K., & Sahlén, B. (2011). 'You sometimes get more than you ask for': responses in referential communication between children and adolescents with cochlear implant and hearing peers. *International Journal of Language & Communication Disorders*, 46(4), 375-385.
2. Sandgren, O., Andersson, R., van de Weijer, J., Hansson, K., & Sahlén, B. (2012). Timing of gazes in child dialogues: a time-course analysis of requests and back channelling in referential communication. *International Journal of Language & Communication Disorders*, 47(4), 373-383.
3. Sandgren, O., Andersson, R., van de Weijer, J., Hansson, K., & Sahlén, B. (submitted manuscript). Coordination of gaze and speech in communication between children with hearing impairment and normal-hearing peers.
4. Sandgren, O., Andersson, R., van de Weijer, J., Hansson, K., & Sahlén, B. (submitted manuscript). Impact of cognitive and linguistic ability on gaze behavior in children with hearing impairment.

Papers 1 and 2 have been reprinted with permission from Wiley-Blackwell.

# Tack!

Först och främst vill jag tacka min huvudhandledare **Birgitta Sahlén** som med entusiasm, energi och stor generositet har delat med sig av sitt kunnande, sina visioner och sitt kontaktnät. Det har varit fantastiskt att tillsammans med Birgitta få utforska möjligheterna som skapats genom CCL-samarbetet och som har gett oss möjlighet att ta oss an våra frågeställningar med nya metoder och med nya samarbetspartner. Trots att mitt arbete ibland har avvikit en hel del från den utlagda planen har jag inte för en stund känt mig ensam i det, och aldrig har jag behövt vänta mer än några enstaka timmar för att få svar på de frågor som har dykt upp. Jag är också mycket glad att Birgitta har gett mig friheten att själv ansvara för min tid. Det har bland annat gett mig möjlighet att prova på undervisning och kursutveckling på logopedutbildningen och att sätta mig in i arbetet på avdelningen, institutionen och fakulteten. Utan att ha varit doktorand hos någon annan vågar jag påstå att Birgitta förstår det verkliga syftet med forskarutbildning.

Jag vill också tacka min bihandledare **Kristina Hansson**. När huvudhandledaren under min tid som doktorand har vistats på inte mindre än tre andra kontinenter än vår egen har Kristina ofta varit den som har fått hantera alla mina praktiska frågor, om allt från transkriptionsregler till statistiska beräkningar och funderingar om språkets struktur. Med en avundsvärd detaljkänedom har Kristina varit ett ovärderligt stöd, och tillsammans med huvudhandledaren utgjort den perfekta kombinationen av långsiktig vision och praktiskt genomförande.

Vidare vill jag tacka alla på avdelningen för logopedi, foniatry och audiologi, men några förtjänar ett särskilt omnämnande. Stort tack till **Annika Dahlgren Sandberg** som först var min mentor, och som jag var tillsagd att inte prata om forskning med. Våra intressen var dock alltför närliggande och Annika har varit ett stort stöd under avhandlingsarbetet. Tack också till **Pernille Holck** som började som rumskompis och doktorandkollega, men ganska snart blev bara kompis och kollega. Tack till dig, Bosse och Amanda för mycket trevliga middagar. Tack till **Ulrika Nettelbladt** för att ha väckt forskningsintresset hos mig redan under logopedutbildningen och för givande diskussioner och läsning under arbetets gång. Tack till **Anders Löfqvist** för tips ur redaktörens synvinkel. Tack också till **Lena Asker-Årnason, Tina Ibertsson, Jonas Brännström** och **Viveka Lyberg Åhlander** som delat med sig av sina erfarenheter av avhandlingsskrivande, mycket användbara nu på upploppet. Särskilt tack till Viveka som, i egenskap av programdirektör, även har visat mig förtroendet att utforma och genomföra undervisning och som har varit ett stort stöd när jag handlett mina första magisterstudenter. Stort tack också till vår tidigare avdelningschef **Eva Wigforss** som visat hur man gör sin röst hörd

som ledamot i en institutionsstyrelse. Aldrig hade jag anat att en genomgång av institutionens ekonomi kunde vara så underhållande.

Jag vill rikta ett särskilt stort tack till mina nuvarande doktorandkollegor på avdelningen **Karolina Löwgren, Ketty Holmström, Susanna Whitling** och **Emily Grenner** som följt med i med- och motgångar i avhandlingsarbetet. Det har varit en styrka att kunna följas åt under utbildningen och hjälpa och lära av varandra. Ett särskilt stort tack till Ketty som har förmågan att ställa de rätta frågorna som tvingar mig att tänka till innan jag formulerar mig, och som alltid kan tipsa om tre referenser som håller med mig om formuleringen trots det föregick tanken. Tack också till Peter, middagarna hos er kan lysa upp även forskarutbildningens mörkaste stunder.

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Slutligen ber jag att få tacka Linnémiljön **Thinking in Time: Cognition, Communication, and Learning** för att ha finansierat min forskarutbildning. Särskilt tack till de ursprungliga sökande **Peter Gårdenfors, Germund Hesslow, Magnus Lindgren, Birgitta Sahlén** och **Sven Strömqvist** som såg potentialen i ett fakultetsöverskridande samarbete om kognition, språk och lärande och förmådde **Vetenskapsrådet** att göra detsamma (anslag 349-2007-8695).

Jag vill också tacka **min familj** som alltid står vid min sida, trots att de nog aldrig har fått någon uttömmande beskrivning av vad mitt doktorandprojekt egentligen har handlat om. Jag hoppas att avhandlingen kan rätta till det. Jag vill också tacka **Akademiska kapellet** och alla **vänner** som har gjort de här fyra åren ännu mer meningsfulla. Tiden har gått enormt fort, och det tyder ju på att det har varit roligt!

## Swedish summary

I den svenska skolan går uppskattningsvis femtusen elever med hörselnedsättning. Ungefär tvåtusen av dessa har en så allvarlig hörselnedsättning att den kräver insatser i form av hörapparat eller hörseltekniska hjälpmedel i klassrummet. För ett fåtal vållar hörselnedsättningen inga betydande svårigheter, men för elever med hörselnedsättning som grupp noteras ändå signifikant lägre slutbetyg från grundskolan än för elever med normal hörsel, och en större andel elever med hörselnedsättning misslyckas med att nå godkända betyg i de ämnen som krävs för fortsatta studier på gymnasiet. Dessa akademiska svårigheter bekräfts, och endast cirka tio procent av elever med hörselnedsättning söker eftergymnasial utbildning, att jämföra med cirka femtio procent av elever med normal hörsel. Siffrorna avspeglar att elever med hörselnedsättning som grupp har svårt att nå skolans mål, och att insatserna som ges dessa elever är otillräckliga.

Många studier har påvisat språkliga svårigheter hos barn och ungdomar med hörselnedsättning, även hos de med milda till måttliga nedsättningar. Såväl språkets form (fonologi och grammatik) och innehåll (semantik) som hur språket används i samspelet med omgivningen (pragmatik) har undersökts, och upprepade studier har konstaterat särskilda svårigheter gällande fonologiska färdigheter, det vill säga förmågan att hantera språkets ljudsystem. Som en konsekvens drabbas språkliga färdigheter som är beroende av

fonologisk förmåga, exempelvis ordförståelseutveckling och, för många, även läs- och skrivfärdigheter. I flera studier har konstaterats att hos ungefär hälften av barn med hörselnedsättning är svårigheterna av sådan omfattning att de språkliga kriterierna för den kliniska diagnosen specifik språkstörning uppfylls. För att kunna ge individanpassad behandling och pedagogiska insatser är det av största vikt att dessa barn tidigt identifieras. Värt att notera är att graden av språkliga svårigheter inte enkelt går att koppla till graden av hörselnedsättning. En allvarligare nedsättning av hörseln behöver alltså inte betyda större språkliga problem, utan den språkliga förmågan påverkas av flera samverkande faktorer, både inom individen (exempelvis minnesfunktioner och förmågan att planera och kontrollera sitt beteende och sin uppmärksamhet) och i omgivningen (exempelvis kvalitet och omfattning av de insatser och den språkliga stimulans som ges barnet).

I den här avhandlingen undersöks om, och i så fall hur, dessa språkliga svårigheter påverkar förmågan att samspela med en normalhörande omgivning. Vi undersöker barn och ungdomar med sensorineural hörselnedsättning, en bestående typ av hörselnedsättning som orsakas av skada på innerörats snäcka eller på nervförbindelsen med hjärnans hörselområden. Förmågan till samspel undersöks i en så kallad referentiell kommunikationsuppgift där barnet i samarbete med en normalhörande kamrat ska lösa

en matchningsuppgift (beskrivning-bild). I uppgiften beskriver kamraten bilder på ansikten medan deltagaren med hörselnedsättning ska hitta samma bild och placera den på rätt plats. För att kunna göra detta måste barnet efterfråga ytterligare information från kamraten. Dessa frågor, liksom övriga yttranden från barnet med hörselnedsättning, utgör en del av datamaterialet i avhandlingen.

I samtal förmedlas emellertid den språkliga informationen inte enbart med talet. Viktig information förmedlas även med gester, mimik och blickar. Det har tidigare föreslagits att dessa icke-verbala kommunikativa uttryck utnyttjas i större utsträckning av individer med hörselnedsättning, som ett sätt att kompensera för de försämrade hörselintrycken. Tidigare studier har också visat att blicken används aktivt för att reglera turtagning i samtal. Det är exempelvis känt att talaren tittar mindre på lyssnaren än omvänt, och att byte av rollerna som talare och lyssnare i ett samtal sker i samband med en kort stunds ögonkontakt som avbryts när den nya talaren tar till orda. Utnyttjandet av samtalspartnerns icke-verbala kommunikativa signaler, och användandet av blickutbyten för att reglera turtagning, påverkar i vilken utsträckning deltagarna i samtal tittar på sin samtalspartner. Med hjälp av ögonrörelsemätning under samtalsgången kan användningen av blicken avläsas. Tillsammans med medarbetare vid Humanistlaboratoriet utrustade vi därför deltagarna med ögonrörelsemätningstrustning då de utförde matchningsuppgiften. Registreringen av blickbeteende i samband med produktionen av

barns språkliga yttranden i referentiell kommunikation är den första i sitt slag och utgör den andra delen av datamaterialet som har analyserats i avhandlingen.

Avhandlingens första artikel tar vid där en föregående doktorands arbete avslutades. Tina Ibertsson (2009) visade i sin avhandling att barn och ungdomar med grav sensorineural hörselnedsättning ställde fler frågor under matchningsuppgiften än deras kamrater med normal hörsel, och att den typ av frågor som ställdes skilde mellan grupperna. Deltagarna med hörselnedsättning ställde i större utsträckning frågor som kunde besvaras med ja eller nej. Det föreslogs att den ökade användningen av denna frågetyp syftade till att göra samtalspartnerns svar på frågan mer förutsägbart och därmed lättare att förstå trots nedsatt hörsel. I artikel 1 undersöktes svaren på frågorna för att se om denna strategi hade önskad effekt. Resultaten visade att andelen ja- och nej-svar var betydligt mindre än andelen ja- och nej-frågor. Det omvända förhållandet gällde för frågor som inte införde någon begränsning på svaret, exempelvis "Vilken färg har hon på håret?". Denna frågetyp var ovanlig, men likväl omfattade nära hälften av alla svar information som inte hade efterfrågats. Som strategi för att begränsa samtalspartnerns svar förefaller således en ökad användning av ja- och nej-frågor fungera dåligt. Icke desto mindre tycks den stora mängden icke efterfrågad information inte vålla några kommunikativa svårigheter, utan tolkas istället som en effekt av att samtalspartnern har en god förståelse för målet med uppgiften och därmed kan föregripa kommande frågor.

I avhandlingens andra artikel infördes mätningen av deltagarnas ögonrörelser. I analysen undersöktes alla blickar som riktades mot tre förutbestämda områden; spelkorten med bilder, samtalspartnerns ansikte, eller någon annanstans i rummet. Analysen fokuserade på blickbeteendet vid tidpunkten för lyssnarens produktion av språkliga yttranden (frågor, påståenden, återkopplings signaler, samt vid tyst lyssnande på talaren) eftersom tidigare studier har visat att visuell information används såväl för att forma egna yttranden som för att tolka andras. Barn och ungdomar med normal hörsel undersöktes för att skapa referensvärden att använda vid senare jämförelse med deltagare med hörselnedsättning. Resultaten visade att sannolikheten att blicken riktades mot samtalspartnerns ansikte steg signifikant i samband med att frågor ställdes jämfört med då påståenden gjordes, ett resultat som stöder tolkningen att blick på samtalspartnern används för att markera turbyten i samtalet. Som kontrast noterades en minskad sannolikhet att titta på kamratens ansikte i samband med att denne gavs återkopplings signaler ("Mhm", "Ja") jämfört med då kamraten talade. Detta tyder på att tal och blick kompletterar varandra. Resultaten bekräftade således ett samband mellan produktionen av yttranden och användningen av blick.

Avhandlingens tredje artikel bygger vidare på resultaten från artikel 2 genom att ställa frågan huruvida barn och ungdomar med hörselnedsättning tittar mer på samtalspartnern än normalhörande. Forskningspersonerna hade mild till

måttlig, dubbelsidig, sensorineural hörselnedsättning och jämfördes med normalhörande, jämnåriga kamrater. Deltagarna med hörselnedsättning uppvisade högre sannolikhet att titta på samtalspartnern vid frågor, påståenden, återkopplings signaler och tyst lyssnande på partnern.

Eftersom upprepade studier har visat att många andra faktorer än hörseln skiljer barn och ungdomar med hörselnedsättning från normalhörande kamrater undersökte avhandlingens fjärde artikel huruvida det är hörselnedsättningen eller språkliga faktorer som ligger bakom den uppmätta skillnaden i blickanvändning. I en statistisk modell undersöktes om den signifikant högre sannolikheten för blick på partnern hos deltagarna med hörselnedsättning kvarstår då man statistiskt kontrollerar för deras grammatiska förståelse, ordförråd, arbetsminneskapacitet och fonologiska korttidsminne. På grupp nivå hade deltagarna med hörselnedsättning mindre ordförråd och sämre fonologiskt korttidsminne (en förmåga som mäts med repetition av påhittade ord, så kallade nonord). Ingen signifikant skillnad uppmättes däremot på grammatisk förståelse eller arbetsminneskapacitet. Resultaten visade att de hörselskadade deltagarnas högre sannolikhet för blick på samtalspartnern kvarstod även då deras grammatiska förståelse, ordförråd och arbetsminneskapacitet togs med i beräkningen. Skillnaden mellan grupperna försvann däremot när den statistiska modellen justerades för deltagarnas fonologiska korttidsminneskapacitet. Denna förmåga visade sig interagera med

hörselnedsättningen, och de deltagare med hörselnedsättning som också hade sämre fonologiskt korttidsminne uppvisade en fördubblad sannolikhet att titta på samtalspartnern jämfört med jämnåriga, normalhörande kamrater. De som istället hade ett gott fonologiskt korttidsminne uppvisade däremot en lägre sannolikhet för blick på partnern. Resultaten från artikel 4 visar att de hörselskadade deltagarnas högre sannolikhet att titta på samtalspartnern inte enbart orsakas av deras sämre hörsel utan att också deras nedsatta fonologiska förmåga bidrar.

Sammanfattningsvis belyser resultaten av avhandlingen kommunikationens mångfacetterade natur. Ökad blickanvändning hos barn och ungdomar med hörselnedsättning ska inte betraktas som isolerade svårigheter med signalöverföring utan uttrycker även de språkliga svårigheter som för många åtföljer hörselnedsättningen – språkliga svårigheter som bidrar i lika stor, eller rentav större, utsträckning som den nedsatta hörseln till de svårigheter gruppen har att nå skolans mål. Fortsatta studier behövs för att utreda orsaken till den ökade blickanvändningen som förefaller uttrycka såväl kompensation för nedsatt hörsel och fonologisk förmåga som icke-verbala reglering av turtagning i samtal. De stora språkliga svårigheterna hos gruppen med hörselnedsättning understryker behovet av interprofessionellt omhändertagande. Utöver regelbundna audiologiska kontroller, som löpande utvärderar förändringar av hörseln för att optimera hörsel-

villkoren, måste språkliga och kommunikativa förmågor utvärderas. Om den språkliga förmågan är påverkad bör riktad logopedisk intervention ges för att förbättra fonologisk förmåga och ordförråd för att därigenom motverka svårigheter med läs- och skrivinlärning, eller för att instruera i användningen av fråge- och svarsstrategier och icke-verbala signaler som stöd under samtal. Denna behandling måste åtföljas av anpassningar i pedagogiken för att befästa samma aspekter. Det är emellertid av största vikt att behandlingen aldrig ges rutinmässigt eller utan individanpassning. Eftersom många studier konstaterar betydande språkliga svårigheter hos endast ungefär halva gruppen av barn och ungdomar med hörselnedsättning finns annars en risk att den del av gruppen som har normal språklig utveckling möts av sänkta krav, färre utmaningar och alltför förenklat språk från omgivningen.

Vidare måste den ökade användningen av blick under samtal beaktas i undervisningssituationen. Med pedagogik som alltmer förespråkar samspel mellan elever med utgångspunkt i uppgifter som ska lösas i par eller mindre grupper bör lärare och elever göras uppmärksamma på effekterna av en hörselnedsättning, och hur andra kommunikativa uttryck än de talade kan användas för att underlätta för elever med hörselnedsättning. I fortsatta studier ska användbarheten av nonordsrepetition som klinisk markör för språkstörning hos barn och ungdomar med hörselnedsättning utredas.

# Sensorineural hearing impairment

Sensorineural hearing impairment (SNHI) is a complex condition, with medical, communicative, social, and even cultural consequences. In SNHI, cochlear and/or auditory nerve dysfunction impairs the conversion of motion energy (propagated from the tympanic membrane by the bones in the middle ear) to electric nerve impulses. The consequence is a reduced, distorted, or absent signal to be interpreted by the auditory cortex. The location of the dysfunction and the tonotopic organization of the auditory periphery (in which hair cells selectively respond to stimulation on different frequencies) determine the individual audiologic profile. SNHI is a condition separate from conductive hearing impairments, in which transient or permanent dysfunction blocks the flow of sound through the outer or middle ear. Whereas conductive hearing impairments are often medically or surgically treatable, no cure is available for SNHI.

## Etiology

A distinction is made between congenital and acquired SNHI. Genetic and environmental factors contribute approximately equally to congenital SNHI. More than

half of children born with SNHI have inherited the condition (Smith, Bale, & White, 2005). However, congenital SNHI is equally likely to be caused by fetal infections (for example, rubella, cytomegalic, and herpes simplex viruses), prematurity or perinatal trauma (for example, asphyxiation). Vaccinations and improved health care have led to a decline in impairments with infectious etiology, instead increasing the relative contribution of genetic impairments (Smith et al., 2005), and our knowledge of the genetic causes of SNHI is growing (Dahl et al., 2006). Acquired SNHI in infants and younger children is also often the result of infectious disease, most commonly bacterial meningitis, whereas noise related damages increasingly contribute in middle childhood and adolescence (Smith et al., 2005).

## Identification and intervention

Sweden, and many other countries, has introduced hearing screening of all newborns (evaluating the otoacoustic emissions generated by activity in the outer hair cells), providing a first indication of a possible hearing impairment within the child's first days of life. Together with



other objective auditory measures, for example, auditory brainstem response, and auditory steady-state response, this enables early intervention beneficial for language development (Moeller, 2000; Yoshinaga-Itano, Coulter, & Thomson, 2001; Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998). More detailed audiologic evaluation must await subjective testing, in which the child provides an overt response, for example, pressing a button when presented with a stimulus sound. Hearing acuity is typically measured as the better ear average pure-tone hearing threshold across the frequency range critical for perceiving speech (0.5-4 kHz; ISO 8253-1, 2010; WHO, 2013). By measuring the difference in hearing thresholds between air conduction (listening through earphones) and bone conduction (perceiving sound vibrations through the skull), the audiologist differentiates between conductive and sensorineural impairments.

Audiologic testing will determine the extent of the impairment, and also clarify which type of intervention is likely to be most beneficial. The intervention varies depending on the degree of the impairment (see Concepts below). For children with mild-to-moderate bilateral impairments, the combination of hearing aids, hearing assistive technology systems, and counselling is often recommended. Children with severe-to-profound impairments are evaluated further regarding candidacy for cochlear implantation and preferred mode of communication. Given the genetic contribution to the con-

dition, consideration is taken to the communication mode of other family members.

## Prevalence

Estimates of prevalence differ greatly depending on the degree of the impairment and the samples studied. From studies of clinical samples (that is, studies of children known to audiologic services, for example, using hearing aids) reported prevalence is low, approximately 0.1-0.3 percent (Fortnum, Summerfield, Marshall, Davis, & Bamford, 2001; Sehlin, Holmgren, & Zakrisson, 1990; Vartiainen, Kemppinen, & Karjalainen, 1997). In the Swedish annual cohort of 100 000 newborns these rates translate to 200 children, of which approximately 55 are candidates for cochlear implantation (SBU, 2006). In contrast, epidemiological studies estimating the prevalence in larger, representative population samples, report the rates for slight-to-mild impairments alone to be approximately 1-3 percent (Bess, Dodd-Murphy, & Parker, 1998; Niskar et al., 1998; Wake et al., 2006), and 5 percent if unilateral impairments are included (Bess et al., 1998). This range of prevalence exceeds that of, for example, autism, and approaches those of attention-deficit/hyperactivity disorder, dyscalculia, and dyslexia (Butterworth & Kovas, 2013). Furthermore, the discrepancy in prevalence between clinical and population samples indicates that a large proportion of chil-

dren with SNHI are at risk of not receiving intervention (Wake & Poulakis, 2004).

Audiologic diagnostics determine the extent of the impairment. Audiologic intervention ranges from counselling for mild impairments, via hearing aids and hearing assistive technology systems for moderate-to-severe impairments, to cochlear implantation with or without spoken language as the main mode of communication for severe-to-profound SNHI. Cross-disciplinary collaborations help manage sequelae of the impairment.

## Summary

SNHI is a lasting damage to the cochlea and/or cochlear nerve, reducing, distorting, or preventing auditory sensation.

## Concepts

### *Degrees of hearing impairment*

BEHL 0.5-4 kHz	10 dB HL	Normal	Normal	Normal
	25 dB HL	Slight		Mild
	40 dB HL	Mild	Slight	Mild
	55 dB HL	Moderate	Moderate	Moderate
	70 dB HL	Moderately severe		
	90 dB HL	Severe	Profound	Severe
		Profound		Profound

ASHA (Clark, 1981) WHO (WHO, 2013) EU working group (Stephens et al. 1996)

Degrees of hearing impairment according to the recommendations of the American Speech-Language-Hearing Association (Clark, 1981), the World Health Organization (WHO, 2013), and the European working group on the genetics of hearing impairment (Stephens, Read, & Martini, 1998). All classifications are based on average better ear hearing level (BEHL) measured at 0.5, 1, 2, and 4 kHz.

# Language and cognition in SNHI

Despite regular assessments and appropriate audiologic intervention, children with hearing impairment are at an increased risk for cognitive and linguistic impairments. Importantly, the level of language problems exhibited is not easily predicted from audiologic data, for example, degree of hearing impairment, or even age at identification and amplification (although earlier identification of course enables earlier intervention). The large individual variability in outcome stresses the need for careful investigation of the child's cognitive and linguistic skills in order to identify those who – beyond audiologic intervention – would benefit from speech and language services. This chapter reviews some of the research on the language development of children with SNHI, focusing on studies of children with mild-to-moderate impairments (that is, better ear pure tone average between 26 and 55 dB HL), comparable in degree to the population studied in the present thesis (papers 3 and 4).

## Vocabulary

A large body of research on the lexical development of children with SNHI has produced similar, yet not identical, find-

ings. Even the mildest hearing impairments have been shown to have adverse effects on vocabulary development (as well as on non-linguistic skills and academic achievements; Bess et al., 1998; Davis, Elfenbein, Schum, & Bentler, 1986; Wake, Hughes, Poulakis, Collins, & Rickards, 2004). However, not all children with SNHI appear to suffer these consequences (Gilbertson & Kamhi, 1995; Lederberg, Prezbindowski, & Spencer, 2000). In a study of novel word learning in 8-10 year-old children with SNHI, Gilbertson and Kamhi (1995) tested acquisition and retention of novel word forms, as well as receptive and expressive vocabulary, and phonological processing. Whereas half of the children with SNHI were found to acquire novel word forms similarly to their normal hearing peers, the authors found the subgroup performing low on the novel word learning task (those needing more exposures to acquire the novel word forms, and exhibiting greater difficulties identifying the new words) to also suffer delays on other linguistic measures. The novel word learning was tightly linked to receptive vocabulary, such that a larger vocabulary facilitated additional growth (Gilbertson & Kamhi, 1995; for similar findings in typical vocabulary development, see Gray, 2004). Similar results were presented by Stelmachowicz,

Pittman, Hoover, and Lewis (2004) who found receptive vocabulary to be the best predictor of novel word learning in 6-9 year-olds with SNHI, with significant contributions also from stimulus presentation level (higher dB better) and number of repetitions (more is better). In contrast to the findings of Gilbertson and Kamhi (1995), Stelmachowicz et al. (2004) found no support of a subgroup of children with hearing impairment performing on par with peers with normal hearing, nor did a follow-up study find improvement of novel word learning from increased frequency bandwidth (that is, a signal allowing clearer detection of high pitch phonemes, for example, /s/; Pittman, Lewis, Hoover, & Stelmachowicz, 2005). Studies using parent reports of both expressive (Mayne, Yoshinaga-Itano, Sedey, & Carey, 1998) and receptive vocabulary (Mayne, Yoshinaga-Itano, & Sedey, 1998) have confirmed a delayed vocabulary development among children with mild-to-moderate SNHI. Lederberg, Prezbindowski, and Spencer (2000) investigated the reason for the delay and found children with moderate-to-profound hearing impairment to exhibit normal inferential behavior (for example, mapping a novel word with a novel object rather than with a familiar one). However, a subgroup of the children with SNHI needed more instruction for doing this, and exhibited the behavior a year later than their normal hearing peers (Lederberg et al., 2000).

Hansson, Forsberg, Löfqvist, Mäki-Torkko, and Sahlén (2004) found 9-12

year-old children with mild-to-moderate SNHI to outperform same-age peers with Specific Language Impairment (SLI; see Concepts below) on novel word learning. The ability to acquire novel words was best predicted by working memory capacity, and was found not to be related to degree of hearing impairment. In a comparison of a younger sample from the same subject populations, Sahlén and Hansson (2006) failed to find the same difference in novel word learning between children with SNHI and SLI, but again found no relation between novel word learning and degree of hearing impairment. For both groups, aspects of lexical ability provided the best prediction of novel word learning, with receptive vocabulary being the strongest predictor among the participants with SLI, and auditory associations (a measure of lexical organization and retrieval) providing the best prediction for the children with SNHI (Sahlén & Hansson, 2006). Replicating earlier findings (Gilbertson & Kamhi, 1995; Lederberg et al., 2000), Sahlén and Hansson (2006) also found a subgroup of children with SNHI meeting the linguistic criteria of a diagnosis of SLI.

## Phonology

With a known effect on vocabulary development (Gathercole, Willis, Emslie, & Baddeley, 1992), a number of studies have examined deficits in phonological processing as a possible origin of the delayed vocabulary development of chil-

dren with SNHI. Many studies show consistent results. From mild to profound impairments, children with SNHI perform below age norms on phonological sensitivity (for example, identification and manipulation of speech sounds) and phonological short term memory (often assessed with nonword repetition, that is, repetition of phonologically plausible, yet non-existent, nonsense words; Briscoe, Bishop, & Norbury, 2001; Sahlén, Hansson, Ibertsson, & Reuterskiöld Wagner, 2004; Wake et al., 2006; Wass et al., 2008). In an epidemiological sample of 6240 elementary school-age children, Wake et al. (2006) found 55 children (0.88 percent) with bilateral, mild-to-moderate SNHI. These children performed significantly below peers with normal hearing on aspects of phonological processing – including nonword repetition, phonological discrimination (distinguishing between two speech sounds in minimal word pairs), and phonological awareness (for example, finding rhyming words) – yet exhibited age-appropriate levels on, for example, receptive and expressive language, and reading (Wake et al., 2006). Similar conclusions had previously been reached by Briscoe et al. (2001) and Sahlén et al. (2004) in studies of 5-10- and 9-12 year-olds, respectively. The children with SNHI performed below age norms, and even on par with children with SLI (Briscoe et al., 2001), on phonological short term memory, phonological discrimination, and phonological awareness, again without apparent consequences on literacy development (Briscoe et al., 2001; Sahlén et al., 2004). The dissociation between phonological

skills and general language ability in children with SNHI indicates differences in the relative contribution of phonological ability during language development, compared to children with normal hearing.

## Grammar

In a study of 11-15 year-olds, Delage and Tuller (2007) investigated whether a normalization of the language ability can be expected over the course of development. Also within this age range, phonological impairment, as well as problems with grammar (morphosyntax), were significant. However, the authors found no support for more general language abilities (oral comprehension, lexical and grammatical judgment, and literacy) being affected. In contrast to most other studies, Delage and Tuller (2007) found a relation between the degree of hearing impairment and the severity of the linguistic symptoms. The authors suggested this to be an effect of the age range, with larger individual differences in linguistic profiles obscuring the effect of the hearing impairment at younger ages. Similarly to previous studies (Gilbertson & Kamhi, 1995; Lederberg et al., 2000; Sahlén & Hansson, 2006), Delage and Tuller (2007) found half of the participants with SNHI to perform particularly low (below  $-1.65 SD$ ), whereas the other half performed within the normal range. Although the prevalence is far too high for simple comorbidity, the authors concluded that a subgroup of children with SNHI exhibit a language impairment

(Delage & Tuller, 2007). However, sharing symptoms (for example, deficits in phonological processing) does not necessarily entail sharing etiology or outcome. A more accurate estimate of the consequences of the hearing impairment must take into account the input to the child (for example, qualitative and quantitative differences are seen in caregiver input to siblings with and without language impairment; Conti-Ramsden, Hutcherson, & Grove, 1995), and evaluate possibly intervening factors in the child, not as likely as linguistic skills to be affected by the degree of hearing impairment (for example, cognitive ability and executive functioning; Blamey et al., 2001).

Whereas Delage and Tuller (2007) found children with SNHI to exhibit grammatical deficits, other studies have not. Norbury, Bishop, and Briscoe (2001) investigated the production of finite verb morphology in 5-10 year-old children with SNHI, SLI and typical language development. On a group level, the children with SNHI outperformed children with SLI, and did not differ from typically developing peers. However, 22 percent of the children with SNHI, the youngest in the group, displayed problems equivalent to those seen in the children with SLI with respect to marking the verb for English third person and past tense. The authors concluded that the hearing impairment was, indeed, a risk factor for a delayed grammatical development. However, the impact on grammar was not as great as on phonological discrimination, leading to the conclusion that the problems with

grammar could, in fact, be the consequence of reduced phonological short term memory capacity (Norbury et al., 2001).

## Cognition

Several studies have investigated the effect of various cognitive abilities on the impact of a hearing impairment. Working memory capacity (see Concepts below) has been extensively investigated for its role in vocabulary development (see, for example, Gathercole & Baddeley, 1993). As previously described, working memory capacity (as measured by tasks tapping simultaneous judgment of the semantic acceptability of sentences and recall of the last words) was the best predictor of novel word learning in Hansson et al.'s (2004) study of 9-12 year-old children with SNHI, such that children with better working memory capacity learned more novel words. The authors also found a significant correlation between working memory capacity and receptive vocabulary size (Hansson et al., 2004). In a study of 6-9 year-old children, Stiles, McGregor, and Bentler (2012) investigated whether the smaller receptive vocabularies seen in many studies of children with hearing impairment are caused by a reduction in working memory capacity, in the Stiles et al. study assessed within the Baddeleyan model with tasks tapping the phonological loop (forward digit span, sequential encoding, articulation rate) and the central executive (backward digit span, recall in noise conditions). Again, Stiles et al. (2012)

confirmed smaller receptive vocabularies among the participants with SNHI. However, these deficits were not explained by differences in working memory capacity. The children with SNHI performed on par with peers with normal hearing on working memory tasks and also exhibited an auditory advantage, yielding better spans for stimuli presented in the auditory than in the visual modality, an advantage generally considered to indicate an active role of the phonological loop in memory encoding (Stiles et al., 2012). A group difference was, however, found on a test of articulation rate. Articulation rate provides an estimate of the amount of verbal information possible to keep in subvocal rehearsal, and a reduced rate has been associated with limited processing capacity in children with severe-to-profound hearing impairment and cochlear implants (Pisoni & Cleary, 2003). In the laboratory setting, Stiles et al. (2012) also found no reduction in working memory capacity in the presence of background noise. Taken together, the results of Hansson et al. (2004) and Stiles et al. (2012) indicate similar contributions of working memory to language development in children with and without hearing impairment. The authors of both studies conclude that the deficits in vocabulary often reported for children with SNHI are unlikely to be solely caused by a reduction in working memory capacity. However, as stated by Stiles et al. (2012, p.166), recognition of the language problems exhibited by children with SNHI requires additional research to determine under which conditions language learning might be im-

peded. On the other hand, the developmental trajectory of children with SNHI may be beyond exhaustive description (as suggested for SLI by Corriveau, Pasquini, & Goswami, 2007). Complex interaction between the auditory deficit, the interplay between phonology, vocabulary, and syntax during development, and social cognition and environmental factors, contributes to great heterogeneity among children with SNHI and makes an accurate prediction of the language outcome challenging. The present thesis investigates the performance of children with SNHI using a referential communication task requiring not only language skills, but a broader range of executive functions and perspective-taking involved in communication.

## Summary

The language development of children with mild-to-moderate SNHI has repeatedly been shown to depart from the typical trajectory. Several studies find approximately half of children with SNHI to exhibit substantial language problems. Evidence is converging on vocabulary as a particularly vulnerable area, indicating deficits in phonological processing as the underlying cause, whereas uncertainties remain regarding grammatical development. Numerous factors likely contribute to the heterogeneity in language outcome; intrinsic (for example, cognitive ability) and extrinsic (for example, adequacy of audiologic and linguistic intervention, quality and quantity of linguistic input, feedback, and teaching), as well as

compensatory strategies drawing on aspects from both.

## Concepts

### *Specific Language Impairment (SLI)*

SLI is the clinical diagnosis of deficient child language development in the absence of apparent cause. The disorder may affect the language form (phonology, grammar), content (semantics), or use (pragmatics), of a child with normal non-linguistic abilities, neurological development, hearing, and language input (Bishop, 2006). Similarities in the language profiles of the groups make the theoretical framework of SLI applicable for identifying clinical markers and understanding the language symptoms of children with SNHL.

### *Working memory*

Two dominant models of working memory have been presented; Baddeley and Hitch's (1974) multicomponent model (revised in Baddeley, 2000), and Daneman and Carpenter's (1980) capacity theory of comprehension. Baddeley (2000) describes a system of limited capacity for simultaneous processing and storing of information. The model consists of three subsystems; the phonological loop (retaining and processing speech material for a short period of time, approximately 2 seconds), the visuospatial sketchpad (holding and processing visual and spatial information), and the episodic buffer (binding information in a multimodal code from the phonological loop, the visuospatial sketchpad, and long-term memory). A central executive component is in charge of the flow of information in working memory. It controls allocation and coordination of resources, directs attention to relevant features and inhibits attention to irrelevant ones.

Whereas Baddeley (2000) considers storage and processing as separate processes, not sharing the same mental resources, the capacity theory of comprehension (Daneman & Carpenter, 1980) suggests the capacity of the working memory to be a trade-off between the two. An accurate estimate of working memory capacity requires tasks that simultaneously tap storage and processing, for example, assessing the acceptability of sentences while recalling the last words.



# Communication and pragmatic ability

The primary purpose of our language ability is communication, that is, to interact with the people around us, to state our wants and needs and respond to those of others. Language ability, at least narrowly defined as the capacity to form linguistically coherent messages, is, however, merely one tool necessary for successful communication. This chapter briefly summarizes how verbal (here, speech) and nonverbal (gaze, gestures) modalities are integrated with contextual factors (for example, the topic of conversation, and influences from the conversational partner) to shape our communicative ability.

## Pragmatics

Communication refers to a wide concept of mutual sharing of ideas and influences between individuals (Nettelbladt & Salameh, 2013). In part, communication is covered by pragmatic ability, that is, the appropriate use of language in a particular setting. Different theoretical perspectives (for a summary, see Perkins, 2007) consider pragmatics to be either the third part of the language ability (alongside linguistic form and content) or inseparably interwoven with all linguistic domains (and perhaps even underlying

language development itself, with the need to communicate driving the evolution of language). Of central importance to the latter view is the notion of interpersonal, or dialogic, influence, stating that complete understanding of communication will not be reached by studying only one of the interlocutors, or without taking into account contextual factors (Nettelbladt & Salameh, 2013; Perkins, 2007). A challenge for either view is clinical evidence of a dissociation between language and pragmatic ability, as evidenced by aphasic patients sometimes still able to communicate well using gestures and mimicry, or, conversely, individuals with autism spectrum disorders exhibiting great difficulties communicating despite adequate linguistic ability (Perkins, 2007). This evidence points to the theoretical and clinical importance of examining the numerous sources of information used in interaction between individuals.

## Perspective-taking

Adaptation to the perspective of the communicative partner can be seen as a pragmatic ability (Nettelbladt & Salameh, 2013). This perspective-taking, related to theory of mind (see Concepts below), has

been observed in children as young as two to three years of age (Akhtar, Carpenter, & Tomasello, 1996; Perner & Leekam, 1986). However, despite exhibiting the ability under experimental conditions, children still fail to utilize the capacity for communication several years later. The perspective-taking ability appears dependent on task demands and inhibitory control. Nilsen and Graham (2009) investigated perspective-taking during conversation in 3-5 year-old children, studying the child's ability to adapt to the partner's perspective. When asked to describe objects, differing in size and color, either visible to both speaker and listener, or only to the speaker, the children were shown to tailor their description differently depending on whether the objects were visible to the listener or not. For example, referring to an object as 'the big duck' is unnecessary when the child can see that 'the small duck' is obscured from the listener's view. Similarly, in the role of listener, eye movement data showed that the children did not equally consider both 'ducks' but instead paid more attention to the one visible to the speaker, when presented with a description referring to 'the duck' (Nilsen & Graham, 2009; see also Nadig & Sedivy, 2002). The perspective-taking ability was linked to inhibitory control, as measured by the ability to inhibit naming object colors and instead provide a learned label, a finding previously produced by others (Carlson, Moses, & Claxton, 2004; Hala, Hug, & Henderson, 2003). According to the authors, communication poses similar demands, requiring inhibition of the own perspective in favor of taking the perspective of the

partner (Nilsen & Graham, 2009). Others argue for additional demands on working memory capacity in order to simultaneously combine the own view with that of the partner (Davis & Pratt, 1995; Gordon & Olson, 1998). As stated by Brennan and Hanna (2009), the mutual benefits of taking into account the perspective of the partner are likely to outweigh the additional cognitive demands. However, perspective-taking is not a static ability, it varies depending on the demands on working memory and inhibitory control, as shown by an increase of egocentric interpretations in more demanding communicative situations (Nadig & Sedivy, 2002).

The Nilsen and Graham (2009) study provides an example of how contextual cues (the partner's visual perspective) guide the child to make relevant descriptions and interpretations. Other studies, mostly on adult participants, and often drawing on eye movement data, have shown that similar adaptations to the production and interpretation of messages are made from knowledge of the partner's physical constraints (only searching for requested objects outside the reach of the speaker; Hanna & Tanenhaus, 2004), and preexisting knowledge about the world (Kamide, Altmann, & Haywood, 2003). Hanna and Brennan (2007) looked more specifically at how the actual gaze direction of the partner influenced interpretation. The authors showed gaze direction to influence interpretation (choosing the right object), even to the point of allowing the listener to make the

judgment in advance of the spoken description. Similarly, Macdonald and Tatler (2013) found that listeners, following instructions to build a model, used information from the partner's gaze direction to find the right building block, however, only when the verbal description lacked sufficient detail. Also speakers react to nonverbal information, continuously monitoring the listener's reaction (gaze, gestures) to prevent misunderstanding (Clark & Krych, 2004).

Studies of pragmatic ability and perspective-taking in children with hearing impairment are sparse. A study by Most, Shina-August, and Meilijson (2010) provides an exception, investigating aspects of pragmatic ability of 6-9 year-old children with severe-to-profound hearing impairment (using hearing aid/s and/or cochlear implant/s) from video recorded spontaneous conversation with a speech-language pathologist. Although not consistently impaired, the children with hearing impairment showed particular problems continuing the topic of the partner, and adding relevant information. Most et al. (2010) argued that the problems observed in the children with hearing impairment are attributable a delayed language development, limited exposure

to various pragmatic behaviors due to limited input, and consistent with limited perspective-taking. Compatible with a delayed language development, Toe and Paatsch (2010) presented results showing 7-12 year-old children with mild-to-profound hearing impairment to request repetition and clarification of questions to a significantly higher extent than peers with normal hearing, results corroborating those for adolescents with profound SNHI and cochlear implants reported by Ibertsson, Hansson, Mäki-Torkko, Willstedt-Svensson, and Sahlén (2009).

## Summary

Efficient communication relies on more than the exchange of spoken messages. Interlocutors continuously merge the verbal message with information gathered from the partner's field of vision, gaze direction, and gestures, as well as knowledge about the world, the context, and the topic of conversation. This requires efficient use of linguistic, cognitive, and socio-cognitive resources. A hearing impairment may lead to misallocation of resources, and an increased risk of pragmatic difficulties.

## Concepts

### *Theory of mind*

Theory of mind refers to the ability to attribute thoughts, beliefs, and feelings to ourselves and others, and the knowledge that others may have mental states which differ from our own. Theory of mind is necessary for understanding and predicting the behavior of others, and considered a cornerstone of pragmatic ability. Many factors are likely to contribute to the development of theory of mind, including, exposure to communication and language, joint attention, and pretend play (Dahlgren Sandberg & Dahlgren, 2011).

Evaluation of theory of mind often involve false-belief tasks. In one version of the task, a child is asked what's inside a Smarties box, shown that the Smarties box actually contains pencils, and then asked what other children will think is inside the Smarties box. Typically, children younger than approximately three and a half years will fail false-belief tasks (Perner & Lang, 1999).

# Referential communication

The present thesis uses a modified version of Glucksberg and Krauss's (1967) referential communication task, an experimental paradigm tapping the communicative ability used in everyday activities such as giving instructions, describing things or events to a listener, and asking questions. In a referential communication task, the speaker is provided with an array of referents (pictures or physical objects), arranged in a predetermined pattern. Typically, the speaker's task is to describe each picture/object, and its position, to enable the listener to arrange his/her array in the same way. Referential communication tasks allow investigation of the participants' ability to produce (when in the 'speaker' role) and perceive (when in the 'listener' role) spoken messages. More specifically, the task seeks to investigate whether the speaker can form contextually relevant messages, providing the listener with necessary, yet non-redundant, information. The listener is evaluated on the ability to detect and resolve ambiguities through his/her use of questions. If, for example, the speaker describes a picture of a face as "It's a man with a beard" this would provide sufficient information if all other referents lacked these characteristics. However, if the competing referents were all men

with beards the listener would have to request additional information, for example "Is he wearing glasses?"

Many studies have remained faithful to the paradigm described by Glucksberg and Krauss (1967), for example, preventing visual exchanges between the conversational partners, and scripting any comments from the listener, for example, questions necessary to disambiguate the referent. While such measures provide a rigorously controlled experimental condition – which, admittedly, is hard to find in studies of conversation – the 1967 paradigm has been subjected to criticism for over-restricting the interaction. As a consequence, subsequent studies – including the present one – have often adapted the task, for example, allowing eye contact and free, unscripted flow of conversation, and varying the choice and number of referents to suit the sample studied, in an attempt to make the task more ecologically valid.

## Required skills

Referential communication requires several abilities. Of course, a basic level of linguistic skills is necessary, including

phonology, syntax, and vocabulary (Bishop & Adams, 1991). However, successful completion of the task requires more than simply producing and perceiving language, as shown by children with SLI outperforming younger children matched for language ability (Meline, 1986), and even performing on par with children with typical language development (Reuterskiöld Wagner, Nettelblatt, & Sahlén, 2001). The linguistic information must be processed and maintained until a referent has been chosen, requiring cognitive processes and working memory capacity, the demands on which are likely to vary depending on the description provided (Dahlgren & Dahlgren Sandberg, 2008). Finally, in order for the speaker to provide an adequately detailed description, and for the listener to adjust his/her questions appropriately, the interlocutors must be able to take the perspective of the conversational partner.

As the cognitive and linguistic skills involved in referential communication develop with age, so does task performance. Nine-year-olds are better “listeners” than six-year-olds, that is, better at identifying the referents and at requesting additional information, although the age groups are equally good “speakers” when describing referents (Lloyd, Camaioni, & Ercolani, 1995). This developmental trend is attributed to growth in procedural knowledge, pragmatic understanding, and metacognition (Robinson & Whittaker, 1987; Sonnenschein & Whitehurst, 1984). Furthermore, the discrepancy between speaker and listener

skills shows that the abilities, although correlated, do not develop in parallel (Lloyd, Mann, & Peers, 1998).

## Referential communication in atypical populations

Apart from providing details on the trajectory of typical communicative development, studies using referential communication tasks have added to our knowledge on the communicative competence of individuals with a range of disabilities. Bishop and Adams (1991) investigated referential communication of children with SLI, a subgroup of which exhibited additional pragmatic impairment in natural conversation, to that of peers with typical language development. The symptoms of the children with pragmatic impairment, for example, conveying too much or too little information, led the authors to predict greater difficulties with the task, due to problems formulating adequate descriptions (that is, speaker skills). However, despite its demands on adequate encoding of verbal descriptions, the referential communication task could not separate the children exhibiting pragmatic impairment in natural conversation from children with SLI without pragmatic problems. As a group, however, the children with SLI were impaired relative to age-matched controls (Bishop & Adams, 1991). When studying speaker skills, Leinonen and Letts (1997) also failed to separate children with and without pragmatic impairment. However, significant group differences

in listener skills were found. Particularly affected was the ability to detect ambiguities in the speaker's description and request clarification and additional information. As stated by the authors, the reasons for the reduced tendency to request clarification are not easily disentangled, and social (wrongfully taking the blame for the misunderstanding), linguistic (difficulties identifying the information needed, and producing the appropriate question), and socio-cognitive (lack of awareness that clarification may be needed) factors may be in play (Leinonen & Letts, 1997). Referential communication tasks have also confirmed deficits in both speaker (Purvis & Tannock, 1997) and listener skills (Nilsen, Mangal, & MacDonald, 2013) among children with attention-deficit/hyperactivity disorder.

A number of studies have used referential communication tasks to investigate the communicative ability of children with varying degrees of hearing impairment. Arnold, Palmer, and Lloyd (1999) compared the listener skills of 5-9 year-old children with moderate-to-severe hearing impairment to those of normal hearing peers and found the participants with hearing impairment significantly less likely to ask for clarifying information. As a consequence, the children with hearing impairment were less successful in finding the correct referent. Similar results were reported by Lloyd, Lieven, and Arnold (2005) in a study of 8-12 year-olds from the same subject population, who found participants with hearing impairment to perform on par with three-and-a-half years younger children with

normal hearing regarding both speaker and listener skills. The results are indicative of developmental lag, although task related (differences in understanding of the task objectives) or social (again, taking the blame for partner's faulty description) factors should not be ruled out (Lloyd et al., 2005).

In an effort to mimic problem solving among peers in a school setting, Ibertsson et al. (2009) substituted the adult conversational partner with a same-age, normal hearing peer. The authors studied the communicative competence of children and adolescents with profound SNHI and cochlear implants. In contrast to the findings of Arnold et al. (1999) and Lloyd et al. (2005), Ibertsson et al. (2009) showed that the participants with SNHI made significantly more requests for clarification than their normal hearing peers. Several factors may have contributed to differences in the results between the Arnold et al. (1999) and Ibertsson et al. (2009) studies, including participant age (Ibertsson et al.'s participants were teenagers), degree of hearing impairment, technological differences between conventional hearing aids and cochlear implants, and, possibly, a less intimidating conversational setting as an effect of performing the task with a known partner.

## Summary

Referential communication tasks are used to investigate crucial aspects of interaction; the relevance of a speaker's instructions, and the listener's ability to

follow them. Applied to clinical populations, for example, children with hearing impairment, the task can provide valuable information on the child's ability to cope in everyday activities, information not easily extracted from standardized test protocols.



# Gaze behavior

Through its combination of bottom-up reactions and top-down actions gaze constitutes a complex area of investigation. The same eye movements are used to express everything from the involuntary reflex to look at a moving object to the intentional gaze exchanges used to establish joint attention (see, for example, Tomasello, 2008) and to regulate speaking turns in interaction. This chapter focuses on the latter, reviewing research on gaze behavior during face-to-face conversation.

## Gaze behavior of speakers and listeners

The gaze behavior of speakers and listeners has repeatedly been found to be asymmetrical, with listeners looking more at speakers than vice versa (Bavelas, Coates, & Johnson, 2002; Goodwin, 1981; Kendon, 1967; Turkstra, Ciccio, & Seaton, 2003). Turkstra et al. (2003) found listeners to look at the speaker on average 65 percent of the time, whereas speakers looked at the listener 40 percent of a conversation on a scripted topic. The authors pointed out that the figures, collected on adolescents with typical development, should be used as reference val-

ues when working with clinical populations where increased eye contact during interaction may be an objective. For neither of the interlocutors, however, the time spent looking at the partner is evenly distributed over the course of the conversation. In part previously described by Kendon (1967) and Duncan and Fiske (1977), Bavelas et al. (2002) described a ‘gaze window’ during which gaze cues are used to manage turn exchanges, that is, change of the speaker and listener roles. A change of roles is initiated by the speaker who, upon completion of the speaking turn, looks at the listener for a brief moment of eye contact. The listener accepts to take over the speaking turn by rapidly looking away and starting to speak (Kendon, 1967; Duncan & Fiske, 1977), or by providing the speaker with confirmation of understanding and the necessary feedback to continue speaking (Bavelas et al. 2002). These conversational dynamics have been suggested to minimize speaker overlap and gaps in conversation, and hold for a cross-cultural comparison of naturally occurring conversations (Stivers et al., 2009).

Perhaps the clearest example of a change of speaker and listener roles, the production of questions and subsequent answers

has been investigated in relation to gaze behavior. As expected, questions are often produced with gaze to the listener (that is, the person intended to answer; Rossano, Brown, & Levinson, 2009). Furthermore, questions produced with gaze to the listener receive answers more quickly (Stivers et al. 2009).

## Avoiding eye contact

Whereas the contribution of gaze to conversation is clear, the absence of gaze equally adds to the communication. Withholding gaze during the ‘gaze window’ can enable the speaker to keep the speaking turn. However, absence of gaze to the partner also serves personal purposes. According to the cognitive load hypothesis (Glenberg, Schroeder, & Robertson, 1998), gaze aversion serves to reduce the cognitive load by blocking out interfering stimuli. This is shown by people closing their eyes, or looking at an empty spot in the ceiling, away from the conversational partner, when asked a difficult question, during memory or word retrieval, or during linguistic planning. Gaze aversion has been shown to increase with the complexity of the question (Doherty-Sneddon & Phelps, 2005). Furthermore, gaze aversion appears to be trainable. Phelps, Doherty-Sneddon, and Warnock (2006) instructed 5-year-olds to increase their use of gaze aversion and, as a consequence, found that these children managed more complicated questions than a control group receiving no instructions in gaze aversion.

## Gaze behavior in hearing impairment

Skelt (2006) conducted a detailed analysis of the gaze behavior of adults with severe-to-profound hearing impairment, a population often described to be more dependent on visual cues than individuals with normal hearing. In conversations with family members or their audiologist, the participants were found to exhibit qualitatively similar gaze patterns to those described by Turkstra et al. (2003), but showed higher rates of gaze to the speaker when listening, and lower rates of gaze to the listener when speaking. Furthermore, Skelt (2006) could show how the participants with hearing impairment were able to control the changes of speaker and listener roles in the conversation through use of gaze initiations and gaze withdrawals. Increased levels of gaze to the speaker when listening fit with theories of visual cues as a way to compensate for reduced hearing (Blamey et al., 2001), whereas decreased levels of gaze to the listener when speaking could be interpreted as a way to manage the higher cognitive and linguistic demands posed by the task on participants with hearing impairment (Doherty-Sneddon & Phelps, 2005).

## Summary

Gaze exchanges are fully integrated in the production and perception of messages in face-to-face interaction. A gaze

at the conversational partner at key moments of an interaction can signal the end of a speaking turn and the readiness of the partner to continue speaking. Conversely, the absence of gaze can signal

unwillingness to relinquish the speaking turn or the need for an extra moment to find the right word or answer to a question.

# Present investigation

The overall aim of this thesis was to explore the interaction of children and adolescents with hearing impairment performing a referential communication task. The common denominator of all papers was the verbal and nonverbal contributions to the interaction, emphasizing verbal questions and answers (paper 1), gaze behavior in relation to the verbal production (papers 2 and 3), and the cognitive and linguistic factors influencing the gaze behavior (paper 4). This chapter presents the aims and main results of each paper.

## Paper 1

Earlier doctoral work from the Dept. of Logopedics, Phoniatics, and Audiology (Ibertsson, 2009) has shown that the use of questions in children and adolescents with profound hearing impairment and cochlear implants, engaged in a referential communication task, differs from that of peers with normal hearing. In particular, the participants with hearing impairment used requests for confirmation (that is, yes/no questions) to a higher extent, a finding interpreted as a strategy used to

gain a greater control of the conversation by limiting the number of possible responses from the partner. Paper 1 expands on this finding by exploring the compliance of the answer with the preceding question, thus investigating the usefulness of yes and no questions as a way to control the course of the conversation.

Paper 1 recruited thirteen children and adolescents (11;9 to 19;1 ys, mean age 15;1 ys) with profound SNHI and cochlear implants – all oral speaking at home and in school, and performing to age norms on non-linguistic tasks – to perform a referential communication task with a same-age partner of their own choice. The results were compared to those of a normal hearing control group, matched for age and gender to the participants with SNHI. The participants were given a referential communication task in which the speaker describes pictures of faces to the listener who, in return, must request additional information in order to solve the task quickly and efficiently. Analyses compared the number and distribution of the main types of questions and answers (see Table 1).

Table 1. Types of questions and answers.

<i>Answers</i>	<i>Questions</i> Request for confirmation of new information	Request for confirmation of old information	Request for elaboration
	<i>Has she got blue eyes?</i>	<i>Did you say she had blue eyes?</i>	<i>What color are her eyes?</i>
Confirmation	Yes (, she has blue eyes)	No (, she hadn't)	-
Elaboration	Yes, and glasses and blond hair	Yes, and a black beret	She has blue eyes

Replicating earlier findings (Ibertsson et al., 2009), participants with hearing impairment were found to ask significantly more questions than peers with normal hearing. Similar overall distributions of request types across groups were found, with requests for confirmation in sum representing approximately 85 percent of requests. Confirmatory responses were found to be less frequent, representing only 55 percent of responses. Conversely, requests for elaboration represented less than 10 percent of requests, although the proportion of elaborated responses was approximately 40 percent. Together the results indicated that the type of question did not reliably control the answer from the partner, thus disproving choice of requests as an effective strategy to control the conversation. The addition of unrequested information to the response was interpreted as an anticipation from the speaker of subsequent questions from the listener, available within a well-defined task with clear objectives for both interlocutors.

To the thesis, paper 1 added methodological knowledge on the applicability of referential communication to investigate alignment of questions and answers. Furthermore, the similarities in question and answer distributions across participant groups suggested further investigations of the interactional ability of children with hearing impairment to include analysis of nonverbal aspects of face-to-face conversation, for example, gaze and gestures.

## Paper 2

Paper 2 added eye tracking to the referential communication paradigm and investigated the relation between the listener's gaze behavior and verbal productions. Drawing on research on the use of visual cues for guiding speech production (for example, Nadig & Sedivy, 2002; Nilsen & Graham, 2009) and interpretation (Hanna & Brennan, 2007; Macdonald & Tatler, 2013; Nilsen & Graham, 2009), as well as knowledge on

how gaze exchanges between interlocutors are used to manage turn-taking in conversation (Bavelas et al., 2002; Miranda, Donnellan, & Yoder, 1983), analyses focused on gazes to the conversational partner at the point in time of verbal production.

With its exploratory aim, using novel methodology and techniques, paper 2 recruited eight children with normal hearing (10;11 to 15;4 ys, mean age 14;3 ys) to perform the referential communication task with a same-age, same-sex partner of their own choice. Participants were fitted with mobile eye tracking equipment,

monitoring gaze focus for the duration of the conversations. Figure 1 shows a sketch of the experimental setting. Gaze to three areas of interest were computed: Task (the pictures of faces), Face (the speaker's face), and Off (elsewhere). Furthermore, time course analysis investigating changes in gaze focus as a function of the verbal production of different utterance types (questions, statements, back channeling, as well as when listening silently to the partner) was conducted, calculating the probability of gaze to the speaker's face within a 3000 millisecond analysis window, centered at the onset of the utterance production.

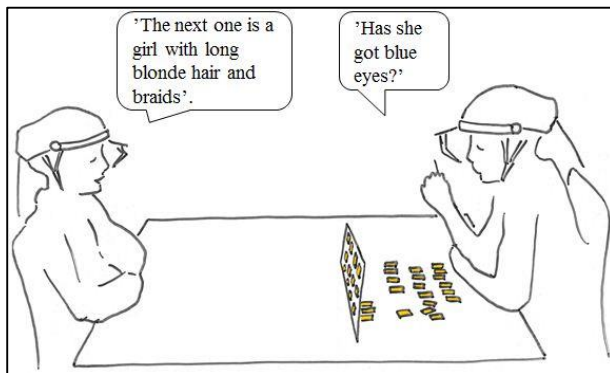


Figure 1. Sketch of the experimental setting showing the speaker (left) describing pictures of faces, and the listener (right) requesting additional information.

Results showed a significant increase in the probability of gaze to the speaker's face for questions (that is, requests for confirmation of new information, requests for confirmation of old information, and requests for elaborations) as compared to statements, supporting a hypothesis that turn shift is associated with

gaze-to-partner. Back channeling, contrasted to a baseline of silent listening to the partner, was associated with a decreased probability of gaze-to-partner, a finding interpreted as a complementary use of visual and verbal modalities. Furthermore, a detailed analysis of the effect on gaze-to-partner of requests for confir-

mation of new and old information, respectively, revealed a higher probability of gaze-to-partner for the former. Together, the results of paper 2 confirmed a relation between the verbal production and gaze behavior, suggesting increased rates of gaze-to-partner as a way to monitor the speaker's answer with two modalities.

Paper 2 contributed reference values on the gaze behavior of children with normal hearing in referential communication to be used in subsequent studies on children with hearing impairment. The paper also led to the development of new data analysis procedures and software (Andersson & Sandgren, submitted).

## Paper 3

Building on the results from paper 2, paper 3 investigated gaze behavior in relation to verbal production in participants with hearing impairment, a population often reported to use visual cues more than peers with normal hearing (Skelt, 2006), and more often exhibiting language delay (Hansson et al., 2004; Moeller, 2000; Wake et al., 2004; Yoshinaga-Itano et al., 1998). Increased use of visual cues in children with hearing impairment has been suggested as a compensation for the degraded auditory input, aiding language processing and comprehension (Blamey et al., 2001), a suggestion supported by findings of improved speech perception for audio-visual speech over speech presented auditorily only (Woodhouse, Hickson, & Dodd, 2009). As in paper 2, analyses focused on the probability of gaze-to-partner during production of questions, statements, and back channeling, as well as when listening to the partner. Table 2 presents examples and group data on the utterance types used in the analyses.

Table 2. Verbal event types, descriptions, examples, and distribution.

Verbal event type	Description	Example	<i>n</i> (SNHI)	<i>n</i> (NH)
Requests	Questions	'Has she got blue eyes'? 'What color are her eyes'?	288	254
Non-requests	Statements	'He looks a bit like your dad'	176	309
Back channeling	Feedback	'Uh-huh', 'Mhm'	269	165
Listening	Partner speaking	-	745	740
<b>Total <i>n</i></b>			<b>1478</b>	<b>1468</b>

Paper 3 recruited ten children and adolescents (9;8 to 15;10 ys, mean age 12;4 ys) with mild-to-moderate, bilateral and symmetric, sensorineural hearing impairment (mean better ear pure-tone average 33.0 dB HL). Mean age at identification of the hearing impairment was 3;7 years and mean age at amplification was 5;2 years. The participants invited a same-age classmate with whom to perform the referential communication task. The task data were compared to those of a control group of participants with normal hearing (verified by pure-tone hearing screening at testing), matched for age and gender, also bringing same-age classmates as conversational partners. No significant differences between target and control participants were found on receptive grammar or non-linguistic skills. Change in the probability of gaze-to-partner over the course of the production of different utterance types was estimated with Kaplan-Meier survival analysis and Mantel-Cox log rank tests (estimating and comparing time to gaze-to-partner within the analysis window) and

odds ratios (comparing number of utterances produced with and without gaze-to-partner across groups).

Compared to controls, the children with SNHI exhibited increased probability of gaze-to-partner when asking questions, making statements, providing back channeling, and listening to the partner, as evidenced by reduced survival rates (that is, shorter duration of utterance production before gaze-to-partner) and increased odds ratios (higher proportion of utterances produced with, as compared to without, gaze-to-partner; see Table 3). The results indicated an increased use of visual cues among children with SNHI, on par with normal hearing controls on measures of receptive grammar and non-linguistic skills.

While confirming the hypothesis of an increased use of visual cues among participants with mild-to-moderate SNHI, paper 3 left unresolved the question of the underlying cause of the increased probability.



Table 3. Data and result summary, paper 3.

Verbal event	Group	Cases with event <sup>1</sup>	Censored cases <sup>2</sup>	Odds ratio (95% CI)	$\chi^2$	Log rank <sup>3</sup> <i>p</i>
Questions	SNHI	136	152	<b>1.5 (1.1-2.1)</b>	4.826	<b>.028</b>
	NH	95	159			
Statements	SNHI	71	105	<b>1.7 (1.1-2.5)</b>	6.354	<b>.012</b>
	NH	89	220			
Back channeling	SNHI	107	162	<b>2.1 (1.4-3.3)</b>	11.801	<b>.001</b>
	NH	39	126			
Listening	SNHI	342	403	<b>1.7 (1.4-2.2)</b>	26.881	<b>.000</b>
	NH	242	498			

**Notes:** <sup>1</sup> Number of utterance productions with gaze-to-partner; <sup>2</sup> Number of utterance productions without gaze-to-partner; <sup>3</sup> Mantel-Cox. *p* value for test of group difference in survival distribution between group with sensorineural hearing impairment (SNHI) and controls with normal hearing (NH).

## Paper 4

With other factors than hearing level repeatedly shown to differ between children with and without hearing impairment, paper 4 delved deeper into the findings of paper 3 by investigating group differences in gaze-to-partner while adjusting for individual performance on receptive grammar, expressive vocabulary, complex working memory, and phonological short term memory. In the col-

lected sample, children with hearing impairment were found to perform significantly below controls on phonological short term memory (measured by NWrep; Sahlén, Reuterskiöld Wagner, Nettelblatt, & Radeborg, 1999; Wass et al., 2008) and expressive vocabulary (BNT; Bruswitz & Tallberg, 2010; Kaplan, Goodglass, & Weintraub, 2001), while non-significant differences were found for receptive grammar (TROG-2; Bishop, 2003, 2009) and complex working memory (CLPT; Gaulin & Campbell, 1994). Table 4 presents descriptive data on included covariates.

Table 4. Descriptive statistics and test of group differences of covariates included in the Cox regression models, paper 4.

Test	Group	Mean (SD)	Range	<i>p</i>
TROG-2 <sup>a</sup>	SNHI	45.6 (17.6)	8-66	.16
	NH	56.9 (16.8)	30-82	
BNT <sup>b</sup>	SNHI	76.7 (9.6)	60-86.7	.05
	NH	84.3 (6.3)	75-91.7	
CLPT <sup>c</sup>	SNHI	62.6 (11.9)	50-85.7	.17
	NH	71.2 (15.0)	38.1-90.5	
NWrep <sup>d</sup>	SNHI	51.3 (20.6)	20.8-79.2	.004
	NH	76.7 (13.4)	58.3-95.8	

**Notes:** <sup>a</sup> Test for Reception of Grammar – Second edition; <sup>b</sup> Boston Naming Test; <sup>c</sup> Competing Language Processing Task; <sup>d</sup> Nonword Repetition. Mean score and standard deviation in percentage correct except TROG-2 in percentiles. *p* value for test of difference between group with sensorineural hearing impairment (SNHI) and normal-hearing (NH) peers.

Paper 4 used Cox proportional hazards regression to model the probability of gaze-to-partner (expressed as a hazard ratio) after adjustment for the effect of group, and cognitive and linguistic covariates. The group difference in gaze behavior first shown in paper 3 remained significant despite adjustment for receptive grammar, expressive vocabulary, and complex working memory, but not nonword repetition, revealing an interaction between hearing impairment and phonological short term memory capacity. Participants with hearing impairment performing low on nonword repetition showed a twofold increase in the probability of gaze-to-partner, whereas those performing high had a reduced probability of gaze-to-partner. Table 5 presents hazard ratios and *p* values for the effect

of Group on the probability of gaze-to-partner at different steps of statistical adjustment.

The findings of paper 4 suggest that the group differences in gaze behavior – with increased probability of gaze-to-partner in children with SNHI – go above and beyond what is explained by the hearing impairment alone, and highlight phonological short term memory capacity as the driving force behind the effect. With future studies necessary to clearly establish its cause, an increased probability of gaze-to-partner should not be regarded as simply a problem of signal transfer but as a sign of the multimodal nature of conversation.

Table 5. Hazard ratios and *p* values for the effect of Group on the probability of gaze-to-partner, for the different steps of adjustment, paper 4.

<b>Contrast</b>	<b><i>n</i></b>	<b>HR (95% CI)</b>	<b><i>p</i></b>	<b><i>p</i> interaction</b>
Group <sup>1</sup>	2946	1.51 (1.34-1.70)	<.0005	
Group <sup>2</sup>		1.45 (1.24-1.70)	<.0005	
Group <sup>3</sup>		3.16 (1.73-5.78)	<.0005	<.0005
Group <sup>4</sup>		2.86 (1.49-5.47)	.001	<.0005
Low NWrep <sup>4b</sup>	1053	2.17 (1.58-2.98)	<.005	
High NWrep <sup>4b</sup>	1893	0.67 (0.50-0.90)	.008	

**Notes:** <sup>1</sup> Model adjusted for Group; <sup>2</sup> Model adjusted for Group, TROG-2, BNT, CLPT; <sup>3</sup> Model adjusted for Group, NWrep, Group × NWrep; <sup>4</sup> Model adjusted for Group, TROG-2, BNT, CLPT, NWrep, Group × NWrep; <sup>4b</sup> Model adjusted for Group, TROG-2, BNT, CLPT stratified on NWrep performance. HR presents hazard ratio estimates for SNHI (with 95% confidence intervals). *p* values present significance of contribution to the model for Group, and Group × NWrep interaction.

## Summary

- Mutual understanding of the objectives of a referential communication task allow speakers to include unrequested information in answers without compromising understanding.
- Higher probability of gaze-to-partner when asking questions than making statements, and lower probability when giving back channeling than listening silently to the partner, support hypotheses of a relation between gaze-to-partner and turn taking in conversation, and a complementary use of verbal and nonverbal modalities.
- Higher rates of gaze-to-partner during production of all utterance types indicate greater use of visual cues among children with mild-to-moderate hearing impairment.
- Children with hearing impairment and reduced phonological short term memory capacity show a doubled probability of gaze-to-partner, compared to peers with normal hearing, results highlighting a link between language functioning and gaze-to-partner in conversation.

# General discussion

With an aim to explore the verbal and nonverbal exchanges during a referential communication task, this thesis has highlighted an increased use of visual cues among children with mild-to-moderate SNHI, and pointed out phonological short term memory capacity as an explanatory factor of the increased use of gaze-to-partner. The findings propose a number of directions for further research, as well as implications for clinical and pedagogical work with children and adolescents with hearing impairment. This chapter discusses the findings within the wider context of the everyday interactions of children with hearing impairment in normal hearing surroundings, emphasizes the multimodal nature of communication, and discusses issues regarding data collection and analysis necessary for valid interpretation of the results.

## Compensation, pragmatics, or both?

As suggested by, for example, Blamey et al. (2001), children with hearing impairment will compensate for the degraded auditory signal by all means available, including using visual information to aid processing and interpretation of verbal

information. Further studies are, however, needed before the increased *use of* gaze-to-partner among participants with SNHI in the present thesis can safely be established as evidence for an increased *need for* visual cues. Indeed, several findings indicate that the group differences in gaze behavior express a compensatory mechanism among the participants with SNHI. The higher probability of gaze-to-partner among the children with SNHI, and in particular among those with reduced phonological short term memory capacity, and the well-established benefits, for listeners with and without hearing impairment alike, of having access to both auditory and visual information for speech perception, support an interpretation of gaze-to-partner serving as compensation. Recently, additional support for this interpretation was provided by results showing participants with normal hearing to rely more on visual information (here, gestures) for correct interpretation of a verbal message presented against babble noise as compared to silence, thereby using visual information to the same extent as participants with hearing impairment performing the task in silence (Obermeier, Dolk, & Gunter, 2012). The adverse listening conditions induced by the babble noise appear to evoke similar gaze behaviors in individ-

uals with normal hearing as those exhibited by the participants with SNHI in the present thesis.

Compensatory mechanisms are, however, not the only possible explanation to the observed gaze behavior, and pragmatic aspects of gaze exchanges, for example, gazes to the conversational partner as a signal of turn shift, must be considered. In the present thesis, increases in probability of gaze-to-partner show a close time-coupling with the production of turn shifts (as in the case of questions) and signals of understanding (back channeling). Importantly, as shown by raw data examination, the time-coupling shows little variation between groups, supporting an interpretation of gaze-to-partner playing a role in turn taking for all participants, hearing impaired or not. Interpretations of the increased probability of gaze-to-partner serving as compensation for degraded auditory input, or as a nonverbal means to assist the pragmatics of communication, are, of course, not mutually exclusive. Indeed, the present findings support the idea of both factors contributing to the increased probability of gaze-to-partner, with the majority of probability variance representing group independent, pragmatic uses of gaze-to-partner. The significant increase from this level among participants with SNHI could, thus, be seen as an expression of a compensatory mechanism.

Future studies delving deeper into the issue of the increased use of visual cues in individuals with hearing impairment

should make efforts to describe the relative contribution of compensatory and pragmatic aspects to the use of gaze-to-partner. Investigation of a compensatory mechanism would benefit from the inclusion of participants with wider ranges of degree of hearing impairment, as well as cognitive and linguistic skills, in order to clarify the relation between the degree of disability and the use of visual cues. Pragmatic aspects of gaze exchanges would, instead, be better understood by modifying the task and setup. Blocking gaze exchanges between the participants and examining the consequences on the conversation (for example, in terms of number of questions asked, or time needed to solve the task) would provide valuable information on the contributions of gaze-to-partner to communication. Furthermore, comparing gaze exchanges during the referential communication task to other communicative settings, for example, free conversation, where questions are less frequently asked, would add to our knowledge of the task dependency of the findings. To further validate gaze-to-partner as a pragmatic expression used in communication, participants with known pragmatic impairments, as established by other measures, should be included. Eye tracking in relation to the verbal production under natural conversational conditions would provide a more detailed description of the gaze behavior of individuals with pragmatic impairments, possibly distinguishing between irregularities regarding gaze focus area (for example, avoiding eye contact) and gaze timing (exhibiting typical, but temporally misaligned, gaze exchanges).

Returning to the issue of factors influencing gaze behavior in the present thesis, the explanatory role of the interaction between phonological short term memory capacity and hearing impairment on the probability of gaze-to-partner requires closer scrutiny. The participants with mild-to-moderate SNHI exhibited a cognitive and linguistic profile similar to that in several other studies (for example, Delage & Tuller, 2007; Stiles et al., 2012; Wake et al., 2006), with significant deficits compared to controls on nonword repetition and expressive vocabulary, but not on receptive grammar or working memory capacity. When entered as covariates in a Cox regression, these variables – with the exception of nonword repetition – were found to have no effect on gaze behavior beyond that already explained by the hearing impairment. Nonword repetition, measuring phonological short term memory capacity, was found to interact with the hearing impairment, significantly increasing the probability of gaze-to-partner. The reduction in receptive vocabulary suggests that phonological processing, still in middle childhood, affects the language functioning of the participants with SNHI in a similar way as described for children and adolescents with SLI. While largely overtaken by short term memory in adolescents with normal hearing and typical language development, phonological representation remains the best predictor of nonword repetition among individuals with SLI (Hesketh & Conti-Ramsden, 2013; Rispens & Baker, 2012). Given the similarities in nonword repetition ability between individuals with SNHI and SLI, differences in the relative contributions

of the abilities underlying successful nonword repetition (short term memory, and phonological representation, encoding, retrieval, and output; Bowey, 2006) between the participants with hearing impairment and the controls in the present thesis cannot be ruled out. As such, the process of identifying the correct picture in the referential communication task may be taxing enough to require the participants with hearing impairment to use additional sources of information, for example, gaze-to-partner, to aid understanding. This, again, suggests gaze-to-partner to function as a mechanism of compensation, however, not only compensating for a hearing impairment, but also for limitations in phonological processing. Future studies comparing the gaze behavior of children with SNHI to that of normal-hearing children with SLI with equivalent deficits in phonological processing could help clarify to what extent gaze-to-partner compensates for degraded auditory input or a reduced capacity to process phonological information.

## Implications

The findings of this thesis regarding gaze behavior and question-answer strategies point to the dialogic nature of communication (Linell, 2009). Although inherent to the concept, many models of communication fail to adequately recognize the important role played by the conversational partner; family, friends, teachers, and others, in understanding and explaining the conditions of children with communicative disorders. Approximately

five thousand students with hearing impairment, two thousand of whom require audiologic intervention, are enrolled in Swedish mainstream education (Specialskolemyndigheten, 2008). These students leave primary education with significantly lower grades than peers with normal hearing, and to a significantly higher extent with incomplete grades in obligatory subjects (Swedish, English, Mathematics), disallowing them to enter secondary education (Specialskolemyndigheten, 2008). At the level of tertiary education, applications from students with hearing impairment are rare, with students with normal hearing four times as likely to apply (Hörselskadades riksförbund, 2006). Many students with hearing impairment are not meeting school demands. The needs of those with subtle deficits, for example, mild-to-moderate hearing impairments, are at an increased risk of being overlooked. Multidisciplinary efforts are required for appropriate diagnosis and intervention. In addition to regular audiologic evaluations, continuously monitoring changes to the hearing profile in order to ensure optimal auditory conditions through use of personal hearing aids and hearing assistive technology systems, language and communication development should be routinely assessed. If affected, speech-language pathology services should be provided, targeting, for example, phonology and vocabulary to prevent adverse effects on reading and writing, or using referential communication tasks to demonstrate and train question-answer strategies and the multimodality of communication. However, in-

tervention should never be provided routinely. In our study, almost half of the participants performed within the normal range on nonword repetition. Similar proportions of children and adolescents with hearing impairment not suffering adverse consequences have been reported previously (Gilbertson & Kamhi, 1995). This points to the risk of using the hearing impairment to make a judgment, intentionally or unintentionally, of a child's language skills. There is, simply, no linear relation between degree of hearing impairment and language deficits, and using one to predict the other goes against the idea of individualized intervention. As pointed out by Gilbertson & Kamhi (1995), there are risks associated both with assuming language problems in all children with SNHI, and with assuming no children with SNHI to exhibit effects on language and cognition. Assuming problems in all would, admittedly, grant all those affected intervention, but would also risk leading to lowered expectations and achievements for children with SNHI without language problems. As indicated by previous studies on the input to children with SLI (Conti-Ramsden et al., 1995), a hearing impairment in a child may influence the language input that the child receives, possibly to the point of adversely affecting aspects of language development. In the light of such findings, the affected vocabulary development among children with minimal hearing impairments (less than 20 dB HL; Bess et al., 1998; Davis et al., 1986) deserves replication with language input statistically controlled.

Increased dependence on visual cues in students with hearing impairment has previously been met by adapting the teaching environment, for example, by seating the child on the front row of the classroom to improve auditory and visual input from the teacher. However, these adaptations may not always be consistent with the teaching style used in the modern classroom. Today many teachers encourage interaction with and among students through the use of group discussions and assignments to be performed in pairs or small groups (Toe & Paatsch, 2010). Although such tasks have apparent benefits for classroom participation, they lead to many speakers scattered over the classroom, often talking at the same time, a situation known to cause difficulties for students with hearing impairment (Stinson & Antia, 1999). Furthermore, increased use of personal computers in the classroom may require the teacher to help and instruct students ‘over their shoulder’, reducing the ability of both interlocutors to use nonverbal cues to aid language production and interpretation. Whereas such findings would seem to propose a return to more traditional ways of teaching children with hearing impairment, pair or small group work is likely to be a conversational setting where individuals with hearing impairment can show their full potential by using both verbal and gaze cues to participate fully in the interaction. This, however, requires interlocutors to be made aware of the effects of hearing impairment, regarding both auditory and visual conditions and consequences on language abil-

ity, again stressing the need for multidisciplinary assessments of children with hearing impairments.

## Validity

Few previous studies have used mobile eye tracking to study children and adolescents, and issues concerning the instrumentation were identified as a possible threat to the internal validity. Indeed, on some occasions, re-calibration of the equipment was necessary, for example, when participants accidentally touched parts of the equipment. These instances were, however, instantly detected and caused no data loss. Furthermore, for the purpose of distinguishing between the three gaze areas of interest; Task, Face, and Off, minor deviations between actual and recorded gaze position, resulting from intermittent difficulties with the calibration procedure, did not affect the measurement accuracy of the dependent variable. The validity of the dependent variable is further supported by similar results provided by the multiple analysis methods used in the different papers (mixed-effects modeling, survival analysis, Cox regression). Independent variables were measured using Swedish adaptations of internationally well-established tests of language and cognition, and data collected and analyzed in accordance with test protocols. However, continued evaluation of the construct validity of nonword repetition as a measure of phonological short term memory capacity in children with SNHI, as well as of the influence of the scoring method on



group differences (Dispaldro, Leonard, & Deevy, 2013; Graf Estes, Evans, & Else-Quest, 2007), should be conducted.

As with many studies of clinical populations, generalization of the findings to other populations and settings, that is, issues concerning external validity, should be made with caution. Replication of the study with a greater number of participants could reveal additional linguistic areas in need of clinical and research attention, possibly interacting with the hearing impairment and phonological processing in influencing the gaze behavior. As evidenced by the data in this study as well as many others, children with SNHI represent a heterogeneous group, differing on several aspects, including etiology of the hearing impairment, age at identification and amplification, quality and quantity of linguistic input, and type and quality of schooling and intervention. Whereas variation on these aspects would advise against a group division based solely on the degree of hearing impairment, such grouping is relevant given the criteria currently used to qualify for audiologic intervention and special needs education. Furthermore, ecological validity is the rationale for using a referential communication task. The task resembles school assignments in requiring collaboration between participants who, without instructions other than the objectives of the task, together have to find the optimal way of reaching

a mutual goal. The extent to which the task is, indeed, representative of naturally occurring communication should be further examined through comparison with conversations less driven by questioning and answering.

## Summary

The findings of this thesis stress the need to look beyond the hearing impairment for correct diagnosis and intervention of mild-to-moderate sensorineural hearing impairment. An increased probability of gaze to the conversational partner's face among participants with SNHI, and in particular among those with reduced phonological short term memory capacity, is interpreted as the combined effect of gaze serving as a nonverbal means to convey pragmatic content in conversation, and as a compensatory mechanism leveling deficits in hearing and phonological processing. While leaving the question of causality unresolved, the findings express the multimodality of communication, and highlight phonology, vocabulary, and principles of conversation as areas to target in intervention. Future research should further address issues of validity and generalizability, and evaluate the usefulness of nonword repetition ability as a clinical marker allowing earlier identification of children with SNHI at risk for persistent language impairment.

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