Reading Intervention to Improve Narrative Production, Narrative Comprehension, and Motivation and Interest of Children with Hearing Loss
Lori A. Pakulski, Ph.D., CCC-A, and Joan N. Kaderavek, Ph.D., CCC-SLP

Parental and Spousal Self-Efficacy of Young Adults Who Are Deaf or Hard of Hearing: Relationship to Speech Intelligibility
Limor Adi-Bensaid, Ph.D.; Rinat Michael, M.A.; Tova Most, Ph.D.; and Rachel Gali-Cinamon, Ph.D.

Changing Trends within the Population of Children who are Deaf or Hard of Hearing in Flanders (Belgium): Effects of 12 Years of Universal Newborn Hearing Screening, Early Intervention, and Early Cochlear Implantation
Leo De Raeye, M.D., and Guido Lichtert, Ph.D.

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ASSOCIATION FOR THE DEAF AND HARD OF HEARING

TEL 202.237.0220 • EMAIL PUBLICATIONS@AGBELL.ORG
WEB WWW.LISTENINGANDSPOKENLANGUAGE.ORG
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The Alexander Graham Bell Association for the Deaf and Hard of Hearing helps families, health care providers and education professionals understand childhood hearing loss and the importance of early diagnosis and intervention. Through advocacy, education, research and financial aid, AG Bell helps to ensure that every child and adult with hearing loss has the opportunity to listen, talk and thrive in mainstream society. With chapters located in the United States and a network of international affiliates, AG Bell supports its mission: Advocating Independence through Listening and Talking!

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Editors’ Preface

This June, nearly 1,200 people converged in Scottsdale to attend the AG Bell 2012 Convention. This biennial event allowed attendees to connect with each other, discover new insights into trends in spoken language acquisition, and be inspired by those around them. And while this event was not specifically focused on research, the underlying motivation for the tips, strategies, and advice provided was evidence-based.

One of the highlights of this event surrounded the Listening and Spoken Language Knowledge Center. Launched in May as the go-to resource for those seeking information related to hearing loss and spoken language, the Knowledge Center structure is ideal for those seeking research-driven data on the abilities of individuals who are deaf and use spoken language.

As you will see in the months to come, The Volta Review will begin to offer more opportunities and more access to evidence-based data online, and continue to explore new technologies that can enhance opportunities for individuals who are deaf. The next monograph, due out in the late fall of this year, will focus on issues of telepractice and how professionals can utilize new communication technologies to provide services to the most remote populations. Finally, later this year The Volta Review has plans to launch an online Continuing Education Units (CEUs) program for readers of the journal.

The Volta Review will continue to publish cutting-edge research that advances outcomes of listening and spoken language, and that information will become a part of the content of the Knowledge Center. This issue alone contains important research on reading intervention strategies to improve literacy skills in children with hearing loss, the results of a self-analysis of individuals who are deaf to be with a partner or raise a child who is either deaf or has typical hearing, and a review of the changing trends in educational support for children with hearing loss in Belgium. Finally, we have included the proceedings from the 2012 Research Symposium, presented during the AG Bell 2012 Convention. Presentations provided a review of new research into the
mechanics of hearing that determine how sound is conveyed to the brain, and also highlighted advances in future implant technologies that will combine the best features of cochlear implants and hearing aids into a single device as well as developments that will help preserve the residual hearing of implant users through otoprotective drugs.

The Volta Review has strived to be a publisher for new authors and professionals in the field. With tools available at www.listeningandspokenlanguage.org, we hope that you will find the right guidance for creating and submitting a manuscript for peer review. As always, please don’t hesitate to contribute to The Volta Review.

Sincerely,

[Signature]

Joseph Smaldino, Ph.D.
Professor, Department of Communications Sciences
Illinois State University
jsmaldi@ilstu.edu

[Signature]

Kathryn L. Schmitz, Ph.D.
Chair, Department of Liberal Studies
National Technical Institute for the Deaf/Rochester Institute of Technology
kls4344@rit.edu
Reading Intervention to Improve Narrative Production, Narrative Comprehension, and Motivation and Interest of Children with Hearing Loss

Lori A. Pakulski, Ph.D., CCC-A; and Joan N. Kaderavek, Ph.D., CCC-SLP

This study examined the effects of a reading intervention on narrative production, narrative comprehension, and reading motivation interest in children with hearing loss. Seven school children between the ages of 9 and 11 were paired with younger “reading buddies” (without hearing loss). The children with hearing loss read storybooks to an assigned reading buddy including one narrative-style book and a matched storybook with manipulatives (i.e., felt board cutouts). Readings occurred for four days. Following the dyadic story readings, narrative production and comprehension were compared across the “reading only” versus “reading + manipulative” conditions. Data demonstrated that the “reading + manipulative” condition resulted in significantly improved narrative quality and comprehension. Pre- and postassessment of the students’ self-ranking of reading motivation and interest were also gathered and revealed a significant improvement in motivation and interest following the intervention. The authors conclude that data provide preliminary evidence that a cross-age reading intervention utilizing manipulative features in dyadic reading can improve the narrative ability, narrative comprehension, and reading motivation and interest of school age students with hearing loss.

Lori A. Pakulski, Ph.D., CCC-A, is a professor and program director in the Judith Herb College of Education, Health Science and Human Service Department of Rehabilitation Sciences at The University of Toledo. Joan N. Kaderavek, Ph.D., CCC-SLP is a professor in the Judith Herb College of Education, Health Science and Human Service Department of Early Childhood, Physical & Special Education at The University of Toledo. Correspondence concerning this manuscript may be directed to Dr. Pakulski at lori.pakulski@utoledo.edu.
Introduction

Children with hearing loss (HL) are typically less-proficient readers (Marschark et al., 2009) and progress more slowly in reading remediation compared to their peers with typical hearing (Charlesworth, Charlesworth, Raban, & Rickards, 2006; Easterbrooks, Lederberg, Miller, Bergeron, & Connor, 2008). Children with significant HL frequently leave high school and enter the job market and college with language, reading, and writing skills that are inadequate for a world greatly dependent on high-level communicative skills (Luckner & Handley, 2008; Sarachan-Deily, 1985). To counteract this trend, educators and interventionists continually seek effective techniques for differentiated instruction and language/literacy interventions.

Unfortunately, much of the available information related to these interventions is anecdotal in nature; relatively few research studies specifically address intervention or instructional techniques to improve narrative ability and story comprehension for children with HL (Paul, 2009). Nonetheless, the current body of research that is available, coupled with advances in early identification and amplification technology, has led to emerging paradigm shifts that suggest a better prognosis for new generations (Easterbrooks et al., 2008). This article describes one intervention designed to improve children’s narrative ability and story comprehension, both of which are fundamental academic skills (Boudreau, 2008; Luckner & Handley, 2008), as well as increase motivation and interest in reading.

Self-Reported Reading Strategies of Children with Hearing Loss

In their recent studies of children with HL, Banner and Wang (2011, based on earlier work by Schirmer, 2003) adopted a somewhat novel approach to examining reading concerns: They investigated self-reported strategies used by readers with HL, who varied both in age (children and adults) and proficiency. Banner and Wang (2011) reported that highly proficient readers demonstrated the highest quantity, quality, complexity, and effective use of metacognitive strategies along three dimensions: (a) constructing meaning from reading, (b) monitoring and improving comprehension, and (c) evaluating one’s own comprehension. Further, while all levels of readers were observed using some metacognitive reading strategies while reading, Banner and Wang reported that the most proficient readers were able to discuss their deliberate use of metacognitive strategies. Similarly, Schirmer (2003), in an examination of reading attempts of elementary school children, reported that although her subjects used one or more strategies in each of the three dimensions of metacognition, they did not demonstrate the full range of metacognitive skills. Thus, confirming the work of Paul (2009) and Strassman...
Schirmer suggested that children with HL may not have the prerequisite skills needed to use the full range of metaskills and may not have sufficient opportunities to develop these skills. This finding suggests that children with HL need explicit opportunities to engage in high-level metacognitive reading tasks (Banner & Wang, 2011; Paul, 2009; Schirmer, 2003).

**Narrative Ability of Children with Hearing Loss**

An oral narrative is a verbal production in which an individual retells past experiences or tells a story (Ukrainetz, 2006). An oral narrative requires the speaker to use story grammar and present the narrated events using an episodic story structure that is organized in terms of a statement of the problem (an event putting the main character in a situation causing subsequent and related events), the plan (representing the main character’s reaction to the initial problem; a cause-and-effect relationship), and a resolution (the outcome of the sequence of events). An individual’s ability to produce a high-quality narrative is associated specifically with reading, and more generally with academic knowledge (Crosson & Geers, 2001; Gillam & Johnston, 1992; Sleight & Prinz, 1995).

Generally, children learn narrative production through incidental exposure, but some children—for instance, those with HL, language delay, or cognitive deficit—benefit from explicit narrative exposure (Crosson & Geers, 2001; Justice, Swanson, & Buehler 2008; Pakulski & Kaderavek, 2003). Although there is a paucity of research on the narrative ability of children with HL specifically, investigators agree that without intervention, children with HL tend to use fewer story grammar elements and produce less-sophisticated narratives (Greenfield, 2002; Pakulski & Kaderavek, 2003; Reuterskiold, Ibertsson, & Sahlen, 2010). It has been postulated that when HL exists, children’s narrative ability may be negatively impacted by: (a) a lack of background knowledge and vocabulary; (b) issues of access to the phonology of spoken language, which may reduce the capacity of short-term or working memory; and (c) a lack story schemata (Justice et al., 2008; Pakulski & Kaderavek, 2003; Reuterskiold et al., 2010; Robertson, Dow, & Hainzinger, 2006; Yoshinaga-Itano & Downey, 1996).

Along with narrative production deficits, children with HL also frequently demonstrate weaknesses in narrative comprehension tasks (Luckner & Handley, 2008; Reuterskiold et al., 2010), such as inferential comprehension in some settings (e.g., Walker, Munro, & Rickards, 1998). Narrative comprehension is described as the active process of constructing meaning from narrative discourse using the listeners’ knowledge of vocabulary, concepts, and story grammar to make inferences and link key ideas (Luckner & Handley, 2008; Vaughn & Edmonds, 2006). An individual who understands the story grammar sequence is more likely to comprehend the story sequence and retain
information presented within the narrative. Meta-awareness of story grammar improves comprehension of narrative stories (Luckner & Handley, 2008).

A number of studies have reported on the narrative ability and outcomes of narrative interventions with a focus on improving the quality of complex, cohesive narratives of children with language delays (e.g., Gillam, McFadden, & van Kleeck, 1995; Hayward, Gillam, & Lien, 2007; Ukrainetz, 1998). Although less research is available regarding narrative interventions for children with HL, there is a consensus that building students’ understanding of story grammar positively impacts narrative quality in students with HL (Justice et al., 2008; Luckner & Handley, 2008; Pakulski & Kaderavek, 2003). Specifically, Justice and colleagues (2008) reported that a narrative-based language intervention (NBLI) improved the narrative quality and syntax of three school-age children who used cochlear implants. In another study, Pakulski and Kaderavek (2003)—after a brief intervention with a group of 14 school-age children with HL who used listening and spoken language—demonstrated that role-playing a story episode, in combination with repeated book readings, improves the quality of oral narratives.

Motivation and Interest in Reading

An essential element of high-quality educational interventions is focused on ensuring positive levels of student motivation and interest (Parault & Williams, 2010). McKenna and colleagues completed seminal work on assessing students’ level of reading motivation and interest (McKenna & Kear, 1990; McKenna, Kear, & Ellsworth, 1995). They developed a pictorial format called the “Elementary Reading Attitude Survey,” wherein cartoon character Garfield is shown in poses ranging from very happy to very upset. Students rated levels of interest in reading by pointing to the picture that best reflected their feelings. In a national sample of 18,000 U.S. children in grades 1 through 6, the trend toward more negative attitudes about reading was related to reading ability and was steepest for the least-able readers (McKenna et al., 1995). There is a consensus that motivated readers read more and become increasingly skilled (Parault & Williams, 2010); on the other hand, students who read infrequently are likely to fall further behind (Stanovich, 1986). Children with HL need to participate in literacy/language interventions that increase motivation and interest so that they read more frequently.

Cross-Age Reading to Improve Motivation and Interest

Many children with HL do not have a high motivation and interest to read and are frustrated by continued language and reading interventions (Parault & Williams, 2010; Schleper, 1995). One intervention used to increase reading motivation and interest for children with reading challenges has been called cross-age reading. It is “a form of cooperative learning in which an older
student, who can benefit from reinforcement, is paired with a younger student, who may or may not be in need of intervention” (Thrope & Wood, 2000, p. 239).

The potential benefits of a cross-age reading program include: (a) expanded opportunities for older students to review reading materials aimed at their competency level (which may be lower than their instructional level); (b) to improve communication skills (Gaustad, 1993); (c) to improve reading fluency and automaticity; and (d) to improve self-efficacy (Fox & Wright, 1997).

First described by Labbo and Teale (1990), cross-age reading was designed to build strategies for effective reading among older students. The program was constructed to provide a genuine purpose for engaging in repeated readings with an authentic audience. By utilizing the framework of storybook reading, students improved their reading fluency and comprehension (Labbo & Teale, 1990). Further, they developed a wider repertoire of strategies for making sense of what they were reading, thus gaining more metacognitive awareness of the processes as readers.

Fox and Wright (1997) implemented a cross-age reading intervention they called Storymates. Older school-age children with reading challenges were paired with younger “reading buddies.” The older children in that study struggled to read books at their grade level. However, the level of the simple storybooks used during the dyadic reading allowed the older readers to have increased confidence and fluency. Importantly, the shared storybook reading context made it appropriate for the older children to read a book with simple story structure and beginner reading level. Parents’ responses at the conclusion of the Storymates intervention indicated a positive effect on the older children’s motivation and interest to read. Both the Storymates cross-age reading intervention and McKenna’s assessment of reading motivation and interest were adapted for children with HL in this current study.

Use of Manipulative Features in Dyadic Reading

Another important element of this study thought to improve narrative production and comprehension is the use of manipulatives to enhance the narrative event. The use of manipulatives during storybook reading shares characteristics of role-play as the reader uses real objects to act out the story. In their investigation of the impact of engaging children in role-play as part of a reading interaction, Pakulski and Kaderavek (2003) reported significantly more sophisticated narrative retellings associated with reading paired with role-play for children with HL. In the current study, it was hypothesized that using manipulatives to reenact the story (e.g., objects representing characters and story events) would enhance students’ meta-awareness of the story grammar and improve narrative comprehension (Black & Stave, 2007; Pataki, Metz, & Pakulski, 2011; Wasik & Bond, 2001). Further, it was hypothesized that incorporating manipulative objects would facilitate a play-like interaction,
potentially fostering higher levels of student interest and motivation to engage in reading interactions.

The aim of this current intervention study was to examine the utility of a cross-age reading program as a means to improve narrative ability, narrative comprehension, and interest and motivation of children with HL to read, and to determine if the use of manipulatives to further enhance narrative quality, narrative comprehension, and motivation in this group of students with HL. Thus, the research questions for the current study are as follows:

1. How does the narrative quality of school-age students with HL differ in response to two cross-age reading conditions: a reading only (RO) storybook reading versus a reading + manipulative (R + M) interaction?
2. Does the narrative comprehension of school-age students with HL vary in response to two cross-age reading conditions: a RO storybook reading versus a R + M interaction?
3. Does participation in a cross-age reading intervention improve the reading motivation and interest of students with HL?

**Method**

**Subjects**

The subjects were 7 students with HL who used listening and spoken language and who were educated in a self-contained classroom at a midwestern school with a county program for children who are deaf or hard of hearing. This program provides an education for all children in the county whose parents select a listening and spoken language approach and desire that their child receive the more specialized attention available in the self-contained classroom as opposed to a mainstream environment available within the local public school system. The subjects comprised a fourth grade class; all were children with HL congenital hearing loss (ages 9 years, 4 months, to 11 years, 1 month) and included 5 females and 2 males. All used spoken language and their primary language was English. One subject had a mild-to-moderate hearing loss (defined as a 35–50 dB HL bilateral sensorineural loss); 2 subjects had moderate-to-severe hearing loss (defined as a 60–85 dB HL bilateral sensorineural loss); and 4 had a severe-to-profound hearing loss (defined as a bilateral sensorineural loss ranging from 85 dB to no response at 110 dB HL). Two subjects used cochlear implants; the remaining subjects used hearing aids. The classroom teacher reported that each subject was reading at or near grade level and was a sufficiently proficient reader for the intervention task. Specifically, the teacher was asked to consider each subject’s reading ability—informally defined as grade level, accuracy, and automaticity based upon classroom performance and school-based evaluations, including the
Dynamic Indicators of Basic Early Literacy Skills (DIBELS) scores (Moats, Good, & Kaminski, 2003). The teacher verified that each subject’s reading competency level was sufficient for the cross-age intervention task (see below for a description of the text level). Subject data is provided in Table 1.

The classroom teacher was an experienced teacher of children who are deaf or hard of hearing (12+ years of experience) and specifically trained in the listening and spoken language approach of communication for children with HL. Reading buddies were selected from the first grade class, all of whom were reported to have typical hearing. First graders were chosen by their teacher, following parent approval for participation and based upon some basic qualifiers: The child would likely be interested in and be able to sit through the proposed reading intervention over the 4-day period, and the child was unlikely to experience negative consequences by missing classroom time. No other specific academic data was collected on these children as they were not targeted as subjects in the study.

**Procedures**

The Strong Narrative Assessment Procedures (SNAP) (Strong, 1998) was adapted for this intervention. SNAP includes data on the expected levels of narrative performance of children developing typically. Although this assessment is no longer available commercially, it was used in the current study because it (a) provides a set of equivalent books appropriate for young children; (b) the books were easily divided into story grammar episodes with associated manipulative objects; and (c) for comparison purposes, there are data regarding the performance level of children developing typically.

The books used in the SNAP protocol are wordless storybooks; however, the SNAP protocol includes specific text to be used during the story presentations. The research team added this written text to the modified storybook. Three sets of books were created for the intervention. Storybook A, the first book set, included a story with written text, colored illustrations, and manipulatives; this

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**Table 1. Subject data**

<table>
<thead>
<tr>
<th>Subject Number</th>
<th>Gender</th>
<th>Age</th>
<th>Severity</th>
<th>Amplification</th>
</tr>
</thead>
<tbody>
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<td>Female</td>
<td>9</td>
<td>Moderate–Severe</td>
<td>Hearing aids</td>
</tr>
<tr>
<td>2</td>
<td>Female</td>
<td>11</td>
<td>Severe–Profound</td>
<td>Cochlear implant</td>
</tr>
<tr>
<td>3</td>
<td>Female</td>
<td>10</td>
<td>Moderate–Severe</td>
<td>Hearing aids</td>
</tr>
<tr>
<td>4</td>
<td>Female</td>
<td>11</td>
<td>Severe–Profound</td>
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<td>Mild–Moderate</td>
<td>Hearing aids</td>
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<td>7</td>
<td>Male</td>
<td>10</td>
<td>Severe–Profound</td>
<td>Hearing aids</td>
</tr>
</tbody>
</table>
set was used by the classroom teacher to train students in the cross-age reading strategies (i.e., instruction to increase students’ awareness of the meta-cognitive strategies included in the reading task). Storybooks B and C were books with colored illustrations and written text; the third book set, Storybook C, included colored illustrations and manipulatives (i.e., a felt board with objects that could be manipulated). The manipulative objects included characters introduced during the narrative stories (e.g., boy, frog, etc.) and key objects (such as a bucket). To help the students use the books, the research team enlarged the pages of the storybook using a copy machine and hand-colored the illustrations. The text for each page was printed on card stock, and the text and illustrations were placed side-by-side in a three-ring binder so they would be viewed simultaneously, much like a typical storybook. Each student dyad received a copy of Story B and Story C. Three of the students with HL received Story B with the manipulative features and a text-only version of Story C. In contrast, the remaining 4 students received Story C with manipulative features and a text-only version of Story B. Sample pages are illustrated in Appendix A.

Story B and Story C were deemed comparable based upon the number of sentences (45 each), number of words (400 in Story B and 386 in Story C), and the number of words per sentence (8.89 in Story B and 8.58 in Story C). Additionally, the readability for the stories was found to be well below grade level for the subjects: Story B was determined to be at Grade Level 1.6, and Story C was determined to be Grade Level 2.10 using the Flesch-Kincaid Grade Level procedure (Flesch, 1948; Kincaid, Fishburne, Rogers, & Chisson, 1975). The protocol for the cross-age reading program was as follows.

Day 1

Students with HL completed a questionnaire (see Figure 1) indicating their level of motivation and interest in reading. The students’ teacher used Story A to present information about strategies to be used during the cross-age reading program and provided instructions on reading aloud and using manipulatives (see the Teacher’s Instructional Guidelines provided by the authors in Appendix B, available online at www.listeningandspokenlanguage.org/TheVoltaReview). Following the teacher’s demonstration, the students practiced individually and as a group reading aloud with Story A, and practiced using the manipulative to role-play the story narrative.

Day 2

The classroom teacher read Story A aloud again and demonstrated the use of manipulatives for storytelling. During the second demonstration, the teacher emphasized the key features of narrative episodic structure (i.e., problem, plan, resolution) and introduced other key narrative features (e.g., use of cohesive

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Faces Rating Scale of Reading Motivation
(J. N. Kaderavek)

Name __________________________

Instructions:
Please circle the face that shows how you feel about each question.

1. How do you feel about making up the stories to tell other people?

2. Pretend your teacher gives you a really good book to read today, but you have to read it during free time. Circle the face that shows how you feel about that.

3. How do you feel about reading storybooks out loud to other people?

4. Some children like to read books and others don’t. Circle the face that shows how you feel about reading books.

Score _____ / 20 points

Figure 1. Faces Rating Scale of Reading Motivation and Interest. Used with permission: Kaderavek, J. N. (2010). (Unpublished instrument). Available from author, Mail Stop 954, University of Toledo, Toledo, OH 43606.
devices such as “because” and “so” to emphasize the story sequence as well as use of formal beginnings and endings to initiate and end the story). Following the reading of Story A, students were given copies of Stories B and C.

The teacher reviewed the guidelines and instructions for cross-age reading and gave the students with HL time to read and familiarize themselves with the story and its manipulatives. The classroom teacher reported that each student read the books independently; none of the students required clarification with vocabulary items.

**Days 3–6**

Each student was paired with a first-grade reading buddy on Day 3 at a predetermined time in the middle of the school day. Reading took place in “reading centers” with carpet squares and soft panel dividers across two classrooms to minimize overhearing/contamination of others’ shared reading as well as other distractions. The classroom teacher and the first author monitored—but did not interact with—the reading buddies after assignments were made. Each student read Story B and C to his/her reading buddy. The book order was randomized, and the presentation of manipulatives with Story B or C was also randomized and counterbalanced. The reading buddies were given approximately 20 minutes on each of the “intervention days,” which was sufficient time to read through both books, including talking about the story with the use of the manipulatives. Consequently, each dyadic pair completed both the story reading (Story B or C) and the story reading plus manipulative interaction (Story B or C) four times. It should be noted that the classroom teachers decided upon the time and intervention days within the latter part of the spring semester.

**Coding and Assessment Instruments**

Following the students’ dyadic reading of the RO and (R + M) across 4 days, each subject was asked to complete the corresponding SNAP story comprehension questionnaire (Strong, 1998), which included five factual and five inferential questions. Sample story comprehension questions (and sample answers) are provided in Table 2. Written answers were scored as incorrect (0) or correct (1) by the first author, based upon criteria provided by Strong (1998), for a total score of 8 for each story. Next, students were asked to individually retell the stories to the first author; the books were not provided during the story retelling. Digital audio and video recordings were made of each retelling. The authors provided training to two graduate students to transcribe the story retellings using the Systematic Analysis of Language Transcripts (SALT) (Version 2004) software program. Inter-rater reliability was established on the coding procedures. A sample of retellings from another project was used for training purposes; none of the children in the training tapes were participants.
in the current study. After initial training, the graduate students and the author achieved a 92% and 94% inter-rater reliability (Brenneise-Sarshad, Nickolas, & Brookshire, 1991; \[Total Agreements/(Total Agreements + Total Disagreements)\] × 100 on the transcripts). Disagreements were discussed. Following the training, the graduate students independently coded the videotapes from the study. The agreement was 92% between the coders.

Transcripts of the children’s oral narrative retelling of both stories were then analyzed using the Story Grammar Analysis Protocol (Pakulski & Kaderavek, 2003), adapted from the Stein and Glenn (1979) story grammar model (see Appendix C online at www.listeningandspokenlanguage.org/TheVoltaReview). A similar protocol has since been published by Heilman,
Miller, Nockerts, and Dunaway (2010). This type of assessment is particularly relevant for children with HL—who are known to include only single events, labels, or other incomplete information—because it provides for scores of story grammar along a wide continuum of performance. Unlike some coding procedures that are more objective and thus easier to code, the assessment used in this study can account for qualitative aspects and inter-utterance concepts that enhance the narrative (Peterson & McCabe, 1983), whereas the simple story grammar approaches are limited in this aspect (Heilman et al., 2010).

Using this protocol, narrative quality was scored along several dimensions. A score of 0 to 3 was assigned for the inclusion of story elements and story grammar propositions: A score of 0 was given when no evidence of the target was present, a score of 1 was given for mention or emerging signs of the target, a score of 2 was given when there was substantial evidence of the target in the child’s retelling, and a score of 3 was given when the child provided a well-defined or developed target. The story elements were grouped into four major narrative domains: awareness of story structure, inclusion of all major plot episodes, use of stylistic devices, and development of coherence. Awareness of story structure was demonstrated by mentioning setting and characters. Use of plot episodes was scored when the student produced a statement of the problem, plan to resolve the problem, and problem resolution. Stylistic devices were noted when the student produced a formal beginning (e.g., “Once upon a time.”) or formal conclusion. Narrative coherence was noted when the student demonstrated a logical story sequence, correct sequence of events, and used transition terms (e.g., then, next, because, or so). An overall score of 30 points was possible if all story elements and story grammar propositions were present and used correctly. Coder reliability for the narrative production was demonstrated by comparing the scores of two independent coders; the raters’ scores achieved a correlation of .88 (Pearson Correlation), resulting in an appropriate level of inter-rater reliability. In the case of a coding disagreement, the two coders discussed their scores and mutually agreed on a final score for each subject.

Additionally, on Day 1, students completed the Faces Rating Scale of Literacy Motivation and Interest questionnaire (Kaderavek, 2010) and then again on Day 6, before providing the retellings. The Faces Rating Scale of Literacy Motivation and Interest is a self-rating task (see Figure 1) adapted from a scale created by McKenna and Kear (1990) to evaluate aspects of children’s attitudes toward literacy. It consists of a 5-point rating scale of simple line drawings of five faces (“faces rating scale”) representing very sad (1), somewhat sad (2), neutral (3), somewhat happy (4), and very happy (5). Four questions regarding students’ attitude toward literacy were combined to form a single dependent variable with a maximum score of 20.
Sample retellings for the subjects’ RO and R + M story conditions are presented in Appendix D. As indicated, sample story comprehension questions and answers are provided in Table 2. Next, a comparison of the dependent variables (student’s narrative production [story retelling] scores) and independent variables (story comprehension scores for the RO and R + M story conditions) are presented (see Table 3 for overview). Lastly, a comparison is provided of each subject’s ratings of his/her motivation and interest for reading (obtained via pre- and postintervention), administration of the Faces Rating Scale of Reading Motivation, and interest. The Wilcoxon Signed Rank Test, a nonparametric procedure—that is, an appropriate statistic for small sample size and nonrandom subject selection—was used to analyze differences in repeated measures (Schiavetti & Metz, 2002). Nonparametric statistics have been used with very small sample sizes (e.g., Ballard, Robin, McCabe, & McDonald, 2010) such as three children with dyspraxia (McDonnell, 1984) and four students with severe disabilities (Ballard et al., 2010).

### Table 3. Mean (M), standard deviation (SD), and Z scores for narrative production scores

<table>
<thead>
<tr>
<th>Narrative Feature</th>
<th>Reading Only</th>
<th></th>
<th>Reading + Manipulative</th>
<th></th>
<th>Z Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>Setting</td>
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<td>.82</td>
<td>1.7</td>
<td>.49</td>
<td>−2.4*</td>
</tr>
<tr>
<td>Character</td>
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<td>.78</td>
<td>1.8</td>
<td>.69</td>
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</tr>
<tr>
<td>Statement of Problem</td>
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<td>1.1</td>
<td>.85</td>
<td>.69</td>
<td>−.27</td>
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<tr>
<td>Statement of Plan</td>
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<td>.9</td>
<td>1.14</td>
<td>.89</td>
<td>−1.4</td>
</tr>
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<td>Problem Resolution</td>
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<td>1.3</td>
<td>1.1</td>
<td>−.83</td>
</tr>
<tr>
<td>Formal Beginning</td>
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<td>1.3</td>
<td>.49</td>
<td>−1.4</td>
</tr>
<tr>
<td>Formal Conclusion</td>
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<td>1.1</td>
<td>1.7</td>
<td>.95</td>
<td>−1.7</td>
</tr>
<tr>
<td>Coherence</td>
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<td>.69</td>
<td>2.6</td>
<td>.53</td>
<td>−2.23*</td>
</tr>
<tr>
<td>Sequencing</td>
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<td>1.1</td>
<td>1.9</td>
<td>1.0</td>
<td>−2.12*</td>
</tr>
<tr>
<td>Transitions</td>
<td>1.57</td>
<td>.54</td>
<td>1.8</td>
<td>.38</td>
<td>−1.0</td>
</tr>
</tbody>
</table>

*p = .05

Table 4. Mean (M), standard deviation (SD), and Z scores for narrative comprehension scores

<table>
<thead>
<tr>
<th>Reading Only</th>
<th></th>
<th>Reading + Manipulative</th>
<th></th>
<th>Z Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>4.4</td>
<td>1.3</td>
<td>6.9</td>
<td>1.8</td>
<td>−2.23*</td>
</tr>
</tbody>
</table>

*p = .026
Subjects obtained a mean narrative production total score of 16.3 (SD = 5.5) for the R + M condition relative to the mean of 11.4 (SD = 7.5) for the RO story condition, scored out of a possible 30 points. There was a significant difference in total narrative production scores for the subjects in relation to R + M or RO condition (z = -2.12, p = .034) (see Table 3). Across all the narrative features, the individual features of “setting,” “coherence,” and “sequencing” were also found to be significantly more sophisticated in the R + M condition as compared to the RO condition. While the other individual narrative features did not demonstrate statistical significance, in all cases each feature was higher in the R + M condition as compared to the RO condition. This is illustrated for each subject in Figure 2.

The mean total score for story comprehension in the R + M condition (M = 6.9, SD = 1.8) was significantly higher than the total story comprehension score for the RO condition (M = 4.4, SD = 1.3; z = -2.23, p = .026). Results are shown in Table 4 and illustrated for each subject in Figure 3. It is also noted that factual comprehension resulted in higher scores overall than inferential comprehension in both conditions. However, when inferential comprehension is considered alone, the R + M condition resulted in higher scores.

Finally, the students’ postintervention rating of reading motivation and interest was significantly higher than their preintervention rating (z = -2.38, p = .017). Specifically, the postintervention rating mean was 17.8 (SD = .9) while the preintervention mean of the Faces Rating Scale of Reading Motivation and Interest was 12.7 (SD = 2.0). Results are shown in Table 5 and illustrated for each subject in Figure 4.

Figure 2. Subjects’ story grammar total scores across conditions.

Subjects obtained a mean narrative production total score of 16.3 (SD = 5.5) for the R + M condition relative to the mean of 11.4 (SD = 7.5) for the RO story condition, scored out of a possible 30 points. There was a significant difference in total narrative production scores for the subjects in relation to R + M or RO condition (z = -2.12, p = .034) (see Table 3). Across all the narrative features, the individual features of “setting,” “coherence,” and “sequencing” were also found to be significantly more sophisticated in the R + M condition as compared to the RO condition. While the other individual narrative features did not demonstrate statistical significance, in all cases each feature was higher in the R + M condition as compared to the RO condition. This is illustrated for each subject in Figure 2.

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In terms of overall frequency counts (see Table 6), all of the subjects demonstrated higher levels of narrative production in the R + M condition as compared to the RO condition, 6 out of the 7 subjects demonstrated higher levels of narrative comprehension in the R + M condition as compared to the RO condition, and all of the subjects demonstrated higher levels of overall reading motivation following their participation in the cross-age reading intervention.

**Discussion**

This study investigated the effects of a cross-age reading intervention on the narrative production abilities, narrative comprehension, and reading motivation levels in a small group of children with HL. Further, it compared the performance in a narrative task across a RO and R + M task. In response to the

**Table 5.** Mean (M), standard deviation (SD), and Z scores for faces rating scale of reading motivation and interest

<table>
<thead>
<tr>
<th>Reading Only</th>
<th>Reading + Manipulative</th>
<th>Z Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>12.7</td>
<td>2.0</td>
<td>17.8</td>
</tr>
</tbody>
</table>

*p = .017*
first research question pertaining to narrative quality across the two contrasting conditions, findings demonstrated the narrative production of students with HL was enhanced when they used manipulatives as part of the cross-age reading task.

Specifically, use of cohesive devices was higher as a result of the manipulative task in all categories including (a) conjunctive cohesion, the use of linguistic features to link ideas across phrases/utterances (e.g., and, but);

**Table 6.** Subjects’ scores by intervention condition

<table>
<thead>
<tr>
<th>Subject</th>
<th>Motivation Scores (0-lowest to 20-highest possible score)</th>
<th>Narrative Production Score by Intervention Condition (0-lowest to 30-highest possible score)</th>
<th>Narrative Comprehension Score by Intervention Condition (0-lowest to 10-highest possible score)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
<td>Reading Only</td>
</tr>
<tr>
<td>1</td>
<td>14</td>
<td>18</td>
<td>3</td>
</tr>
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<td>2</td>
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<td>17</td>
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<td>4</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>19</td>
<td>8</td>
</tr>
</tbody>
</table>

**Figure 4.** Subjects’ “Faces” pre- and postintervention scores.
(b) referential cohesion such as reference to characters, objects and settings; and (c) lexical cohesion, necessary to connect notions across utterances (Heilman et al., 2010). The use of conjunctive cohesion demonstrates that a student can causally and temporally connect information using a conjunction. For example, in the utterance “The boy was surprised because the frog jumped out of the box,” the speaker/reader demonstrates cohesion by using the conjunction “because.” Other conjunctions highlighting linkages between story events include words such as so, before, then, and next. Children who are developing typically often begin to use conjunctions between 3 and 4 years of age; children with HL might not develop these skills until much later or never fully develop them without intervention (Apel & Masterson, 1998; Swanson et al., 2005). The results of the current study documenting improvement in students’ conjunctive cohesion are encouraging, particularly since the intervention was low cost and relatively brief.

Students also demonstrated improved coherence when they used clear referents. For example, a skilled narrator uses a specific noun to describe a person or object the first time the character or object is introduced (“the frog” or “the boy”). In subsequent utterances, the skilled narrator might refer back to the already-introduced character or object with pronouns (e.g., “it” or “he”). A less-skilled narrator might introduce the new character or object with an ambiguous referent such as “it” and “him,” leading to listener confusion (McCabe & Bliss, 2003). While many of the children struggled with the use of clear referents (e.g., boy, dog, and frog all referred to as “he”), transcripts revealed clear differences in referent use between the RO and R+M condition. For example, one subject in the current study started the retelling of his RO story with the sentence, “They went into their fancy restaurant, and he came out of the pocket and went into the musical instrument.” Later in the same retelling he said, “He jumped into the person’s cup and he kissed him on the nose. They felt a little sick and went home.” Within the context of the entire retelling, it is unclear to whom “they” and “he” refer. Conversely, this same subject’s retelling from the R+M condition yielded the following first two sentences, “One day a boy, named Joe, decided he wanted a pet frog. He found a bucket to put it in, and a net, and decided to find one with his dog.” In the R+M condition, the coherence was more sophisticated, and the overall story structure was elaborated.

The intervention did not result in significant levels of improvement in students’ use of episodic story structure. It was hypothesized that this might be due to the limited exposure of the concept during the teacher modeling and training. Van Keer (2004), who designed a cross-age reading program to improve fifth graders’ reading comprehension, reported that students required extensive training to show improvement in this domain. In future studies, the authors will include the use of graphic mnemonics to remind students to include story grammar features during their dyadic story sharing. With this addition, students’ episodic story structure may improve.
In response to the second research question pertaining to relative impacts on students’ narrative comprehension, the data demonstrated a significant improvement in narrative comprehension as a result of the R + M condition. This study is consistent with the findings that role-play participation facilitates story comprehension in students with HL (Justice et al., 2008; Pakulski & Kaderavek, 2003). When factual versus inferential comprehension was considered, factual comprehension was better overall than inferential comprehension in both conditions. However, when inferential comprehension was considered alone, the R + M condition resulted in higher scores.

Although these findings can be viewed only as preliminary due to the small sample size, the data in this study—documenting an improvement in comprehension as a result of the R + M condition—is important because students with HL have difficulty taking the perspective of others, a perspective required to comprehend narrative events (Schick, de Villiers, de Villiers, & Hoffmeister, 2007). The current study’s authors hypothesized that exposure to the manipulatives helped the students with HL act out the characters’ mental states and motivations. Subsequently, the students’ comprehension of the story was enhanced.

Data with regard to the final research question focused on evaluating changes in reading motivation and interest following involvement in a cross-age reading intervention. The results demonstrated a significant improvement in students’ self-rating of literacy motivation and interest to read. It was hypothesized that participation in a shared book reading with younger children would provide a low stakes, high payoff context that was motivating and fulfilling for school-age students with HL. The results of the current study align with data completed by Van Keer (2004), who reported similar findings for children without HL.

The authors hypothesized that interacting with a book designed for use by a younger reader would be likely to contribute to the positive impact on students’ motivation and interest. Many students with HL are reluctant readers; some of this reluctance might be a response to the task demands of an age-appropriate text. However, in the cross-age reading approach, students with HL appropriately use an easier text since they are interacting with a younger child; they are able to practice their reading and narrative skills with a less linguistically challenging context. Fox and Wright (1997) have also suggested that a cross-age reading program improves motivation and interest because it is a real-life experience that is meaningful and rewarding.

It has also been suggested that improving the reading motivation and interest of students with HL might improve the amount of reading time at home and school (Donne, 2006, 2011; Donne & Zigmond, 2008). Specifically, Donne and colleagues reported students with HL read only 6.4 to 12.3 minutes per day across a range of educational settings (e.g., school for the deaf, self-contained classroom, resource rooms, and general education classrooms). Students who were performing below grade level read less than students who
were reading at grade level. Donne and others have stressed the importance of improving students’ motivation to read in order to facilitate more reading time.

In summary, the area of reading motivation is a neglected aspect of reading research (Paul, 2003). Specifically, it has been argued that “researchers should examine the relationships between motivation and interest and comprehension of texts” (Paul, 2003, p. 106). Parault and Williams (2010) reported similar concerns, noting that while research in this area has increased, it has been focused primarily on participants with typical hearing. The current study is a preliminary investigation that responds to this important, but rarely studied, aspect of reading development for students with HL.

This study has several limitations and application of these results should be considered with caution. First, the number of subjects was small and the statistical analyses were nonparametric; some experts suggest nonparametric statistics might have less power than would the corresponding parametric test. The counterargument is that the reduction in power is not great, and if the parametric test is not possible, then the nonparametric test might be more powerful (Lehmann, 2009). Second, this study does not have a randomized, control-group design, and the investigator did not employ a control group (i.e., no treatment comparison). Accordingly, this study is beginning evidence for a Level II study in the evidence-based hierarchy of intervention. Level II is described as findings demonstrated from nonrandomized experiments (with good experimental design) from several different researchers. With confirmatory studies from other researchers, the use of a cross-age reading intervention would qualify as Level II evidence (Gillam & Gillam, 2008). Another concern is that the storybooks had slight differences in text and reading grade levels. However, this concern is mitigated since (a) 3 of the students used Storybook B for the R + M condition and the other 4 used the Storybook C for the R + M condition, and (b) regardless of the book, the R + M condition demonstrated improved performance.

A strength of this study is that the research took place in an ecologically valid setting. The classroom provides a more stringent test of the successful implementation of intervention studies as compared to implementation in a tightly controlled laboratory setting (Van Keer, 2004). The classroom-level implementation is a positive, which underscores the applicability of this intervention to the everyday learning opportunities of students.

In summary, this study offers preliminary support for a cross-age reading program to improve the narrative production, narrative comprehension, and reading motivation and interest in school-age students with HL. Overall, it is suggested that this intervention can be instituted at relatively low cost as a supplement to the reading programs of students with HL. Providing a motivating, contextually rich context, and supplemented with manipulative objects, cross-age reading has the potential to facilitate multiple aspects of student ability linked to reading and academic success.
References


Appendix A. Sample Pages from Adapted Storybooks

Story page for reading-only condition:

The frog jumped inside a musical instrument.

When the musician tried to play music, the sound was terrible.

So he looked inside his instrument to see what was the matter.

Story page for reading + manipulative condition (the boy, net, dog, and frog are some of the manipulative features available to the children):

One day a boy named Joe decided he wanted a pet frog.

He got a net and a bucket to put the frog in.

Then he and his dog started off to find one.
Appendix D. Sample Story Retellings

<table>
<thead>
<tr>
<th>Condition</th>
<th>Subject 1 retellings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading Only</td>
<td>One day, a boy named Joe decided he wanted a pet frog. He brought a bucket and a net to put it in and he and his dog decided to find one. Joe looked everywhere for a frog but didn’t find one. And then he saw a frog sitting on a lily pad. They ran down the hill and they tripped over, they XX, and fell right into the water.</td>
</tr>
<tr>
<td>Reading + Manipulative</td>
<td>A boy named Ben, and his family, were going out to dinner. Ben put on his best clothes. His animals, I mean his pets, watch him get ready. His frog decided to come with him to dinner, so he hopped in Ben’s pocket when he wasn’t looking and Ben did not know. When Ben’s family left, Ben wave goodbye to his pets and the frog secretly did too. They went to a fancy restaurant and the frog came out of his pocket when they looking at their menus and he jumped into a musical instrument. Well, there was a band playing. The musical instrument started playing funny (trumpet sound) and then, I don’t know his name, but that person looked inside the instrument to see what was wrong. The frog fell right onto his face and the man fell backward into a drum. So, the frog hopped away to hide in a green, ucky salad and then the waiter served it to a lady. The lady took a bite of it and the frog peeked out and smiled at her. That made the lady scream and drop the fork and the frog got away. The frog jumped into another person’s cup when the person went to get a drink and the frog kissed him on the nose. That made him and his wife a little sick and went home. The lady that had the salad told the waiter there was a frog in the restaurant then that person got the frog and almost threw him out the front door but Ben said, “Stop, that is my frog.” Ben’s parents told him to be quiet but Ben went over and got his frog and the waiter gave him his frog back. Then they kicked them out of the restaurant and they had to go home and couldn’t have their fine dinner. Everyone in the car was mad. When they got home, Ben’s dad said: “Ben, go right to your bed.” And when Ben went in his bedroom, he sat on the floor and started...then they all had a good laugh together.</td>
</tr>
</tbody>
</table>
Reading Only

Ben dressed to go to dinner and the frog wanted to go, so he jumped in his pocket and Ben said goodbye to his pets and the frog waved goodbye and they went to a fancy restaurant. They went to set down at the table and the frog jumped out into a musical instrument. The waiter was looking inside to see what was wrong and the frog jumped out on his face and he fell on a drum. The frog jumped and landed in a salad and the waiter served the salad to a lady. A lady went to take a bite and the frog peeked out and scared her and the frog jumped out and went into a man’s cup. When the man went to take a drink um, the frog jumped out and kissed him on the nose. Then the waiter saw it when him and his wife was feeling a little sick and then Ben saw his frog. Ben said, “Stop,” and his parents told him to be quiet and then Ben went over there and told him, “Give me back my frog.” The waiter gave him his frog and the waiter told him they have to leave and Ben’s family was mad at him so they couldn’t have their fine dinner and when they got home they told him to go to his room and they got a funny laugh.

Reading + Manipulative

A boy, called Joe, wanted a pet frog and he lived by a lake. He got his bucket and net and went with his dog to look. They looked everywhere to find one. Then his dog and him raced down the hill toward the lake. They didn’t see a branch on the ground and tripped and they landed in the pond, um lake. Joe sat up in the lake with the bucket on his head and was peeking out from it. Then the boy and the dog realized they were looking straight at a frog sitting on a lily pad in the lake. The frog on the lily pad tried not to laugh but he kind of did. Joe tried to catch him but the frog jumped out of the way and landed on an old dead tree sticking out of the water. Joe told his dog to go on the other end of the tree so Ben could trap him in the middle. He tried to grab the frog, I mean he tried to get him in his net, but the frog jumped out of the way and Joe netted his dog instead. The frog didn’t want to be catched and it made him angry. The frog jumped over to a rock far away. Joe was frustrated and decided to give up. Joe put up his fists and waved goodbye and went home with his dog. When he was walking up the hill, the frog got lonely so he decided to follow them. When he got home, Joe was tired so he decided to take a bath. His dog got in the tub too. The frog went in the house and followed their tracks all the way to the bathtub. The boy and the dog were surprised to see the frog in their bathroom and he said, “Here I am, I want to play with you,” said the frog. Then he jumped into the bathtub with them and the three of them were all good friends.
Parental and Spousal Self-Efficacy of Young Adults Who Are Deaf or Hard of Hearing: Relationship to Speech Intelligibility

Limor Adi-Bensaid, Ph.D.; Rinat Michael, M.A.; Tova Most, Ph.D.; and Rachel Gali-Cinamon, Ph.D.

This study examined the parental and spousal self-efficacy (SE) of adults who are deaf and who are hard of hearing (d/hh) in relation to their speech intelligibility. Forty individuals with hearing loss completed self-report measures: Spousal SE in a relationship with a spouse who was hearing/deaf, parental SE to a child who was hearing/deaf, and assessment of speech intelligibility. In general, respondents evaluated their parental SE in relation to a child with hearing loss and their SE toward a spouse with hearing loss as higher than their parental SE toward a child with typical hearing and their spousal SE toward a spouse with typical hearing. Better SE toward a spouse with hearing loss was more prominent for the group that was deaf than for the group that was hard of hearing. In comparing spousal SE and parental SE toward a spouse or child who had typical hearing, all participants reported higher SE as a parent than as a spouse. However, the better parental SE was more prominent among the participants who were deaf. No significant differences emerged in the SE toward a spouse or child with hearing loss among the whole sample or between the two groups (d/hh). Significant relations were found between speech intelligibility and spousal SE among the whole sample and between speech intelligibility and parental SE toward a child with typical hearing among the group that was hard of hearing.

Limor Adi-Bensaid, Ph.D., is a lecturer at Ono Academic College in Israel. Rinat Michael, M.A., is a graduate student at Tel Aviv University in Israel. Tova Most, Ph.D., is a professor at Tel Aviv University in Israel. Rachel Gali-Cinamon, Ph.D., is a professor at Tel Aviv University in Israel. Correspondence concerning this manuscript should be addressed to Prof. Most at tovam@post.tau.ac.il.
Introduction

Self-efficacy (SE) is a key concept in Bandura’s (1986) social-cognitive theory. It is defined as the belief in one’s ability to perform certain tasks, the willingness to initiate certain behaviors, and perseverance in spite of barriers and conflicts. According to Bandura, Barbaranelli, Caprara, and Pastorelli (2001), SE beliefs influence various personal factors, such as level of motivation and perseverance in the face of difficulties and setbacks, resilience to adversity, casual attributions for successes and failures, and vulnerability to stress and depression. Schwarzer and Renner (2000), for example, related SE to proactive coping, counting “coping self-efficacy” as one of the personal resource factors that boost resilience and moderate stress. They defined SE as the optimistic self-belief of being able to cope successfully with the particular situation at hand. Hence, this variable might be especially important in understanding the development of populations with various disabilities, including hearing loss.

People with hearing loss are heterogeneous and function in different ways during daily living. The extent to which hearing loss influences one’s day-to-day activities depends on factors such as the degree of hearing loss, age of onset of the hearing loss, and use of sensory aids (Kretschmer & Kretschmer, 1978; Mayne, Yoshinaga-Itano, Sedey, & Carey, 2000; Quigley & King, 1982; Stach, 1988). These factors have an effect on the acquisition of spoken language and on speech intelligibility (Levitt, McGarr, & Geffner, 1987; Madison & Wong, 1992; McGarr & Osberger 1978; Oller, Jensen, & Lafayette, 1978), as well as on the need to acquire and use other modes of communication, such as sign language or simultaneous communication (speech + signs).

Despite the variety of factors critical to the development of people who are deaf or hard of hearing (d/hh) and the importance of SE to human functioning, the relations between them have not been examined, resulting in a less integrative and insufficient understanding of the impact of hearing loss on the individual’s different life domains. The current study focuses on parental and spousal SE among people who are d/hh, as well as the relations between SE and speech intelligibility.

Self-Efficacy and the Deaf and Hard of Hearing Population

A vast body of literature verifies pervasive influence of SE beliefs across diverse domains of human functioning, including academic, health, organizational, athletic, and sociopolitical spheres (see Bandura, 1997). Through research on youth development, Cinamon (2006, 2009, 2010) emphasized the need to examine the individual’s development in a wide perspective, and to include family roles (spousal and parental) as well as the work role. Indeed, recent studies indicate that different types of SE—such as parental SE and work–family management SE—are important variables explaining achieve-
ment and development in the general population (Cinamon, 2010; Cinamon, Wiesel, & Tzuk, 2007).

Few studies have examined different types of SE among people who are d/hh, indicating a lack of understanding about the influence of the degree of hearing loss and the mode of communication on SE (e.g., Michael, Most, & Cinamon, 2011; Punch, Creed, & Hyde, 2005; 2006).

Research on SE related to family roles is also relatively sparse. Studies that have focused on parental SE—parents’ beliefs in their ability to influence their children’s development and their environment—indicate positive outcomes of high levels of parental SE in the psychological adjustment of parents (see Jones & Prinz, 2005, for a review) and to various aspects of parenting practice, such as parenting responsiveness, monitoring (Bogenschneider, Small, & Tsay, 1997), and acceptance (Dumka, Stoertzinger, Jackson, & Roosa, 1996; Gondoli & Silverberg, 1997). Parental SE also has a positive effect on aspects of child development, such as adolescent adjustment (Steinberg & Morris, 2001), and is negatively related to substance abuse, delinquency (Bogenschneider et al., 1997), and behavior problems (Jones & Prinz, 2005). Much less is known about the influence that spousal SE beliefs exert on human functioning.

In general, studies on parental SE have focused on parents of children who are developing typically and of children with developmental delays or problems (e.g., Cinamon et al., 2007; Spielman & Taubman-Ben-Ari, 2009). The current study focuses on the SE of participants who are deaf or hard of hearing. The study investigates their beliefs in their ability to be a good parent to a child who is either deaf or has typical hearing. In addition, their beliefs in functioning as a spouse to a person who is either deaf or has typical hearing are examined.

When examining parental SE among participants who are d/hh, one must take into account variables of hearing status. According to Leigh, Brice, and Meadow-Orlans, (2004), parenting a child who is deaf comes naturally for parents who are deaf, and they are able to raise him/her based on their own social experience. When persons who are deaf have a child who has typical hearing, however, family functioning and child adjustment become more dependent on parental SE and psychological health. This might imply that both the child’s hearing status and personal efficacy are important factors in the family functioning of people who are d/hh.

Similarly, it may be worthwhile to examine the partner’s hearing status in assessing spousal SE among participants who are d/hh. Not surprisingly, Pimentel (1978) found that persons who are deaf tend to marry other persons with hearing loss. Similarly, Sela and Weisel (1992), who examined the deaf community in Israel, reported that 85% of participants in their study had a spouse who was deaf. Other researchers have reported a connection between choice of partner and mode of communication. Becker (1980) found that persons with hearing loss tend to marry a partner who uses the same mode of communication as theirs (spoken language/sign language). Rice (1984) stated...
that persons with hearing loss who use spoken language have a greater tendency to marry a partner who has typical hearing.

Highlighting two life roles—spousal and parental—is especially crucial when dealing with young adults with special needs, such as people who are d/hh, who may encounter difficulties in these domains, especially when interacting with family members who have typical hearing. Based on the few studies on parenthood and intimacy among persons with hearing loss, the current study hypothesizes that participants with hearing loss will report higher levels of SE toward a child/partner who is deaf compared to a partner who has typical hearing, and participants with different hearing status (i.e., deaf vs. hard of hearing) will rate their SE differently with regard to a child or partner who is hearing/deaf due to differences in their main mode of communication (sign language vs. spoken language).

The crucial impact that parental and spousal SE may have on individual functioning and well-being emphasizes the need to investigate the antecedents of these variables. The current study focuses on a critical factor in the development of persons who are d/hh—speech intelligibility—and its relation to parental and spousal SE.

**Hearing Loss and Speech Intelligibility**

As a result of their hearing loss, many individuals who are d/hh have specific voice and speech characteristics that differ from those of people who have typical hearing (Eisenberg, 2007; Monsen, 1983; Most & Frank, 1994; Peng, Tomblin, & Turner, 2008). The specific characteristics typifying the speech of individuals who are d/hh might affect the others’ ability to comprehend them (Bench, 1992; McGarr, 1987; Monsen, 1983). With poor speech intelligibility, it is not surprising that these individuals may encounter difficulties in communicating ideas through spoken language. However, in addition to impeding communication, difficulties in speech intelligibility might also affect a range of other domains. In fact, several studies have shown that listeners’ evaluations of speakers’ personalities were influenced by the speakers’ spoken language. Speakers with hearing loss were generally evaluated less positively than other speakers (Most, Weisel, & Lev-Matezky, 1996; Most, Weisel, & Tur-Kaspa, 1999). Such evaluations might have a negative impact on social functioning of people who are d/hh.

Indeed, the ability to use spoken language for communication in a coherent, fluent manner appears to constitute a central factor affecting the social relationships of children who are d/hh, particularly with individuals who have typical hearing. Most (2007) examined the relations between speech intelligibility and the socioemotional self-perceptions of children who are d/hh. She found significant correlations between speech intelligibility and loneliness in children who studied in an individual inclusion educational setting with only
children who were able to hear. Children with better speech intelligibility reported being less lonely, probably because their classroom environment required communication dependent on proper use of spoken language; they were better understood by their peers and therefore less lonely.

The above findings suggest that speech intelligibility has a substantial impact on the lives of people who are d/hh. Obtaining intelligible speech skills is essential not only for conveying ideas and communicating with people who have typical hearing, but also for gaining and maintaining social status in and adjustment to predominantly hearing and speaking environments. Thus, it is reasonable to assume that speech skills might have an influence on the individual’s SE as well, especially in interpersonal domains such as family relationships. However, previous studies have not focused on the relations between these two variables. Since SE is a major factor in different personal aspects—such as motivation and resilience (e.g., Bandura et al., 2001)—relationships should be examined between speech intelligibility and SE among people who are d/hh.

The purpose of the present study was to explore the SE of young adults who are d/hh in functioning as a parent or as a spouse—specifically, their SE regarding parenthood to a child who has typical hearing or who is deaf and their SE in a relationship with a partner who is deaf or who has typical hearing. Relationships between these variables and the participants’ speech intelligibility were also examined. The current study hypothesized that reports on both parental SE and spousal SE would be higher with regard to a child/partner who is deaf in comparison to a child/partner who has typical hearing. Researchers further hypothesized that adults who are d/hh would rate their SE differently with regard to a child who is hearing/deaf and to a partner who is hearing/deaf. Finally, researchers assumed a relationship between the self-assessments of speech intelligibility and SE.

**Method**

**Participants**

The sample consisted of 40 individuals ranging in age from 18 to 40 years ($M = 27.95, SD = 5.66$) who are d/hh with different degrees of bilateral sensorineural hearing loss. Twenty-two of the participants were considered deaf and 18 were considered hard of hearing. The researchers made this distinction based on participants’ degree of hearing loss and main mode of communication. Participants who had a profound hearing loss (90 dB HL or poorer) and used sign language as the main mode of communication were referred to as the *deaf group*. In contrast, participants who had a moderate-to-severe hearing loss (55–85 dB HL) and used spoken language as their main mode of communication were referred to as the *hh group*. 

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Table 1 presents the demographic data of the participants. The information is based on self-report questionnaires.

**Table 1. Demographic data of the participants**

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>13</td>
<td>32.5</td>
</tr>
<tr>
<td>Female</td>
<td>27</td>
<td>67.5</td>
</tr>
<tr>
<td>Degree of hearing loss</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profound</td>
<td>22</td>
<td>55.0</td>
</tr>
<tr>
<td>Moderate–severe</td>
<td>18</td>
<td>45.0</td>
</tr>
<tr>
<td>Hearing loss onset</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prelingual (0–3 years)</td>
<td>34</td>
<td>85.0</td>
</tr>
<tr>
<td>Postlingual (3+ years)</td>
<td>3</td>
<td>7.5</td>
</tr>
<tr>
<td>No answer</td>
<td>3</td>
<td>7.5</td>
</tr>
<tr>
<td>Use of hearing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>19</td>
<td>47.5</td>
</tr>
<tr>
<td>Yes</td>
<td>21</td>
<td>52.5</td>
</tr>
<tr>
<td>Mode of communication</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oral</td>
<td>18</td>
<td>45.0</td>
</tr>
<tr>
<td>Signs</td>
<td>22</td>
<td>55.0</td>
</tr>
<tr>
<td>Having a spouse</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>19</td>
<td>47.5</td>
</tr>
<tr>
<td>No</td>
<td>21</td>
<td>52.5</td>
</tr>
<tr>
<td>Hearing status of spouse (out of 19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D/hh</td>
<td>13</td>
<td>68.4</td>
</tr>
<tr>
<td>Hearing</td>
<td>5</td>
<td>26.3</td>
</tr>
<tr>
<td>No answer</td>
<td>1</td>
<td>5.3</td>
</tr>
<tr>
<td>Being a parent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>9</td>
<td>22.5</td>
</tr>
<tr>
<td>No</td>
<td>30</td>
<td>75.0</td>
</tr>
<tr>
<td>No answer</td>
<td>1</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Four self-report measures were used in the study: Assessment of SE in relation to a spouse (hearing/deaf), assessment of SE as a parent to a child (hearing/deaf), assessment of speech intelligibility, and a background questionnaire. All the measures used basic vocabulary and simple language.

The assessment of SE in relation to a spouse (hearing/deaf) consisted of two questions that were developed for the current study on the basis of the SE model and the goals of the current study. In the first question, participants were asked to rate their confidence that they could function successfully as a spouse to a partner who had typical hearing; in the second question, they were asked to do the same in relation to a partner who was deaf. Each question was rated on a 10-point scale ranging from 1 (to a lesser extent) to 10 (to a greater extent), as recommended by Bandura (1995).

The assessment of SE in relation to parenting a child (hearing/deaf) also consisted of two questions. In the first question, the participants were asked to rate their confidence in being able to function successfully as parents to a child who had typical hearing; in the second question, they were asked to do the
same in relation to a child who was deaf. Each question was rated on a 10-point scale ranging from 1 (to a lesser extent) to 10 (to a greater extent).

The assessment of speech intelligibility included a 6-point speech intelligibility scale of five questions regarding the level of intelligibility when talking to familiar and unfamiliar people on familiar and unfamiliar topics. In this scale, 1 represents very poor intelligibility and 6 represents very good intelligibility. The score was calculated by dividing the sum of the scale by the number of items. Thus, each participant’s score ranged from 1 (very poor speech intelligibility) to 6 (speech intelligibility). The internal consistency of the scale was 0.96 (Most, Weisel, & Cinamon, 2008).

The background information questionnaire contained demographic details, including the participant’s gender, onset of hearing loss, degree of hearing loss, use of sensory aids, mode of communication, having a spouse/partner, hearing status of spouse/partner, and being a parent (see Table 1).

 Procedure

All participants agreed to take part in the study. They were recruited through Internet forums and associations and clubs for the deaf and hard of hearing. Each participant was asked to complete the four self-report measures. There was no time limitation. Twenty-six participants completed the questionnaires during a personal appointment, and 14 participants received and completed the questionnaires through email or fax. In cases where participants had difficulty understanding questions because of the wording, a research assistant gave written, spoken, or signed explanations. If needed, explanations were also provided via the Internet.

 Results

Each participant received five scores: SE in relation with a partner (hearing), SE in relation with a partner (deaf), parental SE toward a child (hearing), parental SE toward a child (deaf), and speech intelligibility self-assessment. Table 2 presents the obtained average scores and the SD for all 40 participants.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Range</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spousal SE with a hearing partner</td>
<td>1–10</td>
<td>4.97</td>
<td>2.71</td>
</tr>
<tr>
<td>Parental SE with a hearing child</td>
<td>1–10</td>
<td>8.05</td>
<td>2.28</td>
</tr>
<tr>
<td>Spousal SE with a deaf partner</td>
<td>1–10</td>
<td>8.98</td>
<td>1.75</td>
</tr>
<tr>
<td>Parental SE with a deaf child</td>
<td>1–10</td>
<td>8.97</td>
<td>1.36</td>
</tr>
<tr>
<td>Speech Intelligibility–self-assessment</td>
<td>1–6</td>
<td>4.67</td>
<td>1.11</td>
</tr>
</tbody>
</table>

 Note. SE = self-efficacy.
The first goal of the study was to examine participants’ SE with regard to parenting a child who was hearing/deaf and with regard to spousal relationship with a partner who was hearing/deaf. Research assumptions were that reports on both parental SE and spousal SE would be higher with regard to a child/partner who was deaf in comparison to a child/partner who had typical hearing. In general, participants received high scores in assessing their parental SE in relation to a child who was either deaf or had typical hearing, and their SE in relation to a partner who was deaf (with all three scores above 8 out of a possible 10). Their SE regarding a partner who had typical hearing was lower. They also assessed their speech as being quite intelligible (4.67 out of 6).

Despite high scores on both parental SE assessments, Wilcoxon tests revealed that parental SE in relation to a child who was deaf was significantly higher than parental SE in relation to a child who had typical hearing ($Z = -3.09$, $p < .01$). Differences between the two types of spousal SE were also found to be significant ($Z = -4.60$, $p < .001$). As previously noted, participants rated themselves higher in relation to a partner who was deaf compared to a partner who had typical hearing.

Comparisons between participants’ parental SE and spousal SE revealed a significant difference between these evaluations when SE was assessed with regard to a child or partner who was able to hear. Parental SE was higher than spousal SE ($Z = -4.39$, $p < .001$). Results were not significantly different when parental SE in relation to a child who was deaf was compared to spousal SE in relation to a partner who was deaf.

As mentioned earlier, the research sample included young adults (22 deaf and 18 hh). The second goal of the study was to examine differences in parental and spousal SE among these two groups. Table 3 presents the obtained average scores and SD of the four SE evaluations by the two groups.

Comparisons between the SE scores among the participants who were d/hh did not reveal significant findings. However, as hypothesized, significant results emerged when differences among the four types of SE were examined.

**Table 3.** Means and standard deviations of SE scores among deaf and hh groups

<table>
<thead>
<tr>
<th></th>
<th>Deaf (n = 22)</th>
<th></th>
<th>HH (n = 18)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Spousal SE with a hearing partner</td>
<td>4.05</td>
<td>2.16</td>
<td>6.00</td>
<td>2.93</td>
</tr>
<tr>
<td>Parental SE with a hearing child</td>
<td>8.21</td>
<td>2.37</td>
<td>7.89</td>
<td>2.93</td>
</tr>
<tr>
<td>Spousal SE with a deaf partner</td>
<td>9.05</td>
<td>1.96</td>
<td>8.83</td>
<td>1.54</td>
</tr>
<tr>
<td>Parental SE with a deaf child</td>
<td>9.05</td>
<td>1.57</td>
<td>8.89</td>
<td>1.13</td>
</tr>
</tbody>
</table>

*Note. SE = self-efficacy; hh = hard of hearing.*
To examine differences between types of SE among the two participant groups, four scores were obtained (Table 4):

1. Difference in spousal SE: subtracting the SE score toward a partner (hearing) from the SE score toward a partner (deaf).
2. Difference in parental SE: subtracting the SE score toward a child (hearing) from the SE score toward a child (deaf).
3. Difference in SE in relation to a partner/child (hearing): subtracting the spousal SE score toward a partner (hearing) from the parental SE score toward a child (hearing).
4. Difference in SE in relation to a partner/child (deaf): subtracting the spouse SE score toward a partner (deaf) from the parental SE score toward a child (deaf).

Mann-Whitney tests revealed significant results in two scores: difference in spousal SE ($U = 104.50, p < .05$) and difference in SE in relation to a partner/child who had typical hearing ($U = 81.50, p < .05$). In both cases, greater differences emerged among the deaf group compared to the hh group. Nonetheless, Wilcoxon tests showed that the average spousal SE in relation to a partner who was deaf was significantly higher than the average spousal SE in relation to a partner who had typical hearing in the deaf group ($Z = -3.70, p < .001$) as well as in the hh group ($Z = -2.77, p < .01$), and that the parental SE in relation to a child who had typical hearing was significantly higher than the spousal SE in relation to a partner who had typical hearing among the deaf group ($Z = -3.61, p < .001$) and the hh group ($Z = -2.46, p < .05$).

Comparisons between the two groups revealed no significant findings with regard to differences in the two types of parental SE and with regard to differences between parental and spousal SE when the child or the partner is deaf. However, Wilcoxon tests did reveal significant differences between the two types of parental SE in both the deaf ($Z = -2.03, p < .05$) and hh ($Z = -2.41, p < .05$) groups. In both cases, evaluations of parenting a child who is deaf were higher than parenting a child who had typical hearing. No significant differences were found between parental and spousal SE in relation to a child who was deaf or a partner who was deaf in the two groups.

<table>
<thead>
<tr>
<th></th>
<th>Deaf ($n = 22$)</th>
<th>HH ($n = 18$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>Difference in spousal SE</td>
<td>4.71</td>
<td>3.21</td>
</tr>
<tr>
<td>Difference in parental SE</td>
<td>0.95</td>
<td>2.06</td>
</tr>
<tr>
<td>Difference in SE in relation to a hearing partner/child</td>
<td>3.95</td>
<td>2.58</td>
</tr>
<tr>
<td>Difference in SE in relation to a deaf partner/child</td>
<td>0.10</td>
<td>2.47</td>
</tr>
</tbody>
</table>

Table 4. Means and standard deviations of differences in SE among deaf and hh groups

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Analyses conducted on participants’ demographic data revealed a significant result when comparing parents to nonparents ($\chi^2 = 5.30, p < .05$), whereas no differences emerged among participants who were parents between parental SE toward a child who had typical hearing ($M = 8.67, SD = 1.87$) and parental SE toward a child who was deaf ($M = 8.67, SD = 1.87$); participants who had no children reported lower levels of parental SE toward a child who had typical hearing ($M = 7.86, SD = 2.40$) than toward a child who was deaf ($M = 9.18, SD = 1.06$). No significant findings were found between participants with and without spouses and between participants who were male or female.

The third goal of the study was to explore the relationships between the SE variables and the participants’ speech intelligibility. Self-assessment of speech intelligibility showed that participants rated their speech as quite intelligible ($M = 4.67, SD = 1.11$). A comparison between the speech intelligibility of the hh participants and that of the deaf participants revealed a significant difference ($t(1,37) = 4.16, p < .001$). The speech intelligibility of the hh group was rated higher ($M = 5.33, SD = 0.63$) than that of the deaf group ($M = 4.09, SD = 1.11$).

Pearson correlations between the speech intelligibility of all the participants and each of the SE variables revealed two significant correlations: a significant positive correlation between speech intelligibility and spousal SE with a partner who had typical hearing ($r = .34, p < .05$), and a significant negative correlation between speech intelligibility and spousal SE with a partner who was deaf ($r = -.32, p < .05$). Better speech intelligibility was linked to higher levels of spousal SE with a partner who had typical hearing and with lower levels of spousal SE with a partner who was deaf. Linear regressions that were conducted with speech intelligibility as an independent variable and each of the four SE scores as dependent variables showed similar results. Regressions were significant in relation to spousal SE to a spouse who had typical hearing [$F(1,37) = 4.69, p < .05$] and who was deaf [$F(1,36) = 3.96, p < .05$]. Speech intelligibility explained 11.5% of the variance of spousal SE in relation to a partner with typical hearing ($\beta = .31, p < .05$) and 10.2% of the variance of spousal SE in relation to a partner who was deaf ($\beta = -.32, p < .05$).

Analyses in each group separately revealed a significant correlation between speech intelligibility and parental SE in relation to a child who has typical hearing only among the participants who were hard of hearing ($r = .51, p < .05$). Thus, better speech intelligibility in this group was linked to higher levels of parental SE in relation to a child who has typical hearing. However, no significant regressions were found between speech intelligibility and parental SE.

**Discussion**

The present study focuses on the impact of hearing loss on individuals’ perceptions and beliefs regarding their ability to function as parents and as
spouses. SE in these two domains was assessed in relation to spouses and children with different hearing status (i.e., deaf/ hearing).

In general, participants reported higher levels of perceptions of SE to be parents of a child who is deaf than of a child who has typical hearing. Similar findings were found when participants were compared according to their degree of hearing loss (i.e., deaf or hh) and their main mode of communication. In both groups, parental perceptions of SE in relation to a child who is deaf were higher than parental perceptions of SE in relation to a child who has typical hearing. An explanation of these findings might be that, as a result of their own hearing loss, many persons who are d/hh do not feel comfortable communicating with people with typical hearing; they may prefer communicating with people of similar hearing status (Levinger, 2003). Thus, the higher parental SE in relation to a child who is deaf in both groups might result from a feeling of greater capability in a relationship with a child of the same hearing status. Another possible reason for these findings might be related to environmental attitudes. The hearing environment (such as family members and professionals) could hold negative perceptions concerning the adults’ inability to function as parents to a child who has typical hearing. Indeed, many extended families tend to be overinvolved in their children’s own nuclear families, often doubting their parental role (Levinger & Orlev, 2008). Perceptions such as these may be signaled to the person with hearing loss through implicit—or even explicit—messages and might have a negative impact on his/her parental SE in relation to a child who has typical hearing.

It is important to note, however, that previous results have demonstrated that parents who are deaf are no less capable than parents who have typical hearing. Jones, Storm, and Daniels (1989), for example, studied 19 couples who were deaf raising children who had typical hearing and found that these parents demonstrated good parenting skills. Moreover, some have found that parents who are deaf often have unique relationships with their children who have typical hearing (Filer & Filer, 2000; Preston, 1994; Torres, 2004; Zarem, 2003). Thus, although perceptions of SE are considered strong predictors of behavior, it should be remembered that it is a dynamic concept influenced by accomplishments, role models, and encouragement (Bandura, 1997), and individual SE might change through life experiences.

For spousal SE, participants reported higher levels of efficacy in relation to a partner who was deaf compared to a partner who has typical hearing. This finding supports previous research on the tendencies of people with hearing loss to marry partners with hearing loss (Pimentel, 1978). However, a comparison between participants who were d/hh reveals that high levels of spousal SE in relation to a partner who was deaf were more prominent among the deaf group. This finding supports Sela and Weisel’s (1992) study of the deaf community in Israel, which found a higher rate of intimacy between partners who were both deaf. Since hearing loss can affect the abilities of people who are deaf to communicate with people who have typical hearing, they may prefer a
partner who is deaf. Likewise, Levinger (2003) reported that people who are deaf prefer to live with someone who has a similar life experience. Since the members of the hh group used spoken language as their main mode of communication, it is not surprising that they felt better about their ability to communicate with a partner who was able to hear than did members of the deaf group.

In comparing spousal and parental SE in relation to a spouse or child who had typical hearing, all participants reported a higher sense of parental SE than of spousal SE. However, the difference between the two evaluations was greater in the deaf group than in the hh group. In other words, the deaf group felt more competent in dealing with a child who has typical hearing than an adult who has typical hearing. No differences were found in the SE assessments in relation to a child or spouse who was deaf among the whole sample or between the two groups (deaf or hh). In other words, hearing loss had an impact on the individual’s SE assessment especially when it was related to a spouse or child who has typical hearing.

A possible explanation for these findings might be the assumption that adults who are deaf have more confidence in interacting with a child who is able to hear than a spouse who is able to hear. Children are more likely to accept the hearing loss of their parents and be less judgmental of their abilities compared to the attitude of an adult toward his/her spouse for several reasons. First, the reality of having a parent who is deaf is the only one the child knows; it is a situation to which he/she is accustomed from birth. Second, a child perceives any parent—deaf or hearing—as an authority figure due to the parental role of raising, teaching, and directing offspring, as well as serving as a role model. Thus, parents might be less exposed to criticism by their children than by others. In contrast, relationships between two adults are more mutual and, therefore, might be more judgmental, demanding, and subject to criticism.

The fact that the hh group reported higher levels of spousal SE in relation to a hearing partner compared to the deaf group might be a result of their degree of hearing loss, which has an impact on their mode of communication and their speech intelligibility. As mentioned earlier, the hh group used spoken language; further, their speech intelligibility was significantly higher than the deaf group. Thus, it is possible that they felt more capable of communicating with people who are able to hear, in general, and with a spouse who is able to hear, in particular.

As previously stated, the current study follows Cinamon’s (2006, 2009, 2010) career perspective, which encompasses family as well as vocational roles. In fact, the suggested impact that hearing loss has on parental and spousal SE has been previously reported with regard to career development aspects. Studies have found significant differences among participants who are deaf, hh, and hearing in aspects of role salience, anticipated work–family conflict, and SE to manage this type of conflict (Cinamon, Most, & Michael, 2008; Michael, Most, & Cinamon, 2011).
In addition to the potential effect that hearing loss might have on SE, the current findings suggest that parenthood itself may be an influential factor in the development of parental SE. Among participants who were parents, no differences emerged between parental SE toward a child who was deaf versus hearing. In contrast, participants who had no children reported lower levels of parental SE toward a child who has typical hearing than toward a child who is deaf. Hence, the experience of being a parent might have contributed to participants’ parental SE, particularly toward a child who was able to hear. Interestingly, no significant findings were found between participants with and without spouses in relation to spousal SE. However, participants were not asked about their experiences as spouses, just whether they had a spouse at the time of the study. Future studies should examine the contribution of experience as a spouse to spousal SE among persons with different levels of hearing loss.

Finally, the study's results demonstrate the relationship between speech intelligibility and spousal SE: Better speech intelligibility was related to better SE toward a spouse who has typical hearing and poorer SE toward a spouse who is deaf. In other words, participants with better speech intelligibility, whether deaf or hh, felt more competent being in a relationship with a spouse who was able to hear. In fact, speech intelligibility explained some of the variance of the two types of spousal SE, meaning that it might be one of the factors that contribute to the development of SE beliefs among individuals with hearing loss. These findings are consistent with previous studies on persons with hearing loss that emphasized a relationship between speech intelligibility and different aspects of human behavior (e.g., Most, 2007).

Interestingly, in the current study, speech intelligibility was significantly related to parental SE only in relation to a child who has typical hearing and only among the hh group. The different modes of communication used in the interaction with a child who was able to hear by parents who were d/hh might explain this finding (i.e. spoken language vs. sign language). Consequently, speech intelligibility might be an important factor only in interaction with parents who use spoken language. In contrast, having a child who is deaf might require parents, deaf or hh, to use other modes of communication besides spoken language, causing speech intelligibility to be a less prominent factor. Thus, it is reasonable to conclude that speech intelligibility might have a greater effect on parental SE only when interaction requires spoken language.

**Conclusion**

In summary, young adults with hearing loss, both deaf and hh, evaluated their SE to be a parent to a child who is deaf and their SE to be in a relationship with a spouse who is deaf as higher than their SE to a child and a spouse who have typical hearing. In comparing spousal/parental SE to a spouse or child who has typical hearing, all participants reported higher SE as parents than as
spouses. The better parental SE was more prominent among the deaf group than the hh group. However, in the current study, only general SE was evaluated. Dumka, Gonzales, Wheeler, and Millsap (2010) suggested a distinction between general parental SE (the belief of being a good parent) vs. task-level efficacy (e.g., being able to help children with homework). Future research should expand and include specific assessment tasks in relation to parental SE and perhaps also in regard to spousal SE.

Previous research findings have also emphasized the relationship between speech intelligibility and parental and spousal SE of persons with hearing loss when interacting within a hearing environment. As other research has found (e.g., Most, 2007), speech intelligibility seems not only to influence communication, but is also a factor that should be taken into account when looking at other types of human functioning, such as family roles. In the current study, speech intelligibility was determined by self-reports. Future research should also include an objective assessment of speech intelligibility.

The present study focused on parental and spousal SE. Nevertheless, the sample of participants was relatively small and heterogeneous. Future research with a bigger sample, including more participants with/without spouses differing in their hearing status as well as participants with/without children differing in their hearing status, would enable a comparison of the parental and spousal SE of these subgroups and shed more light on these issues. Further, the relationship between speech intelligibility and other types of SE, such as academic and social SE, should be explored to fully comprehend the impact that speech intelligibility has on the SE of persons with hearing loss. Moreover, in light of the assumption that family roles are relevant to an individual’s career (Cinamon, 2006, 2009, 2010), more research is needed to examine the contribution of speech intelligibility to the career development of persons who are d/hh. Another limitation of the current study is the fact that the data were collected through various avenues, such as the Internet and personal appointments, which might have influenced the participants’ responses.

The results suggest some implications for professionals—such as counselors and teachers of individuals who are d/hh—as well as for the parents of individuals who are d/hh. Since degree of hearing loss and the use of different communication modalities might affect individuals’ future family plans (i.e., choosing a spouse or performing as a parent), it is important to include these issues in the rehabilitation process. Discussion and clarifications of these issues might avoid the dominant effect of the hearing loss on the individuals’ future plans.

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References


Changing Trends within the Population of Children who are Deaf or Hard of Hearing in Flanders (Belgium): Effects of 12 Years of Universal Newborn Hearing Screening, Early Intervention, and Early Cochlear Implantation

Leo De Raeve, M.D.; and Guido Lichtert, Ph.D.

The purpose of this study is to show the changing trends within the population of children who are deaf and hard of hearing in Belgium over the last 12 years. The combination of Universal Newborn Hearing Screening programs, early intervention, and cochlear implants have tremendously influenced the education and support of children who are deaf or hard of hearing in Flanders, Belgium. Today, three times more children with a hearing loss are educated in mainstream settings than 20 years ago. At the same time, the needs of children in special schools for the deaf have become more complex as a significantly greater proportion of these students have additional needs. At a mainstream secondary level, students who are hard of hearing and students who are deaf make different academic choices: More students who are hard of hearing go to vocational training schools, and more students who are deaf attend technical schools. Although all students with hearing loss who attend mainstream

Leo De Raeve, M.D., is director of ONICI, an independent information and research center on cochlear implants in Zonhoven (Belgium), psychologist at the KIDS Institute for the Deaf, and a lecturer in the Speech and Language Department of Hogeschool Zuyd University in Heerlen (the Netherlands). Guido Lichtert, Ph.D., is a professor within the Faculty of Medicine, Experimental ORL of the Katholieke Universiteit Leuven (Belgium), and educational director of the Home Guidance Department of the Royal Orthopedagogic Center Antwerp (Belgium). Correspondence concerning this manuscript may be addressed to Mr. De Raeve at leo.de.raeve@onici.be.
secondary schools in Flanders are entitled to an interpreter, significantly fewer students with a cochlear implant choose this option in comparison to students without a cochlear implant. Of the students with cochlear implants who do request an interpreter, approximately half use a notetaker and half use a sign language interpreter. Among students without a cochlear implant, there is a clear preference for a sign language interpreter.

Introduction

In 1998, Flanders, the Dutch speaking part of Belgium, was one of the first regions in Europe to implement a Universal Newborn Hearing Screening (UNHS) program that combined medical-audiological diagnostics and an early intervention and (re)habilitation program (Van Kerschaver, Boudewijns, Stappaert, Wuyts, & Van de Heyning, 2007). Since then, approximately 98% of all newborns born in Flanders are screened every year. The UNHS program integrates screening, diagnosis, and early intervention and (re)habilitation in one program.

Before implementation of the UNHS program, hearing screening was administered at the age of 9 months by means of the Ewing Behavioral Test (responding to simple sound makers) (Rovers et al., 1999) and the average age for the first hearing aid fitting was 14 months (De Raeve, 2006). Since 1998, however, the average age for the first hearing aid fitting has been reduced to 4 months of age, while referral for a cochlear implant (CI) assessment has become common practice before 9 months of age (Philips et al., 2009). When appropriate, many children receive a CI before their first birthday, and the average age of implantation is currently 16 months old (De Raeve, 2010).

This shift in policy and practice in Flanders has begun to change the demographic of the deaf population entering the education system, and will continue to do so into the future. In 2010, 94% of children who were deaf1 and of preschool age (2.6–6.0 years) were using a CI (Figure 1). For those of primary school age (6.0–12.0 years), this figure was 81%, and at secondary school age it was 49%. Such figures demonstrate that in six years’ time, 80–90% of all Flemish school-aged children who are deaf will use a CI. Children who are hard of hearing2 are not candidates for CIs in Belgium and therefore are not included in Figure 1.

Evidence exists that children who receive a CI at a younger age perform better on a range of language measures than children who receive a CI at an older age. Significant differences have been documented in the listening and

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1 Defined as having an average bilateral hearing loss at 500, 1000, 2000, and 4000 Hz > 90 dB SPL unaided. The term “deaf” in this paper always refers to this definition.

2 Defined as having an average bilateral hearing loss at 500, 1000, 2000, and 4000 Hz < 90 dB SPL unaided. The term “hard of hearing” in this paper always refers to this definition.
spoken language abilities of children who receive CIs under the age of 2 rather than under the age of 4 (Anderson et al., 2004; De Raeve, 2010; Svirsky, Su-Wooi, & Neuburger, 2004). There is also a growing body of research indicating that children who receive CIs under the age of 24 months can match the progress of peers with typical hearing in some areas of language development (Hehar, Nikolopoulos, Gibbin, & O’Donoghue, 2002; Schauwers, Gillis, Daemers, De Beukelaer, & Govaerts, 2004) and that many are ready to enter mainstream education in early primary school grades (Govaerts et al., 2002).

With regard to speech development, Schauwers and colleagues (2004) showed that children who received CIs under the age of 20 months took an average of 1 month of auditory exposure to begin babbling, regardless of the age of implantation. Since babbling in children with typical hearing starts at an average age of 8 months (Gillis & Schaerlaekens, 2000), early cochlear implantation is critical in encouraging the child to begin babbling within the typical range. It has also been found that children who receive a CI before the age of 1 develop preverbal communication behaviors that do not differ significantly in extent from children with typical hearing (Tait, De Raeve, & Nikolopoulos, 2007).

Spoken language acquisition appears to be better facilitated when there is a shorter interval between the onset of hearing loss and cochlear implantation. The largest study in Belgium—conducted by Philips and colleagues (2009) on 391 children with CIs—confirmed that the implementation of the UNHS program has resulted in earlier amplification (with conventional hearing aids) and earlier implantation, both of which are known to have a positive influence on auditory receptive skills, speech intelligibility, and language development.
(Boons et al., 2012; De Raeve, 2010; Van Deun et al., 2010). Additionally, the use of the most recent speech coding strategies and electrode design, proper programming of the implant map, and an educational environment that focuses on the development of auditory and speech skills can play a critical role in facilitating the development of spoken language and reading (van der Kant, Vermeulen, De Raeve, & Schreuder, 2010).

Thus, with earlier screening, earlier cochlear implantation, and improved technology, there is every reason to be optimistic about the development of speech, language, reading, and writing skills of children who are deaf or hard of hearing.

**Educational System for Children with Hearing Loss in Flanders**

If a newborn fails the hearing screening test in Flanders, the Flemish public agency Child and Family refers the parents to a center for further diagnosis and (re)habilitation. This could be the ear, nose, and throat (ENT) department of a university clinic, a center for early intervention for children with hearing loss and their families, or a (re)habilitation center for children with hearing loss. In Flanders, many of the audiological, educational, (re)habilitation, and early intervention services for children who are deaf or hard of hearing are concentrated in one of six regional service centers (one in each province). Three out of six centers offer daycare for infants and toddlers with hearing loss. Most of these daycare centers are located on the same campus, or even in the same building, as the pediatric audiological center or the early intervention team.

Children in Belgium attend preschool by the age of 30 months. When the child has a hearing loss, parents may choose between a special school for children with a hearing loss or a mainstream school environment. All special schools are public schools, and five out of the six Flemish schools use a differentiated educational philosophy (Lichtert, 1990). This means that they differentiate the communication mode based on each child’s communication and/or learning capacities. One school in Flanders has a sign–bilingual approach using Flemish sign language combined with written and spoken (Dutch) language.

In the mainstream class, children who are hard of hearing are entitled to receive additional support from a peripatetic teacher of the deaf or from a specialized speech–language pathologist for 2 hours each week. This support is provided throughout preschool but is limited to only 2 years of primary school and 2 years of secondary school. Therefore, for 4 years during primary school and 4 years of secondary education, there are no public support services offered for children who are hard of hearing. When offered, the peripatetic support staff is provided by the nearest school for the deaf and hard of hearing.
In contrast, children who are deaf are entitled to 4 hours of weekly support throughout their education, and at secondary school (ages 12–18 years) students who are deaf have the added option of an interpreter. This can be a sign language interpreter or a notetaker. A complex system is used to calculate the number of hours per week for which each student is entitled to an interpreter. This depends upon the overall number of interpreter-hours provided by the Government of Education, the total number of students requesting an interpreter, and the educational level of each student. The average allocation is between 4 and 8 hours per week.

**Research Aims**

The central aim of this study was to compare numbers of children with a hearing loss attending special and mainstream schools between 1990 and 2000 (Loots et al., 2003) to data collected in 2010. Both studies collected data in the same region of Belgium (Flanders). In the current study, additional data has been collected on the number of students with a hearing loss who have special needs, the academic choices of these students, and the interpreters’ support in mainstream secondary schools. Four hypotheses were explored:

1. More children with a hearing loss will attend mainstream schools, and fewer children will attend special schools in 2010 compared to 1990.
2. The percentage of children with a hearing loss with additional needs will increase in special schools.
3. Due to improved earlier screening, earlier cochlear implantation, and improved technology, students who are deaf will choose a more theoretical level in mainstream secondary schools.
4. Students wearing cochlear implants in mainstream secondary schools will make different interpreter choices compared to children who are deaf and do not use CIs.

**Methodology**

**Participants**

The present study included 1,336 children who are deaf and hard of hearing between the ages of 2.6–18 from all over Flanders (Belgium). Within this group, 585 children were using CIs. Special education and educational support for children with a hearing loss in mainstream schools are provided for free by the Belgium Government of Education; therefore, nearly all children who are deaf or hard of hearing in Flanders are included in this study.

Between 1990 and 2010, all six Flemish special schools for children who are deaf or hard of hearing developed centers of expertise for children with a
hearing loss, as well as supporting children with hearing loss in mainstream schools and in early intervention. The six Flemish service centers work closely together through a joint working group, acting as a consultative body called CORA.3

Procedure and Statistical Analysis

From 2006 onward, CORA compiled a detailed annual inventory on the population of children who are deaf and hard of hearing in special and mainstream schools in Flanders. Each February, an Excel file is distributed to all members of CORA and data are collected through the end of June. The response so far has been 100%, which gives a complete overview of all school-aged children with a hearing loss in Flanders.

This study will focus in more detail on data collected by February 2010, concentrating on the evolution in education over the last 5 years (De Raeve, 2006), and it will compare these data with the retrospective study by Loots et al. (2003), which reported on data collected between 1990 and 2000. Due to the limit number of service centers in Flanders (n = 6) that provided data, nonparametric statistical analyses was used.

Results

Changes within the Population Attending Special and Mainstream Schools

Figure 2 provides an overview of all children with hearing loss in Flanders in mainstream and special educational settings between the school years 1990–1991 and 2009–2010. Comparing the data from 1991 with the data from 2010, there was a 22% decrease (130 children) in special schools and a 220% increase (592 children) in mainstream schools. This decrease in numbers in special education was significant (Z = 1.892, p = .029, one-tailed) if we compare the data of the six centers from 1990–1991 (M = 98, SD = 36) with those of 2009–2010 (M = 79, SD = 31).

A statistical comparison of the increase of the mainstreamed population was not possible because the detailed data per center were no longer available for 1990–1991, and it was not possible to compare the global results on a yearly basis because data from mainstreamed children who are hard of hearing (2006–2009) were missing. Only for the school year 2009–2010 was all detailed information available. Results shown indicate that not only are more children attending mainstream schools but, overall, more children with hearing loss are attending school than before (mainstream and special school totals combined).

3 Commissie voor Ontwikkeling en Research ten aanzien van personen met een Auditieve beperking [Commission for Development and Research for Persons with an Auditory Impairment].

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However, Figure 2 must be read with some caution. The sudden decrease in numbers of children with hearing loss in mainstream schools between 1995–1996 and 1996–1997 reflects a change in the law on support services for children who are hard of hearing (Lichtert, 2007) rather than an actual reduction in the numbers of children entering mainstream schools. Until 1995–1996, all children who were hard of hearing received 2 hours of weekly support throughout their schooling. From 1996–1997 onward, this changed to 2 hours a week for a maximum of 2 years during primary school and again a maximum of 2 years during secondary school. This means that, as reported earlier, these children were not receiving (public) support for 4 years of primary and 4 years of secondary schooling. The data in Figure 2 include only children who received support during each school year.

Consequently, the data from February 1991 can be accurately compared only with data from 2010 (bar 09–10) if the number of children who are hard of hearing and did not receive support during the 2009–2010 school year are included. These data are represented by the last bar, 09–10 plus, in Figure 2. In February 2010, 65% of children who were deaf or hard of hearing in Flanders were educated in mainstream schools and 35% in special schools. Of the 861 children in mainstream schools, 245 children who were diagnosed as hard of hearing did not receive public support in 2009–2010. This represented 28% of the mainstream population. During that period of no public support, we know from clinical practice that some of these children received assistance from professionals from the early intervention or home guidance services, from (re)habilitations centers, or from private therapists.

Figure 2. Numbers of children with a hearing loss in regular and special schools between 1990–1991 and 2009–2010.
Although 65% of Flemish children with a hearing loss were attending mainstream schools in 2010, this does not necessarily mean that all these students had been in a mainstream school since the beginning of preschool. When examining the subgroups within the 2010 data more closely, it can be seen that the percentage of children with a CI attending mainstream schools, rather than special schools, gradually increased from preschool through primary school and secondary school (see Figure 3). For the cohort of 2010, this increase is significant (KW = 8.851, p = .012) as calculated with a nonparametric ANOVA.

Only 28% of children using a CI entered directly into a mainstream preschool (ages 2.6–6.0) program in 2010, indicating that the majority started in a special school. By primary school (ages 6.0–12.0), 46% of the children using a CI were attending a mainstream school. That number increased to 66% by secondary school (ages 12.0–18.0). Thus, 2 out of 3 Flemish students with a CI were attending mainstream secondary schools in 2010. This represents an increase of 40% when compared with a similar study carried out in the same region in 1999 (De Raeve, 2006).

**Population of Children in Special Schools**

Figure 3. Percentage of children with a cochlear implant in mainstream pre-, primary, and secondary schools from 2006 through 2010.
By reviewing the data in Figures 2 and 3, it can be surmised that the population of students who are deaf and hard of hearing in special schools is decreasing, especially at the secondary level. In 2010, the average number of students per special school at the secondary level, calculated across the six schools for the deaf, was only 23 (SD = 10), compared with an average of 42 in 1991. This means that decreased enrollment in some schools is significant.

Although the actual enrollment in special schools might have decreased, the percentage of children who are deaf or hard of hearing in special schools with additional disabilities has increased by 10% in the last 5 years for both preschool and primary school and by approximately 5% for secondary school (Figure 4). This means that in 2010, approximately 40% of the population in primary and secondary special schools had additional special needs. This increase is significant ($Z = 1.892, p = .029$, one-tailed), especially the numbers of students in secondary school ($Z = 1.841, p = .033$, one-tailed).

*Educational Level in Mainstream Schools*

In Flanders, the educational curriculum of mainstream secondary schools can be divided roughly into three levels: (a) a vocational level, mainly focused on practical subjects; (b) a technical level, which is a combination of practical and theoretical teaching; and (c) a theoretical level. For instance, art and sports are taught at a technical level while science and mathematics are at a theoretical level.

![Figure 4](image-url)  
*Figure 4.* Evolution of the percentage of children who are deaf and hard of hearing with additional needs in special educational settings in Flanders between 2006 and 2010.
level. Analysis of the educational level of students with hearing loss in mainstream secondary schools (Figure 5) shows a significant difference ($\chi^2 = 7.336, p = .025$) in how students with different levels of hearing (deaf or hard of hearing) are distributed across the educational strata (vocational, technical, and theoretical). More students who are hard of hearing (49%) than deaf (36%) favor education at a vocational level, while the reverse is true at a technical level (hard of hearing, 24%; deaf, 41%). The distribution at a theoretical level is similar between the two groups (hard of hearing, 27%; deaf, 23%).

**Interpreters at Secondary School**

In mainstream secondary schools in Flanders, students who are deaf can receive the services of a sign language interpreter and/or a notetaker. The average allocation is between 4 and 8 hours per week. However, a study by Vermeerbergen and Van Herreweghe (2008) found that, in most cases, many teachers did not consider 8 hours enough time, and in response to their concerns, the Ministry of Education in Flanders agreed to gradually increase the number of interpreter-hours available to students who are deaf. In September 2011, parents of two secondary school students who are deaf took the Minister of Education to court, asking for more hours of interpreters for their children. The parents won their case on the basis of equal rights for people

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*Figure 5.* Percentage of students who are deaf or hard of hearing studying at vocational, technical, and theoretical levels in mainstream secondary schools in 2009–2010.
with disabilities. The Government of Education was given a 5-month deadline within which to provide interpreters for a minimum of 70% of the school hours (FEVLADO, 2011). Students who are hard of hearing are not entitled to ask for interpreters.

Data analysis of students’ use of an interpreter at secondary schools during 2010 (Figure 6) showed that fewer students with CIs (53%) made use of some form of interpreter service compared to students without a CI (68%). However, more students with a CI preferred to use a notetaker when compared to students without a CI. Significant differences were found by statistically comparing the preference of interpreter (no interpreter, sign language interpreter, notetaker) of children with CIs to those without CIs ($\chi^2 = 6.720, p = .034$).

**Discussion**

During the last decade, much has been published about the auditory, speech, language, and academic outcomes of the Belgian population of children with hearing loss who were screened early and received CIs early (Baudonck, Dhooge, D’haeseleer, & Van Lierde, 2010; Boons et al., 2012; De Raeve, 2010; Philips et al., 2009; Schauwers, Gillis, & Govaerts, 2005, 2008; Schauwers et al., 2004; Scherf et al., 2007, 2009a, 2009b; Tait et al., 2007, 2010; van der Kant et al., 2010; van Deun et al., 2009a, 2009b). All of these studies have shown significant improvement in the children’s linguistic and academic performance when
compared with their performance before the introduction of the UNHS. However, results also show large individual differences.

Based on this study regarding the educational setting of all children who are deaf and hard of hearing in Flanders, three times more children with a hearing loss are now educated in mainstream settings compared with 20 years ago. This increase can be explained by the number of children moving from special to mainstream schools and by the increased total number of children with hearing loss now receiving support services. In the past, many children with a hearing loss were diagnosed very late. By employing a UNHS program, many children with a mild hearing loss are now diagnosed and supported at a young age, while children who are deaf are offered CIs (when appropriate) at an early age. Children identified early demonstrate improved auditory performance and speech intelligibility (Philips et al., 2009), prompting easier entry into mainstream schooling. It is also possible that the overall number of children who are deaf or hard of hearing has increased over the last 20 years, but there is insufficient data available with which to compare. Therefore, it can only be concluded that in Flanders today, a greater number of children who are deaf and hard of hearing are supported than previously.

However, many support staff start to work as itinerant or peripatetic teachers immediately upon completing their basic teacher training; they have little or no specific experience in educating or supporting children with a hearing loss. In the past, these teachers received their training in schools for the deaf and started working as peripatetic teachers some years later. With more students in mainstreamed classes, more staff is needed to support them in their mainstream school, while fewer staff is required to educate the smaller population in the special schools for the deaf, thus reducing opportunities for experiential training.

As a consequence of the increasing number of mainstream students with a hearing loss, the overall numbers of students in special secondary schools is decreasing. In February 2010, there were only 138 students with a hearing loss attending special secondary schools in Flanders. The current model of special schooling—developed when numbers were much higher—cannot be expected to meet the needs of current students as effectively when their needs are diverse and they are spread across six schools. Perhaps fewer, but more specialized, secondary schools for students who are deaf and hard of hearing and/or more inclusive education alongside children with typical hearing (with or without special needs, either individually or as a group) might be possible solutions to guarantee a rich, differentiated curriculum.

The numbers of students in special schools are not only declining, but that population’s needs are becoming more complex. Recent research by Nikolopoulos, Archbold, and O’Donoghue (2006) and Verhaert, Willems, Van Kerschaver, and Desloovere (2008) shows that in general, 30–40% of the population with hearing loss have additional needs. The growing complexity of this population makes it difficult for teachers in special schools for the deaf in
Flanders because the Government of Education has neither adapted the curriculum nor provided extra financial support. An appropriate education for these students often requires an adapted curriculum with smaller groups and increased multidisciplinary support (Bertram, 2004; De Raeve, Baerts, Colleye, & Croux, 2012); this is currently not the case.

Based on the traditional thinking that the degree of hearing loss influences the development of spoken language (the more severe the hearing loss, the greater the spoken language delay) (Kirk, Miyamoto, Ying, Perdew, & Zuganelis, 2000), it could be expected that at secondary school age, children with a milder hearing loss would follow more difficult (theoretical) courses and that children with a more severe hearing loss would follow easier (vocational) ones. In reality, the opposite is seen. This might be because many children with a CI are functioning at a higher spoken language level than are children who are hard of hearing and use hearing aids (Snik, Vermeulen, Brokx, Beijk, & van den Broek, 1997). In Flanders, it could also be that children who are deaf reach a higher level because they receive more intensive support. In that case, it also means that Belgian legislation on the educational support of children with hearing loss—in which a distinction is made between children who are deaf and those who are hard of hearing based on their audiological threshold without hearing aids—is out of date.

Another interesting trend is that students who use CIs require fewer interpreters at the mainstream secondary school level compared to students who do not have a CI. Students with CIs use half the number of sign language interpreters compared to students without a CI. However, the use of a notetaker by CI students is slightly higher (6%) compared to students without a CI. This is likely due to children mainstreamed early without learning or using sign language. The high need for more notetakers also suggests that the training centers for interpreters should guarantee the competencies of the notetakers as well for sign language interpreters. Again, this is not currently the case in Flanders.

The current population of secondary school students who use CIs are considered “late implanted.” Most of these children received their CIs between the ages of 2 and 6 years, prior to the implementation of UNHS. In the future, it is likely that students who have received uni- or bilateral CIs at younger ages will use even fewer interpreters (both sign language interpreters and notetakers) than the current population.

The choice to begin schooling in special preschools is often made by parents in consultation with professionals. More than 75% of toddlers who are deaf start in special schools because of (a) the small number of children in one class group in special schools, (b) contact with peers who have a hearing loss, (c) good multidisciplinary support for the child and family, (d) good classroom acoustics, and (e) provision of daily auditory and speech-language therapy. Students then move to a mainstream setting between the ages of 4 and 10.
For effective inclusion of children with hearing loss in a mainstream setting, more attention must be given to the number of children in a class and the classrooms’ acoustics in the mainstream schools as well as to the social-emotional development of these children (Rieffe, Kouwenberg, Scheper, Wiefferink, & Smit, 2009).

The fact that increasingly more children with a hearing loss are attending mainstream schools influences the experience and qualifications required by their teachers and support staff. Most teachers of the deaf begin work as soon as they have finished their studies as a teacher or speech-language pathologist. In Flanders, there is no specialized training for teachers of the deaf. Teachers have to follow only a one-year course on “special needs children” to become a “special needs” teacher who is allowed to teach children with a hearing loss. Therefore, many new staff begins work with little or no experience in educating children with a hearing loss. In the past, most of the teachers of the deaf received their training on the job while working in schools for the deaf before moving out as a peripatetic teacher. This is now compromised as the special schools population is decreasing, meaning that Flanders has yet another challenge to meet in providing appropriate specialized training courses for teachers of the deaf.

At the time of writing, research is being conducted at the Katholieke Universiteit Leuven to examine the qualifications and competencies needed for teachers of the deaf to work in all settings with children who are deaf or hard of hearing. One part of this research is embedded in a larger European Leonardo project, which seeks to identify the pan-European core competencies for teachers of the deaf and how they can be acquired (Lichtert & van Wieringen, 2010). Another part of the research is focused on the special language didactic needs of teachers of the deaf. To guarantee a high standard of education for all children with hearing loss in Flanders, the Belgium Government must use this research to invest in the development of training courses tuned to the diverse population of today in combination with good practices and in cooperation with its European partners.

Summary

The data from Flanders, Belgium, provides further evidence that an early UNHS program, early intervention, and early cochlear implantation can influence the educational path of children who are deaf or hard of hearing. Increasing numbers of children with hearing loss are attending mainstream schools, although not always from a young age. Parents of preschool-aged children often choose special educational settings because of (a) small class sizes; (b) opportunities for their children to meet peers with hearing loss; (c) classrooms with a good acoustic environment; (d) provision of intensive auditory, speech, and language therapy; and (e) multidisciplinary support.
These children move to mainstream schools during their primary school years and, by secondary school age, most are in a mainstream setting following a regular curriculum. The numbers of children attending specialized schools for the deaf at secondary level is decreasing while the needs of their population are becoming more complex. In the group of children with a CI at secondary school, there is a shift from the support of a sign language interpreter (chosen by children without CI) to the support of a notetaker or even without an interpreter at all (chosen by students with a CI). Because of the rapidly changing educational landscape, the government has a responsibility to invest in new training possibilities for teachers of the deaf and interpreters to meet the special needs of children with hearing loss in the 21st century.

Acknowledgments

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From the Ear to the Brain: Advances in Understanding Auditory Function, Technology and Spoken Language Development

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The Queens of Audition

By Joseph Santos-Sacchi, Ph.D.

Alexander Graham Bell would have been amazed to find out how the ear uses outer hair cells (OHC) to boost our sensitivity to sounds. OHCs do this by providing mechanical feedback into the organ of Corti, thus enhancing the input to the inner hair cells, which predominantly send information to the central nervous system. Prestin is the protein that drives the OHC mechanical response, and we have learned much since its discovery in the year 2000. Notably, we now know that the cochlear amplifier is controlled by anions interacting with prestin. The upshot is that the OHC evolved to use very primitive constituents to do exquisite things. There is still more to learn.

When I was a teenager I damaged my right ear by standing too close to fireworks on the 4th of July. Tinnitus and hearing loss persist to this day, only enhanced by an additional 45 years of auditory abuse. The culprit of my

Joseph Santos-Sacchi, Ph.D., is a professor in the Department of Otolaryngology at Yale School of Medicine. He has an undergraduate degree in psychology from Columbia College and a Ph.D. in audiology from Columbia University. He joined Yale University in 1991. Prior to that, Santos-Sacchi worked in labs at the City College of New York, Northwestern University and the University of Puerto Rico. He has been funded continuously by NIH/NINCDS/NIDCD since 1984 to study hair cell and supporting cell physiology. More information can be found on his website www.YaleEarLab.org.
problem is the hair cell, probably the outer hair cell (OHC). Hair cells that enable us to perceive sound are fragile, and when lost do not regenerate, causing permanent hearing loss (and sometimes ringing in the ear). They are amazing machines, and the whole of the ear—outer ear, middle ear, inner ear and the auditory brain—is devastated without their sustenance. They are the Queens of Audition!

Pre-Amplification

My Ph.D. thesis was concerned with blood capillary function in the inner ear, an attempt to understand how, at the electron microscopic level, blood-borne molecules enter the inner ear (Santos-Sacchi & Marovitz, 1980). The inner ear is a privileged site that blocks most molecular entry, just as the brain does. I convinced myself (and my doctoral committee) that this was good for the inner ear—namely that the ear protects its hair cells.

Two years later I pursued a postdoc in Peter Dallos’ lab at Northwestern University. I was able to directly investigate what the OHCs were doing by recording electrical activity from them through microelectrodes in living guinea pigs. Research at that time showed that OHCs are sharply tuned to particular frequencies based on the location along the cochlea (Dallos, 1985; Dallos, Santos-Sacchi, & Flock, 1982; Russell & Sellick, 1983). Hair cells in the basal part of the cochlea respond best to high frequency sounds and those in the apex of the cochlea respond best to low frequency sounds. The frequency selectivity and sensitivity of hair cells along the cochlea were predicted based on basilar membrane and eighth nerve fiber measurements (Ruggero & Santos-Sacchi, 1997).

Also during my postdoc research, Dallos and I showed that the supporting cells were electrically coupled by gap junctions (Santos-Sacchi & Dallos, 1983), presaging subsequent independent studies that suggested connexon-based communication among supporting cells was important for potassium sinking and metabolic maintenance within the organ of Corti—two phenomenon that are required for hair cell survival and proper functioning (Santos-Sacchi, 1985). Not surprisingly, connexon mutations are now known to underlie a major proportion of genetically based hearing loss (Kelsell et al., 1997).

Post-Amplification

Something special happens in the inner ear to provide such fine frequency tuning and sensitivity. The momentous identification of otoacoustic emissions (OAE; emissions of sound from the ear canal) by Kemp (1978) did not subdue Brownell’s amazing discovery of OHC electromotility (Brownell, Bader, Bertrand, & de Ribaupierre, 1985). Indeed, the observation that OHCs are not only receptors of sound, but can respond mechanically, and the identification of OAEs prompted a paradigm change in auditory research. I joined the
electromotility club early on, providing evidence that electromotility was
driven by the voltage across the OHC membrane (Santos-Sacchi & Dilger,
1988). Since then I have focused on the biophysical and molecular aspects of
OHC motility.

The Amazing OHC

The OHC is more specialized than its neighbor, the inner hair cell (IHC).
Similar to the IHC, however, OHCs have an apical region of the cell that houses
the sound transduction apparatus, a collection of yet-to-be-identified mechan-
ically activated (MET) channels that reside in the membrane tips of stereocilia.
Stereocilia are tall membrane extrusions that are stiff because they contain a
tightly packed core of actin filaments. Movement of the stereociliar bundle
permits MET channels to allow potassium to enter the cell, and the resulting
receptor potential depolarizes the cell’s membrane. For the IHC, the main
purpose of this depolarization is to evoke neurotransmitter release at the
bottom part of the cell where auditory eighth nerve fibers synapse. OHCs also
have synapses with the eighth nerve but are dwarfed in number by those of the
IHC. Thus, the main job of sending acoustic information to the brain centrally
falls to the IHC.

It’s the middle part of the OHC, which IHCs do not have, that piqued my
interest. Research has shown that the membrane in this region houses the
molecular motors responsible for electromotility (Figure 1). One of the ways to
study the activity of the motors is to measure its conformational change (shape
change) within the membrane when voltage across the membrane is altered, as
might occur when receptor potentials are generated. The conformational
change is associated with the restricted movement of motor-bound charges
within the membrane that can be measured as a nonlinear capacitance (NLC).

Capacitance is the ability to store charge, and normally a membrane will
have a capacitance proportional to its area, just like an electrical capacitor
component. The membrane capacitance, defined as the change in charge
divided by the change in membrane voltage (dQ/dV_m), is the same at any
membrane potential in IHCs, i.e., it is linear because this cell lacks the charged
molecular motors found in the OHC. The OHCs, however, have a voltage-
dependent capacitance that is bell-shaped riding atop a flat linear capacitance
(Figure 2). The peak of the NLC occurs at a membrane voltage where the
voltage sensitivity of motor conformational activity, and consequently,
electromotility, is greatest (called V_h). The range over which NLC extends
across V_m is the operational range of the motor. Research in the previous two
decades has established that NLC and electromotility share such common
characteristics.

In 2000, Dallos and colleagues discovered the motor protein responsible for
electromotility (Zheng et al., 2000). They called it prestin because it is fast. When
artificially expressed in non-auditory cells, it displays all the characteristics that
the native OHC displays, including a NLC with a voltage dependent mechanical response of the membrane. Prestin has been shown to display additional qualities that were previously identified in the native OHC (reviewed in Santos-Sacchi, 2003). Shared qualities include 1) a piezoelectric-like phenomenon, where not only does voltage induce a mechanical response, but reciprocally membrane deformation induces an electrical response; 2) marked temperature sensitivity; 3) a dependence of the protein’s operational...
voltage ranges on resting potential; and 4) a dependence on intracellular chloride.

The latter characteristic, chloride dependence of the motor, has been a topic of focus for 12 years now. The anion appears to work by binding to prestin and affecting the protein’s ability to change conformation within the membrane when voltage is modulated. This chloride sensitivity is not totally unexpected since prestin is part of a family of proteins that transports anions across the membrane. What is surprising is that the protein, unlike its family members, has evolved to aid in cochlear amplification. This was very apparent when, in collaboration with Fred Nuttall’s research group, we were able to reversibly reduce basilar membrane motion in the guinea pig by manipulating chloride levels bathing the OHCs (Santos-Sacchi, Song, Zheng, & Nuttall, 2006). The defeat of cochlear amplification was reversible upon restoring normal chloride levels (Figure 3).

One of the characteristic properties of chloride on prestin is to shift the motor’s operating voltage range; should intracellular chloride levels decrease from normal, a shift of the electromotility function in the depolarizing direction will follow, effectively making the receptor potential incapable of generating mechanical responses. In another demonstration of the importance of prestin’s operating voltage range, Dallos and colleagues (Dallos et al., 2008) were able to knock-in genetically modified prestin molecules into the OHCs of the living mouse. The new prestin was engineered to have its operating range shifted in the depolarizing direction, thus preventing the OHC receptor potential from evoking mechanical responses. Of course, in this case, the hearing loss was irreversible. Experiments such as these support the notion that, in mammals, cochlear amplification results from prestin activity, and not other mechanisms.

**Figure 2.** The molecular motors in the OHC lateral membrane produce a restricted charge movement in the membrane that can be measured as a NLC. The curve can shift along the voltage axis in the hyperpolarizing or depolarizing direction in response to a variety of biophysical forces, indicating that the operational voltage range is not stable for electromotility. $V_h$ of NLC generally coincides with $V_h$ of electromotility; however, see text for new observations.
While we know the effects of anions on the NLC of OHCs and predict their effects on electromotility \textit{in vivo}, little work has been done on OHC mechanics directly. Our predictions assume that NLC exactly characterizes electromotility. Could chloride be working in ways other than changing the OHC operating range? Lately, we have been reinvestigating the coupling between prestin motor conformational change and electromotility. It turns out that the two are variably uncoupled depending on concentration of intracellular chloride; that is, the operating voltage ranges appear to be separately modifiable (Song & Santos-Sacchi, 2012).

To further explain, within the organ of Corti, in order for OHCs to effectively promote enhanced basilar membrane motion, they must exert their forces at the proper moment during sound induced basilar membrane vibration. This is akin to pushing with your child’s movements on a swing, not against her. That is, the timing, or phase of, energy injection must be appropriate. In the past, cochlear modelers have resorted to various strategies to generate enough phase delay between receptor potentials and OHC forces for their models to reasonably describe experimental data. The physiological basis for such delays was always

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Basilar membrane measures are considered the classic assessment of cochlear amplification. Here we show that sharp tuning (black solid line) under normal 140 mM chloride bathing solution is severely reduced by replacement with 5 mM chloride solution (grey solid line). Return to 140 mM chloride solution restores hearing and basilar membrane motion (dotted grey line).}
\end{figure}
removed from the OHC. We think that the variable couplings between conformational changes of prestin (NLC) and electromotility results from a time delay between the two, and we suggest that the mechanical forces of the OHC can be tuned to the requirements of the cochlea by chloride homeostasis. Thus, we believe that anions have a preeminent role in how we hear.

Summary

Over the years that I have been working on the mechanics of hearing, I have learned about many things that the supporting cells and hair cells do right. Unfortunately, these are the same things that can be disturbed and have, I’m sure, contributed to my own hearing problems. But I am convinced that with a better understanding of how things work, we will ultimately know what and how to repair. So tell me more Queens of Audition, I’m listening!

References


Speech Perception and Hearing Loss

By Jont B. Allen, Ph.D., Andrea Trevino, and Woojae Han, Ph.D.

Over 150 years after the early research of Alexander Graham Bell, it remains unclear how the auditory system decodes speech, both in individuals who have “normal ears” and those who have “non-normal ears.” Recent research has shown that normal ears can decode isolated consonants without error. However, when the inner ear is damaged, such as with sensorineural hearing loss where hair cells and synaptic connections are not properly functioning, speech can be heard but not understood. In these cases, two seemingly-normal articulated utterances of the same consonant can result in totally different responses. Such specific and consistent confusions uniquely depend on the auditory system’s function and the utterance. This presentation will discuss the differences between how the auditory systems of normal ears and non-normal ears receive and decode speech.

Jont Allen, Ph.D., is an associate professor in the Department of Electrical and Computer Engineering at the University of Illinois. Allen received a B.S. in electrical engineering from the University of Illinois, Urbana-Champaign, and an M.S. and Ph.D. from the University of Pennsylvania. Upon graduation in 1970, Allen joined Bell Laboratories in Murray Hill N.J. From 1997–2002 he was a member of the newly created Research Division of AT&T (formerly Bell) Labs. In 2003, Allen retired from AT&T and joined the Department of Electrical and Computer Engineering at the University of Illinois. Andrea Trevino is a Ph.D. student in Human Speech Recognition group of the Department of Electrical and Computer Engineering at the University of Illinois, Urbana-Champaign. Woojae Han, Ph.D., is a recent graduate of the Department of Electrical and Computer Engineering at the University of Illinois, Urbana-Champaign and current assistant professor at Hallym University in Korea.
Introduction

Existing clinical methods for diagnosing speech disorders in individuals with damaged inner ears seem fundamentally broken. Today when patients go to an audiology clinic, their pure-tone hearing thresholds are first measured. Based on the degree of tonal hearing loss, a hearing aid may be prescribed, which is subsequently adjusted to partially compensate for the pure-tone loss. This may or may not improve the ear’s speech loss (Walden & Montgomery, 1975). But since the speech loss is infrequently measured (or worse, the method of measurement is ineffective), the change is not quantified.

Based on the evidence available, it has been shown that speech testing has not been successful in fitting hearing aids (Walden & Montgomery, 1975). This seems counterintuitive since the main purpose of wearing a hearing aid is to improve speech understanding. Due to historically poor understanding of the fundamentals of speech perception, it has proven difficult to resolve this inconsistency. First, researchers may not understand the process of learning speech, which typically takes place in the first one to two years of life. Second, due to middle ear infections, young children can temporarily lose their hearing, which can interfere with learning spoken language. It is not until the first year of school when the child is learning how to read that the child’s ability to hear consonants is first fully tested.

Children who cannot accurately decode consonants may have increased difficulty with orthography. For example, if an ear cannot hear the distinction between /b/ and /d/ or between /t/ and /f/, the child is likely to misunderstand the importance of the shape of the letter [loop at bottom, closing to the left (d) or right (b), and curl at top (f) or bottom (t)]. The classroom teacher assumes that if a child’s hearing is normal, then the child can hear the consonant distinctions. However, this assumption can be wrong and if so, the child’s consonant decoding deficiency will go undetected (it will not show up in a pure-tone hearing test). When the child passes a hearing screen it is assumed, incorrectly, that they can decode syllables. What is needed is a targeted consonant discrimination test to predict these reading disorders.

Clinical audiologists can also make the same assumptions about adult speech perception, and research has shown that many of these assumptions can be wrong. The most serious assumption has been that consonants are homogeneous. Research has shown that for “normal ears,” confusions systematically depend on the consonant (Phatak & Allen, 2007; Phatak, Lovitt, & Allen, 2008; Singh & Allen, 2012). For “non-normal ears,” the errors dramatically increase, again depending on the ear, the noise-level, and, most significantly, the utterance.

If consonants were homogeneous, the confusions, as a function of the noise level, would be the same from one consonant to the next. This is not the case, since consonant confusions are highly dependent on the utterance (Han, 2011; Singh & Allen, 2012). While normal ears give similar confusions for a given
utterance as a function of the noise, non-normal ears are idiosyncratic in their error patterns. The idiosyncratic nature of the speech scores implies that they may not be averaged. It is this inappropriate averaging that has led clinicians to believe that speech is not a reliable measure for fitting hearing aids.

In the last few years, the Human Speech Research (HSR) group at the Beckman Institute for Advanced Science and Technology at the University of Illinois, Urbana-Champaign, has determined some key elements in this chain that seem to enlighten responses from both normal and non-normal ears. For our purposes, “normal ears” are defined as those with pure-tone thresholds less than 20 dB-SPL, and “non-normal ears” are defined as having pure-tone thresholds greater than 20 dB-SPL.

Until very recently, it was not understood that the normal ear can detect speech with essentially zero error, down to \(-10\) dB SNR (three times more speech-shaped noise than speech) (Phatak et al., 2008). As the noise increases, the error goes from zero to chance performance over a small signal-to-noise ratio (SNR) range. These new results totally change the understanding of what is happening in normal ears because it means consonant perception is binary (Singh & Allen, 2012).

The focus of this paper is to describe this difference in performance between the normal and non-normal ear at the utterance level. The paper will explain what the HSR group has found, and then predict where this research will go in the next few years. In addition, we will discuss a speech test that teases out such natural occurring idiosyncratic speech confusions, which we argue will eventually be useful for fitting hearing aids.

How Does Speech Perception Fail?

The challenge remains to understand the auditory processing strategy of the auditory cortex, which is wired to non-normal ears. To understand how normal ears decode consonants, the HSR group repeated the classic consonant perception experiments of Fletcher (1922) and Miller and Nicely (1955), among others. This gave us access to important new data and the ability to reassess many widely held assumptions. The first lesson of this research is the “sin of averaging”—while audiology is built on averaging measures, most of the interesting information is lost in these averages. We have shown, for example, that averaging across consonants distorts the measure as does averaging across talkers for a given consonant. We have also found that entropy (a probabilistic measure of consistency) is more robust than the average error.

In 1970–80, a number of studies explored the role of the transitional and burst cues in a consonant-vowel (CV) context. In a review of the literature, Cole and Scott (1974) argued that the burst must play at least a partial role in perception, along with transition and speech energy envelope cues. Explicitly responding to Cole and Scott (1974), Dorman and colleagues (1977) executed an extensive experiment using natural speech made up from nine vowels proceeded by /b,
d, g/. The experimental procedure consisted of truncating the consonant burst and the devoiced transition (following the burst) of a CVC, and then splicing these onto a second VC sound, presumably with no transition component (since it had no initial consonant). Their results were presented as a complex set of interactions between the initial consonant (burst and devoiced cue) and the following vowel (i.e., coarticulations).

The same year Blumstein and colleagues (1977) published a related /b, d, g/ study using synthetic speech that also presented a look at the burst and a host of transition cues. They explored the possibility that the acoustic cues were integrated (acted as a whole). This study was looking to distinguish the necessary from the sufficient cues, and first introduced the concept of conflicting cues in an attempt to pit one type (burst cues) against the other (transition cues).

While these three key studies highlighted the relative importance of the two main types of acoustic cue, burst and transition, they left unresolved the identity and relative roles of these cues. No masking noise was used in the studies, ruling out any form of information analysis. Masking is key to an information theoretic analysis of any communication channel (Allen, 1994, 1996; Fletcher, 1922; Shannon, 1948). As discussed by Allen (2005), based on the earlier work of Fletcher and Galt (1950), Miller and Nicely (1955), and inspired by Shannon’s source-channel model of communication, the HSR group repeated many of the classic experiments (Li & Allen, 2009; Phatak & Allen, 2007; Phatak et al., 2008). The data resulting from our several experiments will be discussed in the remainder of the paper.

**Identifying Perceptual Cues**

Li and colleagues (2010) first described a method to robustly identify speech cues for a variety of naturally produced CV speech sounds. This method uses a 3-dimensional psychophysical approach using a variety of noise levels, time-truncation, and high and low pass filtering. These experiments made it possible, for the first time, to reliably locate the subset of perceptually relevant cues in time and frequency, while the noise-masking data characterizes the cue’s masked threshold (i.e., its strength).

Figure 4 describes the resulting consonant maps. Not surprisingly, the perceptual cues associated with fricative sounds are quite different from the plosives. Timing and bandwidth remain important variables. For the fricative sounds, the lower edge of the swath of frication noise is the perceptual cue.

Briefly summarized in Figure 4, the CV sounds /ta, da/ are defined by a burst at high frequencies, /ka, ga/ are defined by a similar burst in the mid frequencies, and /ba, pa/ were traced back to a wide-band burst. As noise is added, the wide-band burst frequently degenerates into a low frequency burst, resulting in low-level confusions. The recognition of burst-consonants further depends on the delay between the burst and the sonorant onset, defined as the voice onset time (VOT). Consonants /t, k, p/ are voiceless sounds, occurring
about 50 [ms] before the onset of F0 voicing while /d, g/ have a VOT <20 [ms]. Plosive /b/ may have a negative VOT.

Based on the results of Li and colleagues (2010), this study, along with a host of verification experiments on the ~100 CV utterances in the HSR database (Kapoor & Allen, 2012; Li & Allen, 2011; Régnier & Allen, 2008), we have conclusively demonstrated that these features uniquely label the indicated consonant.

Methods

Isolated CVs were taken from naturally produced speech from 18 talkers. Noise was added to the speech with a range from −26 dB to quiet (Q). Both uniform and speech weighted spectrum level noise was added to the speech. The listener corpus consisted of more than 200 normal and 45 non-normal ears, with 9-16 consonant and 8 vowel sounds. To assure the estimates of the error are reliable, a minimum of 10 trials per utterance and SNR are required (Han, 2011; Phatak, Yoon, Gooler, & Allen, 2009; Singh & Allen, 2012). The difference between these new experiments and their classic counterparts is that the utterances of each consonant are not averaged.
Results

In Figure 5, the average probability of the error $P_e(SNR)$ is shown (for speech-weighted noise the SNR is the same as the articulation index). On the left (a), the “average normal hearing” (ANH) score $P_e(SNR)$ (black line), along with the score for each heard consonant /h/, given spoken consonant /s/ as a function of the SNR for flat-spectrum masking noise (Phatak et al., 2009). There is a huge variation in scores across the consonants: the SNR corresponding to the 50% point ranges from $\pm 12\, \text{dB}$ [m, n/] to $+8\, \text{dB}$ [/θ, ð/] [shown as /T/ and /D/ in Figure 5]. Such a large range of scores is not captured by an average. Not shown here, each utterance in the HSR database has a wide range of scores, varying in error from zero to chance depending on the masking noise intensity (Singh & Allen, 2012).

The right panel (b) shows the average scores for the 17 non-normal ears as compared to the average scores of the participants with normal hearing in speech-shaped masking noise. One of the best ears in terms of average error is 36R. Not shown is that his error for /ba/ reaches 100%, while the remaining 13 consonants tested had zero error. Thus, the reported performance is highly distorted, again due to the “sin of averaging.”

Figure 5. LEFT: Shown here is the average error (log scale) for 16 CV consonants as a function of the relative intensity of constant-spectrum-level masking noise (Phatak et al., 2009). The solid black curve labeled “Avg. Normal” shows the average across all the consonants. Note the large variation in error. RIGHT: This family of curves compares the average consonant error for 14 normal and 17 non-normal ears in speech shaped masking noise. For the non-normal ears, there is a large spread in scores due to the variation in hearing loss as compared to listeners with normal hearing (gray region), all of whom are similar in their average performance.
A second major conclusion is that when characterizing a listener with hearing loss, one must look at the individual confusions. In Figure 6, confusion patterns (CPs) are compared to SNR. The CP is a graphical display of the confusion probabilities as a function of the intensity of the masking noise relative to the speech. To estimate a CP requires a totally different clinical measure than is being applied today. CPs allow one to visualize the confusions of each sound as a function of the SNR. From the CP it is easy to identify a sound that primes, meaning that it can be heard as one of several sounds with equal probability by changing one’s mental bias. In this case the CPs show subject responses that are equal (the curves cross each other), similar to the CP of Figure 6(b) at $-8$ dB where one naturally primes /p/, /t/, and, to a lesser extent, /k/ (at $-10$ dB).

When asked, most clinicians report that they do not have the time to make detailed measures. In our opinion, this is more a reflection of old habits than actual time constraints. The confusion sets, and their dependence on the noise, are not predictable without such tests. Utterance confusions and their masked dependence are important because they reveal the mix of underlying perceptual cues being confused with the target sound.

When using an utterance confusion measure, each non-normal ear consistently makes large errors on a small subset of utterances. Furthermore,
for a given utterance, there are patterns in these errors across listeners with hearing loss. In other words, normally spoken utterances are heard idiosyncratically by non-normal ears, yet with correlated error patterns.

**Confusions in Non-Normal Ears**

As a direct extension of earlier studies (e.g., Phatak et al., 2009), four experiments were performed (Han 2011), two of which will be reported on here. In Experiment 1 (Exp-1), full-rank confusion matrices for the 16 Miller-Nicely CV sounds were determined at 6 SNR [Q, 12, 6, 0, –6, and –12 dB] for 46 non-normal ears (25 subjects). In Experiment 2 (Exp-2), a subset of 17 ears were remeasured, but with the total number of trials per SNR per consonant raised from 2–8 (Exp-1) to as high as 20 (Exp-2) to statistically verify the reliability of the subjects’ responses in doing the task.

Figure 7 shows that listeners with hearing loss are using a common strategy that depends systematically on the utterance. Clearly, if such very different scores for the two /ba/ sounds were to be averaged together (i.e., present clinical practice), the idiosyncratic (i.e., the most important) information about the ears would be lost. As discussed earlier, the average score is a distorted metric due to its high variance a) across consonants, b) across utterances for each consonant, and c) across subjects with hearing loss. Entropy gives a direct measure of consistency and is insensitive to mislabeling errors (e.g., consistently across a voicing error, as in reporting /d/ given /t/). Given the observed increased mislabeling of sounds in

![Pie charts showing confusions for two different /ba/ utterances](image-url)
non-normal ears, a high-consistency measure (i.e., entropy) seems to be a better measure.

Summary

This article has reviewed some of what the HSR group has recently learned about speech perception of consonants, and how this knowledge might impact understanding of nonlinear (NL) cochlear speech processing. However, the role of outer hair cell (OHC) processing of speech is still poorly understood (Allen, 2008; Allen & Li, 2009). It is now widely accepted that OHCs provide dynamic range and are responsible for much of the NL cochlear speech signal processing, thus the common element that links all the NL data (Allen, Régnier, Phatak, & Li, 2009). OHC dynamics must be understood before any model can hope to succeed in predicting basilar membrane, hair cell, neural tuning, and NL compression. Understanding the OHC’s two-way mechanical transduction may be the key to solving the problem of the cochlea’s dynamic range and dynamic response (Allen, 2003).

However, the perception of speech by the non-normal ear does not seem to be consistent with the above commonly held view. For example, the large individual differences seem inconsistent with the OHC as the tying link, and seem more likely related to synaptic dead regions (Kujawa & Liberman, 2009). Continued analysis of these confusions will hopefully provide further insights into this important question. The detailed study of how a complex system fails can give deep insights into how the normal system works.

The key open problem here is, “How does the auditory system (e.g., the NL cochlea and the auditory cortex) process human speech?” There are many applications of these results including speech coding, speech recognition in noise, hearing aids, and cochlear implants as well as language acquisition and reading disorders in children. If we can solve the robust phone decoding problem, we will fundamentally change the effectiveness of human-machine interactions. For example, the ultimate hearing aid is the hearing aid with built in robust speech feature detection and phone recognition. While researchers have no idea when speech-aware hearing aids will come to be, and the time is undoubtedly many years off, when it happens, it will be a technological revolution of some magnitude.

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The Restoration of Speech Understanding by Electrical Stimulation of the Auditory System

By Michael Dorman, Ph.D.

The first cochlear implant surgery was performed over 50 years ago and allowed a patient to hear “sounds.” Today, professionals expect high levels of speech understanding for adults who are postlingually deaf and who receive a cochlear implant, and for children who are congenitally deaf—if the children receive a cochlear implant early and if they receive intensive listening and spoken language intervention. This presentation will provide a broad view of the technology underlying cochlear implants and describe possible next steps in the evolution of these devices.

Over 50 years ago, William House, M.D., performed the first cochlear implant surgery. The results were modest—the patient reported hearing “sounds.” Today, professionals expect that the majority of adult patients who are late-deafened, when fit with a cochlear implant, will achieve 80–100% correct scores on tests of sentence understanding in quiet (Wilson & Dorman, 2008). Professionals expect that many children who are congenitally deaf, if fitted with a cochlear implant before the age of 3 and if given extensive (re)habilitation, will perform near the level of their age-matched peers who have typical hearing on tests of speech understanding when in elementary school. These results, for adults and children, underlie the claim that cochlear implants are one of the miracles of modern medicine.

After 50 years of effort, cochlear implantation is now a mature discipline—professionals expect good results for most patients. Nonetheless, researchers continue their work and new developments extend the promise of even higher levels of speech understanding for individuals with hearing loss.

Better Hearing by “Hybrid” Stimulation

One innovation, a relatively simple one at that, is combining electric stimulation with acoustic stimulation. The majority of patients who qualify for a cochlear implant in one ear have some low-frequency acoustic hearing in the

Michael Dorman, Ph.D., is a professor in the Department of Speech and Hearing Sciences at Arizona State University. He received his Ph.D. in experimental child and developmental psychology (with a linguistics minor) from the University of Connecticut in 1971. He is a Fellow of the Acoustical Society of America and the author of over 150 publications in areas including speech perception by infants, adults, listeners with hearing loss and listeners fit with cochlear implants; cortical lateralization of function; and neural plasticity. His work on cochlear implants has been supported continuously by the National Institutes of Health since 1989.
other. Researchers at Arizona State University have found that patients with hearing only at 125 Hz and 250 Hz, i.e., at very low frequencies, can use the information carried by these frequencies to improve speech understanding via their implant. This low-frequency information is especially useful in noise, which is fortunate because cochlear implants alone do not provide high levels of speech understanding when speech is presented against a background of noise.

A recent surgical innovation, hearing preservation surgery, allows surgeons to implant an electrode array and to preserve low-frequency hearing in the implanted ear. This provides much better speech understanding via the implanted ear and provides the listener with two partially hearing ears—the ear opposite the implant and the ear with the implant. Having two partially hearing ears is of benefit in listening environments where noise surrounds the listener.

Hearing preservation surgery allows patients with substantial low-frequency hearing and speech understanding to receive a cochlear implant and to benefit from “hybrid” hearing. Researchers working on this technique expect to see, in the near future, patients with up to 60% word scores by hearing alone to qualify for a cochlear implant. The logical extension of this idea is cochlear implantation for the “common variety” of high-frequency hearing loss. Of course, the greater the amount of hearing and speech understanding, the greater the consequences of losing both, if hearing is not preserved. The calculation for or against cochlear implant surgery for these individuals will not be simple.

Hearing preservation surgery will also create patients with a cochlear implant in each ear and low-frequency hearing in each ear. Researchers have tested several patients like this and, when tested in complex listening situations, find that they benefit from having two implants versus one and having two partially hearing ears versus one.

*Better Hearing through Chemistry*

The odds of retaining low-frequency hearing following cochlear implant surgery can be improved by the administration of protective drugs during the surgical procedure. Studies have shown that some drugs, such as dexamethasone, can prevent inner-ear cell damage from exposure to very loud noises, similar to the noise produced by surgical drilling for cochlear implants. The same drug can rescue cells 24 hours after exposure to loud noises or other drugs that destroy hearing. These results have stimulated researchers to create electrode arrays that both deliver a drug and provide electrical stimulation to the cochlea. The delivery of drugs during cochlear implant surgery and in the weeks and months post-surgery via the electrode array will allow for the maximum conservation of residual hearing in the implanted ear.
This same technology of combined drug delivery and electrical stimulation holds tremendous promise for young children receiving cochlear implants. Research has shown that administration of a class of drugs called neurotropic drugs can stimulate the growth of neurons (Sinohara et al., 2002) and could even promote the growth of neural fibers up the chemical gradient to the electrode that is releasing the drug. If this can be achieved in very young children, then professionals will have a method of preserving the neural elements in the child’s cochlea and a method of getting neural elements very close to the electrode array. The latter would allow very low levels of current to be used for stimulation and should result in much better frequency resolution. Better frequency resolution would lead to better speech understanding and, perhaps, better appreciation of music.

Better Hearing from Early Stimulation

Brain wiring is determined by both intrinsic factors of biology and by environmental stimulation. In the absence of auditory stimulation early in development, the auditory brain will not develop typically and will not have the usual connections to other areas of the brain that process speech and language (Kral & O’Donoghue, 2010). Indeed, in the absence of auditory stimulation, some auditory areas can be usurped by other sensory modalities, such as vision or touch. Thus, early stimulation of the auditory pathways is critical to driving a developing brain into the configuration shown by infants with typical hearing. At issue for parents is, how early is “early” and how late is “late?” If a child has had no auditory stimulation for the first seven years of life, then the odds of achieving reasonable levels of speech understanding via a cochlear implant are poor. A child who receives a cochlear implant by age 2–3 years will have better odds of a good outcome (Svirsky et al., 2007), and age 1 year is now a standard for most children who receive cochlear implants. There is some evidence that receiving a cochlear implant under the age of 1 provides some advantages (Houston & Miyamoto, 2010), but very early implantation must be weighed against surgical risks and other factors (Cosetti & Roland, 2010).

The need for early stimulation to shape connections within and among different areas of the auditory brain puts parents, who wish to wait for something better than a cochlear implant for their child, in a difficult position. Imagine a therapy, for example, based on stem cells that could regenerate the cell bodies and related structures in the cochlea that are absent in a child who has a profound hearing loss. And imagine that this therapy is still 10 years away. What would speech understanding be like for a child with regenerated cells in the cochlea but who had been without stimulation for 10 years? Because the brain would not have developed typical connections within and between brain areas that subserve hearing and language, the value of having new cells in the cochlea could be very small. Early restoration of function should be the
hope of parents who wish their child to experience typical or near typical
development of speech and language skills.

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How do children learn spoken language? Most children with typical hearing learn from infancy the sound of their mother’s voice, a type of speech researchers call infant-directed speech. Mothers, fathers and most adults speak to infants in a sing-song manner, exaggerating the melody and rhythm of their speech. But what happens when this connection is broken, such as with a child who has hearing loss? This article will discuss the importance of infant-directed speech, and how infants with hearing loss respond to such talk in comparison to infants with typical hearing.

How do children learn spoken language? In children who are developing typically, this feat is accomplished more or less naturally through active experiences with caregivers and the child’s environment. Parents don’t enroll infants and toddlers in spoken language classes; instead, they model, encourage, and stimulate their speech and language attempts by responding to the cries and coos of infants and holding simple conversations with toddlers. In fact, caregivers across the world actually speak to their infants and young children using a special style of speech commonly known as “babytalk” or “motherese.” Researchers and scholars call this infant-directed speech. Mothers, fathers, and even strangers off the streets speak to infants in a sing-song manner, exaggerating the melody and rhythm of their speech (e.g., Ferguson, 1964; Fernald, 1989). Caregivers are flexible with this speech style, adjusting the levels of exaggeration according to the social context and their infant’s age (e.g., Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin, 2002; Stern, Speiker, Barnett, & MacKain, 1983). This speech style is now known to contribute in many ways not only to infants’ social-emotional development, but also to their speech, language, and cognitive development (e.g., Liu, Kuhl, & Tsao, 2003).
Sometimes that natural connection between caregivers and infants can be disrupted. For example, caregivers who suffer from depression have difficulty connecting with their children, speaking to them in monotones with flat affect. Researchers have shown that infants of mothers who are depressed have a difficult time learning new associations from such speech (Kaplan, Bachorowski, Smoski, & Hudenko, 2002), which likely has cascading effects on the development of spoken language and cognition. Moreover, children in families with low socioeconomic status are at a serious disadvantage compared to children in families with high socioeconomic status in terms of both spoken language input quantity and quality. Researchers have found that caregivers with fewer financial and educational resources use fewer words in their infant- and child-directed speech than caregivers with greater financial and educational resources (Hart & Risley, 1995). This effect later translates to language abilities, with children from low income homes exhibiting much worse language skills compared to children from high income homes (Hart & Risely, 1995). These studies, among others, highlight the importance of caregivers’ speech to infants as they develop spoken language.

What happens, then, if infants have a hard time hearing their caregivers? How do children who are deaf or hard of hearing learn spoken language? With the advent of new technologies, such as cochlear implants and state-of-the-art hearing aids, children with hearing loss now have the most access to sound and spoken language in their environment than ever before. Because of this, we would expect caregivers to speak to their infants and children with hearing loss just the same as those with typical hearing. And children with hearing loss who use hearing aids or cochlear implants should demonstrate similar spoken language development as children with typical hearing. Children who are deaf or hard of hearing can achieve speech and spoken language abilities on par with their typically developing peers with the use of such assistive devices (e.g., Peterson, Pisoni, & Miyamoto, 2010). However, there are large individual differences among these children; not all children with hearing loss benefit to the same degree from cochlear implants or hearing aids (Pisoni, Cleary, Geers, & Tobey, 1999; Pisoni et al., 2008). As recently as 10 years ago, researchers could only guess at why this is the case because there were no pre-amplification predictors of outcome and benefit. However, recent studies have shown potential predictors of children who will succeed with hearing aids or cochlear implants that are related to early auditory experience (e.g., Bergeson & Pisoni, 2004).

Child Perception of Infant-Directed Speech

The focus of this paper is one of the most important factors that can determine infants’ benefit and success in spoken language development via amplification: early auditory experiences from infants’ interactions with their caregivers, or infant-directed speech. The first question addressed is, do infants
who have hearing loss for the first part of their life pay the same kind of attention to infant-directed speech as infants with typical hearing do? This is one way to determine if infants with hearing loss are reinforcing caregivers’ use of infant-directed speech.

To answer this question, let’s first review what is known about infant attention to maternal speech in typical development. At least two types of infant behaviors have been established by researchers. First, infants with typical hearing, from birth to 12 months old, prefer to listen to infant-directed speech over adult-directed speech (Fernald & Simon, 1984; Fernald et al., 1989; Grieser & Kuhl, 1988; Kitamura et al., 2002; Kuhl et al., 1997). Infants are especially responsive to the melodic quality of infant-directed speech (Fernald & Kuhl, 1987). Infants’ increased attention to infant-directed speech might actually help them process and understand speech and language. For example, infants find it easier to pick out new words from a spoken passage when listening to infant-directed speech rather than adult-directed speech (Thiessen, Hill, & Saffran, 2005). Mothers tend to highlight new words when speaking to infants much more so than when speaking to adults.

Second, infants with typical hearing recognize and prefer to listen to their own mothers’ voice (DeCasper & Fifer, 1980). Amazingly, preference for maternal voices seems to develop even before infants are born. One study found that infants in the womb have different heart rate patterns in response to their mother’s voice as compared to a stranger’s voice (Kisilevsky et al., 2003). These findings also highlight the important effects of very early auditory experience on infants’ speech perception abilities.

But what about infants and toddlers who have congenital hearing loss and receive hearing aids or cochlear implants? Do they pay the same type of attention to speech as infants with typical hearing? Research from the Babytalk Research Laboratory has been addressing this very question. One of the difficulties of assessing attention in this population is that the research participants are preverbal. That is, we cannot simply ask the infants and toddlers, “What do you think about this speech? Do you like this type of speech better than the other?” Instead, we use tried-and-true methods taken from the field of developmental psychology. Infants sit on their caregivers’ laps inside a large sound-proof booth. We draw their attention to a TV monitor in front of them, and then present various audio-visual stimuli. Previous research has shown that infants will naturally look longer towards a visual display near a sound source if they’re interested in what they’re hearing.

In one particular study, we measured infants’ looking time to a red-and-white checkerboard pattern on the TV monitor while listening to four different mothers speaking in either an infant-directed or adult-directed style of speech. The study also included silent trials to determine how much infants prefer speech in general to silence. Infants with typical hearing attended much longer
to speech trials than silent trials, and generally preferred infant-directed to
adult-directed speech. Infants with mild-to-moderate hearing loss who use
hearing aids showed similar patterns, but it took a little longer for them to
develop their preferences than infants with typical hearing. Finally, infants
with cochlear implants did not show a preference for infant-directed speech
over adult-directed speech until approximately 9-12 months post-implanta-
tion. And even then, they did not attend any longer to the adult-directed speech
than to silence! These findings have major implications for child-caregiver
interactions and spoken language development.

There are some studies about recognition of voices in children who are deaf
or hard of hearing. Several studies have shown that cochlear implant users find
it difficult to distinguish the voices of different talkers, particularly if the talkers
are the same sex (Cleary & Pisoni, 2002; Cleary, Pisoni, & Kirk, 2005; Fu,
Chinchilla, & Galvin, 2004). However, one recent study showed that children
ages 5-15 years old who use cochlear implants can tell apart their own mother’s
voice from other men, children, and even other women, although their
performance is not as good as that of children with typical hearing (Vongpaisal,
Trehub, Schellenberg, van Lieshout, & Papsin, 2010).

The Babytalk Research Laboratory is in the midst of conducting another
study to determine whether infants with congenital hearing loss can
distinguish their own mother’s voice from a stranger’s voice. This study uses
a habituation paradigm, in which a series of different women reciting passages
in an infant-directed speech style is presented to infants who have about one
year of hearing aid or cochlear implant experience. The idea is that infants will
again pay attention to a checkerboard pattern on the TV monitor directly ahead
of them when they are interested in the speech sounds. In a habituation
paradigm, it is also expected that infants will start off with a high amount of
interest and gradually become bored as the same category of sound (i.e.,
women’s infant-directed speech) is repeated. Two test trials are presented once
they reach a criterion point of boredom: one is their own mother’s voice and the
other is a stranger’s voice. If they recognize their mother’s voice, infants should
theoretically pay more attention than to the last habituation trial and the test
trial with the stranger’s voice. If they do not recognize their mother’s voice,
then they should pay equal attention to all three trials. Data have been collected
from a handful of infants and toddlers who are deaf or hard of hearing who
have used a hearing aid or cochlear implant for approximately one year. These
children have not yet shown recognition of their own mother’s voice from that
of a strange woman. Future studies will likely be needed to determine how
infants and toddlers learn to recognize their mother’s voice with additional
hearing aid or cochlear implant use.
Thus far, research has shown that infants and young children who are deaf or hard of hearing do not pay attention to infant-directed speech, or even speech in general, in the same way as children with typical hearing until they’ve had at least 9-12 months of auditory experience. Imagine now parents interacting with infants who are deaf or hard of hearing. If their infants are not paying active attention to their attempts to entertain or soothe using infant-directed speech, how must this affect caregivers’ further use of this special speech style? That is, do caregivers speak in the same or different ways to young children with and without hearing loss?

To date there has been very little research on caregiver speech to infants with hearing loss who use hearing aids and cochlear implants. One reason is that, prior to state-mandated universal newborn hearing screening programs, infants were typically not diagnosed with hearing loss until 2–3 years of age (Meadow-Orlans, Spencer, & Koester, 2004). The existing literature suggests that an infant’s hearing status may affect the way in which caregivers speak to their infants. One study of speech to infants with hearing loss showed that mothers with typical hearing tend to increase their use of vocal exaggeration when they first discover their infant’s hearing loss, but gradually decrease the amount of vocal exaggeration over time (Wedell-Monnig & Lumley, 1980). Other studies of mother-child interactions have revealed that mothers tend to be more controlling, more repetitive, and less responsive in their interactions with children who are deaf or hard of hearing than with children who have typical hearing (Cheskin, 1981; Goss, 1970; Henggeler & Cooper, 1983). Mothers also produce fewer and less complex verbal utterances but more nonverbal attention-getting behaviors when interacting with children with hearing loss than children with typical hearing (Goldin-Meadow & Saltzman, 2000; Koester, Brooks, & Karkowski, 1998; Koester, Karkowski, & Traci, 1998). Some researchers have shown, however, more similarities in mothers’ speech styles to both sets of children when the children were matched by linguistic age rather than chronological age (Cross, Nienhuys, & Kirkman, 1985; Nienhuys, Cross, & Horsborough, 1984).

The Babytalk Research Laboratory recently investigated the effects of infant age and hearing loss on several prosodic characteristics of mothers’ speech to infants with typical hearing and infants with hearing loss who use cochlear implants (Bergeson, Miller, & McCune, 2006; Kondaurova, Bergeson, & Xu, 2012). The results of these studies revealed that mothers do use infant-directed speech when interacting with their infants with cochlear implants, and that their vocal styles are more similar to mothers of infants with typical hearing when infants are matched by hearing experience rather than chronological age. Thus, these mothers adapt their prosodic speech style to the hearing experience and linguistic abilities of their infants who are deaf or hard of hearing.
Researchers have proposed that one of the functions of infant-directed speech is to help infants learn about language (e.g., Fernald, 1992). For example, infant-directed speech actually exaggerates certain cues to sentence structure. Caregivers will change the pitch of their voice from the end of one sentence to the beginning of another when speaking to an infant. They will also tend to linger on the last syllable of a sentence and take an exaggerated pause before starting a new sentence. In a recent analysis of maternal speech, we found that mothers use similar sentence boundary cues when interacting with their infants who are profoundly deaf and use cochlear implants (Kondaurova & Bergeson, 2011).

Infant-directed speech might also help infants learn about the sound structure of their language. One study found that mothers potentially help their infants with typical hearing and infants with hearing loss discriminate among vowel categories (e.g., “ah,” “ee,” and “oo”) by exaggerating the differences among them (Dilley & Bergeson, 2010). Another study measured mothers’ exaggeration of cues that commonly distinguish tense vowels (e.g., “sheep”) and lax vowels (e.g., “ship”) in their speech to infants with profound hearing loss. There are two cues to this vowel contrast, one of which should be easily encoded with cochlear implant technology (duration of the vowel) and the other which is more problematic for cochlear implant users (spectrum of the vowel). Results showed that mothers exaggerated duration but not spectrum cues in speech to infants with hearing loss compared to speech to adults (Kondaurova, Bergeson, & Dilley, in press).

Taken together, these studies suggest that mothers’ speech is sensitive to their young children’s linguistic and hearing levels. In other words, mothers seem to be providing their infants and toddlers who are deaf or hard of hearing with speech cues tailored to their individual abilities. These findings are important given previous research that shows that the features of infant-directed speech have significant effects on language and cognitive development (Hart & Risley, 1995; Kaplan et al., 2002; Liu et al., 2003; Meadow-Orlans & Spencer, 1996; Pressman, Pipp-Siegel, Yoshinaga-Itano, & Deas, 1999; Spencer & Meadow-Orlans, 1996).

Nevertheless, there are still several unanswered questions regarding the acquisition of speech and language skills in both populations. Which aspects of infant-directed speech make it particularly beneficial for language acquisition? It could be that infant-directed speech is most beneficial because the vowel/consonant categories are clearer or more exaggerated. Or it could be the case that more general exaggeration (e.g., higher pitch or slower speaking rate) in mothers’ speech to infants elicits and maintains infants’ attention, which then allows the infants to pay attention to particular sounds or sentence structures.
Moreover, infants with hearing loss may benefit from different features of infant-directed speech than infants with typical hearing. What is the best way for a mother (or a speech-language pathologist) to speak to an infant, and is this the same for infants who use a hearing aid or a cochlear implant? Preliminary data in the Babytalk Research Laboratory shows that some features of mothers’ speech to infants with hearing loss, such as use of repetition, is associated with their infants’ ability to learn new words and other speech and language outcomes. Answers to these questions will provide valuable new information to parents and clinicians of infants who are deaf or hard of hearing and use hearing aids and cochlear implants.

References


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