ABSTRACT

Title: SOCIAL AND EMOTIONAL FUNCTIONING OF CHILDREN WITH COCHLEAR IMPLANTS

Efrat Altshul Schorr,
Doctor of Philosophy, 2005

Directed By: Professor Nathan A. Fox
Department of Human Development

Studies of infants and children have demonstrated the importance of sensory processing in facilitating social and emotional development. Children who are deaf are deprived of the information typically provided by the auditory modality that is necessary to the development of basic social and emotional skills, which serve as the foundation upon which complex social and emotional constructs are built. Children with cochlear implants experience extended periods of total auditory deprivation during early childhood, followed by the introduction of auditory stimulation.

Thirty-nine children with cochlear implants, aged five through fourteen, as well as an age and sex matched group of normal hearing peers, participated in assessment of the integrated perception of multimodal stimuli, processing of facial and vocal expressions of emotion, and emotion understanding skills. These dimensions of basic social and emotional functioning are vulnerable to the effects of atypical early experience. The age at which children received their cochlear implant and the length of time that they have used the cochlear implant were hypothesized to predict performance on the assessments.

Results showed that the age at implant predicted performance on the McGurk fusion task, which requires the integration of multimodal sensory stimuli. Specifically, children who received their cochlear implant prior to age 30 months accurately identified the incongruent auditory-visual stimuli, whereas children who received their cochlear implant after 30 months of age did not. Age at implant and duration of implant use did not predict performance on the other experimental tasks. Comparison of groups revealed that performance of children with cochlear implants did not differ from children with normal hearing in a facial emotion identification task and in 2 components of emotion understanding: receptive identification of facial expressions and affective-perspective taking. Children with cochlear implants demonstrated poorer performance than children with normal hearing in tasks requiring free labeling of facial expressions of emotion, and vocal emotion identification. This research suggests sensitive periods in multimodal sensory integration. The present study provides understanding of the social and emotional influences of early experience with the auditory system on children with cochlear implants.

SOCIAL AND EMOTIONAL FUNCTIONING OF CHILDREN WITH COCHLEAR IMPLANTS

By

Efrat Altshul Schorr

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2005

Advisory Committee:
Professor Nathan Fox, Chair
Professor Sandra Gordon-Salant
Associate Professor Froma P. Roth
Dr. Sue Schwartz
Assistant Professor Min Wang

DEDICATION

There are so many people who are important to me; it makes dedicating this work to some one person very difficult. The work involved in this project has truly been a labor of love, for one of my favorite people is a child with hearing loss and I have two favorite normal hearing controls. The work I have done is dedicated to my children, Moshe Refael, Adira Tova, and Meira Bracha, who have taught me more than I have learned from anyone or anywhere else. It is my hope and prayer that the world they grow to inherit will understand more about what is important to the development of children, with hearing and without hearing, than they do today.

This dissertation must be dedicated to my mother, Sharon Marks Altshul. The dedication of words on paper pales in comparison to the rarely recognized dedication involved in motherhood. The fact that I live and breathe are owed to her, but for whatever accomplishments attained by my siblings and myself, we are indebted to her. I have now finished a project.

ACKNOWLEDGEMENTS

I gratefully acknowledge the support provided by the Eugene L. Derlacki Award for Excellence in the Field of Hearing Research from the American Hearing Research Foundation and the Ruth L. Kirschstein Predoctoral National Research Service Award (NRSA) from the National Institutes of Deafness and Other Communication Disorders, National Institutes of Health (NIH). The support of these institutions has made this work possible.

I appreciate the efforts of my mentor, Dr. Nathan Fox, in dragging me into the world of research (however kicking and screaming). Thank you for letting my do my own thing – and for teaching me a great deal about how research ought to be done.

I am grateful to my dissertation committee members, Drs. Froma Roth, Sandra Gordon-Salant, Sue Schwartz, and Min Wang for their important suggestions and advice. You have helped me formulate this project and your feedback has taught me a great deal. To Dr. Roth, in particular, you have gone from being my hardest teacher to a friend and fellow investigator. Thank you for your expertise, support, and friendship.

I would like to thank the outstanding group of students who have assisted in all aspects of this study. Jessie Sue Smith, Nicole Garra, Margot McGrath, Jaime Openden, Jessica Lisogorsky, Erika Palmer, Denise Grosberg, Lindsay McCleane, Andrea Krkmar, Roni Tessler, Brooke Solarz, Meredith Cordisco, Shani Sterling, Victoria Hsieh, Dianna Russo, Laura Meador, and Adina Rogers – the data would not be here without you.

I am indebted to the fellow inhabitants of the windowless attic of the Benjamin Building, without whom, I would not have gotten through grad school. Cindy Polak-Toste, Koraly Perez Edgar, Amie Hane, Heather Henderson, Peter Marshall, Dalit

Himmelfarb Marshall, Michael Crowley, Stacey Barton, Jennifer Martin, Melissa Ghera, Kate Nichols, Bella Guner, I appreciate your friendship and good humor. I have learned so much from you and I thank you.

It took a village to bring this complex research project to fruition. I appreciate the assistance of Dr's. Johanna Nicholas, Virginie van Wassenhove, Jaewha Choi, Karen I. Kirk, Seth D. Pollak, Sherri Widen, and James Russell in sharing the materials required for this research.

I am indebted to the parents and children with cochlear implants and with normal hearing who sometimes went many extra miles to participate in this study. Their altruism has made an impression that I will not forget.

I appreciate the encouragement of my dear friends Rivky Krestt and Sara Eichler, without which I would not have finished this work. They are the best friends I can imagine.

My family has been so supportive of me. I would like to thank my siblings and siblings-in-law, Asher and Anat, Ora and Naftali, Esty, Aryeh and Zahava, Eliana, Tunie and David, Yonit and Raphi, and Dina and my niece and nephews, Aharon, Eitan, Elchanan, Rika, and Gavri. I'd like to thank my Mom and Dad, Julie and Yaakov Schorr for their love, guidance, and care. Thank you Imma and Abba, for everything you have done to help me through graduate school and all of my other pursuits before this one. I appreciate my grandparents, Ruth and Jack Spanglet and Beverly and Harold Marks for believing in me and being my fan club.

And to my best friend and husband Elli, I don't know who I might be without you, let alone imagine how I might have done this without your unwavering optimism and support. Thank you for taking my dreams even more seriously than you do your own.

I love you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

Studies of infants and children have demonstrated the importance of sensory processing in facilitation of social and emotional development. Children of hearing parents, who are deaf, are deprived of the information typically provided by the auditory modality that facilitates the development of basic social and emotional skills. These skills, in turn, serve as the foundation upon which complex social and emotional constructs are built. Children with cochlear implants experience extended periods of total auditory deprivation during early childhood, followed by the introduction of auditory stimulation, albeit of variable quality. The experiences of these children afford the opportunity to understand more about the relationship between sensory functioning and social and emotional development.

The present study assessed the functioning of several perceptual aspects of the social and emotional development of children with cochlear implants that were hypothesized to be vulnerable to the effects of atypical early sensory experience: the integrated perception of multimodal stimuli, processing of facial and vocal expressions of emotion, and emotion understanding.

Deaf children who experience auditory deprivation often experience limited interactions with significant others during infancy and then continue to have difficulty forming and maintaining positive relationships with parents and peers during early childhood due to the inability to communicate effectively. These children may not receive adequate interactive feedback that is necessary to learn to accurately interpret the emotional expressions of others. The negative outcomes that have been linked to inaccurate perception of emotional expressions include low self-esteem, loneliness, and peer rejection during later childhood. These outcomes are particularly influential factors later on in adolescent and adult social and emotional problems.

In the present study thirty-nine children with cochlear implants, aged five through fourteen, were assessed with tasks that measure the processing of basic social and emotional stimuli. An age and sex matched group of thirty-seven normal hearing peers was assessed for control purposes. In addition, oral language proficiency was assessed and used to control for the influence of language skills on the social and emotional functioning of the participants. The age at which children received their cochlear implant and the length of time that they have used it were expected to be closely associated with performance on the assessments.

The main purpose of this study was to examine whether the age at which a child receives a cochlear implant, and therefore begins to receive auditory stimulation, influences the development of social and emotional functioning. This research project is important because it offers an opportunity to explore the role of sensory mechanisms that shape the social and emotional functioning of children with normal hearing as well as children with cochlear implants. It also examines evidence for sensitive periods in social and emotional development. Furthermore, understanding the social and emotional impact of early auditory experience of children with cochlear implants will enable the development of preventative interventions to encourage healthy social and emotional development of children with profound hearing loss as well as children with other communication disorders and sensory deficits. The present study is especially important given the dearth of empirical studies on the social and emotional development of children with cochlear implants.

CHAPTER II: REVIEW OF RELEVANT LITERATURE

2.1.General Background

2.1.1 Cochlear Implants

The cochlear implant is an electronic device that provides a sense of sound to people who are profoundly deaf. The device consists of four primary components: microphone, speech processor, transmitter, and electrodes. The microphone detects sound in the environment and directs it to the speech processor, which is worn on the body or behind the ear. The speech processor then converts sound into digital impulses and sends them to the transmitter, which conveys the signals through the skull to the electronic receiver/stimulator package. Then the receiver/stimulator package relays the signal to the electrodes and converts them to electric impulses. The electrodes, which are surgically placed under the skin behind the ear in the cochlea, in turn, transmit the signal to the auditory nerve that delivers the signals to the brain where they are interpreted as sound.

The cochlear implant has become one of the most important intervention options available to individuals with profound hearing loss. It is estimated that approximately 13,000 adults and almost 10,000 children have received cochlear implants so far in the United States (NIDCD, 2002). The use of cochlear implants is becoming more frequent in children with profound hearing loss (Pisoni, Cleary, Geers, & Tobey, 1999). Furthermore, more children with hearing loss are being diagnosed at younger ages than ever before, and many of them are using cochlear implants (Houston & Pisoni, 2002).

The most dramatic change in functioning for recipients of cochlear implants is the opportunity to access and participate in oral communication with others. This outcome is particularly important for young children, for whom communication is vital to normal cognitive, language, social, and emotional development (Marschark, 1993). Understanding how children are affected by variable periods of auditory deprivation is of utmost importance for those children and their families. It also can provide insight into the role of sensory perception in normal development.

Congenital hearing loss can be caused by genetic factors or prenatal teratogenetic factors, which lead to the malformation or malfunction of many parts of the outer, middle, or inner ear. Other causes of significant hearing loss in early childhood include disease, ototoxicity, and trauma. Children who receive cochlear implants typically have a bilateral sensorineural hearing loss, meaning that some or most of the hair cells in the inner ear are damaged and therefore remain uncharacteristically motionless, even in the presence of sound. Sensorineural hearing loss can range from mild to profound in severity. To qualify for cochlear implant candidacy, a child must have a profound (90db+) or severe-to-profound (75-90dB) sensorineural hearing loss in both ears and receive little to no benefit from hearing aids (NIH Consensus Statement Online, 1995). The cochlear implant permits the incoming sound to bypass the damaged inner ear and deliver sensation to the remaining auditory nerve fibers to be transmitted to the brain.

2.2 Importance of Early Experience

Research focusing on early experience, sensitive periods, and critical periods in development has received enormous attention from both scientists and the popular media in recent years. This body of research addresses the relative importance of the earliest period in child development and the implications of deprivation during this time. Overwhelmingly, atypical experience – which in reality is most often the experience of deprivation – has been shown to prevent or disrupt the healthy developmental processes in children.

Deprivation can be conceptualized as the absence or restricted access to a necessary input that is available during healthy development. Indeed, a classic study on the effects of early experience was the deprivation of sensory experience in cats. Hubel and Wiesel (e.g. 1965, 1970) reported on the abnormal visual development of kittens that were deprived of visual input. Their findings demonstrated that there was a certain amount of time during which the areas of the brain responsible for vision was especially sensitive to the effects of abnormal experience. These studies have sparked interest in the effects of early experience on developing systems that has stimulated research for the past forty years.

The literature on auditory deprivation has focused primarily on the impact on neurobiological and cognitive aspects of development. There has been less attention to the effects of auditory deprivation on social and emotional aspects of development. This may be because of the complexity of the developmental processes in the social and emotional domains or the relative difficulty of assessment of social and emotional outcomes. Nonetheless, the effects of auditory deprivation during early childhood can be pervasive and profound, far exceeding the obvious effects on the neurological development of the auditory system or the development of spoken language (Marschark, 1993). Many questions about the precise nature of far-reaching behavioral effects of auditory deprivation on the developing child and which processes produce these effects remain to be answered.

2.2.1 Impact of Sensory Deprivation on Early Experience

The literature on sensory deprivation has elucidated several basic premises of the effects of early experience on later development (for a discussion see Bornstein, 1989; Knudsen, 1999). First, many developing systems, in both humans and animals, require input or experience after birth in order for the typical sequence of development to unfold (experience-dependent) (Greenough, Black, & Wallace, 1987). Second, there are sensitive periods during the course of development when the brain is especially receptive to the effects of experience, for a limited period of time (experience-expectant) (Greenough et al., 1987). Third, there are critical periods in development when atypical or absent experience causes significant and long-lasting alterations in the typical processes of development (Knudsen, 1999). Last, although systems may be deprived of normal experience or input, individual systems retain a certain degree of plasticity, often for a remarkably long period of time (Knudsen, 1999). This plasticity makes it possible for typical developmental processes to be resumed at the introduction or onset of experience or input, albeit with variable degrees of both quality and quantity of compensation achievable. Finally, despite the neural plasticity, there are often subtle, enduring effects of altered or absent early input that may remain or appear later on in development. Description of several relevant findings in investigations of sensory deprivation will elucidate these basic premises.

2.2.2 Early Experience and Visual Development

Maurer, Lewis, and colleagues have illuminated these basic principles of the effects of early experience on subsequent development with research on children with bilateral cataracts, who are deprived of visual stimulation for extended periods of time during infancy (for a review see Maurer and Lewis, 1993; 2001). After treatment to remove the cataracts, infants were found to have significantly diminished visual acuity as compared to age-matched controls (Maurer & Lewis, 2001), reduced spatial and temporal contrast sensitivity (Ellemberg, Lewis, Maurer, Liu, & Brent, 1999), reduced stereovision (Birch, Stager, Leffler, & Weakley, 1998), and reduced sensitivity in the visual field (Bowering, Maurer, Lewis, & Brent, 1997). Infants ranged from 1 week to 9 months of age at the time of surgical removal of the cataracts. At assessment immediately following the surgery, the infants with cataracts, had visual acuity of newborn infants, indicating that no increase in acuity had taken place during the period of deprivation of visual input. Remarkably, the infants with cataracts showed improvement in visual acuity during tests administered one hour and then one month after the removal of the cataract (Maurer, Lewis, Brent, & Levin, 1999), reflecting the relative plasticity of the visual system despite deprivation of visual experience. However, acuity of infants whose cataracts were removed later in the first year of life was delayed relative to age-matched infants with normal vision. This finding demonstrates the existence of a sensitive period for visual experience during which the longer the deprivation continues, the less likely the possibility of correcting or compensating for the effects of the early deprivation later during development. Finally, longitudinal study of the visual development of children who received treatment for bilateral cataracts in infancy has shown that these children demonstrate poorer acuity than age mates throughout childhood and adolescence (ages 5 to 19) (Lewis, Ellemberg, Maurer, & Brent, 2000). Decreased acuity was documented even when the period of visual deprivation in infancy was as short as seven weeks (Ellemberg, Lewis, Maurer, Lui, & Brent, 1999). This research has led to an appreciation of the experience-dependent development of the visual system and has provided insight into the nature of the effects of deprivation on the immature visual system.

2.3 Early Experience and the Development of the Auditory System

Auditory deprivation is the absence of stimulation to the auditory system, often called deafness. Without auditory stimulation early in life, the central auditory pathways of the brain fail to follow the typical maturational process that occurs during childhood in individuals with normal auditory perception (Eggermont, Ponton, Don, Waring, & Kwong, 1997; Sharma, Spahr, Dorman, & Todd, 2002). The effects of auditory deprivation during early childhood can be pervasive and profound, far exceeding the obvious effects on the neurological development of the auditory system or on the development of spoken language (Marschark, 1993). However, little is known about the precise nature of these far-reaching behavioral effects of auditory deprivation on the developing child and what processes produce these effects.

2.3.1 Auditory Deprivation and the Development of the Central Nervous System

Research on cortical organization following auditory deprivation in animals has yielded important information regarding the effects of auditory deprivation on the development of the auditory cortex. Considerable research has been conducted on mammalian and avian orders. Studies of guinea pigs revealed that when reared in conditions of auditory deprivation, they failed to develop the normal mapping of auditory space (Binns, Withington, & Keating, 1995). In a similar vein, Zheng and Knudsen (1999) found that when barn owls were subjected to monaural auditory deprivation during early experience, they developed highly atypical patterns of representation of auditory cues that are necessary for sound localization (mapping) in the auditory areas of the forebrain.

Animal studies of congenitally deaf white cats have provided an important opportunity to learn about the physiological changes in the structure and function of the auditory system that result from congenital deafness. Ryugo, Pongstaporn, Huchton, and Niparko (1997) found that in congenitally deaf white cats, as early as 6 months after birth, the synaptic characteristics of the endbulb of Held, a key auditory nerve terminal in the cochlear nuclei of the brainstem, were noticeably altered. These changes included reduced terminal branching, decreased synaptic vesicle density, altered structural features of the mitochondria, abnormal thickening of postsynaptic densities, and enlargement of synapse size. The neural efficacy of the endbulbs deteriorated with time. The authors argued that the deaf white cat serves as a useful model of the impact of congenital deafness in humans. As the degenerative neurological process progresses in the deaf white cats, the efficiency of the auditory system and specifically temporal processing is reduced. The implication of this research for children with congenital deafness is that as the duration of deafness increases, the ability of the auditory system to process acoustic stimuli decreases.

Studies of the effects of auditory deprivation on the human auditory nuclei have revealed similar patterns to those found in animal studies. For example, Moore, Niparko, Miller, and Linthicum (1994) examined the size of a particular population of neurons on the ventral cochlear nucleus in normal hearing versus profoundly deaf subjects. Cell size of the neural population in the profoundly deaf group varied from normal to more than fifty percent reduced as compared to normal hearing subjects. A significant factor in the variability of the reduction of cell population was the duration of auditory deprivation experienced by the deaf individual.

The maturational process of auditory cortex functioning can be measured in humans using electrophysiological recordings, in particular, examining the latency and amplitude of evoked potentials. This type of investigation has yielded particularly important information for the study of sensory deprivation in children and the effects of cochlear implantation. Specifically, researchers have found that certain aspects of the cortical auditory areas do not mature in children with profound hearing loss (Ponton, Don, Eggermont, Waring, & Masuda, 1996; Ponton, Moore, & Eggermont, 1999).

Ponton, Eggermont, and colleagues have been studying the maturation of the cortical auditory system by charting the changes in late evoked potentials in children with cochlear implants over time. Ponton, et al. (1999) have demonstrated prior to cochlear implantation, the P1-N1-P2 complex of evoked responses fails to follow the typical maturational pattern of development that begins at birth and culminates during early adulthood, without auditory input. When a child receives a cochlear implant, the onset of auditory stimulation triggers the maturational processes of the P1 peak. The P1 originates from the secondary auditory cortex, located in the lateral part of Heschl's gyrus (Liegeois-Chauvel, Musolino, Badier, Marquis, & Chavel, 1994). In children with normal hearing, the latency and amplitude of the P1 decrease steadily throughout childhood, reflecting progressively more efficient auditory processing. After the onset of auditory stimulation with a cochlear implant, the P1 latency decreases at the same rate of maturation found in children with normal hearing, and the delay in maturation is roughly equivalent to the period of auditory deprivation. This finding implies that some aspects of the cortical auditory system can retain their potential for normal maturational processes despite auditory deprivation (Ponton, Don, Eggermont, Waring, Kwong, & Masuda, 1996). However, there are limitations on the resumption of the normal maturational processes. Despite the gains made by children with cochlear implants, by adolescence their P1 latencies were still longer and P1 amplitudes were much larger than those of normal hearing peers.

Sharma, Dorman, and Spahr (2002) specifically examined the relative plasticity of the P1 component. They assessed the maturation of the P1 component latency in 104 congenitally deaf children who received cochlear implants and compared them to age-matched children with normal hearing. The duration of deafness prior to implantation was the independent variable; it varied from 1.3 years to 17.5 years. However, all of the children had used their cochlear implants for approximately the same period of time, three years. The children who had experienced the shortest period of auditory deprivation and who received cochlear implants before 3.5 years of age demonstrated age-appropriate P1 latencies in the six months following the introduction of cochlear implant use. However, children with more than 7 years of auditory deprivation generated atypically delayed P1 responses. The authors argued that their findings provide evidence for a sensitive period in central auditory system development after which system plasticity is significantly diminished.

Researchers have investigated the N1b evoked potential that is thought to represent activity in the primary auditory cortex, as well as other cortical areas (Naatanen & Pickton, 1987). In contrast to the P1, the emergence of the N1b potential is absent in almost all pediatric cochlear implant recipients (Ponton, Don, Eggermont, Waring, Masuda, 1996). Ponton and Eggermont (2001) have proposed that the absence of the N1b peak is caused by the lack of maturity of the superficial layer axons in the auditory cortex.

The mismatch negativity (MMN), a late event-related auditory potential, also has been used to explore the effects of auditory deprivation on the maturation of the central auditory system. The automatic MMN response is elicited by an oddball paradigm during which a subject is presented with deviant or atypical stimuli interspersed in a standard, repeating stimulus. The MMN is thought to reflect processing of auditory discrimination in the absence of attention, which originates in the auditory cortex (Naatanen & Alho, 1995) with an additional contribution generated in the frontal lobe (Alho, 1995; Naatanen & Alho, 1995).

Kraus et al. (1993) assessed the MMN response in adult cochlear implant users who were characterized as “good” users based on their own reports of satisfaction with the implant and speech perception performance. In these cochlear implant users, the MMN was present in reaction to speech stimuli and their MMN morphology was very similar to those of adults with normal hearing. Ponton et al. (2000) have described the maturation of the MMN in children with cochlear implants and reported that in spite of the abnormal P1-N1-P2 morphology, the MMN response is robust in children with good speech perception. Children with normal hearing tended to generate larger MMN responses in the contralateral hemisphere, while children with cochlear implants showed a more symmetrical response. These findings suggest that while children with cochlear implants generate atypical patterns of cortical processing, they still maintain the functional ability to discriminate auditory stimuli in the environment.

In summary, research on auditory system maturation following periods of auditory deprivation presents evidence of aspects of adaptive plasticity as well as limitations on this plasticity. Without auditory stimulation, the central nervous system pathways and structures fail to mature and neural structures in the auditory pathways deteriorate. Ponton et al., (1999) argue for the existence of a critical period for maturation of auditory cortex function. They found that the opportunity for normal maturation of the auditory cortex ceases after a certain age. The authors articulated the clear implication of their research for deaf children: "…the shorter the period of deafness before implantation, the better is the prospect for normal cortical maturation and likely adequate development of verbal language and communication skills" (Ponton et al., 1999, p. 21).

2.3.2 Early Auditory Experience and Language Acquisition

Neville (1990; Neville & Bruer, 2001; Neville & Mills, 1997) described how auditory deprivation affects the development of brain areas that are considered specialized for language. Her research has revealed several important differences in brain functioning that result from auditory deprivation, reflecting the variable plasticity of various cortical areas in response to experience. First, Neville and colleagues documented altered functioning of the dorsal visual system in deaf adults, but not of the ventral visual system (Neville, 1995; Neville & Bavalier, 1998). ERPs in response to visual stimuli, located in the center of the subject's field of vision, were identical in congenitally deaf adults and in normal hearing controls. However, visual stimuli located in the peripheral areas of the deaf subjects' field of vision evoked an ERP response that was characterized by higher amplitude and atypical morphology relative to normal hearing subjects.

Second, when deaf adults read a text in written English, they did not display typical patterns of activation in the left hemisphere areas that are considered critical to language processing, including Broca's area, Wernicke's area and the angular gyrus (Neville, Bavalier, Corina, Rauschecker, Karni, Lalwani, et al., 1998). Instead, when deaf adults who were native American Sign Language (ASL) users processed sentences in ASL, they displayed activation of the language areas of the left hemisphere in addition to anterior areas of the right hemisphere. This finding suggests that the functioning of cortical areas changes in response to atypical stimulus characteristics. Third, Neville documented altered functioning of the grammatical processing system, but not the semantic processing system, in deaf adults during tasks involving reading English (Neville et al., 1998; Neville, Coffey, Lawson, Fischer, Emmorey, Bellugi, 1997). During semantic processing tasks, deaf and hearing adults generate the same ERP characteristics of latency, amplitude, and scalp distribution. However, during grammatical processing, deaf adults exhibited bilateral activation instead of the typical left lateralized activation evident in normal hearing adults.

In summary, through ERP investigations with deaf and hearing adults, Neville has demonstrated that there are significant modifications in the functioning of language specialized cortical areas in individuals who experience auditory deprivation. In addition, they demonstrate cortical changes in visual processing of motion and spatial location as well as grammatical processing of written English, domains that might initially be beyond the scope of a narrow investigation of altered experience in the auditory modality. The implication of Neville's findings is that deprivation of one sense leads to modified functioning in many, perhaps unanticipated, areas. This body of research clearly demonstrates that the brain is remarkably plastic and responsive to the variable sensory input it receives. Furthermore, each of the aspects of cortical processing of language stimuli considered by Neville could be involved in the development of social and emotional functioning.

2.4 Conceptual Model of Emotion Understanding Development

Emotion understanding is the ability to take the emotional perspective of another person and infer or estimate his/her likely feeling or perception, despite not feeling that emotion or sharing that person's perspective (for review of studies of emotion understanding development, see Harris, 1993; Schwartz & Trabasso, 1984). Cutting and Dunn (2002) describe emotion understanding as the capacity to comprehend and infer meaning from the actions, goals, and perspectives of other people that are necessary to facilitate meaningful and appropriate social interactions. In plain terms, emotion understanding is the ability to "understand what others are feeling" (Saarni, Mumme, & Campos, 1998, p. 265). Emotion understanding involves attending to and interpreting the emotional valence of an emotional expression in facial expression, vocal expression, and "situational elicitors of emotion" (Saarni, Mumme, & Campos, 1998, p. 266).

Harris (1989) presents a cogent and compelling conceptual framework for the development of emotion understanding. His framework begins at birth and charts the understanding of emotion through childhood, as it becomes progressively more sophisticated and complex. According to the model, emotion understanding is learned first through interactive give-and-take with significant others during infancy. These interactive routines are practiced and refined with peers in preschool and school years. Denham and Dunn have emphasized the role that parents play in emotion understanding development later in the toddler and preschool years (Denham, Zoller, & Couchoud, 1994; Dunn, Bretherton, & Munn, 1987; Dunn, Brown, & Beardsall, 1991).

Emotion understanding learning takes place in a social context. The foundation is laid at birth, when the parent-child relationship begins. The intimacy and reciprocity of the parent-child relationship in infancy introduce the child to emotion-laden messages in the interactions with others. From the youngest age, infants can discriminate between different emotional expressions on the faces of their caretakers (for review see Gross & Bailif, 1991; Izard & Harris, 1995). During the first year of life, the infant develops this ability to interpret and appreciate the valence of the differentiated emotional states. Interactions between the child and parent or caregiver are the main mechanism employed to accomplish this goal. Interactive strategies that are important during the first years of life such as infant-directed speech, social referencing and joint attention all contribute to increased understanding of emotions.

The emergence of the cognitive ability to take the emotional perspective of another person while not necessarily feeling that same emotion of him or her is the achievement that Harris calls “imaginative understanding” (Harris, 1989, p.39). Reaching this developmental endpoint requires the successful emergence of four abilities. First, the child must have the awareness of one’s own mental state that emerges with and is facilitated by spoken language. Second, the child must have the capacity for imagination that is indicated by and reflected in the emergence of pretend play. Third, the child must be able to distinguish between reality and fantasy or imagination. This enables the understanding that one’s own feelings can be and indeed are different from those of another person. Last, the child must develop the ability to discern the desire of another person and then imagine the emotional state or feelings of this person in light of that person's hypothesized desire (Harris, 1989). The child appreciates what the other person is likely feeling even though the child does not feel that emotion. This impressive accomplishment for a relatively novice social being is emotion understanding.

In the second and third years of life, the child takes on the role of agent in situations that provide emotional learning opportunities. Harris (1989) describes the active role that the child plays as an elicitor of emotion, both by comforting and by hurting others. Research on the behavior of children during this stage reveals that they employ deliberate and often quite effective strategies to comfort a caregiver, sibling, or peer (Dunn, Kendrick, &MacNamee, 1981; Zahn-Waxler & Radke-Yarrow, 1982) or to hurt them (Dunn & Munn, 1985; 1986).

Peers serve as important communication partners during early childhood and play with peers provides an important opportunity to put emergent social skills into practice (Hartup, 1983). Brown, Donelan-McCall and Dunn (1996) found that preschool–aged children used language involving mental states more frequently in conversations with peers and siblings than in conversations with their mothers, even though mothers often used these terms with them. Also, pretend play time served as the context for a large part of the mental state talk that occurred between children.

Harris emphasizes the role of siblings and peers during the development of "imaginative understanding." He argues that they serve as the most salient and clear source of information and feedback on important social interactions involving turn-taking and sharing (Dunn & Munn, 1987).

The importance of parents, specifically, conversations with parents, during this period of emergence of these perspective-taking skills has been reinforced by findings that conversation with parents on emotion understanding issues plays a significant role in development of emotion understanding ability (Denham, Zoller, & Couchoud, 1994; Dunn, Bretherton, & Munn, 1987; Dunn, Brown, & Beardsall, 1991). As the typically developing child proceeds through early childhood, there is increased opportunity for progressively more complex emotional learning through conversations about emotions and emotional experiences.

The activities of this period are considered critical in the development of emotion understanding (Denham, 1986). The capability to talk about emotions emerges around 18 months of age and the use of emotional words increases dramatically throughout the third year of life. During the preschool years, ages 3-5, children develop the ability to communicate verbally about their emotional observations of themselves and others. This language ability facilitates the discussion of past or future events and experiences. It allows the child to reflect on his own feelings and the feelings of others. The child can then receive reaction and further interaction from parents and other significant communication partners (Bretherton, Fritz, Zahn-Waxler, & Ridgeway, 1986). The development of an integrated and complex ability of emotion understanding is supported by the individual components beginning at a basic level of sensory functioning and the level of processing of social and emotional input. Several of these aspects of functioning will be described in greater detail in the review that follows.

2.5 Processing of Perceptual Information

2.5.1 Sensory Integration of Multimodal Stimuli

The integration of multimodal sensory stimuli is an important basic perceptual skill because it provides the essential foundation for the interpretation and understanding of more complex stimuli. The integration of sensations that consist of simultaneous experiences in different modalities is particularly adaptive because it facilitates quick and efficient processing of sensory stimulation by reducing the total amount of perceptual information that must be processed (Lewkowicz, 2000). An example of the benefit of sensory integration in perceptual processing can be seen in the facilitation effect of synchronous auditory and visual stimuli in speech perception. Dodd (1977) reported that hearing subjects are most accurate in their perception of difficult-to-hear words when auditory and visual information are provided. The perception of speech is not an exclusively auditory experience. Investigators have demonstrated that information obtained by watching the speaker’s face or lips provides a considerable advantage in understanding the speaker (Dodd, 1977; Grant, Ardell, Kuhl, & Sparks, 1985; Sumby & Pollack, 1954).

Studies of the abilities of infants to perceive emotional expressions have clearly indicated that multimodal presentation of emotional stimuli facilitates the most effective detection, discrimination, and recognition of these emotional stimuli (E. J. Gibson, 1991; Klinnert, 1984; Walker-Andrews, 1997; Walker-Andrews & Lennon, 1991). Walker-Andrews (1997) argued that infants first perceive multimodal stimuli, which provide the richest context from which the infant can begin to understand and interpret the social expressions of others. Furthermore, when multimodal and unimodal stimuli are presented to infants, only the multimodal stimuli are differentiated and recognized by infants at the youngest ages, between 5 to 7 months, whereas infants can only accurately perceive unimodal stimuli at older ages, closer to 12 months. The perception of multimodal stimuli is developmentally important because it provides the infant adequate clues to facilitate efficient early learning.

The effects of multimodal presentation of stimuli on perception are apparent in the performance of individuals on the McGurk task (McGurk & MacDonald, 1976). When individuals are presented with an auditory syllable /pa/ simultaneously with a visual syllable /ka/, they typically report having heard a fused, virtual syllable /ta/ or /tha/. The implication of the McGurk illusion is that conflicting multimodal sensory information is integrated and processed as a novel stimulus. This illusion has been demonstrated with preschool children, elementary school children, and adults (McGurk & MacDonald, 1976).

Performance on the McGurk task is measured by fusion rate, which is the percentage of total responses in which the subject reports having heard the fused or novel syllable. In the case of children with cochlear implants, it would be expected that McGurk task performance would be highest for the children who received their cochlear implant at the youngest age. Children with the earliest auditory stimulation from cochlear implants would be expected to report the McGurk illusion syllable /ta/ or /tha/ at a higher rate than children who received their cochlear implants at later points in development, who would be hypothesized to report a visual-only response, /ka/, similar to the task performance of individuals with normal hearing in sub-optimal auditory environments (Grant et al., 1985).

This hypothesis is supported by evidence of cross-modal plasticity in adult and child cochlear implant users. Giraud, Price, Graham, Truy, and Frackowiak (2001) reported that postlingually deafened adults who use cochlear implants show activation of the early visual cortex (V1/V2) while listening to sounds with their eyes closed. The authors argued that cochlear implant use promoted the recruitment of visual cortex areas and increased multimodal activity and synchrony. Since the auditory signal provided by the cochlear implant is imprecise, the listener tended to rely on visual information to supplement the auditory information. Activation was found to increase as the length of time the person used a cochlear implant increased. Based on this research, the hypothesis guiding the McGurk task fusion rate performance, which represents synchrony of sensory integration and synthesis of multimodal stimuli, is that early age at implantation and increased duration of cochlear implant use will predict increased McGurk fusion rate.

2.5.2 Processing of Facial Expressions of Emotion

The perception of facial expressions of emotion is a fundamental aspect of emotion processing. It reflects the basic interpretation of social cues upon which consequent social interactions and behavior depend (Pollak, Cicchetti, Hornung, & Reed, 2000). The ability to accurately perceive and encode emotional facial expressions is considered essential to the development of socially competent behavior (Gross & Ballif, 1991). Young hearing children tend to rely heavily on the facial expressions of others to provide cues that are salient enough to allow them to make sense of the information being communicated to them (Nelson & deHahn, 1996). As children get older and gain more social experience, they begin to utilize verbal explanations and analyses provided by their parents to make the connections; more complex information is required to understand more complex social situations (Dunn, Brown, & Beardsall, 1991; Snitzer Reilley, McInitre, & Bellugi, 1990).

In studies of emotional development of hearing children, the age-appropriate ability to accurately discern the facial expressions of emotion, such as anger, happiness, sadness, fear, and disgust, has been linked to social competence and social acceptance by peers in the preschool years (Cassidy, Parke, Butkovsky, & Braungart, 1992; Denham, McKinley, Couchoud, & Holt, 1990; Walden & Field, 1982) and in later childhood (Custrini & Feldman, 1989; Edwards, Manstead, & MacDonald, 1984). There also is substantial evidence indicating that children with abnormal early experiences of affective communication, such as children with emotional disorders and children who are maltreated, show deficits in their accuracy of discrimination of facial expressions of emotion (Camras, Grow, & Ribordy, 1983; Feldman, White, & Lobado, 1982; Pollak, Cicchetti, Hornung, & Reed, 2000; Pollak, Cicchetti, Klorman, & Brumaghim, 1997; Walker, 1981).

Of particular relevance is provocative research on the ability of children who have been physically neglected or physically abused to discriminate between different facial expressions of emotion. Pollak Cicchetti, Hornung, and Reed (2000) found that children who were physically neglected discriminated less accurately between facial expressions of anger, sadness, and fear than children who were physically abused and normal controls. The hypothesis that was proposed to explain this difference is that neglected children, in particular, suffer from “impoverished opportunities for interactions with adults” (Pollak et al., 2000, p. 680) that result in the diminished ability to perceive emotions accurately. Children who experience physical neglect appear to suffer from the effects of social neglect as well.

In the case of deaf children, parent-child communication is often impaired. From early childhood, social information needed to interpret emotional states is reduced, in both frequency and complexity, in children with hearing loss, (Marschark, 1993). Research on the perception of facial expressions by children with hearing loss is sparse. Odom, Blanton, and Laukhuf (1973) found that deaf children were grossly delayed in their ability to match facial expressions of emotions to pictures of emotion-arousing situations. Serious methodological concerns arise in consideration of the study by Odom et al. (1973), and make it difficult to draw conclusions about the functioning of deaf children as a group. In Odom et al. (1973) the subjects were 15 deaf 7- and 8-year-olds at a residential school who were compared to normal hearing kindergarteners and second graders. The small size of the sample of deaf children and the questionable generaliziability of deaf children who are educated in a residential setting are particular concerns. Nonetheless, this study is widely cited in the literature on deaf children, perhaps because no other studies addressed this issue for quite some time.

More recently, Hosie, Russell, Gray, Scott, and Hunter (1998) found no significant differences between the abilities of deaf and hearing children to match pictures of facial expressions of emotion and to label the emotions demonstrated in pictures. There are no data currently available on the perception of facial expressions of emotion by children with cochlear implants.

Discrimination between the multiple factors informing the outcomes of physically neglected children may illuminate the effects of the unique situation of children with cochlear implants. Children with cochlear implants are not a clinically referred population who has experienced severe physical neglect. There is no evidence to indicate that they experience grossly inappropriate or deficient physical care. Rather, the exclusive difference in their experience is the early and often profound disruption of communication due to their inability to hear others. Assessment of the performance of children with cochlear implants in discriminating facial expressions of emotion will allow us to parse the effects of diminished communication from the possible social neglect that confound the results of Pollak et al.'s (2000) sample. This information may help clarify our understanding of the impact of diminished communication on emotional development.

2.5.3 Processing of Vocal Expressions of Emotion

The perception of emotion in the vocal expressions of others is vital to accurate understanding of emotional messages (Banse & Scherer, 1996; Frick, 1985; Scherer, 1986). The emotional information conveyed by auditory stimuli provides significant cues to the emotional intent or perspective of the emoter. For example, studies of emotion regulation in infancy have demonstrated the importance of vocal signals in conveying emotional information. In novel toy studies, an infant and mother are seated in a room and an unfamiliar toy is introduced. The mother or an experimenter reacts to the toy with an expression of positive, negative, or neutral emotion. When the adult's emotional response was conveyed exclusively through facial expression, infants did not respond differently to a happy, fearful, or neutral face (Klinnert, 1984; Mumme, 1993; Zarbatany & Lamb, 1985). However, when the adult generated both a facial and vocal response, infants were more hesitant to approach the toy in response to negative facial and vocal reactions from the adult as opposed to positive reactions (Mumme, Fernald, & Herrera, 1996). In habituation tasks requiring discrimination between emotional states by infants as young as 5 months of age, infants are most accurate when both facial and vocal information is presented together (Walker-Andrews & Lennon, 1991).

There is markedly less research on the role of vocal expressions of emotion in emotional development during infancy than on the role of facial expressions (Scherer, 1986; Walker-Andrews & Lennon, 1991). Nonetheless, studies of the role of vocal expressions of emotion in infancy have focused attention on the importance of the vocal expressions in emotion regulation (Mumme, Fernald, & Herrera, 1996). The role that affective features of the vocal stimulus play in “motherese” or infant-directed speech (Fernald, 1989; 1993; Furrow, Nelson, Benedict, 1979; Nelson, 1973) highlights the importance of the vocal expressions of emotion of others on infant development. When adults speak to infants, they speak slower, adjust their frequency and range and exaggerate the contours of their speech (Fernald, 1989; Newport, 1977; Walker-Andrews, 1997; Vorster, 1975). Infant-directed speech conveys emotional information that is thought to assist the infant’s understanding of the meaning of communicative messages, thereby facilitating language and emotional development (Papousek, Bornstein, Nuzzo, Papousek, & Symmes, 1990; Walker-Andrews, 1997).

Fernald’s (1993) studies of infant-directed speech have highlighted the important, particularly social, functions of infant-directed speech. Fernald (1993) argued that infant-directed speech initially serves to attract the attention of and then soothe or entertain the infant. Then, throughout the first year of life, infant-directed speech serves as a first tool of emotional instruction for the infant, allowing parents to present socially salient information about feelings and intentions. In fact, mothers tailor their infant-directed speech to the specific developmental needs of their infants, providing more affective material in their speech to younger infants although they speak more overall to older infants (Bornstein, Tal, Rahn, & Galperin, 1992).

There is, understandably, no research on the performance of deaf children on tasks requiring the identification of vocal expressions of emotion. Children with cochlear implants provide a first opportunity to assess the accuracy of identification of emotional signals that are expressed through vocal expressions. Hosie et al., (1998) posit that deaf children may have under-developed abilities to recognize nonverbal signals of emotion due to their general lack of experience in social interactions and that this deficit would most likely affect their ability to interpret the vocal expressions of others. The deficits in processing of facial expressions of emotion and hypothesized deficits in vocal expressions both are hypothesized to affect other aspects of social and emotional functioning.

2.6 Social and Emotional Implications of Atypical Early Auditory Experience

Historically, auditory deprivation has been considered a significant disability that affects all aspects of psychological functioning (Myklebust, 1960). Myklebust (1960) advanced the argument that the sensory experience of deaf individuals is limited and thus fundamentally altered from the typical sensory experience of those with normal auditory functioning. Furthermore, he argued that the altered sensory experience produces broad changes in many aspects of psychological functioning of the individual, including intelligence, memory, emotional adjustment, motor functioning, and social maturity.

More recently, Marschark (1993) has revisited the issues related to the general social and emotional development of deaf children. He differentiated between the direct effects of deafness and the “secondary effects” of deafness. He argued that the direct effects of deafness are those that specifically affect hearing and speech. However, the secondary effects of deafness profoundly influence a deaf child's interactions with the wider environment around him. These are broad aspects of development such as cognition, social functioning, emotional development (Marschark, 1993). Thus, for children raised by deaf parents, who are skilled at nonverbal communication, there might be little or no impact of deafness on the mother-child relationship and early interactions. However, the overwhelming majority of parents of deaf children are hearing (Gallaudet Research Institute, 2002). Mitchell and Karchmer (2004) have recently reanalyzed the demographic information available on deaf children and found that up to 96% of deaf children are born to hearing parents. Most hearing parents are unfamiliar with the communication needs of deaf infants, and many do not realize that their child is deaf until after the secondary effects of deafness are already noticeable.

Thus, auditory deprivation places emotion understanding learning at risk by its effects on parent-infant interactions in the first months of life. Most hearing parents have no prior exposure to or experience with the unique communication needs of deaf infants (Marschark, 1993). We will now review the developmental processes that take place in each of the periods of emotion understanding development and consider how auditory deprivation influences the normal acquisition of emotion understanding.

2.6.1 Effects of Atypical Early Auditory Experience on Interactions with Parents

Infancy

Appropriate and reciprocal parent-infant interaction is thought to be susceptible to several risk factors for children with disabilities. These include: disruption of communication as a result of complications after birth and especially premature birth, hindrance of emergence of intuitive responses by parents due to parents' anxiety about the child's disability, a pronounced discrepancy between infant and parent communication style, and a prolonged period of time when the child requires communication accommodations that are usually made for only infants (Papousek & Papousek, 1992). Each of these risk factors is of significant concern for deaf infants (For a review of the research on parent-child interactions of deaf children see Lederberg & Prezbinowski, 2000; Spencer & Lederberg, 1997).

Altschuler (1974) argued that the interactions between parent and deaf infant are degraded in nature due to the absence of auditory input. Specifically, the auditory modality usually allows parents to soothe their infant, convey emotional information through their tones of voice, and thereby connect emotionally with the infant without physical contact. When a child is deaf, this important avenue for emotional connection is unavailable. Worse yet, when parents realize that their child is not soothed by their voices, they may feel rejected by the infant and begin to doubt their parenting ability (Marchark, 1993). The development of the parent-child relationship almost inevitably suffers. According to Maher (1989), when a child is deaf, the development of reciprocal interactions between parents and child is disrupted as early as the first weeks of life.

Because hearing loss has been typically detected after the age of early infancy when infant-directed speech, joint attention, and social referencing skills first emerge, there is little research on the use of these communicative strategies in deaf infants (Koester, Karkowski, & Traci, 1998). However, considerable attention has been placed on these areas during toddler years and early childhood. Researchers have documented that deaf mothers make adaptations in their manual communication with their infants, which are typical of infant directed speech (Erting, Prezioso, & O'Grady Hynes, 1990; Maestas y Moores, 1980). Mothers who are deaf modify their sign expressions by producing them closer to the infant's body, while showing their faces, and by lengthening the sign to provide more time for the infant to see the sign (Erting et al., 1990). Deaf mothers simplify and enlarge their signs in a similar way to the adaptation of spoken communication by hearing mothers (Spencer & Lederberg, 1997). There is no research on the prosodic characteristics of infant-directed speech of hearing mothers to deaf infants (Spencer & Lederberg, 1997). However, Spencer (1993) reported that hearing mothers typically shorten their communicative utterances for deaf infants.

The majority of the research on social referencing examines the facial and vocal relative contributions to the infant's comprehension of the emotional valence of a situation. The novel toy paradigm is of limited use to assess the social referencing skills of deaf infants because of their obviously limited awareness of auditory information. However, several studies have reported on the face-to-face interactions of mothers and deaf infants in the “still-face” paradigm, during which the mother is present but unresponsive to the infant for a short time. Koester (1995) found that deaf infants exhibit similar patterns of gaze and gaze aversion as hearing infants. However, when mothers did not respond with an obvious facial expression, deaf infants generated fewer signaling behaviors to try to elicit their mothers' response as compared to hearing infants. Koester concluded that deaf infants may not try as hard to obtain their mothers' attention because their attempts to repair communication break-downs are often unsuccessful.

Koester, Brooks, and Karkowski (1998) evaluated the face-to-face interactions of both hearing and deaf mothers with either their hearing or deaf 9-month-old infants. The researchers reported that the deaf infants of hearing mothers produced similar patterns of vocalizations as other infants. Hearing mothers with deaf infants engaged in vocal and visual games and interactions with their deaf infants in order to make vocal communication more accessible and meaningful to their infants.

Joint attention involves the infant's coordination of attention between both a caregiver and an object of interest. For hearing children, joint attention is an integrated, simultaneously auditory and visual experience (Bruner, 1972; 1981). The child visually focuses on an object while at the same time listening to the parent talk about the object. This strategy provides valuable opportunities for social interaction and learning about objects for hearing infants, but it is more problematic for deaf infants. Wood, Wood, Griffiths, and Howarth (1987) explained that instead of being helpful, joint attention is challenging to deaf infants because they are required to make sense of two different visual inputs at the same time. This competition for visual attention usually results in disruption of the timing and coordination of these vital early social interactions.

Prezbindowski, Adamson, and Lederberg (1998) examined the joint attention behavior of 24 deaf and 24 hearing toddlers, aged 20 to 24 months and their mothers. They found that deaf children spent an increasing amount of free-play time in joint attention activity with their mothers during this period. However, the focus of the joint attention activities was different for the deaf and hearing children. The hearing children spent much of the time in joint attention that was characterized as symbol-infused. Symbol-infused joint attention provides the opportunity to share information verbally, allowing for communication about memories and imaginary beings, which is not possible in communication about objects (Adamson & Chance, 1998). Symbol-infused joint attention activity emerges in typically developing children around 18 months of age (Adamson & Chance, 1998). Deaf children spent significantly less time engaged in symbol-infused joint attention than hearing children. This finding is particularly relevant to emotion understanding learning because it means that deaf children are restricted in access to this important opportunity to discuss emotion-related experiences.

Waxman, Spencer, and Poisson (1996) examined the dyadic interactions of toddlers, aged 24-28 months, and their mothers. They sought to investigate reports of the lack of reciprocity in communication between deaf children and their hearing mothers (Meadow, 1980; Spencer & Gutfreund, 1990; White & White, 1988). Their sample consisted of 10 hearing toddlers with hearing mothers, 10 deaf toddlers with deaf mothers, and 10 deaf toddlers with hearing mothers, and they observed the toddlers and mothers during free play situations in their homes. The deaf children of hearing mothers appeared to ignore their mothers' efforts to obtain their input more often than the other children. The authors suggested that the deaf children were unaware of their mothers' attempts to initiate communication. Also, because the mothers' attempts to respond went unnoticed by the children, it is likely that the children sensed a lack of reinforcement for their actions. The authors concluded that the play interactions of deaf toddlers and hearing mothers were less synchronous, less reciprocal, and less predictable than those of hearing toddlers with hearing mothers and deaf toddlers with deaf mothers.

Loots and Devise (2003) reviewed previous research on parent-infant relationships in deaf children and found that the focus of the research tended to be on the detrimental effects of the child's deafness on the parent-child relationship. More optimistically, Traci and Koester (2003) reviewed more recent studies that shed light on the strategies employed by deaf parents of deaf infants to enable reciprocal communication. They argued that hearing parents indeed make similar adaptations to enable them to understand their newly diagnosed deaf infant. Parents of deaf children borrow strategies that are typically employed by deaf parents such as using bold facial expressions and maximizing physical contact especially to attract attention (Koester, Papousek, & Smith-Gray, 2000). Indeed, more recent research has found that hearing parents compensate for the lack of auditory communication by using visual and tactile cues to communicate with their infants (Koester, Brooks, & Karkowski, 1998).

In summary, through examination of the parent-child relationship, evidence emerges that children with hearing loss have difficulty understanding their mothers' communication with them. This, in turn, is hypothesized to upset the normal development of the mother-child relationship (Harris, 1978; Schlesinger & Meadow, 1972; Wedell-Monnig & Lumley, 1980). This lack of social experience is further exacerbated because the deaf child receives socially salient information that is reduced both in quantity and quality (McGinnis, Orr, & Freutel, 1980). The deaf child is often left with degraded or insufficient experience in their interpersonal interactions with their parents. This deficit is significant in its own right. But it also deprives the deaf child of the social and emotional experiences that are required for further social and emotional development.

2.6.2 Effects of Atypical Early Auditory Experience on Interactions with Peers

Children with hearing loss encounter an additional obstacle in the path to social and emotional development when they reach the preschool years. They have fewer opportunities for social interactions with peers and therefore have less opportunity to learn about emotion and emotional experiences. This phenomenon has been documented through observation of two aspects of social interaction: the failure of deaf children to gain entry to play situations and diminished opportunities to participate in social pretend play experiences. Both of these aspects of peer interaction are considered integral to the social development of children. Gaining entry to the play with peers is considered a crucial social skill for young children (Dodge, Schlundt, Schocken, & Delugach, 1983; Pullataz & Gottman, 1981a, 1981b; Pullataz & Wasserman, 1989, 1990). Furthermore, social pretend play is considered a vehicle of development of many social and cognitive skills important to emotion understanding (Black, 1989; Bruner, 1972; Garvey, 1990; Gottman & Parker, 1986; Vygotsky, 1976).

Vandell and George (1981) assessed the initiation behaviors used by deaf and hearing children who were paired with same-sex, same-age preschoolers during a laboratory free play period. An initiation was considered any act directed toward the other peer and not a continuation of a prior interaction. Success of an initiation was determined by its effectiveness in eliciting a response from the other peer within five seconds. The authors found that deaf children often missed the social signals of hearing peers because the deaf children were not looking at the time the hearing children used a particular gesture. Deaf children initiated interactions more often than hearing children, but the initiation attempts of the deaf children were more likely to be unsuccessful than those of hearing peers.

Similarly, Roberts, Brown, and Rickards (1995) observed the naturalistic social pretend play entry behaviors of deaf and hearing children in the home corner of their preschool classrooms. This study did not reveal significant differences in the frequency of attempts to initiate the play as a result of hearing status. However, the deaf children employed a smaller repertoire of social behaviors to initiate play entry and were less likely to persist at attempting to gain entry to the play once initially rejected. The inability to gain entry to the play situation at the same rate as children with normal hearing limits the opportunities which deaf children can have to interact with peers.

In the domain of social pretend play, there is evidence that deaf children engage in less complex social pretend play with peers and engage in play less frequently than children with normal hearing (Darbyshire, 1977; Esposito & Koorland, 1989; Higginbotham & Baker, 1981; Mann, 1984). However, much of this research has been criticized for the brief observation of children's interactions and the unrealistic settings in which they are observed (Messenheimer-Young & Kretschmer, 1994).

In some investigations, language skill played an important role in predicting participation in social pretend play for deaf children. Deaf children who had higher language levels demonstrated higher levels of symbolic play behaviors (Casby & McCormack, 1985; Schrimer, 1989; Spencer & Deyo, 1993). However, other studies have found that deaf children's language skill is not predictive of the quality of interaction with peers (Lederberg, Chapin, Rosenberg, & Vandell, 1986; Lederberg, Rosenblatt, Vandell, & Chapin, 1987; Lederberg, 1991). Results of these studies indicated that the choice of playmate by deaf children was more influenced by the playmate's age, sex, and ethnicity, as opposed to the playmate's language proficiency.

Overall, the children who do not have adequate use of the symbolic language that is required to participate in pretend play, are often excluded. Inability to access the play group and exclusion from play experiences with peers deprive the children of the typical opportunities to acquire the social problem-solving skills that are important to the development of emotion understanding. It also compounds the social and emotional experience deficit incurred in parent interactions leaving the deaf child with further diminished social and emotional experience.

2.6.3 Implications of Atypical Auditory Early Experience on Emotional Learning via Affective Communication

As the typically developing child proceeds through early childhood, there is increased opportunity for more complex emotional learning through conversations about emotions and emotional experiences. The capability to talk about emotions emerges around 18 months of age, and the use of emotional words increases dramatically throughout the third year of life. During the preschool years, ages 3-5, children develop the ability to communicate verbally about their emotional observations of themselves and others. This skill facilitates the discussion of past or future events and experiences, and allows children to reflect on their own feelings and the feelings of others. It also allows children to receive feedback and further interaction from parents and other significant communication partners (Bretherton, Fritz, Zahn-Waxler, & Ridgeway, 1986).

As children become more skilled communicative partners, parents engage in more frequent and more complex emotional discussions with them. Denham, Zoller, and Couchoud (1994) termed this type of emotional communication *emotion-related parental didactic practices*, in which parents initiate emotionally oriented discussions in disciplinary situations and engage in conversations with their children about their own or their child’s emotions. This type of communication plays a significant role in children’s development of emotional understanding (Denham, Zoller, & Couchoud, 1994; Dunn, Bretherton, & Munn, 1987; Dunn, Brown, & Beardsall, 1991).

Dunn, Brown, and Beardsall (1991) recorded conversations between mothers and 36 month-old children about feeling states (e.g. happy, sad). The authors described feeling-state talk as multi-turn conversations about feelings that featured a specific reference to a feeling state. They later assessed the children's performance on an affective-perspective-taking task at 6 years of age. They hypothesized that conversations about feeling states, in general, would be positively related to the ability to understand the emotions of others at a later age. Indeed, children who grew up in families where feeling-state talk occurred most often were more accurate in making judgments about the emotions of others three years later. These results remained stable even after considering the child's verbal fluency, measured by mean length of utterance (MLU).

Dunn, et al. (1991) found differences in later emotional understanding in children who had engaged in feeling-state talk, after controlling for the effects of general verbal fluency. However, there is evidence that the conversations about emotions depend on the growing vocabulary and language skills of the developing child (Beeghly, Bretherton, & Mervis, 1986; Dunn, Bretherton, & Munn, 1987). Furthermore, emotional understanding has been linked to development of language skills, although not in a clear causal relationship (Cutting & Dunn, 1999; Dunn, Brown, & Maguire, 1995). Dunn, Brown, and Maguire (1995) suggested that children's language skill and emotional understanding are enmeshed in interactions with their mothers and siblings early in life, but the impact of language skill and emotional understanding emerge as independently significant factors in subsequent social development later on in childhood.

Research on deaf children overwhelmingly reports that they experience significant delay in language development (Geers, Moog, & Schick, 1984; Geers &

Schick, 1988; Mogford, 1988; Rodda & Grove, 1987). There is serious concern that the language deficits of young deaf children impair the ability to engage in emotional communication about feelings and emotional situations (Compton & Niemeyer, 1994; Nicholas & Geers, 1997). Specifically, Meadow (1976) found that deaf children and their hearing parents only were able to communicate about concrete situations in which a visual referent was available. The implication of this limitation is that parent-child conversations would not be able to provide the usual opportunity for deaf children to learn about emotions and emotional experiences.

Marschark (1993) described the implications of the absence of ample emotional conversation. He reported that parents give less explanation about emotions, provide less reasoning for taking certain actions, and less explanation for consequences of specific behaviors to deaf children than they do to hearing children. Many deaf children simply cannot hear enough to understand the meaning of these abstract conversations that require complex language. The gradual but persistent effects of this reduction in social and emotional information that is normally acquired through emotional conversation, in combination with the diminished experience in early interactions with parents and in play with peers, is hypothesized to contribute to decreased accuracy in the identification and interpretation of emotional cues of others.

Research on the social implications of language deficits for deaf children provides support for this hypothesis. Lederberg and Mobley (1990) found that hearing mothers of deaf toddlers with, ages 18 to 25 months, interacted less and had more miscommunications with their children compared to mothers with hearing toddlers. However, they also found that the overall rating of quality of the mother-child relationship was not negatively affected by the communication challenges posed by the toddlers' deafness. Based on their results, the authors posited that the negative effects of impoverished parent-child communication become more noticeable and detrimental later in childhood as spoken language becomes more important. Since the vast majority of deaf children are born to hearing parents, the concern about the impact of communication difficulties on the parent-child relationship is a serious one.

Greenberg (1980) examined the influence of communicative competence in mother-child relationships during the play interactions of 28 deaf children, aged 3 to 5 ½ years, and their hearing mothers. The author hypothesized that independent of communication mode (manual sign language or oral language), the mother-child dyads with higher levels of communicative competence would demonstrate more positive affect during interactions and would engage in longer and more complex interactions. Results showed that the dyads demonstrated higher levels of communicative competence did have more complex, successful interactions.

Lederberg and Everhart (1998) examined the communication between deaf children and their mothers during early childhood and found that at 3 years of age, the language development of deaf children was significantly delayed. The children were enrolled in an educational program that emphasized both oral and visual language (called total communication), but researchers found that the mothers communicated with their children in spoken language and were not fluent in sign communication. At 22 months, most of the deaf children used neither spoken nor sign language. By 3 years, most children were generating one-word utterances and using gesture to communicate. They lagged far behind the communication of hearing children, who typically use spoken language comfortably by 3 years. The deaf children were almost completely unable to convey the symbolic information required for emotion understanding learning that usually takes place at this stage in development.

2.7 Outcomes for Children with Cochlear Implants

In efforts to demonstrate the efficacy of cochlear implants, researchers have focused first and foremost on the improvements in speech and language performance of children after receiving a cochlear implant. Studies of the speech and language of children with cochlear implants have demonstrated gains in many aspects of oral language use, such as speech recognition/perception (Fryauf-Bertschy, Tyler, Kelsay, Gantz, & Woodworth, 1997; Illg, von der Haar-Heise, Goldring, Lesiniski-Schiedat, Battmer, & Lenarz, 1999; Meyer, Svirsky, Kirk, & Miyamoto, 1998; Mondain, Sillon, Vieu, Lanvin, Tobey, & Uziel, 1997; Miyamoto, Kirk, Robbins, Todd, & Riley, 1996), speech production (Tomblin, Spencer, Flock, Tyler, & Gantz,, 1999; Tye-Murray, Spencer, & Woodworth, 1995), speech intelligibility (Miyamoto et al., 1996), and language comprehension (Tomblin et al., 1999). These results reflect gains in essential aspects of functioning of children who receive cochlear implants.

An increasing number of studies have examined a variety of aspects of speech and language development in children with cochlear implants. Some have focused on the emergence of language skills in the first years of life (Miyamoto, Houston, Kirk, Perdew, & Svirsky, 2002). Others have investigated specific aspects of language development, such as morphology. Both Svirsky, Stalling, Lento, Ying, and Leonard (2002) and Szagun (2000) reported that the morphological development of children with cochlear implants did not follow the typical developmental pattern, but rather was influenced by the extent to which morphological forms were perceptually prominent. Still others have focused on a range of language skills in small samples of children with cochlear implants (Ertmer, 2001; Ertmer & Mellon, 2001). Young and Killen (2002) found that after five years of implant use, their 7 participants demonstrated strengths in semantics, particularly expressive vocabulary, but relative weaknesses in syntax and morphology.

Thus far, the most comprehensive research by Geers, Nicholas, and Sedey (2003) examined the language skills and factors predictive of language outcomes in study of 181 eight and nine year old children with cochlear implants. The participants were implanted by 5 years of age and used either oral or total communication. The test battery included measures of speech production, receptive and expressive semantics, syntax, morphology, and narrative discourse. As in other studies, the test battery was administered to each participant in his or her preferred communication mode (i.e. spoken English or total communication). The comparison to children with normal hearing was made on the basis of normative data provided by standardized tests. Information on family characteristics, cognitive functioning, and other demographic data were collected on all participants.

Results indicated that child and family factors accounted for 27% of the variance in the total language scores with higher nonverbal intelligence, higher socio-economic status, smaller family size, and female gender associated better language performance. Analysis of linguistic skills of these children revealed greater strengths in expressive vocabulary and narrative production with relative weaknesses in expressive morphology and receptive morphology and syntax. Specifically, more than half of the participants scored in the average range on measures of utterance length, lexical diversity, and narrative production, while only 27% and 30% of participants fell in the average range on tasks assessing production of bound morphemes and syntactic comprehension respectively. These results are consistent with previous findings that children with cochlear implants demonstrate enormous gains in speech and language development. However, language skill level is not uniform across all subsystems of language.

Little is known about the social and emotional functioning of children with cochlear implants (Bat-Chava & Deignan, 2000; Heinberg & Hayes, 2000). Because of the enormous risk posed by auditory deprivation, it is essential to understand the factors that might be involved in altered social and emotional development in children with cochlear implants. Examination of the influence of auditory deprivation on basic perceptual, social, and emotional functioning can enable further understanding of the development these domains in children with cochlear implants. This information is essential to meet the needs of these children and their families. There is no research on the ability to integrate multimodal stimuli or to identify emotions conveyed through facial expressions or vocal expressions of children with cochlear implants of which we are aware. Thus, the proposed study will provide insight into the impact of the cochlear implant on children's development in areas that have not yet been explored.

There is some research on the peer relationships of children with cochlear implants. Knutson, Boyd, Reid, Mayne, and Fetrow, (1997b) and Boyd, Knutson, and Dahlstrom, (2000) reported on the social competence of children with cochlear implants. They have found that, as a group, children with cochlear implants display less competent social behavior than normal hearing children, as indicated by the children's relative inability to enter into group play with peers.

In a study of peer relationships, Bat-Chava and Deignan (2001) found that parents of children with cochlear implants indicated that the cochlear implant had overall improved their children’s social relationships. The parents also reported that their children still had difficulty communicating and that this posed a challenge to their social interactions. However, this study relied exclusively on parent report and did not assess the children with cochlear implants directly.

These findings (Bat-Chava & Deignan, 2001; Knutson et al., 1997b; Boyd et al., 2000) strengthen the case for an investigation of the basic, fundamental skills involved in processing of emotional expressions and interpersonal interaction. When considered in light of the high incidence of emotional disorders documented in children with severe-profound hearing impairment (Meadow, 1980; Meadow & Trybus, 1979), they provide cause for concern and justification for more comprehensive investigation.

2.8 Age at Implantation and Duration of Cochlear Implant Use as Predictors of Social and Emotional Outcomes

The age at which children receive cochlear implants and the duration of cochlear implant use influence many different cognitive and language outcomes (Nikolopoulos, O’Donoghue, & Archbold, 1999; O’Donoghue, Nikolopoulos, Archbold, & Tait, 1998; Pisoni et al., 1999; Tos, Hedergaard Jensen, Salomon, Jonsson, Post, Thomsen, 2000). There is mounting evidence that children who receive cochlear implants at a younger age receive more benefit from them (Fryauf-Bertschy et al., 1997; Illg et al., 1999). The evidence of enhanced performance in speech and language domains of children receiving cochlear implants at younger ages (Fryauf-Bertschy et al., 1997; Illg et al., 1999; O’Donoghue, et al. 1999; Tye-Murray et al., 1995; Tyler, Fryhauf-Bertschy, Kelsay, Gantz, Woodworth, & Parkinson, 1997) can be understood in the context of what is known about the neurobiological development of auditory system.

Investigations are underway on the impact of variable durations of auditory deprivation on the language development of children with cochlear implants (Houston & Pisoni, 2002). The present study builds on this work and considers the impact of age of implantation and duration of use on social and emotional aspects of functioning. Thus, the present research provides information about the role of auditory perception and deprivation on the social and emotional development of children.

2.9 Summary and Model for Present Study

The present study investigated the role of auditory deprivation and auditory perception in the development of social and emotional functioning. By considering the age at implantation and duration of cochlear implant use, this study examined evidence of sensitive periods in early social and emotional development of children who experience auditory deprivation. Children who experience auditory deprivation may have difficulty with accurate identification of emotional expressions in facial expression and may completely miss the cues expressed through vocal expressions. The implications of auditory deprivation on early family and peer relationships are considerable. Children who experience auditory deprivation often develop strained relationships with parents and peers in early childhood due to the inability to communicate effectively. The picture that is portrayed is one in which the child who experiences prolonged periods of auditory deprivation is at significant risk for difficulties in meeting the normal challenges of social and emotional development during childhood.

The focus of this study is the unique experience of children with cochlear implants. Many of these children have experienced a period of total auditory deprivation, followed by the introduction of auditory stimulation, albeit of variable quality. To what extent are children who receive cochlear implants able to compensate for the restricted experiences of early childhood after the onset of auditory stimulation and carry on with the typical social and emotional development? How well are they able to catch up to the developmental activities of their normal hearing peers and carry on with the work of growing up? Specifically, how does the age at which a child receives a cochlear implant and begins to receive auditory stimulation influence the development of the social and emotional skills and objectives? This dissertation begins to answer these important questions.

CHAPTER III: METHOD

3.1 General Overview

The present study sought to examine the integration of multimodal stimuli, the processing of facial and vocal expressions of emotion, and emotion understanding that are considered the building blocks upon which more complex social and emotional functioning is constructed. Specifically, the goals of the present study were to:

1. Assess sensory integration of multimodal stimuli, which contain conflicting visual and auditory information, of children with cochlear implants
2. Assess the accuracy of identification of facial expressions of emotion of children with cochlear implants
3. Assess the accuracy of identification of vocal expressions of emotion of children with cochlear implants
4. Assess the emotion understanding of children with cochlear implants
5. Compare the performance of children with cochlear implants to that of children with normal hearing in these four key areas

3.2 Participants

3.2.1 Overall Experimental Group and Control Group Characteristics

The participants in this study were thirty-nine children with cochlear implants, aged 5:0 to 14:11 years (mean: 9:0 years). Table 1 presents details on each of the participants with cochlear implants. There were 19 male and 20 female participants. An identical assessment battery was administered to an age and sex matched control group of thirty-seven children with normal hearing. There were 19 male and 18 female control participants. They were individually matched to the children with cochlear implants based on sex and age. Each control child was matched to within 3 months of cochlear implant match's birth date.

The inclusion of a control group with normal hearing is of utmost importance because most previous studies have not included a control group, thereby severely limiting both the interpretation and the generalizability of the results obtained (Hindley, 1997; Marschark, 1993). Furthermore, selection of an appropriate control group is essential. Children with profound hearing loss who do not use cochlear implants would not provide meaningful comparison to children with cochlear implants. This is because it is hearing children who make up the naturally occurring social comparison group against whom these children with cochlear implants are compared. The majority of children with cochlear implants in this sample are educated in mainstream settings in public or private elementary schools, and therefore, their social behavior is routinely compared to those of hearing children. In other aspects of development, such as speech and oral language development, children with cochlear implants have been approximating the developmental trajectory of normal hearing children and not that of young deaf children who do not use cochlear implants (Ertmer, Strong, & Sadagopan, 2003). Ertmer, Strong, and Sadagopan (2003) make the argument that the language development of children with cochlear implants must be compared to that of normal hearing children. A study of social and emotional domains should follow this example. Finally, the purpose of this study was to investigate the particular experience of children with cochlear implants to determine the unique factors that influence their social and emotional functioning. Comparative research on children with profound hearing loss who do and do not have cochlear implants is beyond the scope of this investigation.

To insure limited variability in the cochlear implant group, potential participants were excluded from the proposed study if they: (a) suffered from any additional disability (such as blindness, autism); (b) did not use oral communication as their primary method of communication; (c) were not deaf from birth; (d) did not have a general language proficiency of 5 years of age; (e) were deafened by meningitis; (f) did not have a minimum of one year of cochlear implant experience; or (g) had a nonverbal IQ below the normal range.

A total of 55 children with cochlear implants participated in the study protocol and 16 were excluded from the main analyses in the present study. Nine participants were excluded due to the late onset of deafness that occurred after birth. Of these nine, 5 were deafened by meningitis, 1 by Kawasaki disease, 1 by sudden onset sensorineural hearing loss, and 2 by unknown causes. An additional five participants did not meet the language proficiency cut-off of 5 years that was established to ensure comprehension of the study content. Finally, two participants were excluded due to their diagnosis with additional disabilities.

3.2.2 Age of Participants

Children from age 5 through 14 years were selected as the participants in the present study. The rationale for this selection was that 5 years of age was the minimum age expected to fully understand the content of the social and emotional tasks in the test battery. Fourteen years of age was selected as the maximum because it is the end of the preadolescent period, when the character of social and emotional issues facing children change significantly. This age range was chosen because it permitted meeting the minimum language proficiency requirement and would still allow for variability of age at implantation.

3.2.3 Range of Age at Implantation and Length of Time with Cochlear Implant

The age at implantation and duration of cochlear implant use were the primary predictor variables for the present study. This information was provided by parent report. Age at implant was calculated from the date of implant activation (generally six weeks after cochlear implant surgery). The mean age at implant was 3.25 years (SD = 23.78 months). The range of age at implant was 1.3 years to 8.3 years. The mean duration of cochlear implant use was 5.8 years (SD = 22.93 months). The range of duration of cochlear implant use was 1.6 years to 11.6 years. Table 1 provides information on age at implant and duration of implant use for individual participants. Table 2 presents group information on age at implant and duration of implant use for the participants.

3.2.4 Recruitment of Participants

Recruitment of participants was a significant and comprehensive effort involving many different organizations and individuals. The River School, in Washington, DC, provided a list of children with cochlear implants. New York League for the Hard of Hearing, Alexander Graham Bell Association for the Deaf and Hard of Hearing, Cochlear Corporation, and Advanced Bionics Corporation assisted in locating additional families of children with cochlear implants. Recruitment took place with the assistance of hospital-based cochlear implant centers, speech-language pathologists and audiologists throughout the mid-Atlantic United States. Several families contacted us through a website set up to advertise the study. Families were contacted by mail or phone and invited to participate in the study. The control group was recruited from a sample of children in a current database at the Child Development Lab, University of Maryland, College Park.

3.3 Assessments

The present study sought to take into account the influence of intelligence and language proficiency on social and emotional functioning. Pisoni et al. (1999) found that cognitive and language functioning accounted for a considerable amount of the variance in outcomes for children with cochlear implants. By assessing cognitive functioning and language proficiency, this study attempted to account for a considerable portion of the variability among children with cochlear implants. These factors have not been systematically studied and have not been examined at all in relation to the social and emotional development of children with cochlear implants.

Every assessment was administered to each participant, regardless of hearing status. The present study utilized the following battery of assessments:

3.3.1. Background Information Provided by Parents

Child's Hearing History – This parent-report questionnaire collected the following data for statistical analyses: the age of the child at implantation and the length of time that the child has used the implant. Information about the age at onset of deafness, age at diagnosis, age child first received amplification, use of any sign language in early development, model of cochlear implant and number of electrodes used, and type of speech processor strategy used by the child's cochlear implant was requested. Appendix B contains a complete copy of the parent questionnaire.

Demographic Questionnaire – This parent-report questionnaire was administered to parents of children with cochlear implants as well as parents of children with normal hearing and collected information such as educational history, family size, classroom type (mainstream/special education), Hollingshead's (1979) four-factor index of social status based on the education and current occupation of the child's father and mother, and the child's ethnicity.

3.3.2 Child Background Assessments

Table 3 presents descriptive statistics for all background measures for both cochlear implant and normal hearing groups.

Lexical Neighborhood Test (LNT) and Multisyllabic Lexical Neighborhood Test (MLNT) (Kirk, Pisoni, & Osberger, 1995). The *LNT* and *MLNT* measure speech perception through assessment of open-set word recognition. This screening device provided a measure of speech perception for all participants. This information was used for descriptive purposes and assisted in presenting a comprehensive portrayal of the background of the participants. The collection of background information such as speech perception performance is considered customary in research involving children with cochlear implants.

The *LNT* contains two 50-item lists of monosyllabic words, and the *MLNT* consists of two 24-item lists of two- and three-syllable words. In each test, half of the words are considered lexically "easy", meaning that they occur often and there are few phonemically similar words. Half are considered lexically "hard" in that they occur infrequently and have many phonemically similar words. The pair of tests was designed specifically for children with hearing loss who use cochlear implants. Good test-retest reliability ($\geq .83$ for lists one and two, both hard and easy components) and inter-list equivalency have been demonstrated (Kirk, Eisenberg, Martinez, & Hay-McCutcheon, 1999).

The participant was seated in a quiet room and the examiner sat next to the child. Stimulus words were presented via loudspeaker at 70dB SPL. The participant was asked to repeat what they heard and the response was transcribed verbatim immediately by the examiner. Once the participant responded, the next word was presented. Responses were summed and scored as percent of words and phonemes correctly identified. If the answer was unintelligible, the participant was asked to repeat the word and to write or explain the answer ("What is that?' or "What do you do with that?"). If a participant was unable to clarify an unintelligible response, the response was phonetically transcribed and scored for phonemes correct and no word credit was given.

Percent correct words for the *LNT* easy word list, *LNT* hard word list, *MLNT* easy word list, and *MLNT* hard word list were scored and an average of the four subtests was calculated. This score is the dependent variable called s*peech perception*. Table 4 presents scores for each of the word lists individually.

Kaufman's Brief Intelligence Test (*K-BIT*; Kaufman & Kaufman, 1990). The *K-BIT* is a brief, individually administered screening measure of verbal and nonverbal intelligence. This screening measure of cognitive functioning was used for two purposes. First, nonverbal intelligence scores were obtained to ensure that each participant's nonverbal cognitive functioning was in the normal range. Second, *K-BIT* performance was used for descriptive purposes and assisted in presenting a comprehensive portrayal of the background of the participants.

The Vocabulary (verbal) subtest contains expressive vocabulary and definitions components, measuring knowledge of words and their meanings. The Matrices subtest (nonverbal) measures fluid thinking – the ability to solve new problems through perceiving relationships and completing analogies. All matrices items contain pictures and abstract designs rather than words so nonverbal ability can be assessed independently of language ability (test-retest: vocabulary = .86 to .97, matrices =.80 to .92, IQ Composite =.92 to .95 (depending on age); internal consistency reliabilities: vocabulary = .93, matrices = .88, IQ Composite = .94; Kaufman & Kaufman, 1990). This screening measure was selected because it contains both verbal and nonverbal subtests, it is simple to administer and score, and it is highly correlated with Wechsler intelligence scales (*WISC-III*, Boyd & Dumont, 1996; *WAIS-R*, Naugle, Chelvne, & Tucker, 1993).

<u>Language Battery</u> The language battery consisted of administration of the *Peabody Picture Vocabulary Test – III*, (*PPVT-III*; Dunn & Dunn, 1997) and a grammatic understanding subtest. The *PPVT-III* assesses the comprehension of spoken vocabulary words in standard English. The grammatic understanding subtest assesses the acquisition of English structural rules at a spoken sentence level. For participants aged 5:0-7:11, the Grammatic Understanding subtest of the *Test of Language Development – Primary* (*TOLD-P*: 3rd ed., Newcomer & Hammill, 1997) was used. The participants responded to a verbal sentence stimulus by pointing to one of four pictures. For participants aged 8:0-11:11, the Grammatic Understanding subtest of the *Test of Language Development – Intermediate* (*TOLD-I*: 3rd ed., Hammill & Newcomer, 1997) was administered. The participant was asked to listen to a series of sentences and identify them as either correct or incorrect. For participants aged 12:0-14:11, the Listening/Grammar subtest of the *Test of Adolescent and Adult Language -Third Edition* (*TOAL-3*, Hammill, Brown, Larsen, & Wiederholt, 1994) was used. Each of these three

subtests provided standardized language scores. Each of the measures in the battery was standardized and normed on large samples.

The administration of language measures served two purposes in this study. First, gross language age was determined to ensure a consistent minimum language proficiency. Participants met the age cut-off on both the *PPVT-III* and the age-appropriate grammatic understanding subtest to be included in the study sample. Age 5 years, 0 months was set as a cut-off for language age required of participants to properly meet the language demands of the study protocol. This minimum language age was determined through consultation with Dr. Johanna Nicholas, Assistant Research Scientist at Center for Childhood Deafness and Adult Aural Rehabilitation, Central Institute for the Deaf, St. Louis, MO.

The second purpose of this procedure was to produce an index of general language proficiency, which was used to account for the effects of language ability on participant performance on the study tasks. There is great variability in the language proficiency of children with cochlear implants (Pisoni et al., 1999), and language proficiency in typically developing children has been closely related to emotion understanding (Cutting & Dunn, 1999; Dunn, Brown, & Maguire, 1995). Therefore, an investigation of children with atypical language skills must control for the variance in emotional processing performance that can be explained solely through language proficiency.

Advanced graduate students in Speech-Language Pathology administered the language battery. A certified speech-language pathologist supervised administration. The language battery was scored by the testers, and 15% of the tests were “double scored” (independently reviewed by a different tester) to ensure reliability of the scoring. The standard scores of the *PPVT-III* and of the grammatic understanding subtest were summed to produce an index of language proficiency, which is the dependent variable called *language proficiency*. Table 5 presents descriptive statistics of each of the components of the language proficiency variable.

3.3.3 Child Assessment Measures

McGurk Illusion Task The McGurk task was administered using stimuli adapted from vanWassenhove, Poeppel, and Grant (2005). The stimuli consisted of a video recording showing a woman mouthing CV syllables dubbed with a different synchronous audio syllable. Seven types of stimuli were presented: the incongruent audio-visual pair ("McGurk fusion condition" consisting of audio /pa/ dubbed onto visual /ka/), the audio-alone stimuli (both /pa/ and /ka/), the visual-alone stimuli (both /pa/ and /ka/) and congruent audio-visual pairs (both /pa/ and /ka/). Ten trials of each stimulus type were presented for a total of 70 trials. The stimuli were presented in a blocked random design. Participants were asked to report what the woman on the screen was saying, and participant responses were recorded verbatim. Stimuli were presented using PsyScope 1.2.5. stimulus presentation software with Mac OS 9.2. Participants were seated 50cm from the monitor, facing it directly at 0° azimuth. Testing took place in quiet room with indoor lighting. Videos were displayed centered on a 15-inch Apple G4 monitor on a black background. Sounds were presented at 75dB SPL.

Performance was measured by fusion rate: percent of incongruent auditory/visual trials in which the participant correctly identified the fusion token (/da/ or /ta/ /tha/). Auditory-only performance, visual-only performance, and AV congruent performance are the percent correct in all auditory, visual, and AV congruent trials. The dependent variables were *fusion rate, % correct visual only, % correct auditory only,* and *% correct AV congruent*.

Facial Emotion Identification Task (Pollak & Kistler, 2002) The ability to identify the emotion portrayed in facial expressions was assessed with a Facial Emotion Identification Task. The stimuli consisted of four series of morphed images on a continuum ranging from a prototypical happy expression to fearful, happy to sad, angry to fearful, and angry to sad. The stimuli were designed by Pollak and Kistler (2002) by selecting prototype images of facial expressions from a set of published photographs (Ekman & Friesen, 1976) and morphing the prototypes to create a linear continuum of facial images between the two endpoints. Pertinent anatomical areas such as mouth, eyes, nose, and hairline were used as control points. These points were then shifted by an equal percentage of the total distance between their initial and final positions. After completion of this preparation process, the stimuli consist of four continua each containing 11 male and 11 female facial expressions. At each end is the unmorphed prototype of each emotional expression. The images differ in emotional intensity each by 10% in pixel intensity. The middle face in each continua is a 50% blend of each pair of emotional prototypes.

Stimuli were presented with STIM Stimulus Presentation System (James Long Company). During the task, the participant was seated in front of a 15-inch computer monitor. Each of the 44 morphed and prototypes faces was presented on the screen in a randomized order to assess how well participants identified stimuli that vary along a continuum. The participant was asked to choose the emotion that the face resembled most by selecting one of the two emotion labels provided. Each image from 0% to 30% and 70% to 100% were presented four times each, and images 40% through 60% were each presented eight times. A total of 224 trials were presented. Performance on the trials was summed for each emotion category and presented as percent correct for each participant. The dependent variables were *accuracy of identification for happy, sad, fearful, and angry emotions*.

Emotional Understanding Tasks

A set of emotion understanding tasks, based on Denham's (1986) affective labeling and affective perspective-taking tasks, were adapted for administration in this study. These tasks involve naming the facial expressions of emotion in photographs and predicting how the protagonist in an emotion-eliciting scenario would feel. Denham's (1986) methodology and procedure were followed but the particular photographic stimuli and vignettes were adapted to be developmentally-appropriate for older children. Denham's (1986) tasks were designed for use on 3-to-5 year olds and included facial expressions and vignettes that are inappropriate for children in middle childhood. The following three tasks represent careful reproduction of Denham's (1986) tasks with slightly different stimuli.

Affective Labeling Task The ability to identify prototypical facial expressions of emotion through a free naming, open-set procedure was assessed with a free labeling task. The picture stimuli were adapted by Widen and Russell (2003) for a study of preschool aged children. They were originally designed by Camras, Grow, and Ribordy (1983) and meet the specifications of Ekman and Friesen's (1978) Facial Action Coding System. The stimuli consist of two sets of seven black and white photographs of facial expressions of emotion, one set created by a female poser and the other set by a male poser. The stimuli consist of a neutral, happy, sad, angry, disgusted, scared, and surprised expression. The stimulus pictures are presented in Appendix D.

All photographs were presented on a 15-inch Apple G4 monitor. The participant was first introduced to the poser with the picture of the neutral facial expression. Then the series of 6 photographs was presented in random order to the participant. This procedure was repeated with the set of photographs of the second poser so that each participant was asked to label a total of 12 faces. The participant was asked to report orally how the poser in each photograph was feeling and this was recorded verbatim by the examiner. The examiner requested clarification if the response was difficult to understand or unclear by asking “Could you please repeat that?” Performance on the trials was scored rating correct labeling of the expression if at least one face for each emotion (out of two) was correctly labeled. Accuracy was summed and reported as number correctly labeled with a maximum score of 6 and minimum of 0. This task provided information different from the other emotion identification tasks because of its elicitation of independently generated expression labels and inclusion of an expanded set of emotional expressions. The dependent variable was called *accuracy of free-labeling*.

Next, the participant was shown a display on the computer monitor with all 6 emotional faces of the poser visible at once. The examiner asked the participant to point to the face where the poser looks angry, sad, and so forth. Participants were asked to identify each emotion face for both the male and female posers by pointing to the picture that matched the given emotion label. The performance in this receptive format of the assessment was scored as a sum of the correct identifications, with a maximum score of 6 and minimum of 0. The dependent variable was called *accuracy of identification*.

Affective Perspective-Taking Task The ability to identify the emotion felt by the protagonist in an emotion-eliciting situation was assessed in an affective perspective-taking task. A series of emotion-eliciting vignettes developed by Ribordy, Camras, Stefani, and Spaccarelli (1988) for use with children as young as age 5, were used for this task. The emotion categories include: happy, sad, surprised, disgusted, afraid, and angry. Four different vignettes for each emotion category, for a total of 24 vignettes, were administered. The text of the vignettes is presented in Appendix E.

Participants were presented with a written copy of each vignette, and the examiner read the vignette aloud to ensure that all participants understood the situation. Participants responded either with an oral response or by pointing to one of the set of pictures of facial expressions used in the Affective Labeling Task. One point was given for a correct response and zero points were given for an incorrect response, for a maximum score of 24 and minimum of 0, which is presented as percent correct. The dependent variable was *accuracy of affective perspective-taking*.

Differing from Denham's (1986) scoring procedure, the total scores received on the free-labeling and identification portions of the Affective Labeling Task and on the Affective Perspective-Taking Task were not summed but instead were each analyzed independently.

Vocal Emotion Identification Task (Pollak, Holt, & Wismer Fries, 2004) The ability to identify the emotional valence of sounds was assessed. Sounds (e.g. cries, giggles, gasps) were delivered via loud speakers in a quiet room to individual participants at approximately 75 dB SPL. A list of the sounds is presented in Appendix F. Four negative, four positive, and four neutral stimuli were presented three times each for a total of 36 trials. After the stimulus was played, the participant was asked to report or imitate what sound they heard. This response was recorded verbatim. Next, they were asked to classify the sound as a positive, negative, or neutral sound. Responses were accepted verbally or by pointing to a positive, neutral, or negative icon. Results were scored as either correct or incorrect. The performance on the trials was summed separately for each condition and reported as percent correct for each condition. The dependent variables are called *accuracy of identification of positive sounds, of neutral sounds, and of negative sounds*.

3.3 Procedure

Identified families were scheduled to participate in a one-day assessment at the Child Development Lab. Appendix A presents a sample protocol for the study visit. Upon arrival, participants were given a tour of Child Development Lab and all aspects of the procedure were explained to both the child and the accompanying parent(s). Informed consent forms were given to the accompanying parent(s) and the child was given an assent form explaining the procedure in depth. Consent of the parent(s) was obtained before proceeding. The accompanying parent(s) completed the parent questionnaire. Several participants were assessed at a different site to permit the participation of children who lived a significant distance from the Child Development Lab to participate in the study. Conditions in all testing locations were kept as similar as possible. Child assessments were administered individually in a quiet testing room. The battery of assessments was administered in two sessions, morning and afternoon, with breaks included in the schedule. The assessments were administered to each participant in random order. Order of presentation of assessment depended on availability of examiners for different tasks and testing rooms and was determined based on these considerations on the day of testing.

3.4 Research Hypotheses

1. Performance on the McGurk task, as measured by *fusion rate, visual only, auditory only,* and *AV congruent* will vary based on the chronological age at which children received their cochlear implants and duration of cochlear implant use.
2. *Accuracy of identifying facial expressions of happy, sad, fearful* and *angry emotions* will vary based on the chronological age at which children received their cochlear implants and duration of cochlear implant use.
3. *Accuracy of free labeling, facial identification,* and *affective perspective-taking* will vary based on chronological age at which children received cochlear implants and duration of cochlear implant use.
4. *Accuracy of identifying vocal expressions of positive sounds, neutral sounds,* and *negative sounds* will vary based on chronological age at which children received cochlear implants and duration of cochlear implant use.
5. There will be mean differences between children with cochlear implants and children with normal hearing on all tasks. Performance of children with cochlear implants who received cochlear implants at the youngest age and have had the longest duration of cochlear implant use will demonstrate performance most closely approximating the performance of children with normal hearing.

CHAPTER IV: RESULTS

4.1 Introduction

4.1.1 Data Analysis Plan

Data analyses were based on a seven-step analytic plan. First, histograms of task performance on all outcome variables were examined to verify that the outcome data met assumptions of normality. Outliers, data points 3 standard deviations below the group mean, were then excluded from the analysis of that task. Second, Pearson correlations were obtained to examine the relations within all outcome variables and between each outcome variable and key background variables. Third, scatterplots of performance on each outcome variable relative to age at implant and duration of implant use were reviewed. Fourth, analysis of variance (ANOVA) procedures were performed to test the differences in background measures between cochlear implant and normal hearing groups. Fifth, multiple linear regressions were conducted for each outcome variable to test whether age at implant and duration of implant use predicted task performance. A model of the regression analyses used to predict age at implant is presented in Figure 1. A model of the regression analyses used to predict duration of implant use is presented in Figure 2. Sixth, analysis of covariance (ANCOVA) procedures were conducted to determine whether there were significant differences in performance between the cochlear implant group and the normal hearing group. Last, post-hoc analyses were conducted to determine if any additional variables could predict task performance with measures that were not predicted by age at implant or duration of implant use.

4.1.2 Preliminary Analyses

Preliminary analyses were conducted at the outset of the data analysis phase of the present study. The data were reviewed for interrelations of criterion variables. Tables 6-8 present correlation matrices for all participants, participants with cochlear implants and participants with normal hearing. Based on the non-significant relations between most criterion variables, analyses were run using individual task outcomes, rather than composite measures.

Zero order correlations were generated to determine the relation of potential control variables such as chronological age of child, child sex, socioeconomic status (SES), nonverbal IQ, speech perception scores, and language proficiency scores with the criterion variables (outcome measures). Correlations among these background variables are presented in Tables 9 and 10. Due to the number of variables, the correlations between potential control variables and the criterion variables are presented in Tables 12, 15, 16, and 17.

4.1.3 Analyses Conducted Prior to Regression Procedures

The participants were matched individually based on age and gender. There were no significant group differences in these variables (all *p's*>.05). One-way analysis of variance (ANOVA) procedures were performed to test whether children with cochlear implants and children with normal hearing differed significantly on the following measures: *nonverbal IQ*, *socioeconomic status (SES)*, *speech perception*, and *language proficiency*. Significant group differences were identified for all four variables: *nonverbal IQ* ($F(1,73) = 9.59, p<.01$), *SES* ($F(1,70) = 5.45, p<.05$), *speech perception* ($F(1,73) = 222.37, p<.01$), and *language proficiency* ($F(1,74) = 55.76, p<.01$). In each case, children with normal hearing obtained significantly higher scores than children with cochlear implants. In light of the discrepancy between groups, *nonverbal IQ*, *socioeconomic status (SES)*, and *speech perception* variables were utilized as covariates in the regression models. Chronological age was included as a covariate to control for the potential influence of maturation-linked improvement in performance on the tasks. Given that this is a within-group analysis, we did not control for *language proficiency* since this could account for a great deal of the variance. However, for the between-group analyses (see below), language proficiency was controlled for. This was done to ensure that any emotion related differences were not simply reflecting the inherent language differences in children with hearing loss and those with normal hearing. It was not included as a covariate because it is significantly correlated with both *speech perception* and SES and it was hypothesized to influence performance on the tasks that required a response in spoken language. In all regression procedures, these four variables (*nonverbal IQ, speech perception, SES, and age*) were entered at once in the first block and then age at implant or duration of implant use was entered in the second block. Figures 1 and 2 present a model for the regression procedures. Table 11 presents descriptive statistics for all criterion measures.

4.2 Hypothesis 1: Performance on the McGurk Task

4.2.1 Preliminary Analyses

First, interrelations among the four different conditions presented in the McGurk task were examined with Pearson correlations. Table 12 presents correlations for the McGurk Task variables and background variables. For the children with cochlear implants, there was a significant negative correlation between the *fusion* and *visual only* condition, ($r(31) = -.390, p<.05$), the *fusion* and *auditory only* condition ($r(31) = -.512, p<.01$), and the *fusion* and *AV congruent* condition ($r(31) = -.538, p<.01$), which indicates that improved performance on the *fusion* condition was associated with poorer performance on trials in each of the other conditions. A non-significant relation between *visual only* and both *auditory only*, ($r(31) = .242, p>.05$), and *AV congruent* conditions ($r(31) = .078, p>.05$) indicated that there were no relations between these measures. Participants with better *auditory only* performance also had higher performance in the *AV congruent* condition ($r(31) = .582, p<.01$). In children with normal hearing, the only significant correlation between conditions was between the *auditory only* condition and the *AV congruent* condition, ($r(30) = .469, p<.01$).

4.2.2 Hypothesis 1

Age at Implant

To examine the relationship between age at implant and performance on the McGurk task conditions, four linear multiple regressions were conducted corresponding to the four dependent variables of *fusion rate, visual only, auditory only,* and *AV congruent* conditions. A significant relationship between age at implant and *fusion rate* was found, ($F(1,27) = 5.475$, $p<.05$, R^2 change = .139). Specifically, younger age at implant was associated with more accurate performance in the *fusion* condition ($\beta = -.540$). The model as a whole, accounted for 28.6% of the variance. Table 13 presents relevant statistics for the regression procedure predicting fusion performance based on age at implant. There were nonsignificant findings for the analyses between relationship between age at implant and the *visual only* ($F(1,24) = 1.669, p>.05$, R^2 change = .036), *auditory only* ($F(1,24) = 2.873, p>.05$, R^2 change = .081), and *AV congruent*, ($F(1,24) =

.205, *p*>.05, R^2 change = .008) conditions. Figure 3 presents scatterplots of the performance in each of the four conditions and age at implant.

Duration of Implant Use

To examine the relations between duration of implant use and performance on the McGurk task conditions, four multiple regressions were conducted. Dependent variables were performance scores on the *fusion rate, visual only, auditory only,* and *AV congruent* conditions. No significant relationships were found between duration of cochlear implant use and these four variables (all *p's*>.05).

4.2.3 Post-Hoc Analyses

Several analyses were conducted to examine the finding that age at implant predicted performance in the *fusion* condition. Careful examination of the distribution of participant performance revealed that only children who had received their cochlear implant prior to 30 months of age received accuracy scores of 80% or better. The cochlear implant group was divided into two groups: those who received their cochlear implants before 30 months and those who received them after age 30 months. There were 18 participants with cochlear implants in the *implant prior to 30 months* group and 16 participants in the *after 30 months* group. The performance of these two groups was compared to the performance of 2 groups of participants of the age- and gender-matched participants with normal hearing. There were 18 and 15 participants in these groups respectively.

Further analyses were conducted to examine differences between these 2 groups and the matched groups with normal hearing. Two sets of one-way ANOVAs were conducted. The first compared performance of the *implant prior to 30 months* group and its matched comparison group of normal hearing participants and the second compared performance of the *after 30 months* group and its matched normal hearing group. A one-way ANOVA procedure was performed for each of the four McGurk conditions with cochlear implant vs. normal hearing group as the between-group factor for the *implant prior to 30 months* group and *after 30 months* group. The one-way ANOVA procedure indicated that participants who received their cochlear implants prior to 30 months of age did not differ significantly in fusion condition performance versus participants with normal hearing ($F(1,34) = .465$, $p > .05$). However, participants who received their cochlear implants after 30 months performed significantly worse than children with normal hearing ($F(1,30) = 14.189$, $p < .01$). Neither the participants who received their cochlear implants prior to 30 months of age ($F(1,34) = 1.369$, $p > .05$) nor those who received their cochlear implant after 30 months ($F(1,30) = 1.432$, $p > .05$) differed significantly from participants with normal hearing in performance on the *visual only* condition. Both the participants who received their cochlear implants prior to 30 months of age, ($F(1,34) = 17.906$, $p < .01$), and the participants who received their cochlear implants after 30 months, ($F(1,30) = 19.454$, $p < .01$), performed significantly poorer than participants with normal hearing in the *auditory only* condition. Finally, in the *AV congruent* condition, the participants who received their cochlear implants after 30 months performed significantly poorer than participants with normal hearing ($F(1,30) = 4.17$, $p < .05$), while participants who received their cochlear implants prior to 30 months of age did not perform significantly differently from participants with normal hearing ($F(1,34) = 1.41$, $p > .05$). Despite the significant difference in performance, the participants who received their cochlear implants after 30 months were accurate in the *AV* *congruent* condition in a remarkable 92% of trials. Table 14 presents descriptive statistics for the *implant prior to 30 months* group, *after 30 months* group and normal hearing comparison groups. In summary, the experience of periods of auditory deprivation, regardless of the age at introduction of auditory input with a cochlear implant adversely affected the processing of auditory information, but it did not affect visual processing. Interestingly, participants who received cochlear implants before 30 months of age were able to compensate in the *fusion* and *AV congruent* conditions, while participants who received cochlear implants at a later age were not.

Finally, thirty-seven of the 39 participants with cochlear implants received aural habilitation with hearing aids prior to cochlear implantation. Thus, the regression model was modified to determine whether the age at which amplification via hearing aids was introduced could explain the outcome on McGurk *fusion* performance. This procedure indicated that age at introduction of amplification did not predict performance in the McGurk *fusion* condition, ($F(1,26) = 1.124$, $p > .05$, R^2 change =.03). It seems that the auditory benefit provided by hearing aids was not sufficient to influence the development of auditory-visual integration in the conflict condition. In conclusion it must be noted that consonant-vowel syllables are very difficult to identify, as opposed to words, sentences or other meaningful speech units and despite the difficulty, children with cochlear implants still obtained remarkably high scores in the *auditory only* and *AV congruent* conditions.

4.3 Hypothesis 2: Performance on the Facial Emotion Identification Task

4.3.1 Preliminary Analyses

Interrelations among the four different emotions assessed in the Facial Emotion Identification Task were examined with Pearson correlations. Table 15 presents correlations for the Facial Emotion Identification Task variables and background variables. For the participants with cochlear implants, a significant relationship between *happy* and *fearful* category, (*r*(32) = .361, *p*<.05), the *happy* and *angry* category (*r*(32) = .409, *p*<.05) was found, which indicates that improved performance in the identification of *happy* faces was associated with improved performance in identification of *fearful* and *angry* faces. There was a non-significant relation between the *happy* and *sad* category, (*r*(32) = .319, *p*>.05). A significant relation between accuracy of identification of *fearful* and *sad* faces (*r* (32) = .589, *p*<.01) was found. Participants who demonstrated improved performance on the *fearful* faces had improved performance in identification of sad faces. There were no other significant relationships between the four emotion categories (all *p's*>.05).

4.3.2 Hypothesis 2

Age at Implant

To examine the relation between age at implant and performance on the Facial Emotion Identification Task, four multiple regressions were conducted. Dependent variables were a*ccuracy of identifying facial expressions of happy, sad, fearful* and *angry emotions*. No significant relations were found between age at implant and these four measures (all *p's*>.05).

Duration of Implant Use

To examine the relations between duration of cochlear implant use and performance on the Facial Emotion Identification Task, four multiple regressions were conducted using the same dependent variables noted above. No significant relations were found (all *p's*>.05).

4.4 Hypothesis 3: Performance on the Emotion Understanding Task

4.4.1 Preliminary Analyses

Interrelations among the three components of the Emotion Understanding Task, *free labeling, facial identification,* and *affective perspective-taking* were examined with Pearson correlations. Table 16 presents correlations for the Emotion Understanding Task variables and background variables. The relations between these three components were non-significant (all *p's*>.05).

4.4.2 Hypothesis 3

Age at Implant

To examine the relationship between age at implant and performance on the emotion understanding task, three multiple regressions were computed. Dependent variables were a*ccuracy of free labeling*, *identification*, and *affective perspective taking*. There were no significant relations (all *p's*>.05).

Duration of Implant Use

To examine the relations between duration of implant use and performance on the emotion understanding task, three multiple regressions were conducted. Dependent variables were a*ccuracy of free labeling*, *identification*, and *affective perspective taking*. Again, no significant relations were found (all *p's*>.05).

4.5 Hypothesis 4: Performance on the Vocal Emotion Identification Task

4.5.1 Preliminary Analyses

Preliminary analyses examined the interrelations among the three criterion variables: *positive sounds, neutral sounds,* and *negative sounds*. The interrelations were examined and no significant relations were found (all *p's*>.05). Table 17 presents the correlations for Vocal Emotion Identification Task variables and background variables. Examination of the descriptive statistics revealed large standard deviations for each of the emotion categories, perhaps due to the relatively small number of trials in each emotion category. However, due to the non-significant correlation among the three emotion categories analyses were carried out separately by category. This decision was supported by the similar trial size and design in other studies using these non-linguistic vocal stimuli (Pollak, Holt, & Wismer Fries, 2004). Figure 4 presents the data on accuracy in identification of emotion for each participant.

Next, a review of the description or imitation of the sounds provided by each participant assessed whether participants with cochlear implants could accurately perceive the nonlinguistic sounds. Participants were asked to report what exactly they heard or imitate the sound heard. This information was recorded verbatim and was coded as correct or incorrect, with a score of 1 or 0 obtained for each sound stimulus. Children with cochlear implants accurately recognized and identified the sounds in 28 out of 36 trials, whereas children with normal hearing accurately recognized and identified the sounds in 35 out of 36 trials. Table 11 presents the descriptive statistics for the recognition of the sounds stimuli. An analysis of variance (ANOVA) revealed that the differences between the recognition of sounds by the cochlear implant and the normal hearing groups were significant for the *positive*, ($F(1,72) = 9.904$, $p<.01$), *neutral* ($F(1,70) = 4.740$, $p<.01$), and *negative* ($F(1,74) = 17.466$, $p<.01$).

4.5.2 Hypothesis 4

Age at Implant

The relationship between age at implant and performance on the vocal emotion identification task was also examined using three multiple regressions. Dependent variables were *positive sounds, neutral sounds,* and *negative sounds*. The relation between age at implant and the variables was nonsignificant (all *p's*>.05).

Duration of Implant Use

Multiple regression analyses were also used to examine the relations between the duration of implant use and performance on the vocal emotion understanding task. Dependent variables were *positive sounds, neutral sounds,* and *negative sounds*. Again, all results were nonsignificant (all *p's*>.05).

4.6 Hypothesis 5: Group Differences between Participants with Cochlear Implants and Participants with Normal Hearing

To compare the performance of participants with cochlear implants and the children with normal hearing, an analysis of covariance (ANCOVA) procedure was performed for each of the criterion variables. *Language proficiency* and *sex* were used as covariates in the analyses. *Language proficiency* was selected as a covariate because there are core differences between the language proficiency of children with hearing loss and those with normal hearing. Sex was selected as a covariate because of the literature on gender differences in emotion processing (Dunn et al., 1987). Table 18 presents descriptive statistics for males and females on each of the tasks.

4.6.1 Group Differences in McGurk Task Performance

The ANCOVA procedure was performed for *fusion rate, visual only, auditory only,* and *AV congruent* conditions. ANCOVAs for the *fusion* ($F(1,63) = 5.569$, $p<.05$) and *auditory only* ($F(1,63) = 11.208$, $p<.01$) conditions revealed that children with cochlear implants performed significantly poorer than children with normal hearing, after controlling for the effects of language and sex. ANCOVA procedure for McGurk *visual only* ($F(1,63) = .116, p>.05$) and *AV congruent only* ($F(1,62) = .286, p>.05$) conditions revealed that there were no significant differences in performance in children with cochlear implants and children with normal hearing, after controlling for the effects of language. Descriptive statistics are presented in Table 19.

4.6.2 Group Differences in Facial Emotion Identification Task Performance

To investigate group differences in the four categories of emotional faces *happy, sad, fearful* and *angry*, a repeated measures ANCOVA was conducted with 2 (group) x 2 (gender) x 4 (emotion category) design, using *language proficiency* as a covariate. The dependent variable was emotion category. In this analysis, participants with cochlear implants and participants with normal hearing did not obtain significantly different scores on any of the four dependent variables (all *p's*>.05). There was no significant main effect of group.

Analyses of Facial Emotion Identification Task Performance

In the Facial Emotion Identification Task categorical variables were set on a continuum, allowing for a graded analysis of the effect. Specifically, each continuum had two different emotion prototypes at the endpoints and the facial expressions between these endpoints were morphed at a constant 10% from the prototype per photograph. These stimuli enabled determination of the point at which participants determined that the emotion category had changed. To measure identification of each image, a two-parameter logistic model was fit to the data for each participant with the formula:

$$P = \frac{1}{1+e^{-(x-a)/b}}$$

in which P is the probability of identification and x is the strength of the signal. Two parameters were estimated: a is the function midpoint, and b represents the slope of the line of identification. Steeper slopes of the line of identification reflect categorical perception of the faces, indicating a clear differentiation of the categories of the facial expressions. A shallower slope would indicate more continuous perception of the facial expressions. The data and the functions fitted to the lines are presented in Figure 5 with data points and a slope for each group. There are 4 panels, presenting performance on faces in each of the four continua. Perceptual threshold estimates are presented in Table 21.

A 2 (group) x 2 (gender) x 4 (emotion category) repeated measures ANOVA was conducted. The main effect of emotion category was significant ($F(3,268) = 10.42$, $p<.01$) due to the highly accurate differentiation between happy and sad faces relative to the other continua. In addition, there was a main effect of gender ($F(1,268) = 7.49$, $p<.01$) indicating that girls are more proficient in discrimination. There was no main effect of group. Each of the significant main effects was qualified by 3-way interaction between continua, group, and gender ($F(3,268) = 7.06$, $p<.01$). A review of the data show that this is due to the fact that gender differences in performance are only significant among children with cochlear implants. Descriptive statistics are presented in Table 20.

4.6.3 Group Differences in Performance on the Emotion Understanding Task

The ANCOVA procedure was performed for the *free labeling*, *identification*, and *affective perspective taking* components of the Emotion Understanding Task. ANCOVA procedure for *free labeling* component ($F(1,67) = 6.42$, $p<.05$) revealed that children with cochlear implants performed significantly poorer than children with normal hearing, beyond the effects of language. ANCOVA procedure for the *identification* (*F*(1,67) = 2.98, *p*>.05), and *affective perspective taking* (*F*(1,67) = 2.11, *p*>.05) components revealed no significant difference in performance between the groups, after controlling for the effects of language. Descriptive statistics are presented in Table 22.

Post-Hoc Analyses

Further comparison of the performance of children with cochlear implants and children with normal hearing was performed using ANCOVA for each emotion category in the *affective perspective-taking* task because this component of the emotion understanding tasks has been analyzed by emotion category in other investigations (Ribordy et al., 1988). This comparison revealed that the responses of participants with cochlear implants and participants with normal hearing did not differ in the *happy*, *sad*, *scared*, and *surprise* categories (all *p's*> .05). However, in the *angry* (*F*(1,67) = 4.25, *p*>.05) and *disgust* (*F*(1,67) = 7.16, *p*>.01) categories, participants with cochlear implants were significantly less accurate in their prediction of the protagonist's likely emotion than were participants with normal hearing. The participants with cochlear implants were more likely to select sadness as the emotion elicited when presented with an angry scenario. Table 23 presents the emotion category responses for both children with cochlear implants and children with normal hearing. In the *disgust* category, they did not indicate a clear emotion substitution.

4.6.4 Group Differences in Vocal Emotion Identification Task Performance

A 2 (group) x 2 (gender) x 3 (emotion category) repeated measures ANCOVA was conducted. The main effect for group was significant (*F*(1,71) = 7.430, *p*<.01), indicating that participants with cochlear implants were less accurate than participants with normal hearing in identification of emotion-eliciting sounds. In addition, there was a main effect of gender ($F(1,71) = 4.772$, $p<.05$), indicating that girls are more proficient than boys in the identification of the emotional valence of the vocal stimuli. Third, the main effect of emotion category was significant ($F(1,71) = 7.687$, $p<.01$), due to the lower accuracy in identification of *negative sounds*, followed by greater accuracy for *neutral sounds* and then *positive sounds* in both groups. There were no significant interactions. Descriptive statistics are presented in Table 24.

Post-Hoc Analyses

Further descriptive comparison of the performance of participants with cochlear implants and participants with normal hearing was performed within the set of four negative sounds stimuli. This comparison revealed that the participants with cochlear implants accurately identified 3.56 out of 6 of the negative sounds of “oww” and “ugh,” while participants with normal hearing identified 4.03 out of 6. However, in the two crying sounds, participants with cochlear implants were accurate in 3.41 out 6 sounds, while participants with normal hearing accurately identified 5.41 out of 6 sounds. Participants with cochlear implants were just as likely to classify the cries as *positive sounds* (46%) as *negative sounds* (51%), while participants with normal hearing identified the cries overwhelmingly as *negative sounds* (94%).

CHAPTER V: DISCUSSION

The present study sought to assess and describe the social and emotional functioning of children with cochlear implants. As well, by evaluating the basic processes that support social and emotional development, this study sought to shed light on the role of sensory input in key aspects of social and emotional functioning during childhood. The hypothesis that the age at which children received cochlear implants and the duration of cochlear implant use would predict performance on the social and emotional functioning tasks was largely not supported. Age at implant predicted performance in the McGurk fusion condition, an important perceptual ability, but not in the remaining tasks assessing facial and vocal emotion identification and emotion understanding. Indeed these tasks involved more complex behaviors. This outcome can be understood through the prism of Knudsen's (2004) perspective on the effects of atypical early experience and the plasticity of systems affected by absent or diminished input.

Knudsen (2004) described the heightened influence of experience on the developing brain during periods called "sensitive periods." Some sensitive periods can be critical periods, during which specific input is required for the development of neural systems that support behavior and after this period, acquisition of the behavior is no longer possible. Knudsen's theory applies to the present study in particular due to his consideration of feasibility of assessment of the impact of abnormal early experience through examination of complex behaviors. He argued that abnormal sensory experience does indeed cause subtle but real changes in the underlying neural circuits of the organism. However, evidence of altered circuits may not be detectible through the observation of complex behaviors such as those involved in social and emotional domains. Organisms are often able to develop compensatory or alternative strategies or pathways that permit typical functioning in these domains despite underlying differences in the basic processes that were affected by abnormal early experience.

The results of this study show that there are clearly effects of auditory sensory deprivation on social and emotional functioning, above and beyond those attributable to deficits in communication and linguistic skills. Children with cochlear implants demonstrated different patterns of performance compared to children with normal hearing in certain aspects of the four tasks assessed in the present study. Their mean scores on several components of the tasks were significantly lower than those obtained by children with normal hearing. In other task components, they showed differences in performance that were not reflected in the mean score for the task as a whole.

In any event, age at implant and duration of cochlear implant use were not the obvious predictors of the social and emotional outcomes. The hypothesized relationship between these predictors and the outcome variables was based on what is known of the psychophysiological level of auditory functioning. Rejection of this hypothesis implies that development of social and emotional skills takes place without auditory input, to whatever extent it is hampered by auditory deprivation. Furthermore, after the introduction of auditory input with a cochlear implant, children clearly seem able to obtain the social and emotional understanding required to develop skills on par with children with normal hearing. This finding suggests that in many areas of social and emotional functioning, the audiological benefit provided by the cochlear implant is sufficient to support normative social and emotional development.

Deeper understanding of these findings and their implications for children with cochlear implants in their day-to-day lives is of practical importance to parents, educators, and the professionals who work with children with cochlear implants. The findings of this study also are important to those interested in the perceptual processes that serve as the building blocks of social and emotional development.

The results of this study reveal largely normal functioning on the part of children with cochlear implants in the processing of social and emotional stimuli that is heartening for those who have advocated cochlear implantation, intensive speech therapy and aural habilitation, and mainstream education. It is necessary to view the children with cochlear implants' differences in performance in a broad perspective and realize that their functioning, especially in areas of identification of facial expressions of emotion and emotion understanding, does not differ from children with normal hearing. This is certainly an indication of the general success of these children. Specifically, with cochlear implants, children are able to acquire developmentally appropriate emotion understanding skills. Even in the areas where the children with cochlear implants do perform poorer than children with normal hearing, especially tasks involving vocal expressions of emotion, their accuracy is remarkably good. Their performance is noteworthy considering how challenging the ordinarily basic process of hearing can be for them. The older and worrisome stereotype of deaf children with severe emotional dysfunction and alarming rates of severe mental illness or disturbance (Arnold, 1999; Hindley, 1997) is no longer applicable, at least to orally educated children with cochlear implants. While the children with cochlear implants demonstrated areas of weakness as compared to children with normal hearing, they were more similar than they were different, and that certainly reflects a move in the right direction.

The present study is distinct from previous studies involving this special population in several fundamental ways. First, all children with cochlear implants described in this study were deaf from birth. This feature of the research design allowed for the more precise examination of the effects of auditory deprivation and the subsequent introduction of auditory stimulation. Second, this study included a control group that was matched to the experimental group based on age and gender. The use of a matched control group allows true comparison of the performance of children with cochlear implants to normal hearing peers and is an unusual feature of research on children with cochlear implants. Third, identical tasks were administered to all participants, regardless of hearing status, in the identical manner. This study applied the generally accepted norms of psychological testing to a population with whom this level of scientific control is seldom found.

To appreciate the broad perspective on the strengths and weaknesses of children with cochlear implants, it is necessary to elucidate the meaning of the specific findings of the study. Following a discussion of the McGurk task, Facial Emotion Identification task, Emotion Understanding Task, and Vocal Emotion Identification Task individually will be a discussion of the general portrait of the social and emotional functioning of children with cochlear implants that is conveyed by the specific findings of the study.

5.1 Implications of McGurk Task Performance for Understanding of Effects of Atypical Early Sensory Experience

In this study, an intriguing pattern of performance on the McGurk Task emerged. First, performance of children with cochlear implants was comparable to that of matched controls in the *visual only* condition; percent correct for both groups was approximately 55%. In the *auditory only* condition, children with cochlear implants were significantly less accurate in their interpretation of the syllables than children with normal hearing. However, the mean accuracy rate for children with cochlear implants is surprisingly high in the *auditory only* condition (65%), considering that this group had experienced profound hearing loss since birth. Furthermore, in the *auditory-visual congruent* condition, which is the most comparable to realistic speech situations, the children with cochlear implants were highly accurate (90%). Clearly, the addition of visual speech information contributed to an increase in accuracy of identification for the children with cochlear implants. This finding is consistent with the literature on multimodal speech that has demonstrated the important facilitation effect of visual information on speech perception in suboptimal conditions, such as noise or reverberation, or for listeners with hearing loss (Grant, Walden, & Seitz, 1998; van Wassenhove et al., 2005). The performance of children with cochlear implants in the *auditory only* and *auditory-visual congruent* condition is encouraging, as the children obtained considerable accuracy in identification of acoustic stimuli despite years of deprivation of auditory experience during infancy and early childhood.

Taken together, these findings reflect several underlying aspects of the relationship between unimodal and multimodal processing. While auditory processing is associated with improved auditory-visual congruent processing, visual processing did not contribute to the multimodal condition processing. The significant negative association between *visual only* and the *fusion* condition indicates that children with superior *visual only* performance demonstrated poorer performance in the *fusion* task that requires integration of both visual and auditory inputs. Furthermore, *visual only* performance was not significantly associated with the *auditory only* nor *AV congruent* conditions indicating that improved visual processing was not associated with superior auditory nor with multimodal congruent processing.

The results suggest that the integration of auditory and visual sensory information in the challenging condition of conflicting auditory and visual stimuli requires the experience of auditory input during a sensitive period in auditory system development. Earlier age at implantation predicted increased accuracy in identification of the *McGurk fusion* condition trials. This finding is consistent with reports of recent investigations of the development of auditory cortical functioning, speech perception, and language skills in children with cochlear implants which have found that earlier chronological age at cochlear implantation predicts improved outcomes in each of these domains (Kirk et al., 2002; Ponton & Eggermont, 2001; Tyler et al., 2000).

In addition, this study shows that children who experience auditory deprivation that extends beyond this sensitive period evidently experience disruption in the processes that underlie the organization of integrated sensory perception. The introduction of sensory input from the previously absent modality after this point is not sufficient to permit the typical development of multimodal sensory integration. Performance in the *auditory-visual congruent* condition is spared, but the processing of the McGurk incongruent stimulus is affected by the absence of auditory stimulation. There is clearly plasticity in the developing auditory system because, in spite of a significant period of auditory deprivation, the introduction of auditory stimulation provided by a cochlear implant before 30 months of age apparently facilitated the typical development of multimodal integration. These findings provide insight into the sensitivity of the developing auditory system to the effects of auditory deprivation. There is remarkable plasticity in the ability of the system to begin functioning and attain high levels of auditory discrimination after an extended period of auditory deprivation. But the results of this study suggest that there are constraints on this plasticity as well.

5.2 Subtle Differences in the Identification of Facial Expressions of Emotion

The hypothesis regarding identification of facial expressions of emotion was overwhelmingly unsupported by the results of this study. The inference made was that the performance of children with cochlear implants would resemble that of children who are neglected. Neglected children are thought to receive less social and emotional information from parents and therefore accrue a general deficit of social and emotional information that affects accuracy of identifying facial expressions of emotions (Pollak et al., 2000). This study's findings indicate that children with cochlear implants were able to identify the facial expressions of emotion of the experimental task with equivalent accuracy to children with normal hearing. The literature on identification of facial expression of emotion by deaf children most often cited, Odom et al. (1973), is apparently outdated based on the findings of the present study. At the very least, the expectation of dismal performance in a task of identification of facial expressions of emotion is not appropriate for orally-educated children with cochlear implants.

The performance of children with cochlear implants differed from Pollak et al.'s (2000) sample of children who were physically neglected and demonstrated significantly poorer performance on the task of facial expressions of emotion. It is possible that the children with cochlear implants were able to obtain enough social and emotional information from their interactions with caregivers and significant others despite their auditory deprivation early in childhood, through nonverbal communication. Alternatively, Pollak et al. (2000) explained the deficit in emotion discrimination as resulting from diminished opportunities for interaction with significant others. The performance of children with cochlear implants may have differed from that of Pollak's sample because they were able to communicate effectively enough with significant others after receiving their cochlear implants to acquire adequate social and emotional information necessary to develop skills of identification of facial expressions of emotion.

The results of this study demonstrate gender differences in the performance of children with cochlear implants on the task of identification of facial expressions of emotion. Girls with cochlear implants received significantly higher scores on identification of *happy*, *sad*, and *fearful* facial expressions than boys with cochlear implants. There were no significant differences in performance between boys and girls with normal hearing. In fact, the girls with cochlear implants were more accurate than the girls with normal hearing in the happy (94.82% vs. 85.93%), sad (90.50% vs. 83.54%), and fearful conditions (91.14% vs. 83.36%).

It is possible that the differences in performance between girls and boys with cochlear implants are related to the frequency and content of conversations about emotions with girls versus boys. Fivush (1991) and Dunn et al. (1987) reported on the differences in mothers' conversations with their daughters as opposed to sons. Fivush (1991) found that mothers tended to favor conversations focusing on sadness with daughters while focusing on anger in conversations about emotions with sons. Dunn et al., (1987) reported that daughters received more information about emotions from their mothers through comments and questions about feelings than did sons, even though boys and girls initiated such conversations with their mothers with similar frequency. Perhaps, this discrepancy is not detectibly consequential to boys with normal hearing, as long as they receive a minimum of emotional information. Boys with cochlear implants may have more difficulty understanding the abstract conversations about emotions and feelings, especially at younger ages when, presumably their language skills are poorer, and therefore the decreased conversation from mothers about feelings may produce a subtle deficit in emotion identification skills. This possibility is supported by the significant relation between age and performance on sad and fear categories in boys with cochlear implants. Older boys with cochlear implants were more accurate in their identification of facial expressions of emotion than younger boys. It also is possible that this gender discrepancy described in the general developmental literature is intensified by the relative paucity of exposure to emotional language and conversation that results from the difficulty children with cochlear implants are presumed to have overhearing the conversations of other people (Gray, Hosie, Russell, & Ormel, 2001; Marschark, 1993).

The results suggest that there is improvement in accuracy for boys with cochlear implants with age. These findings can viewed in light of Knudsen’s (2004) perspective on the sensitivity of the observation of complex behaviors to detect effects of atypical early experience. There are no obvious differences in the performance of children with cochlear implants and children with normal hearing on the Facial Emotion Identification Task. However, upon closer examination, there are fine differences in performance within the children with cochlear implants who had atypical early sensory experience.

5.3 Emotion Understanding and the Influence of Language Proficiency

The results of this study indicate that there were no significant differences in either the accuracy of receptive identification of facial expressions of emotion or ability to take the affective perspective of a protagonist in a hypothetical emotion-eliciting scenario between children with cochlear implants and children with normal hearing. This task involved an expanded set of emotions beyond the Facial Emotion Identification Task, with the inclusion of surprise and disgust, understanding of which typically emerge later in childhood (Lewis & Michalson, 1983; Markham & Adams, 1992). The findings of this study imply that even when testing a wider range of emotions with complex stimuli, specifically emotion-eliciting scenarios that require taking the perspective of another person, children with cochlear implants do not display decreased accuracy in understanding of these emotions relative to children with normal hearing.

There are several caveats to this general statement. First, children with cochlear implants were significantly less accurate in expressive spontaneous generation of an emotion label to identify the protagonist's facial expression than children with normal hearing. This difference remained significant even after controlling for the effects of language proficiency. However, review of the errors made by both groups showed that both groups made more errors in labeling facial expressions of disgust, surprise, and fear, which is likely due to the effects of developmental progression of emotion understanding. Also, the children with cochlear implants did not differ from children with normal hearing on performance on the affective perspective-taking task, tapping these very emotion categories, in which identification of the emotion category could be indicated by pointing to the corresponding facial expression. Therefore, it is possible that the differences in performance reflect the weaker ability of children with cochlear implants to spontaneously produce an emotion label rather than their true emotion understanding ability.

This result raises the issue of the importance of language proficiency to emotion understanding, and specifically to emotion understanding performance. The general developmental literature links the development of emotion understanding with language skills (Beeghly et al., 1986; Dunn et al., 1987). For the analyses conducted in this study, language proficiency was used as a covariate, to determine whether there were differences in emotional processing and understanding that were not an artifact of language deficit on the part of children with cochlear implants. The results of the affective-perspective taking task do not show evidence of primary social disorder or dysfunction. However, in day-to-day social interactions it is impossible to "control for" the effects of decreased language proficiency. Spoken language deficits must surely impact emotion understanding performance in real-time interactions. This is a limitation of the present study and further investigation of these issues is worthwhile.

5.4 Responses to Anger and Disgust Scenarios in the Emotion Understanding Task

Examination of the responses of children with cochlear implants to the emotion-eliciting scenarios presented in the affective perspective-taking task in each of the emotion categories individually revealed that children with cochlear implants were significantly less accurate than children with normal hearing only in scenarios eliciting anger and disgust. Review of the actual responses that the children with cochlear implants provided to these scenarios reveals that children with cochlear implants tended to designate sadness as the emotion elicited in the anger scenarios. They did not demonstrate a specific pattern of response for the disgust scenarios. These scenarios were the most ambiguous for children with normal hearing as well, and difficulty with understanding and characterizing disgust is documented in the general developmental literature (Bullock & Russell, 1984; Widen & Russell, 2003).

However, the substitution of sadness in anger-eliciting situations parallels the findings of Rieffe, Meerum Terwogt, and Smit (2003) who reported that deaf children were most likely to predict that the protagonist in the scenario would feel sadness in negative situations, whereas children with normal hearing were much more likely to predict angry feelings and anticipate that the protagonist would prepare to fight the outcome of the upsetting situation. The deaf children did not recognize an opportunity to rectify the situation; they merely persevered on the initial desire of the protagonist that was thwarted. As a second step, the authors altered the outcome of the scenarios; in certain cases the negative outcome (e.g., parents cancelled a trip to the circus) was controllable (it was being cancelled because the parent decided the child should clean her room), while in others it was uncontrollable (it was cancelled because the family car had broken down). The authors reported that the deaf children did not differentiate between situations in which the protagonist's parents could control the outcome of the situation and those in which they could not. This would be important information to take into account to generate a socially appropriate response to the negative situation. The results of the present study do not address all of the issues raised in Rieffe et al.'s (2003) study but suggest a similar pattern of thinking on the part of children with cochlear implants as other deaf children.

The unexpected response of sadness to an anger-eliciting situation raises a concern of whether children with cochlear implants are developing healthy attitudes of self-efficacy and locus of control. Individual children interpret the cause of their successes or failures in social interactions in different ways. Children who demonstrate a pattern of behavior characterized by helplessness tend to ascribe social failures to their own lack of ability. They tend not to make further attempts to attain the social goal and retreat from the social situation (Goetz & Dweck, 1980). On the other hand, children who show mastery-oriented responses to social encounters tend not to blame themselves for the social failure and continue to try to reach the desired outcome (Goetz & Dweck, 1980). Unfortunately, children with the learned helpless attribution style are at great social risk because they come to expect themselves to fail in their social interactions (Sobol & Earn, 1985) and resort to decreasingly effective social strategies after initial failure (Diener & Dweck, 1978).

Children with hearing loss, in general, are at risk for developing the learned helpless attribution style for several possible reasons (McCrone, 1979). First, learned helpless children often attribute failure to lack of ability (Goetz & Dweck, 1980) and the children with hearing loss have obvious lack of ability: hearing. Children with hearing loss are described as being overprotected in childhood (Gregory, 1976; Marschark, 1993), in part, because of the real dangers that children with hearing loss face (Arnold, 1999). However, parents' appropriate desire to protect their children can translate into a detrimental attitude in which parents focus on the few areas where the children show a lack of ability and view their children as unable in many domains (Arnold, 1999; Meadow, 1976). Children with hearing loss may receive the implicit message that they are ineffective in general from self or parental interpretations of their areas of difficulty. It is possible that children with hearing loss in general, and specifically children with cochlear implants, who are expected to keep pace in a hearing environment, may resign themselves to negative outcomes because they do not feel effective enough to change them. This issue deserves careful consideration and further investigation.

5.5 Relative Accuracy in the Vocal Emotion Identification Task

The results of this study show that children with cochlear implants had more difficulty than children with normal hearing in the classification of emotional valence of non-linguistic sounds. However, they also had more difficulty with the auditory recognition of the sound stimulus indicating that some of the difficulty in classification could be attributed to poor auditory recognition of the sound. Beyond their poorer performance relative to children with normal hearing, the children with cochlear implants were able to recognize and classify the emotional valence of the non-linguistic sounds surprisingly well. The performance of children with cochlear implants was remarkably good in light of the expected challenge of this particular type of task (Dillon, Burkholder, Cleary, & Pisoni, 2004).

While the results of the accuracy of identification by emotional valence (positive, negative, and neutral) are to be considered with caution due to the small number of repetitions, there are trends in these findings that deserve exploration. First, while the performance of the children with cochlear implants was less accurate in general, relative to children with normal hearing, they demonstrated a similar pattern of classification of emotional sounds with the exception of the cries in the negative sounds. The children with cochlear implants were not able to discern the negative valence of the sound of crying, confusing it with a positive sound. This could have implications for social interactions if they were to react to this sound in socially inappropriate ways as a result of their misinterpretation (e.g., laugh in response to someone crying). In addition, the misperception of this type of auditory input may be amenable to training, as are other nonlinguistic sound inputs, such as music, appear to be (McDermott, 2004). Finally, if the auditory perception provided by cochlear implants is sufficient to allow children to make relatively accurate interpretation of the sounds they hear, it is reasonable to focus intervention and training on the accurate identification of sounds conveying emotion. This area may have been overlooked, especially in light of the assumption that cochlear implants did not provide an adequately complex sound to make such training worthwhile.

Knudsen's (2004) conceptualization of the effects of atypical early experience, describes the plasticity that is characteristically maintained by certain circuits, but not others. The accurate performance of children with cochlear implants on tasks requiring identification of vocal expressions of emotion suggests the relative plasticity of auditory functioning despite deprivation of experience. Above and beyond the ability to recognize sounds, children who had experienced prolonged periods of auditory deprivation, were able to develop the ability to obtain some information about the emotional quality of non-linguistic acoustic stimuli from a presumably degraded signal. This suggests that children with cochlear implants are able to obtain significant accuracy of sound identification with their cochlear implants.

5.6 Limitations to the Current Work

The findings of the current study are somewhat limited by the nature of the experimental tasks administered to the children with cochlear implants. The individually-administered laboratory assessments do not provide information of the actual social and emotional performance of children with cochlear implants in their everyday environments. There was no observation of parent-child interaction or of child interactions with peers at play or in the classroom. The assessment of basic processes in social and emotional functioning was an important first step in learning more about the development of children with cochlear implants. But further research is necessary to investigate issues such as these.

The current work specifically examined orally-educated children with cochlear implants who did not have additional disabilities. In reality, many deaf children are not orally educated and an estimated 30% of deaf children suffer from an additional disability (Van Naarden, Decoufle, & Caldwell, 1999). Therefore, the current study may reflect the best social and emotional functioning that deaf children can expect, but perhaps not the average functioning of deaf children as a whole. The generalizability of the findings of the present study should be considered in light of the uniqueness of the sample.

Finally, there is a certain element of frustration with having many more questions than answers. Every field of research must begin somewhere, however modestly, and expect to need to continue to seek answers to the questions that arise from initial investigations. There are little data on the social and emotional functioning of deaf children in general, and very little on that of deaf children with cochlear implants. Therefore, understanding the implications of the findings of the present study is constrained by the scarce information available with which to compare.

5.7 Conclusions

The results of this study are important in their expansion of the understanding of the social and emotional functioning of children with cochlear implants. In particular, this study examined the effect of age at implant and duration of cochlear implants use on the processing of integrated multimodal stimuli. It also highlighted several underlying differences in the processing of facial and vocal emotional information as well as the interpretation of emotional situations by children with cochlear implants. This study sheds light on the subtle effects of auditory deprivation during early childhood and the clearly ongoing effects of decreased auditory perception. At the same time, this work shows that to a great extent, children with cochlear implants demonstrate patterns of social and emotional performance that closely resemble those found in children with normal hearing.

Table 1 - Details of the 39 Participants with Cochlear Implants According to Age, Age at implant, Duration of Cochlear Implant Use, Gender, and Etiology

	Age	Age at Implant	Duration	Gender	Etiology
	←	(months: years)	→		
1	6:3	1:4	4:11	M	CMV
2	6:7	1:4	5:3	F	unknown
3	9:8	2:6	7:2	M	unknown
4	10:4	4:6	5:10	F	unknown
5	9:5	3:0	6:5	M	genetic
6	12:5	6:6	5:11	M	unknown
7	8:11	5:1	3:10	M	CMV
8	7:0	3:2	3:10	M	unknown
9	14:11	4:2	10:9	M	genetic
10	9:11	3:6	6:5	F	unknown
11	8:10	2:6	6:4	M	unknown
12	8:5	1:4	7:1	F	unknown
13	10:4	3:10	6:6	F	unknown
14	5:4	1:9	3:7	M	unknown
15	10:5	7:6	2:11	F	hyperbilirubinemia
16	9:11	2:4	7:7	M	Waardenburg Syndrome
17	6:5	1:6	4:11	F	unknown
18	10:4	2:1	8:3	M	unknown
19	8:3	3:7	4:8	F	unknown
20	8:2	1:9	6:5	F	unknown
21	7:8	1:11	5:9	F	unknown
22	5:10	1:3	4:7	F	genetic
23	9:8	1:4	8:4	F	genetic (Connexin 26)
24	13:9	3:3	10:6	M	unknown
25	14:2	2:6	11:8	M	genetic (Connexin 26)
26	7:0	1:11	5:1	M	unknown
27	13:0	8:2	4:10	F	unknown
28	5:8	1:8	4:0	M	unknown
29	11:3	4:10	6:5	F	unknown
30	7:4	2:9	4:7	M	unknown
31	6:10	1:6	5:4	F	unknown
32	11:10	3:1	8:9	F	unknown
33	7:11	2:6	5:5	F	unknown
34	7:5	2:0	5:5	M	unknown
35	6:6	1:5	5:1	F	unknown
36	10:10	4:4	6:6	M	unknown
37	8:11	7:3	1:8	F	unknown
38	7:4	2:0	5:4	F	unknown
39	10:3	2:1	8:2	F	unknown

Table 2 – Descriptive Statistics for Age at Implant and Duration of Cochlear Implant Use

	M	**(SD)**	**Min.**	**Max.**
Age at Implant	3:3	1:11	1:4	8:4
Duration of Implant Use	5:10	1:11	1:8	11:8

Table 3– Descriptive Statistics for All Background Measures

	Cochlear Implant		Normal Hearing	
	M	**(SD)**	***M***	**(SD)**
Chronological Age at Visit (years:months)	9:1	2:5	8:11	2:3
Nonverbal IQ (*KBIT* matrices)	111.13	11.86	120.08	13.18
Socioeconomic status (Hollingshead scale: max. score of 66)	56.38	9.49	60.94	6.66
Speech perception (*LNT* & *MLNT* composite)	69.85	10.55	96.25	2.16
Language Proficiency Score	95.59	19.90	124.65	13.58

Table 4 – Speech Perception Scores

Speech Perception Test Component	Cochlear Implant *M*	Cochlear Implant *SD*	Normal Hearing *M*	Normal Hearing *SD*
Lexical Neighborhood Test (LNT)				
Lexically Easy - Words (% correct)	73.47	12.32	97.04	3.63
Lexically Easy – Phonemes (% correct)	84.84	9.25	99.17	1.60
Lexically Hard - Words (% correct)	60.63	13.53	94.55	3.42
Lexically Hard – Phonemes (% correct)	75.62	11.23	96.79	4.04
Multisyllabic Lexical Neighborhood Test (MLNT)				
Lexically Easy - Words (% correct)	80.37	13.36	95.72	5.44
Lexically Easy – Phonemes (% correct)	88.98	8.51	98.18	2.37
Lexically Hard - Words (% correct)	71.02	16.63	98.65	3.12
Lexically Hard – Phonemes (% correct)	81.73	10.60	99.49	1.27
	N = 38		N = 37	

Table 5 – Language Measures included in the Language Proficiency Score

	Cochlear Implant		Normal Hearing	
Language Score Component	***M***	**(SD)**	***M***	**(SD)**
Language Proficiency Score	**95.77**	**19.62**	**124.51**	**13.11**
PPVT-III Standard Score	**87.33** N = 39	**17.81**	**111.62** N = 37	**12.64**
TOLD-P Standard Score	**9.19** N = 16	**2.88**	**12.21** N = 19	**3.05**
TOLD-I Standard Score	**7.56** N = 18	**1.65**	**14.79** N = 14	**2.61**
TOAL-3 Standard Score	**9.20** N = 5	**3.42**	**12.67** N = 3	**.58**

Table 6 - Correlations between All Criterion Variables for All Participants

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. McGurk - Fusion	--												
2. McGurk - Visual only	-.260*	--											
3. McGurk - Auditory only	-.127	.161	--										
4. McGurk - AV congruent	-.288*	.028	.588**	--									
5. Facial Emotion Identification Happy faces	.101	-.007	-.068	.074	--								
6. Facial Emotion Identification Sad faces	.129	.164	.050	.115	.283*	--							
7. Facial Emotion Identification Fearful faces	-.010	.220	-.130	-.042	.383*	.591**	--						
8. Facial Emotion Identification Angry faces	.089	-.005	-.016	.113	.499**	.115	.130	--					
9. Emotion Understanding Free Labeling	.079	.214	.354**	.188	.063	.266*	.155	-.163	--				
10. Emotion Understanding Identifications	-.006	.187	.238	.467**	-.073	.154	.188	.031	.151	--			
11. Emotion Understanding Vignettes	.339**	.099	.211	.081	-.053	.397**	.122	.180	.248*	.082	--		
12. Vocal Emotion - Positive	.241*	-.066	.102	.100	.054	.026	-.147	.060	-.027	-.046	.168	--	
13. Vocal Emotion – Neutral	.090	-.059	.121	.220	.093	.292*	.027	.068	.084	.027	.334**	.218	--
14. Vocal Emotion – Negative	.163	.090	.359**	.158	-.011	.275*	-.013	.134	.105	.143	.487**	.271*	.351**

Table 7 - Correlations between All Criterion Variables for Participants with Cochlear Implants

Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1. McGurk - Fusion	--												
2. McGurk - Visual only	-.390*	--											
3. McGurk - Auditory only	-.512**	.242	--										
4. McGurk - AV congruent	-.538**	.078	.582**	--									
5. Facial Emotion Identification Happy faces	.293	.166	-.115	-.031	--								
6. Facial Emotion Identification Sad faces	.192	.221	-.151	.090	.316	--							
7. Facial Emotion Identification Fearful faces	.233	.249	-.040	.018	.395*	.596**	--						
8. Facial Emotion Identification Angry faces	.298	.166	-.142	.091	.452**	.287	.246	--					
9. Emotion Understanding Free Labeling	-.128	.320	.139	.263	.100	.082	.059	-.153	--				
10. Emotion Understanding Identifications	-.199	.145	.207	.528**	-.093	.053	.257	.131	.071	--			
11. Emotion Understanding Vignettes	.021	.157	-.071	-.055	-.219	.402*	.068	.004	.144	-.023	--		
12. Vocal Emotion - Positive	.044	.042	-.180	-.062	.040	-.013	-.126	-.064	-.028	-.087	-.165	--	
13. Vocal Emotion – Neutral	.059	.047	-.068	.140	.003	.355*	-.043	-.060	.289	-.025	.418*	-.055	--
14. Vocal Emotion – Negative	-.019	.193	.144	.016	.017	.378*	.171	.113	.002	.073	.354*	-.069	.195

Table 8 - Correlations between All Criterion Variables for Participants with Normal Hearing

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1. McGurk - Fusion	--												
2. McGurk - Visual only	-.124	--											
3. McGurk - Auditory only	- -.296	.176	--										
4. McGurk - AV congruent	-.116	-.083	.469**	--									
5. Facial Emotion Identification Happy faces	-.001	-.221	.262	.452**	--								
6. Facial Emotion Identification Sad faces	-.023	.101	.256	.097	.274	--							
7. Facial Emotion Identification Fearful faces	-.037	.207	.232	.182	.377*	.702**	--						
8. Facial Emotion Identification Angry faces	-.096	-.166	-.057	-.018	.568**	-.082	.078	--					
9. Emotion Understanding Free Labeling	.027	.177	.344*	-.101	.096	.365*	.324	-.218	--				
10. Emotion Understanding Identifications	.285	.369*	.014	-.038	.034	.374*	.314	-.236	.198	--			
11. Emotion Understanding Vignettes	.489**	.040	.008	.060	.199	.277	.373*	.334	.088	.056	--		
12. Vocal Emotion - Positive	.260	-.212	-.125	.231	.134	-.055	-.061	.150	-.209	-.252	.319	--	
13. Vocal Emotion – Neutral	-.038	-.190	.082	.293	.245	.153	.180	.160	-.262	-.020	.072	.414*	--
14. Vocal Emotion – Negative	.099	-.024	.156	.214	.016	.008	-.022	.118	-.104	.060	.419*	.519**	.401*

Table 9 - Correlations between Background Variables for Cochlear Implant Group

Variable	1	2	3	4	5	6	7
1. Age at Time of Study Visit	--						
2. Sex	.137	--					
3. Nonverbal IQ	-.040	-.107	--				
4. SES	.141	.310	-.067	--			
5. Speech Perception	-.023	.384*	.118	.182	--		
6. Language Proficiency	-.217	.269	.126	.388*	.425**	--	
7. Age at Implant	.594**	-.033	.103	.172	.112	-.065	--
8. Duration of Implant Use	.642**	.210	-.158	.003	-.144	-.210	-.214

**significant at the .01 level
*significant at the .05 level

Table 10 - Correlations between Background Variables for Normal Hearing Group

Variable	1	2	3	4	5
1. Age at Time of Study Visit	--				
2. Sex	-.134	--			
3. Nonverbal IQ	.093	-.058	--		
4. SES	-.129	.211	.217	--	
5. Speech Perception	.388*	-.068	-.016	-.220	--
6. Language Proficiency	.101	-.020	.591**	.113	.336*

**significant at the .01 level
*significant at the .05 level

Table 11 – Descriptive Statistics for All Criterion Measures

	Cochlear Implant		Normal Hearing	
	M	**(SD)**	***M***	**(SD)**
McGurk Task (% correct)				
fusion condition	35.29	38.71	60.56	36.98
visual only condition	55.69	24.55	54.77	21.65
auditory only condition	65.73	22.11	90.30	8.92
auditory-visual congruent condition	90.00	14.25	95.45	5.78
Facial Emotion Identification Task (% correct)				
happy emotions	90.76	11.61	89.46	10.13
sad emotions	87.32	8.90	90.19	7.90
fearful emotions	87.58	11.80	82.65	14.77
angry emotions	74.93	13.00	77.18	14.00
Emotion Understanding Task				
free labeling (out of 6)	4.57	.65	5.14	.77
emotion identification (out of 6)	5.59	1.01	5.91	.37
affective perspective-taking (% correct)	70.66	13.36	82.62	13.16
Vocal Emotion Identification – (% correct)				
Recognition of sounds				
Positive	82.41	20.29	99.07	3.53
Neutral	87.84	22.45	99.69	1.60
Negative	69.37	22.83	98.77	3.02
Identification of Emotion of Sounds				
Positive	73.21	18.59	85.95	15.75
Neutral	69.85	23.07	81.96	19.68
Negative	57.69	24.88	78.60	16.96

Table 12 - Correlations between McGurk Task Variables and Background Variables for Cochlear Implant Group

Variable	1	2	3	4	5	6	7	8	9
1. **Age at Time of Study Visit**	--								
2. **Sex**	.137	--							
3. **Nonverbal IQ**	-.040	-.107	--						
4. **SES**	.141	.310	-.067	--					
5. **Speech Perception**	-.023	.384*	.118	.182	--				
6. **Language Proficiency**	-.217	.269	.126	.388*	.425**	--			
7. **McGurk - Fusion**	-.116	-.146	.281	.082	-.288	-.155	--		
8. **McGurk – Visual Only**	.563**	-.063	-.307	-.110	.025	-.042	-.390*	--	
9. **McGurk – Auditory Only**	-.131	.122	-.367*	.190	.426*	.271	-.512**	.242	--
10. **McGurk – AV Congruent**	-.001	.105	.007	.042	.293	.291	-.538**	.078	.582**

Table 13 – Predicting McGurk Fusion Performance by Age at Implant

Variable	**R^2**	**Adj-R^2**	β
Step 1 (df 4/25)	.113	-.029	
IQ			0.219
SES			0.168
Speech Perception			-0.317
Chronological Age			-0.090
Step 2 (df 1/24)	.286	.137	
Age at Implant			-0.540*

**significant at the .01 level
*significant at the .05 level

Table 14 – Descriptive Statistics for McGurk Fusion Performance for Participants Who Received Cochlear Implants Prior to and After 30 Months

	Prior to 30 Months		**Normal Hearing**	
	M	**(SD)**	***M***	**(SD)**
McGurk Task (% correct)				
fusion condition	52.22	41.52	61.05	35.90
visual only condition	44.75	20.41	52.36	18.59
auditory only condition	62.57	23.33	87.50	8.95
auditory-visual congruent condition	88.06	16.73	93.04	5.97

	After 30 Months		**Normal Hearing**	
	M	**(SD)**	***M***	**(SD)**
McGurk Task (% correct)				
fusion condition	16.25	24.73	60.00	39.33
visual only condition	67.99	23.43	57.88	24.36
auditory only condition	69.28	20.81	93.72	7.63
auditory-visual congruent condition	92.19	10.95	98.33	4.08

Table 15 - Correlations between Facial Emotion Identification Task Variables and Background for Cochlear Implant Group

Variable	1	2	3	4	5	6	7	8	9
1. Age at Time of Study Visit	--								
2. Sex	.137	--							
3. Nonverbal IQ	-.040	-.107	--						
4. SES	.141	.310	-.067	--					
5. Speech Perception	-.023	.384*	.118	.182	--				
6. Language Proficiency	-.217	.269	.126	.388*	.425**	--			
7. Happy Faces	.008	-.386*	.009	-.043	-.154	-.209	--		
8. Sad Faces	.349**	-.392*	.260	.075	-.026	.001	.316	--	
9. Fearful Faces	.362*	-.335*	-.114	.040	-.210	-.353*	.395*	.596**	--
10. Angry Faces	.098	-.117	.032	-.137	-.057	.000	.452**	.287	.246

Table 16 - Correlations between Emotion Understanding Task Variables and Background for Cochlear Implant Group

Variable	1	2	3	4	5	6	7	8
1. Age at Time of Study Visit	--							
2. Sex	.137	--						
3. Nonverbal IQ	-.040	-.107	--					
4. SES	.141	.310	-.067	--				
5. Speech Perception	-.023	.384*	.118	.182	--			
6. Language Proficiency	-.217	.269	.126	.388*	.425**	--		
7. Free Labeling	.268	.131	.114	.087	.191	-.090	--	
8. Identification of Faces	.204	.006	.065	-.103	-.083	-.068	.071	--
9. Vignettes	.262	.263	.263	.251	.256	.407*	.144	-.023

Table 17 - Correlations between Vocal Emotion Identification Task Variables and Background for Cochlear Implant Group

Variable	1	2	3	4	5	6	7	8
1. Age at Time of Study Visit	--							
2. Sex	.137	--						
3. Nonverbal IQ	-.040	-.107	--					
4. SES	.141	.310	-.067	--				
5. Speech Perception	-.023	.384*	.118	.182	--			
6. Language Proficiency	-.217	.269	.126	.388*	.425**	--		
7. Positive Sounds	.164	-.231	.030	.247	-.295	-.048	--	
8. Neutral Sounds	.054	-.153	.416**	-.037	-.130	.158	-.055	--
9. Negative Sounds	.179	-.096	-.125	.036	.317	.088	-.069	.195

Table 18 – Descriptive Statistics for All Criterion Measures for Males and Females
(means are presented)

	Cochlear Implant		Normal Hearing	
	Females	**Males**	**Females**	**Males**
McGurk Task (% correct)				
fusion condition	40.56	29.38	66.99	54.18
visual only condition	57.13	54.06	50.00	59.92
auditory only condition	63.22	68.55	87.06	93.79
auditory-visual congruent condition	88.61	91.56	95.29	95.61
Facial Emotion Identification Task (% correct)				
happy emotions	94.82**	85.93**	89.68	89.25
sad emotions	90.50**	83.54**	90.51	89.89
fearful emotions	91.14**	83.36**	81.15	83.99
angry emotions	76.45	73.13	78.50	75.99
Emotion Understanding Task				
free labeling (out of 6)	4.50	4.67	5.00	5.16
emotion identification (out of 6)	5.60	5.61	6.00	5.79
affective perspective-taking (% correct)	66.88	74.88	83.33	81.13
Vocal Emotion Identification – (% correct)				
Recognition of sounds				
Positive	88.89*	75.92*	98.44	100.00
Neutral	90.35	85.19	100.00	99.24
Negative	74.12	64.35	98.44	99.24
Identification of Emotion of Sounds				
Positive	77.35	68.85	87.04	84.91
Neutral	73.26	66.27	84.72	79.35
Negative	60.00	55.26	82.87	74.56

**significant at the .01 level
*significant at the .05 level

Table 19 – Mean Differences in Performance by Group (CI vs. NH) on McGurk Task with Language Performance and Sex as Covariates - ANCOVA

	Cochlear Implant	**Normal Hearing**		
	M **(SD)**	***M*** **(SD)**	***df***	***F***
McGurk Task (% correct)				
fusion condition	35.29 (38.71)	60.56 (36.98)	1,63	5.569*
visual only condition	55.69 (24.55)	54.77 (21.65)	1,63	.116
auditory only condition	65.73 (22.11)	90.30 (8.92)	1,63	11.208**
AV congruent condition	90.00 (14.25)	95.45 (5.78)	1,63	.286

**significant at the .01 level
*significant at the .05 level

Table 20 – Mean Differences in Performance by Group (CI vs. NH) on Facial Emotion Identification Task with Language Performance and Sex as Covariates – Repeated Measures ANCOVA

	Cochlear Implant	Normal Hearing		
	M (SD)	*M* (SD)	*df*	*F*
Facial Emotion Identification Task (% correct)				
happy emotions	90.76(11.61)	89.46(10.13)	1,66	.117
sad emotions	87.32(8.90)	90.19(7.90)		
fearful emotions	87.58(11.80)	82.65(14.77)		
angry emotions	74.93(13.01)	77.18(14.00)		

**significant at the .01 level

*significant at the .05 level

Table 21 – Perceptual Threshold Estimates for Facial Emotion Identification Task

	Cochlear Implant		Normal Hearing	
	a	***b***	***a***	***b***
Continuum				
Anger-fear	3.86	1.84	4.42	1.92
Anger-sad	4.38	1.16	4.48	1.23
Fear-happy	4.21	0.81	4.03	0.92
Happy-sad	5.72	1.21	5.32	1.07

The *a* = function midpoint, b = slope

Table 22 – Mean Differences in Performance by Group (CI vs. NH) on Emotion Understanding Task with Language Performance and Sex as Covariates – ANCOVA

	Cochlear Implant	**Normal Hearing**		
	***M* (SD)**	***M* (SD)**	***df***	***F***
Emotion Understanding Task				
Free Labeling (out of 6)	4.57 (.65)	5.14 (.77)	1,70	3.789*
Emotion Identification (out of 6)	5.59 (1.01)	5.91 (.37)	1,70	2.325
Affective Perspective-Taking (% correct)	70.66 (13.36)	82.62 (13.16)	1,65	2.659

**significant at the .01 level
*significant at the .05 level

Table 23 – Response Decisions in Angry Vignettes of Emotion Understanding Task

(out of a total of 144 vignettes)

Emotion Selected	Cochlear Implant		Normal Hearing	
	Frequency	Percent	Frequency	Percent
Happy	4	2.8	0	0
Surprise	5	3.5	0	0
Sad	41	28.5	26	19.1
Angry	79	54.9	102	75.0
Disgust	8	5.5	5	3.6
Scared	5	3.5	1	.7
Other	2	1.4	2	1.5
	N=36		N=34	

Table 24 – Mean Differences in Performance by Group (CI vs. NH) on Vocal Emotion Identification Task with Language Performance and Sex as Covariates – Repeated Measures ANCOVA

	Cochlear Implant	Normal Hearing		
	M (SD)	*M* (SD)	*df*	*F*
Recognition of sounds (% correct)				
Positive	82.41 (20.29)	99.07 (3.53)		
Neutral	87.84 (22.45)	99.69 (1.60)	1,59	38.410**
Negative	69.37 (22.83)	98.77 (3.02)		
Identification of Emotional Valence of Sounds				
Positive	73.21 (18.59)	85.95 (15.75)		
Neutral	69.85 (23.07)	81.96 (19.68)	1,71	7.430**
Negative	57.69 (24.88)	78.60 (16.96)		

**significant at the .01 level
*significant at the .05 level

Figure 1 – Model of Regression Analyses for All Task Performance for Age at Implant

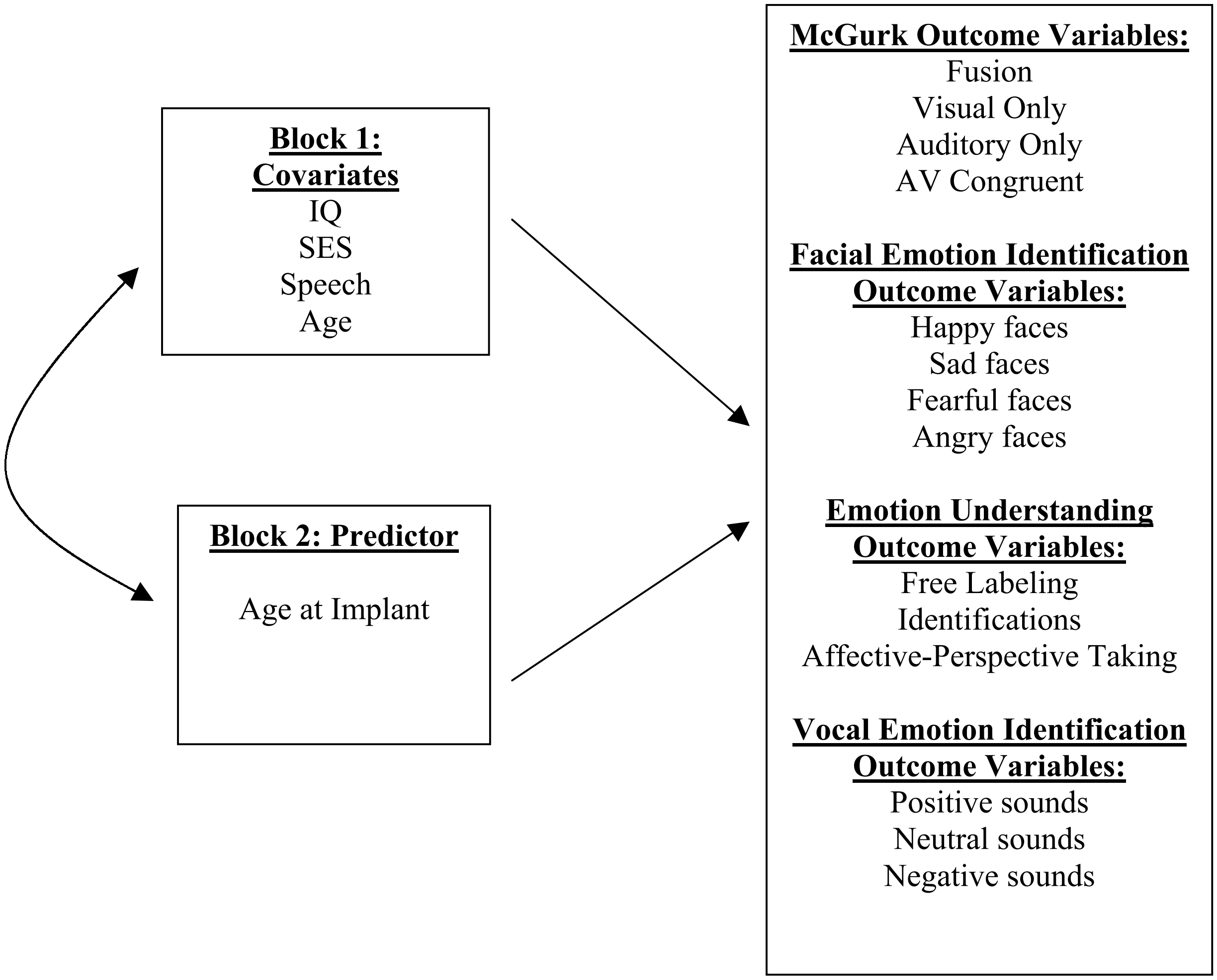


Figure 2 – Model of Regression Analyses for All Task Performance for Duration of Implant Use

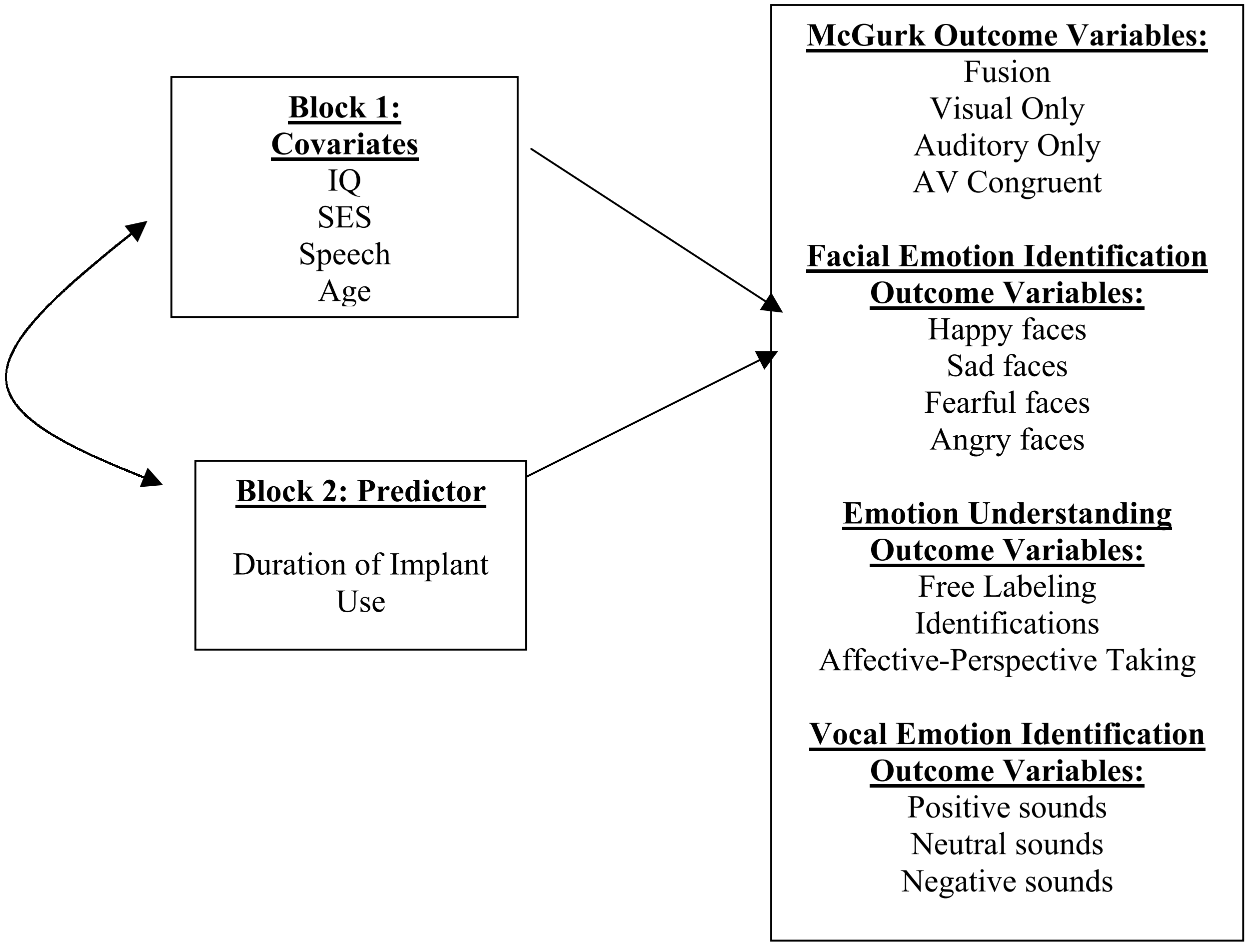


Figure 3 – McGurk Task Performance

Percent of trials identified correctly. The *x* axis indicates the age at which children received cochlear implants (in months). The *y* axis indicates the percent of trials identified correctly. Each panel shows the results for 34 children with cochlear implants. (**A**) The results for the McGurk condition. (**B**) The results for the visual only condition. (**C**) The results for the auditory only condition. (**D**) The results for the auditory-visual congruent condition.

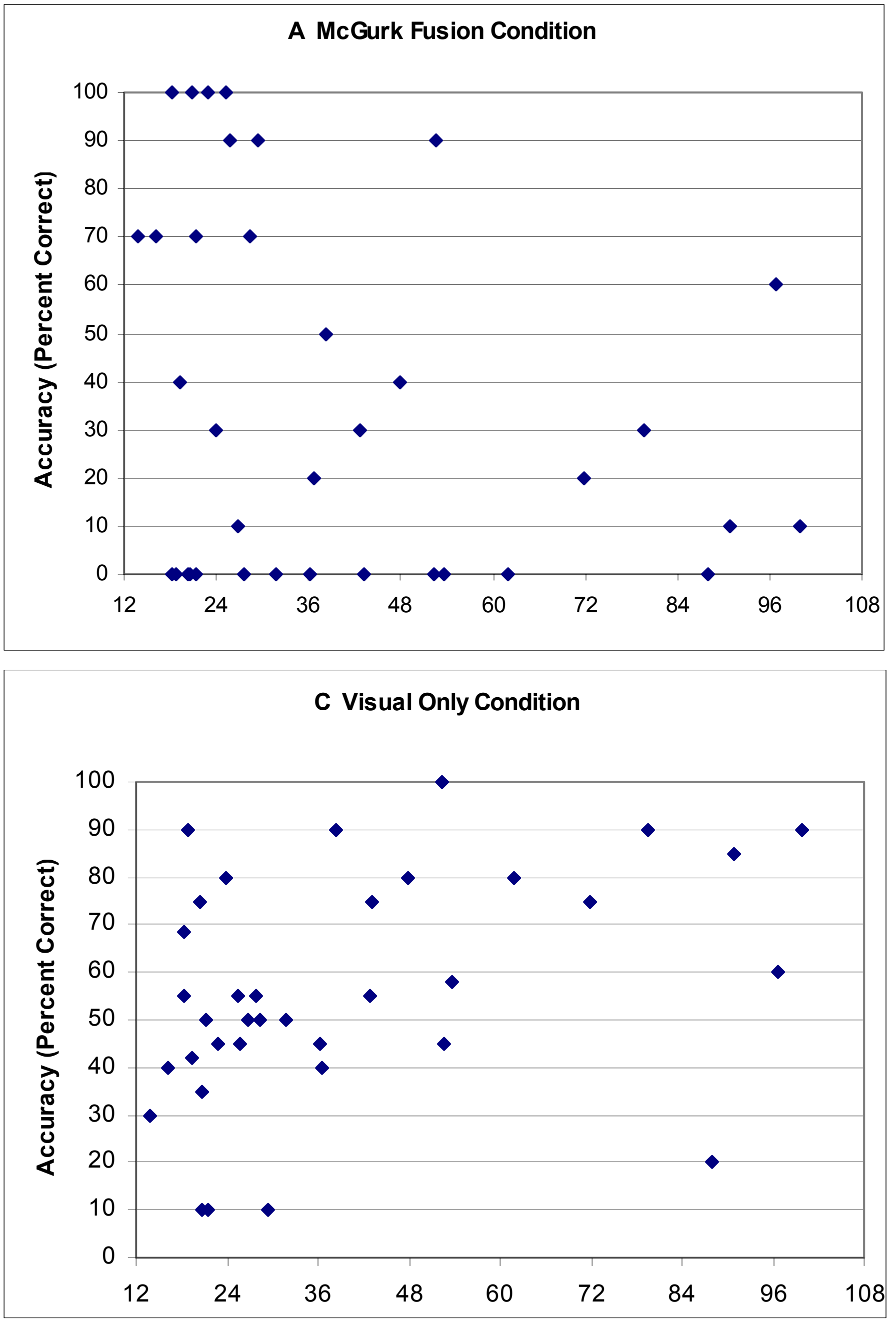
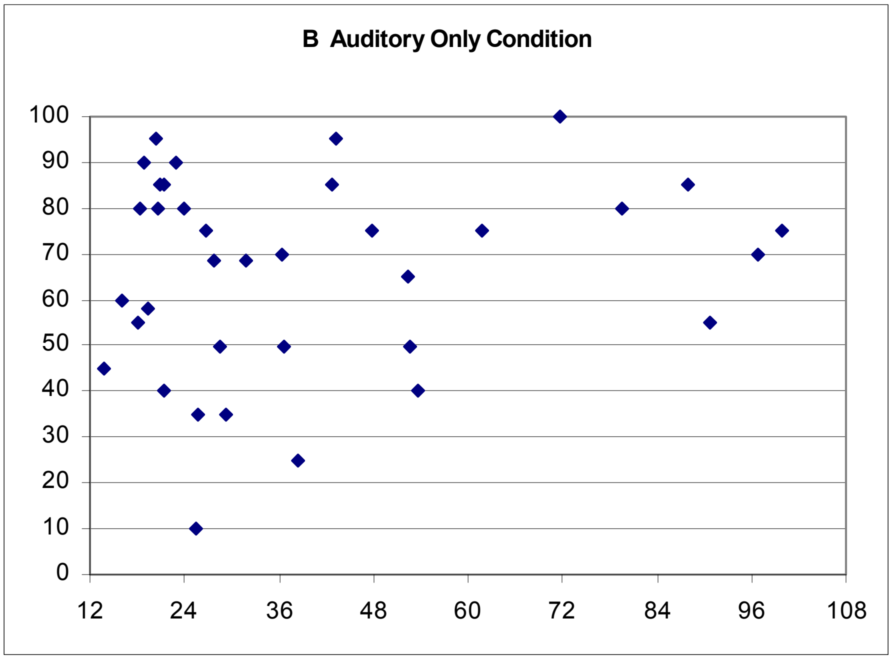


Figure 3 - continued



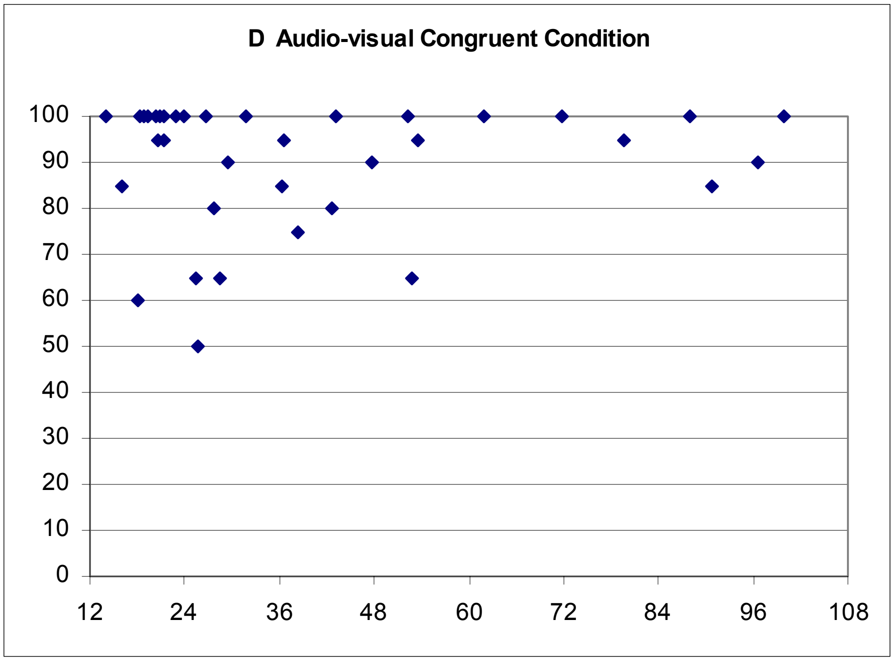


Figure 4. Performance of All Participants in the Vocal Emotion Identification Task
The *x* axis indicates participant's group and each participant is represented individually with a bar. The *y* axis presents percent correct performance on all of the task trials (total: 36 trials).

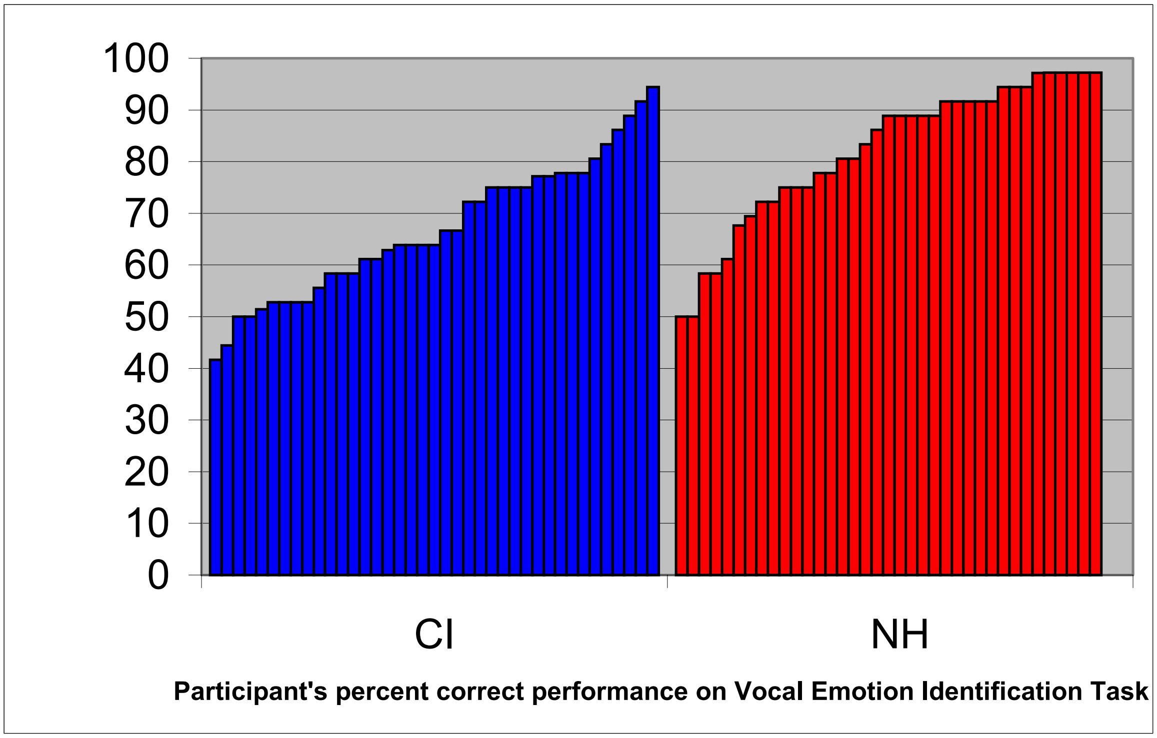
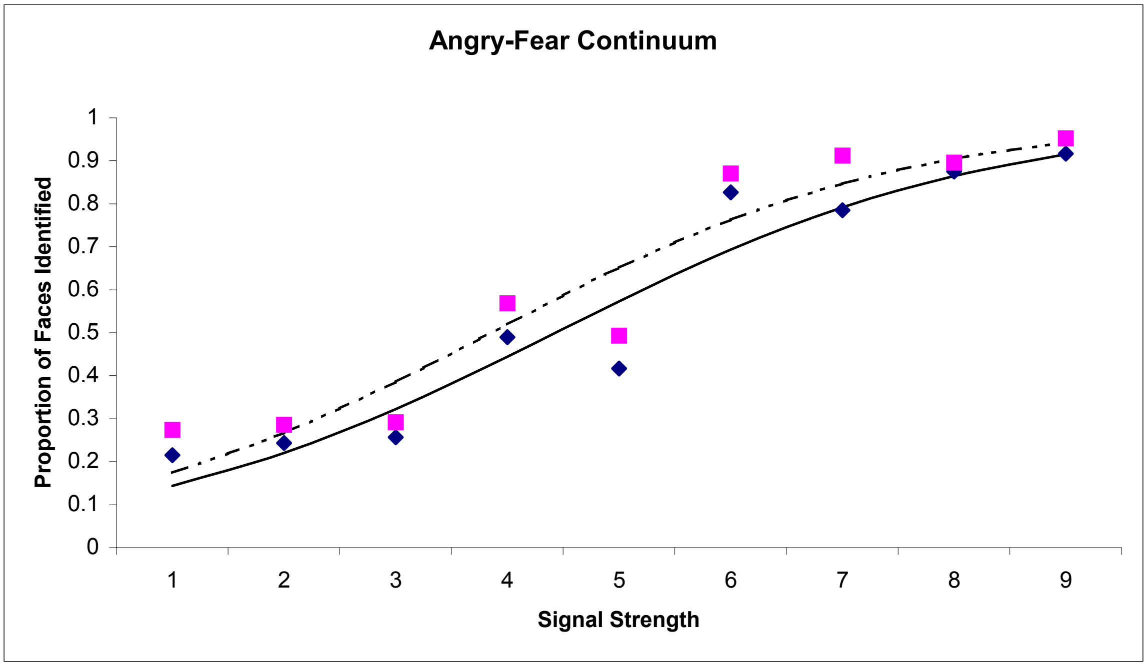
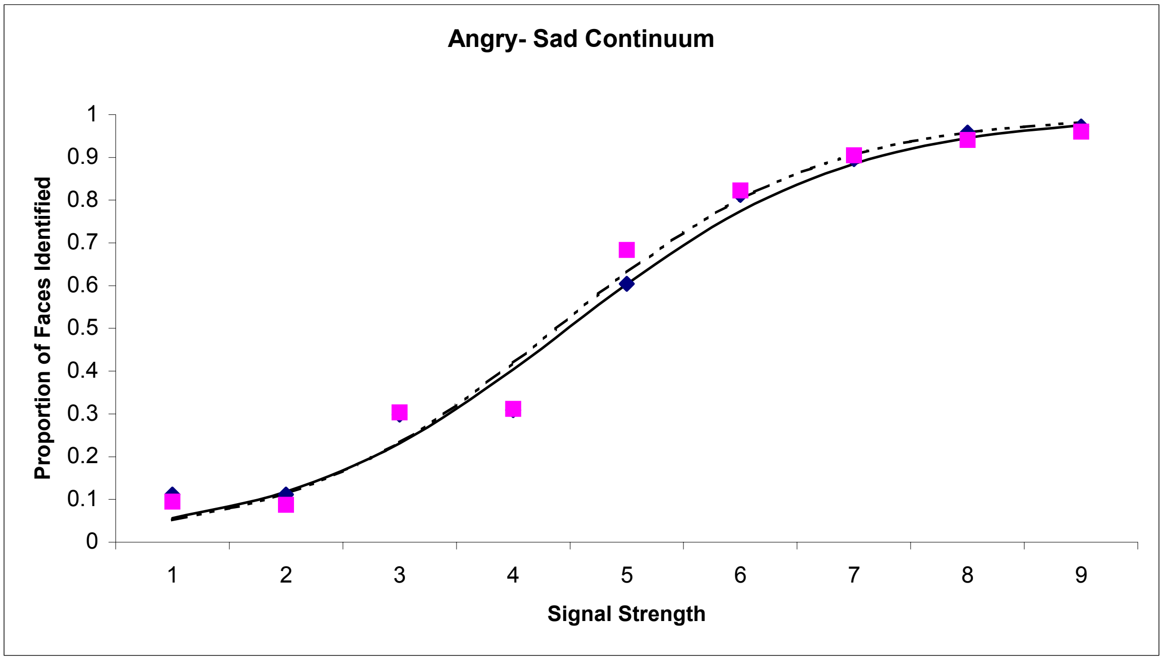
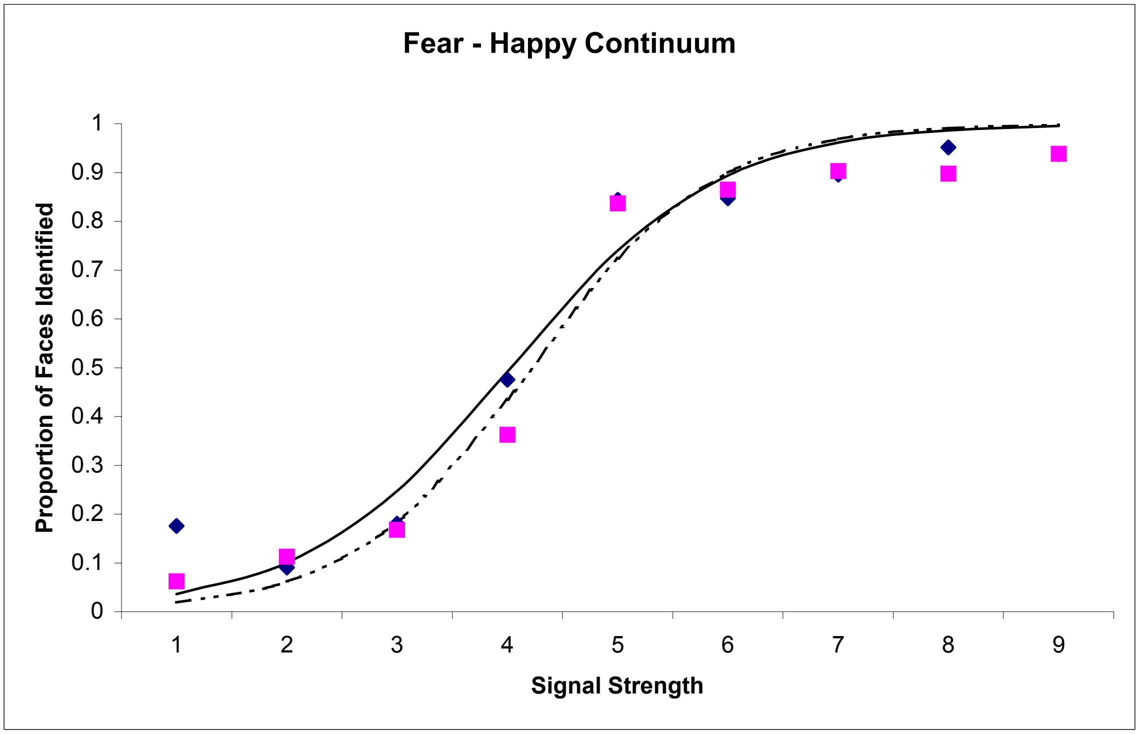


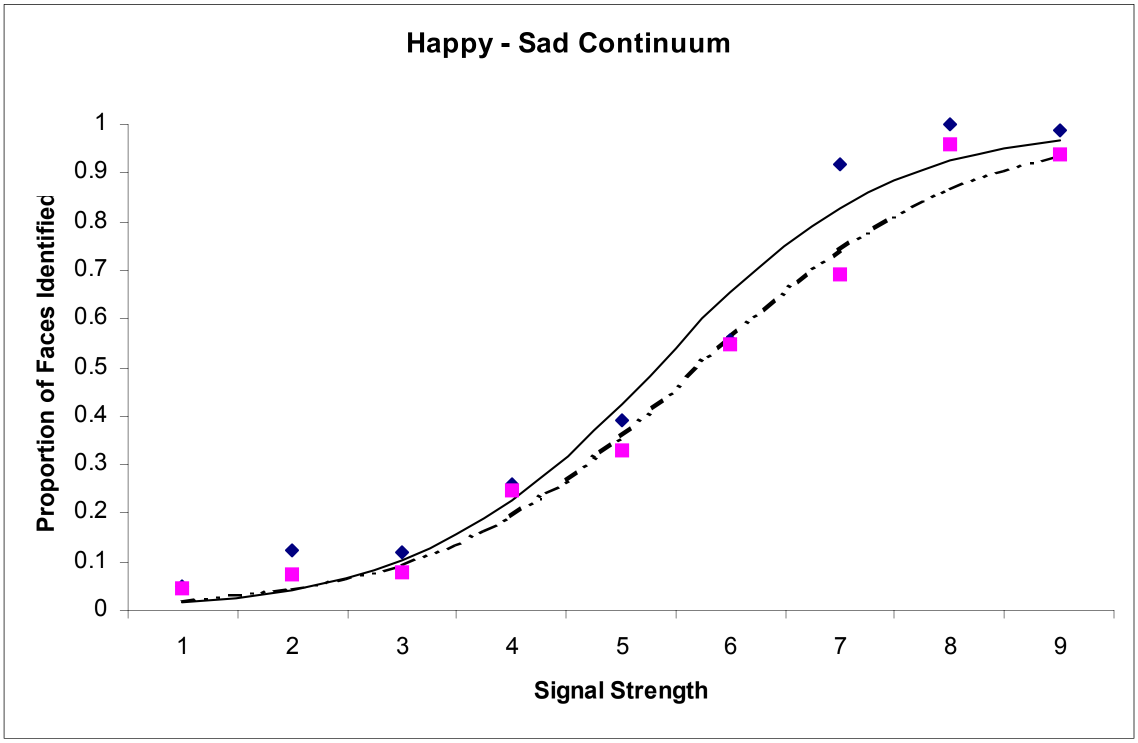
Figure 5. Performance on the Facial Emotion Identification Task for each emotion continuum The *x* axis indicates signal strength, which represents the proportion of trials in which responses matched the identity of the second emotion in the pair relative to the first emotion in the pair (e.g., for the anger-fear pair, signal strength 1 = 90% angry/10% fear, while at the other extreme 9 = 10% happy/90% fear. The y axis indicates the proportion of faces identified. Slope for cochlear implant group is plotted in dashed line and for normal hearing group in solid line.



(squares=Cochlear Implant, diamonds=Normal Hearing)




Fear - Happy Continuum
Proportion of Faces Identified
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1
2
3
4
5
6
7
8
9
Signal Strength


Happy - Sad Continuum
Proportion of Faces Identified
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1
2
3
4
5
6
7
8
9
Signal Strength

APPENDICES

Appendix A: Sample Protocol for Study Visit

Arrival at the lab, brief tour, introductions, and explanation of the study, explanation and signature of informed consent form by parent and assent form by child.

McGurk Illusion Task: Assessment of intermodal sensory processing

Facial Emotion Identification Task: Assessment of ability to identify facial expressions of emotion

At this point in the visit, the child was given a short break to use the bathroom, have a snack, etc.

Lexical Neighborhood Test and Multisyllabic Lexical Neighborhood Test: Screening of speech perception

Emotion Understanding Tasks: Assessment of the ability to identify facial expressions of emotion with independently generated labels and identify the emotion felt by protagonist of a emotion-eliciting hypothetical vignette

Vocal Emotion Identification Task: Assessment of ability to identify emotion in vocal sounds

At this point in the visit, child and parent(s) was invited to lunch at a restaurant on the University of Maryland campus. The conversation will be audio taped to provide a sample of child's spoken language in an unstructured situation.

Kaufman's Brief Intelligence Test: Screening of cognitive functioning

Language Battery: Assessment of language skills

At this point in the visit, child was given a short break to use the bathroom, have a snack, etc.

Language Battery: Completion of the language tasks

Appendix B: Parent Questionnaire

A copy of the questionnaire to be completed by the accompanying parent at the day of the visit:

Child Information

Date Completed: ___/___/___

Name of Child____

Child Date of Birth: ___/___/___ Child's Gender: ___ Female ___ Male

Current Address____
Street Apt. #

____
City State Zip Code

Telephone ( ) __________________

Child's Ethnicity: ___ Caucasian ___ African American ___ Hispanic

___ Asian ___ Native American ___ Other

Birth and Infancy

Was mother's condition during pregnancy good to excellent? ___ Yes ___ No

If not, please explain ____

____

Was baby born at term (due date) or within two weeks before or after due date?
___ Yes ___ No

What was birth weight? __________________________

Was child adopted? ___ Yes ___ No

Developmental History

Skill	Age	Skill	Age
Sitting Unassisted	____	Babbling	____
Crawling	____	First Words	____
Walking	____	Combining Words	____

Handedness: right______ left______

Does child seem to understand what is said to him/her? ___ Yes ___ No

Does child follow spoken directions? ___ Yes ___ No

Does child talk in: ____Single words ____ Phrases

____ Complete but grammatically incorrect sentences

____ Complete and grammatically correct sentences

Other (please specify) ____________________________________

Does child tell stories or experiences that can be understood? ___ Yes ___ No

Educational Information

Child's Current Grade Level_____________

Name of Current School____

Describe your child's current school setting:

___ Public School ___ Private ___ Home-schooled ___ None

Comments: ____

____

____

Placement in School: ____ Mainstream/General Education Classroom
____ Partial Mainstream
____ Self-Contained Special Education Classroom
Other____

Describe your child's classroom communication mode right now:
___ Cued speech
___ Auditory-oral
(encourages lipreading and listening to the speaker)
___ Auditory-verbal
(children are taught to rely on listening alone to understand)

Previous School: ____

Placement: ____ Mainstream/General Education Classroom
____ Partial Mainstream
____ Self-Contained Special Education Classroom
Other____
Communication Mode(s)___________________________________

Previous School: ____

Placement: ____ Mainstream/General Education Classroom
____ Partial Mainstream
____ Self-Contained Special Education Classroom
Other____
Communication Mode(s)___________________________________

Previous School: ____

Placement: ____ Mainstream/General Education Classroom
____ Partial Mainstream
____ Self-Contained Special Education Classroom
Other____
Communication Mode(s)___________________________________

Did your child attend preschool? ___ yes ___ no

At what age? _____________ For how long? ________________

School Name ____

Did you child attend an Early Intervention program? ___ yes ___ no

At what age did your child attend? _____________

Name of Program ____

How often did the program meet? ______________________________________

Size of the program ____

Communication mode:
___ Cued speech
___ Auditory-oral
___ Auditory-verbal

Educational History

Age at which intervention first began: _____years, _____months

Please describe this intervention: ____

____

____

____

____

Communication mode:
___ Cued speech
___ Auditory-oral
___ Auditory-verbal

Who worked with your child?

___ Speech-language pathologist ___ Special Educator

___ Teacher of the deaf ___ Early childhood teacher

___ Early intervention specialist Other (please specify)____________

How frequently did the intervention/therapy take place?

___ Once per month ___ Twice per month

___ Once per week ___ Twice a week

Other: please specify ____

How long were the intervention/therapy sessions?

___ 30 minutes ___ 45 minutes

___ 60 minutes Other: please specify _______________________

How many children were in the therapy group?

___ Only my child ___ Number of other children

Did the clinician use signs to communicate during therapy sessions?

___ Usually ___ Sometimes ___ Never

Did the clinician use cued speech?

___ Usually ___ Sometimes ___ Never

Did this intervention include parent training?

___ Yes ___ No

Comments ____

____

____

____

Health Information

Besides hearing loss, does your child have any:

Visual impairment ___ yes ___ no

If "yes" please explain: _______________________________________

Physical/motor disability ___ yes ___ no

If “yes” please explain: ____

Mental Retardation ___ yes ___ no

If “yes” please explain: ____

Attention Deficit Disorder ___ yes ___ no

If “yes” please explain: ____

Learning Disability ___ yes ___ no

If “yes” please explain: ____

Emotional Disorder ___ yes ___ no

If “yes” please explain: ____

Cerebral Palsy ___ yes ___ no

If “yes” please explain: ____

Brain damage/injury ___ yes ___ no

If “yes” please explain: ____

Developmental/Cognitive delay ___ yes ___ no

If “yes” please explain: ____

Autism/PDD ___ yes ___ no

If “yes” please explain: ____

Balance disorder ___ yes ___ no

If “yes” please explain: ____

Seizures/Epilepsy ___ yes ___ no

If “yes” please explain: ____

Central processing disorder ___ yes ___ no

If “yes” please explain: ____

Cleft lip/palate ___ yes ___ no

If “yes” please explain: ____

Sensory/Motor integration problem ___ yes ___ no

If “yes” please explain: ____

Other conditions ___ yes ___ no

If “yes” please explain: ____

Has your child had any severe illnesses or surgeries?

____

____

Does your child have any medical concerns or illnesses right now?

____

Audiological History

Was child’s hearing tested at birth before he/she left the hospital? ___ Yes ___ No

If yes, was this part of a newborn screening program? ___ Yes ___ No

Age of onset of hearing loss:

___ Not known ___ Present at birth

___ Acquired after birth If so, at what age? _________

Did you or other caregivers suspect that your child had a hearing loss before he/she was tested? ___ yes ___ no

If yes, what age was your child when hearing loss was first suspected?

______years, ______months

Age at which hearing loss was confirmed: _______years, _______months

Type of hearing loss:

___ Sensorineural ___ Conductive ___ Fluctuating

___ Mixed ___ Don't know

Cause of hearing loss:

___ Unknown

If known, ____

Age at which your child first received amplification: _______years, _______months

What type of amplification was used?

___ None ___ Hearing aids

___ FM auditory trainer ___ Tactile aid

Age of child at implant surgery: ________years, _______months

Date of surgery: ____________ Date of implant activation: ______________

Cochlear implant model: __________________________

# of electrodes being used: _________________________

Type of speech processor strategy used: _____________________________________

Is the implant functioning properly at the current time? ___ yes ___ no

If "no" please explain: ____

Any medical implications or problems related to the implant? ___ yes ___ no

If "yes" please explain: ____

____

Results from any previous speech or language assessments:

____

Family Information

Are there any foreign languages spoken at home? _____ Yes _____ No

If Yes, what language _______________________ By whom: ___________________

Communication mode used n the home:
___ Cued speech
___ Auditory-oral
___ Auditory-verbal

Mother:

Name ____ Age: ______

Occupation: ________________________ Hours/week___________________

Title: ____

Education: ___ Graduate or Professional School ___ College Graduate

___ Partial College (completed at least 1 year) ___ High School Graduate

___ Partial High School (completed 10th or 11th grades) ___ Junior High School (completed 7th-9th grades)

___ Less than 7 years of school

Hearing Status: ___ Normal Hearing ___ hard-of-hearing ___ Deaf

Father:

Name ____ Age: ______

Occupation: ________________________ Hours/week___________________

Title: ____

Education: ___ Graduate or Professional School ___ College Graduate

___ Partial College
(completed at least 1 year)

___ High School Graduate

___ Partial High School
(completed 10th or 11th grades)

___ Junior High School
(completed 7th-9th grades)

___ Less than 7 years of school

Hearing Status: ___ Normal Hearing ___ hard-of-hearing ___ Deaf

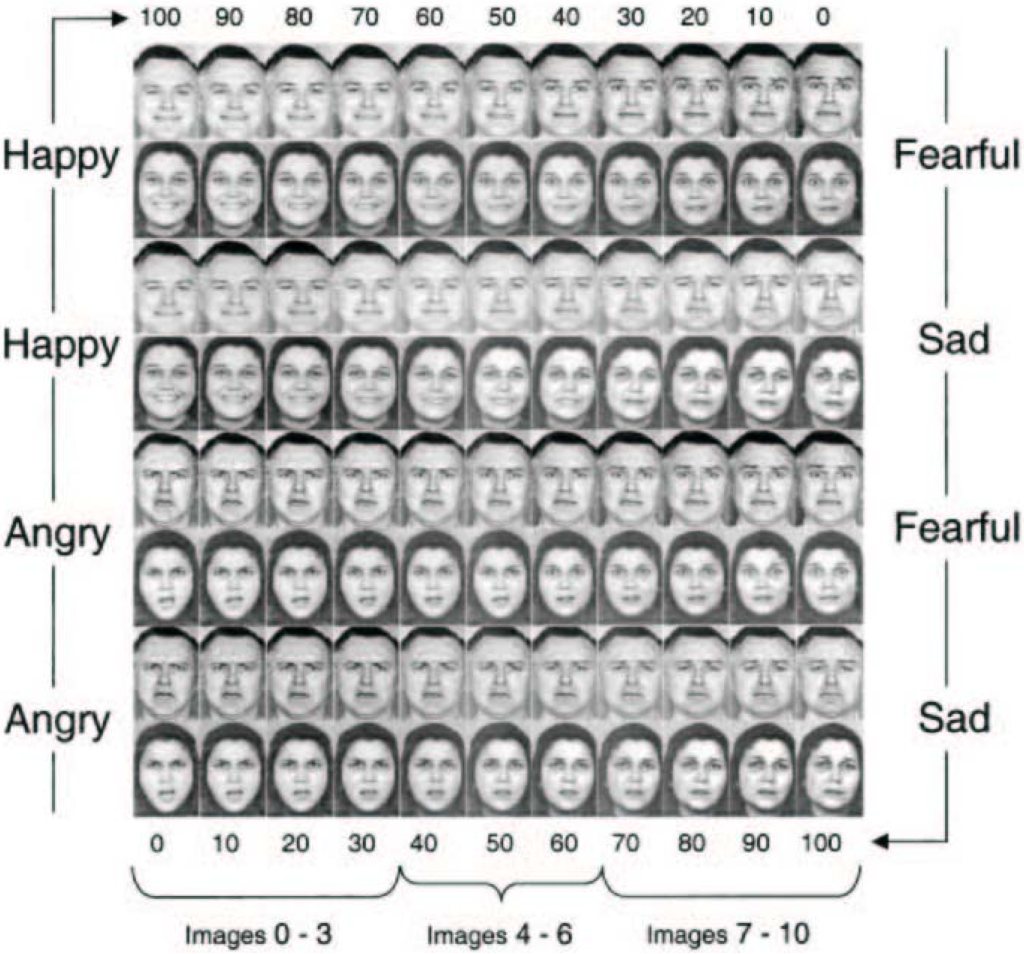
Siblings:

Name	Age	Do they have hearing loss?
________________	________	_________________
________________	________	_________________
________________	________	_________________
________________	________	_________________

Child lives with: ________ both biological parents
________ other arrangement. Please explain _________________
____

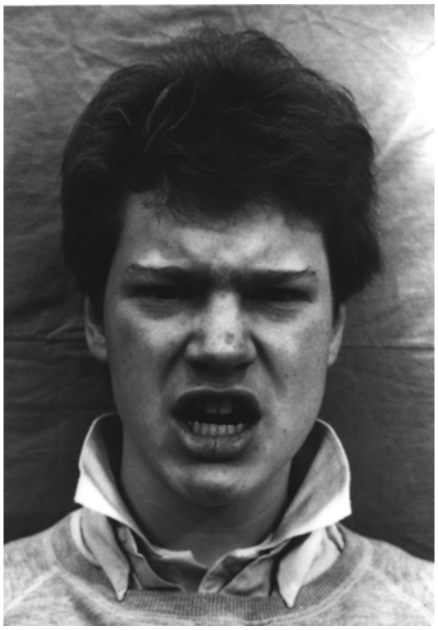
Appendix C: Stimuli for the Facial Emotion Identification Task

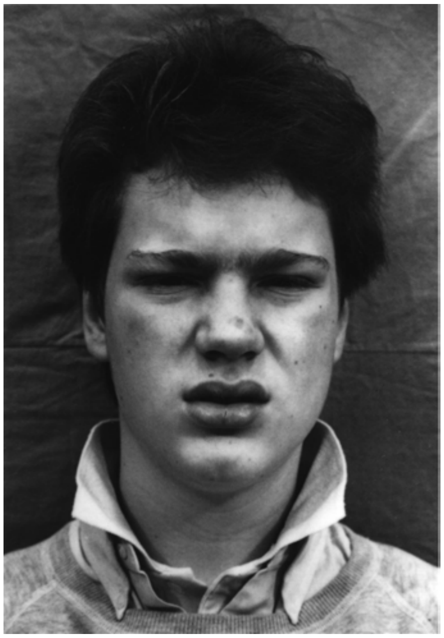
Examples of the photographs of prototypical faces morphed along continua.

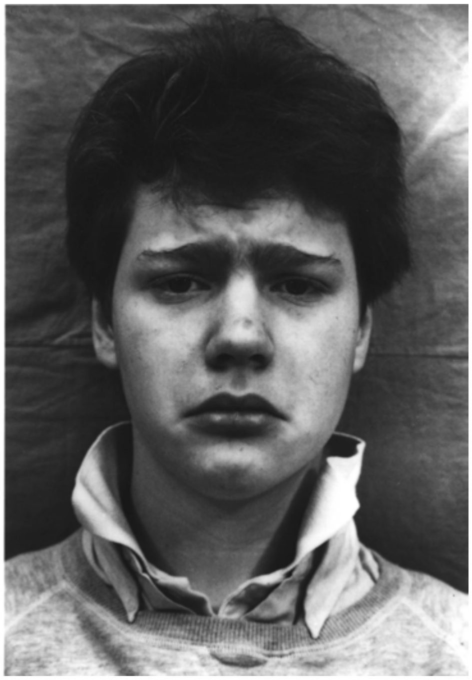


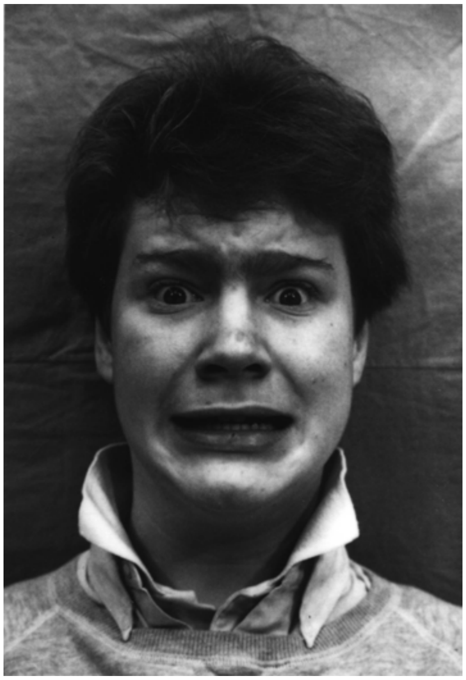
Appendix D: Stimuli for Emotion Understanding Tasks

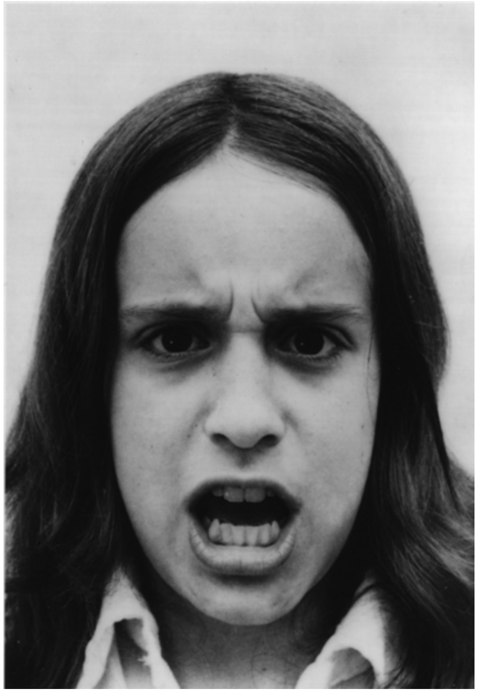
Examples of male and female photographs of prototypical faces for affective labeling task.

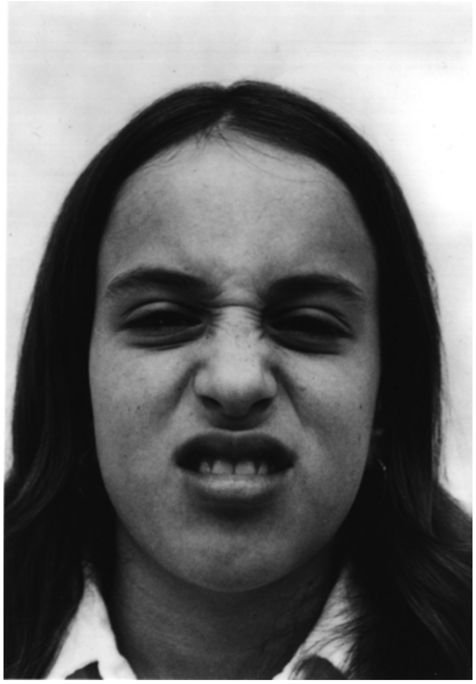












Appendix E: Vignettes for Affective Perspective-Taking Task

A list of emotion-eliciting vignettes.

Happy

1. Johnny/Rachel wanted his/her friends to come over to play. So he/she asked them, and they came to play with him/her at his/her house.
2. Johnny/Rachel worked hard on a picture and showed it to his/her father. His/her father really liked it and said Johnny/Rachel did a good job.
3. Johnny/Rachel went to the zoo, and his/her aunt bought him/her a really nice balloon that he/she liked a lot.
4. It is Johnny's/Rachel's birthday. He/she is given a party with lots of cake and fun games to play, and presents too.

Sad

1. Johnny/Rachel and his/her little sister have a pet dog. The dog is sick and going to die.
2. Johnny's/Rachel's friend, who he/she really liked to play with, moved away. Johnny/Rachel couldn't play with his/her friend any more.
3. Johnny/Rachel couldn't play a game, and some of the kids laughed at him/her.
4. Johnny's/Rachel's favorite sweater that he/she liked a lot was very old and worn out. He/she had to throw ir away and gave it to his/her mom to get rid of it.

Surprised

1. When Johnny/Rachel went to bed, he/she was in his/her own bed, and when he/she woke up, he/she was on the couch.
2. Johnny/Rachel had a dog named Bowser who always barked at him/her when he/she came home from school. One day when Johnny/Rachel came home, he/she said "Hi, Bowser!" and Bowser said "Hi, Johnny/Rachel!"
3. It was summertime, and when Johnny/Rachel went to bed, the weather was warm. When he/she got up, there was snow on the ground.
4. Johnny/Rachel was walking home from school and suddenly out from behind a tree jumped his/her father, who said, "Boo!"

Disgusted

1. Someone threw up on Johnny/Rachel during lunch at school.
2. A friend gave Johnny/Rachel an apple. Johnny/Rachel bit into the apple and found a smelly, squashed, dead worm.
3. Johnny's/Rachel's friend brought his dog over to Johnny's/Rachel's house. The dog made a mess on the carpet and Johnny/Rachel stepped in it.
4. Johnny/Rachel went to a movie with a friend. In the movie, people were eating bugs and worms.

Afraid

1. Johnny/Rachel was dreaming about a monster in his/her nightmare.
2. When Johnny/Rachel went to bed, he/she thought there was something in his/her closet trying to get him/her.
3. Johnny/Rachel was walking in the woods and met a hungry bear who likes to eat little children.
4. A bad man was chasing after Johnny/Rachel.

Angry

1. Johnny's/Rachel's little brother broke his/her favorite toy on purpose.
2. Johnny/Rachel was trying to tell his/her mom about something exciting, but his/her little brother kept interrupting.
3. Johnny/Rachel let his her/best friend use his/her new ball. His/her friend was not careful and lost the ball and wouldn't give Johnny/Rachel another one.
4. Johnny's/Rachel's friend gave him/her a present because Johnny/Rachel helped him with his homework. Later, Johnny's/Rachel's friend changed his mind and took the present back.

Appendix F – Vocal Emotion Identification Task Sounds

A list of the non-linguistic emotional sounds.

Neutral Sounds
hmm

ahh

umm

mhm

Positive Sounds

woohoo

oooh

giggle

mmm

Negative Sounds

oww

ugh

cry

cry

REFERENCES

Adamson, L. B., & Chance, S. E. (1998). Coordinating attention to people, objects, and language. In A. M. Wetherby, S. F. Warren, and J. Reichle, (Eds), *Transitions in prelinguistic communication: Perspectives to intentional and presymbolic to symbolic* (pp.15-37). Baltimore: Brookes.

Alho, K. (1995). Cerebral generators of mismatch negativity (MMN) and its magnetic counterpart (MMNm) elicited by sound changes. *Ear and Hearing, 16*, 38-51.

Altschuler, K. Z. (1974). The social and psychological development of the deaf child: Problems, their treatment and prevention. *American Annals of the Deaf, 119*, 365-376.

Arnold, P. (1999). Emotional disorder in deaf children. In V. L. Schwean & D. H. Saklofske (Eds.), *Handbook of psychological characteristics of exceptional children* (pp. 493-521). New York: Kluwer Academic/Plenum.

Banse, R., & Scherer, K. R. (1996). Acoustic profiles in vocal emotion expression. *Journal of Personality and Social Psychology, 70*, 614-636.

Bat-Chava, Y., & Deignan, E. (2001). Peer relationships of children with cochlear implants. *Journal of Deaf Studies and Deaf Education, 6*, 186-199.

Beeghly, M., Bretherton, I., & Mervis, C. B. (1986). Mothers' internal state language to toddlers. *British Journal of Developmental Psychology, 4,* 247-260.

Binns, K. E., Withington, D. J., & Keating, M. J. (1995). The developmental emergence of the representation of auditory azimuth in the external nucleus of the inferior colliculus of the guinea-pig: the effects of visual and auditory deprivation. *Developmental Brain Research, 85*, 14-24.

Birch, E. E., Stager, D., Leffler, J., & Weakley, D. (1998). Early treatment of congenital unilateral cataract minimizes unequal competition. *Investigative Ophthalmology and Visual Science, 39*, 1560-1566.

Black, B. (1989). Interactive pretense: Social and symbolic skills in preschool play groups. *Merrill-Palmer Quarterly, 35*, 379-397.

Bornstein, M. H. (1989). Sensitive periods in development: Structural characteristics and causal interpretations. *Psychological Bulletin, 105*, 179-197.

Bornstein, M. H., Tal, J., Rahn, C., & Galperin, C. Z. (1992). Functional analysis of the contents of maternal speech to infants of 5 and 13 months in four cultures: Argentina, France, Japan, and the United States. *Developmental Psychology, 28*, 593-603.

Bowering, E., Maurer, D., Lewis, T. L., & Brent, H. P. (1997). Constriction of the visual field of children after early visual deprivation. *Journal of Pediatric Ophthalmology and Strabismus, 34*, 347-356.

Boyd, C. L., & Dumont, R. (1996). Inquiring psychologists want to know: How well does the K-BIT predict WISC-III results? *Communiqué, 24*, 24.

Boyd, R. C., Knutson, J. F., & Dahlstrom, A. J. (2000). Social interaction of pediatric cochlear implant recipients with age-matched peers. *Annals of Otology, Rhinology, and Laryngology, Supplement, 185*, 105-109.

Bretherton, I., Fritz, J., Zahn-Waxler, C., & Ridgeway, D. (1986). Learning to talk about emotions: a functionalist perspective. *Child Development, 57*, 529-548.

Brown, J. R., Donelan-McCall, N., & Dunn, J. (1996). Why talk about mental states? The significance of children's conversations with friends, siblings, and mothers. *Child Development, 67*, 836-849.

Bruner, J. (1972). Nature and uses of immaturity. *American Psychologist, 27*, 687–708.

Bruner, J. (1981). The social context of language acquisition. *Language and Communication, 1*, 155-178.

Bullock, M., & Russell, J. A. (1984). Preschool children's interpretation of facial expressions of emotion. *International Journal of Behavioral Development, 7*, 193-214.

Camras, L. A., Grow, G., & Ribordy, S. C. (1983). Recognition of emotional expressions by abused children. *Journal of Clinical and Child Psychology, 12*, 325-328.

Casby, M. W., & McCormack, S. M. (1985). Symbolic play and early communication development in hearing-impaired children. *Journal of Communication Disorders, 18,* 67-78.

Cassidy, J., Parke, R., Butkovsky, L., & Braungart, J. (1992). Family-peer connections: The roles of emotional expressiveness within the family and children's understanding of emotions. *Child Development, 63*, 603-618.

Compton, M., & Niemeyer, J. (1994). Expressions of affection in young children with sensory impairments: a research agenda. *Education & Treatment of Children, 17,* 68-85.

Custrini, R., & Feldman, R. S. (1989). Children's social competence and nonverbal encoding and decoding of emotion. *Journal of Child Clinical Psychology, 18*, 336-342.

Cutting, A. L., & Dunn, J. (1999). Theory of mind, emotion understanding, language, and family background: individual differences and interrelations. *Child Development, 70*, 853-865.

Darbyshire, J. O. (1977). Play patterns in young children with impaired hearing. *Volta Review, 79*, 19-26.

Denham, S., (1986). Social cognition, prosocial behavior, and emotion in preschoolers: Contextual Validation. *Child Development, 57*, 194-201.

Denham, S., McKinley, M., Couchoud, E., & Holt, R. (1990). Emotional and behavioral predictors of preschool ratings. *Child Development, 61*, 1145-1152.

Denham, S., Zoller, D., & Couchoud, E. (1994). Socialization of preschoolers' emotion understanding. *Developmental Psychology, 30*, 928-936.

Diener, C. I., & Dweck, C .S. (1978). An analysis of learned helplessness: Continuous change in performance, strategy, and achievement cognitions following failure. *Journal of Personality and Social Psychology, 36*, 451-462.

Dillon, C. M., Burkholder, R. A., Cleary, M., & Pisoni, D. B. (2004). Nonword repetition by children with cochlear implants: Accuracy ratings from normal-hearing listeners. *Journal of Speech, Language, & Hearing Research, 47*, 1103-1116.

Dodd, B. (1977). The role of vision in the perception of speech. *Perception, 6*, 31-40.

Dodge, K. A., Schlundt, D. C., Schocken, I., & Delugach, J. D. (1983). Social competence and children's sociometric status: The role of peer group entry strategies. *Merrill-Palmer Quarterly, 29*, 309-336.

Dunn, J., Bretherton, I., & Munn, P. (1987). Conversations about feeling states between mothers and their young children. *Developmental Psychology, 23*, 132-139.

Dunn, J., Brown, J., & Beardsall, L. (1991). Family talk about feeling states and children's later understanding of others' emotions. *Developmental Psychology, 27*, 448-455.

Dunn, J., Brown, J. R., & Maguire, M. (1995). The development of children's moral sensibility: individual differences and emotion understanding. *Developmental Psychology, 31*, 649-659

Dunn, L. M., & Dunn, L. M. (1997). *Peabody Picture Vocabulary Test – III*. Circle Pines, MN: American Guidance Service.

Dunn, J., Kendrick, C., & MacNamee, R. (1982). The reaction of first-born children to the birth of a sibling: Mothers' reports. *Annual Progress in Child Psychiatry & Child Development*, 143-165.

Dunn, J., & Munn, P. (1985). Becoming a family member: Family conflict and the development of social understanding in the second year. *Child Development, 56*, 480-492.

Dunn, J., & Munn, P. (1986). Siblings and the development of prosocial behavior. *International Journal of Behavioral Development, 9*, 265-284.

Dunn, J., & Munn, P. (1987). Development of justification in disputes with mother and sibling. *Developmental Psychology, 23*, 791-798.

Edwards, R., Manstead, A., & MacDonald, C. J. (1984). The relationship between children's sociometric status and ability to recognize facial expressions of emotion. *European Journal of Social Psychology, 14*, 235-238.

Eggermont, J. J., Ponton, C., Don, M., & Waring, M. D. (1997). Maturational delays in cortical evoked potentials in cochlear implant users. *Acta Otolaryngolica, 117*, 161-163.

Ekman, P. & Friesen, W. V. (1976). Measuring facial movement. *Journal of Environmental Psychology and Nonverbal Behavior, 1*, 56-75

Ekman, P. & Friesen, W. V. (1978). *The facial action coding system (FACS): A technique for the measurement of facial action*. Palo Alto, CA: Consulting Psychologists Press.

Ellemberg, D., Lewis, T. L., Maurer, D., Lui, C. H., & Brent, H. P. (1999). Spatial and temporal vision in patients treated for bilateral congenital cataracts. *Vision Research, 39*, 3480-3489.

Erting, C. J., Prezioso, C., & Hynes, O. G. (1990). The interactional context of deaf mother-infant communication. In V. Voltarra & C. J. Erting (Eds.), *From Gesture to Language in Hearing and Deaf Children* (pp. 97-106). Berlin: Spinger-Verlag.

Ertmer, D. J. (2001). Emergence of a vowel system in a young cochlear implant recipient. *Journal of Speech, Language & Hearing Research, 44*, 803-814.

Ertmer, D. J., & Mellon, J. A. (2001). Beginning to talk at 20 months: Early vocal development in a young cochlear implant recipient. *Journal of Speech, Language & Hearing Research, 44*, 192-207.

Ertmer, D. J., Strong, L. M., & Sadagopan, N. (2003). Beginning to communicate after cochlear implantation: Oral language development in a young child. *Journal of Speech, Language, and Hearing Research, 46*, 328-340.

Esposito, B. G. & Koorland, M. A. (1989). Play behavior of hearing impaired children: Integrated and segregated settings. *Exceptional Children, 55*, 412-419.

Feldman, R. S., White, J. B., & Lobado, D. (1982). Social skills and nonverbal behavior. In R. S. Feldman (Ed.), *Development of Nonverbal Behavior in Children* (pp. 259-277). New York: Springer-Verlag.

Fernald, A. (1989). Intonation and communicative intent in mothers' speech to infants: is the melody the message? *Child Development, 60*, 1497-1510.

Fernald, A. (1993). Approval and disapproval: Infant responsiveness to vocal affect in familiar and unfamiliar languages. *Child Development, 64*, 657-74.

Fivush, R. (1991). Gender and emotion in mother-child conversations about the past. *Journal of Narrative and Life History, 1*, 325-341.

Frick, R. (1985). Communicating emotion: The role of prosodic features. *Psychological Bulletin, 97*, 412-429.

Fryauf-Bertschy, H., Tyler, R. S., Kelsay, D. M. R., Gantz, B. J., & Woodworth, G. G. (1997). Cochlear implant use by prelingually deafened children: The influences of age at implant and length of device use. *Journal of Speech, Language, and Hearing Research, 40*, 183-199.

Furrow, D., Nelson, K., & Benedict, H. (1979). Mothers' speech to children and syntactic development: Some simple relationships. *Journal of Child Language, 6*, 423-442.

Gallaudet Research Institute. (1996). *Who and where are our children with cochlear implants?* Paper presented at the Convention of the American Speech-language-Hearing Association, Boston, MA.

Gallaudet Research Institute. (January 2002). *Regional and National Summary Report of Data from the 2000-2001 Annual Survey of Deaf and Hard of Hearing Children and Youth.* Washington, DC: GRI, Gallaudet University.

Garvey, C. (1990). *Play (enlarged ed.).* Cambridge, MA: Harvard University Press.

Geers, A. E., Moog, J., & Schick, B. (1984). Acquisition of spoken and signed English by profoundly deaf children. *Journal of Speech and Hearing Disorders, 49*, 378-388.

Geers, A. E., Nicholas, J. G. & Sedey, A. L. (2003). Language skills of children with early cochlear implantation. *Ear & Hearing, 24 (1S),* 46S-58S.

Geers, A., & Schick, B. (1988). Acquisition of spoken and signed English by profoundly deaf children. *Journal of Speech and Hearing Disorders, 49*, 136-143.

Gibson, E. J. (1991). The ecological approach: A foundation for environmental psychology. In R. M. Downs & L. S. Liben (Eds.), *Visions of aesthetics, the environment & development: The legacy of Joachim F. Wohlwill* (pp. 87-111). Hillsdale, NJ: Erlbaum.

Giraud, A. L., Price, C. J., Graham, J. M., Truy, E., & Frackowiak, R. S. J. (2001). Cross-modal plasticity underpins language recovery after cochlear implantation. *Neuron, 30*, 657-663.

Goetz, T. E., & Dweck, C. S. (1980). Learned helplessness in social situations. *Journal of Personality & Social Psychology, 39*, 246-255.

Gottman, J. M., & Parker, J. G. (1986). *Conversations of friends: Speculations on affective development*. Cambridge, MA: Cambridge University Press.

Grant, K. W., Ardell, L. H., Kuhl, P. K., & Sparks, D. W. (1985). The contribution of fundamental frequency, amplitude envelope, and voicing duration cues to speechreading in normal-hearing subjects. *Journal of the Acoustical Society of America, 77*, 671-677.

Grant, K. W., Walden, B. E., & Seitz, P. F. (1998). Auditory-visual speech recognition by hearing-impaired subjects: Consonant recognition, sentence recognition, and auditory-visual integration. *Journal of the Acoustical Society of America, 103*, 2677-2690.

Gray, C. D., Hosie, J. A., Russell, P. A., & Ormel, E. A. (2001). Emotional development in deaf children: Facial expressions, display rules, and theory of mind. In M. D. Clark & M. Marschark (Eds.), *Context, cognition, and deafness* (pp. 135-160). Washington, DC: Gallaudet University Press.

Greenberg, M. (1980). Social interaction between deaf preschoolers and their mothers: the effects of communication method and communication competence. *Developmental Psychology, 16*, 465-474.

Greenough, W. T., Black, J. E., & Wallace, C. S. (1987). Experience and brain development. *Child Development, 58*, 539-559.

Gross, A. L., & Ballif, B. (1991). Children's understanding of emotion from facial expressions and situations: A review. *Developmental Review, 11*, 368-398.

Hammill, D. D., Brown, V. L., Larsen, S. C., & Wiederholt, J. L. (1994), *Test of Adolescent and Adult Language -Third Edition (TOAL-3)*. Austin, TX: Pro-Ed.

Hammill, D. D., & Newcomer, P. L. (1997) *Test of Language Development – Intermediate (TOLD-I: 3rd ed.)*. Austin, TX: Pro-Ed.

Harris, R. I. (1978). The relationship of impulse control to parent hearing status, manual communication, and academic achievement. *American Annals of the Deaf, 123*, 52-67.

Harris, P. L. (1989). *Children and emotion: The development of psychological understanding*. New York: Blackwell.

Harris, P. L. (1993). Understanding emotion. In M. Lewis & J. M. Haviland (Eds.), *Handbook of emotions* (pp. 237-246). New York: Guilford Press.

Hartup, W. W. (1983). Peer relations. In P. H. S. E. Mussen & E. M. V. E. Hetherington (Eds.), *Handbook of Child Psychology: Vol. 3. Socialization, personality, and social development* (pp. 103-196). New York: Wiley.

Heinberg, L. J. & Hayes, C. A. (2000). Social and emotional adjustment of young adults with cochlear implants: Addressing challenges and building strengths. *Volta Voices*, 19-23.

Higginbotham, J., & Baker, B. M. (1981). Social participation and cognitive play differences in hearing impaired and normally hearing preschoolers. *Volta Review, 83*, 135-149.

Hindley, P. (1997). Psychiatric aspects of hearing impairments. *Journal of Child Psychology and Psychiatry, 38*, 101-117.

Hollingshead, A. A. (1979). *Four-factor index of social status*. Unpublished manuscript. Yale University.

Hosie, J. A., Russell, P. A., Gray, C. D, Scott, C., & Hunter, N. (1998). The matching of facial expressions by deaf and hearing children and their production and comprehension of emotion labels. *Motivation and Emotion, 22*, 293-313.

Houston, D. M., & Pisoni, D. B. (2002, June). *Early speech perception and language development in normal-hearing and deaf infants following cochlear implantation.* Paper presented at the Research Symposium at the AG Bell Convention, St. Louis, MO.

Hubel, D. H., & Wiesel, T. N. (1970). The period of susceptibility to the physiological effects of unilateral eye closure in kittens. *Journal of Physiology, 206*, 419-436.

Illg, A., von der Haar-Heise, S., Goldring, J. E., Lesiniski-Schiedat, A., Battmer, R. D., & Lenarz, T. (1999). Speech perception results for children implanted with Clarion cochlear implants at the Medical University of Hanover. *Annals of Otology, Rhinology, and Laryngology, 108*, 93-98.

Izard, C. E., & Harris, P. (1995). Emotional development and developmental psychopathology. In D. Cicchetti & D. J. Cohen (Eds.), *Developmental psychopathology, Vol. 1: Theory and methods.* (pp. 467-503). New York: John Wiley & Sons.

Kaufman, A. S., & Kaufman, N. L. (1990). *Kaufman Brief Intelligence Test (K-BIT).* Circle Pines, MN: American Guidance Service, Inc.

Kirk, K. I., Eisenberg, L. S., Martinez, A. S., & Hay-McCutcheon, M. (1999). Lexical Neighborhood Test: Test-retest reliability and interlist equivalency. *Journal of the American Academy of Audiology, 10*, 113-123.

Kirk, K. I., Pisoni, D. B., & Osberger, M. J. (1995). Lexical effects of spoken word recognition by pediatric cochlear implant users. *Ear and Hearing, 16*, 470-481.

Klinnert, M. D. (1984). The regulation of infant behavior by maternal facial expression. *Infant Behavior and Development, 7*, 447-465.

Knudsen, E. I. (2004). Sensitive periods in the development of the brain and behavior. *Journal of Cognitive Neuroscience, 16*, 1412-1425.

Knutson, J. F., Boyd, R. C., Reid, J. B., Mayne, T., & Fetrow, R. (1997). Observational assessments of the interaction of implant recipients with family and peers; Preliminary findings. *Otolaryngology, Head and Neck Surgery, 117*, 196-207.

Koester, L. S. (1995). Face-to-face interactions between hearing mothers and their deaf or hearing infants. *Infant Behavior & Development, 18*, 145-153.

Koester, L. S., Brooks, L. R., & Karkowski, A. M. (1998). A comparison of the vocal patterns of deaf and hearing mother-infant dyads during face-to-face interactions. *Journal of Deaf Studies & Deaf Education, 3*, 290-301.

Koester, L., Karkowski, A., & Traci, M. (1998). How do deaf and hearing mothers regain eye contact when their infants look away? *American Annals of the Deaf, 143*, 5-13.

Koester, L. S., Papousek, H., & Smith-Gray, S. (2000). Intuitive parenting, communication and interaction with deaf infants. In P. E. Spencer & C. J. Erting (Eds.), *Deaf child in the family and at school: Essays in honor of Kathryn P. Meadow-Orlans* (pp. 55-71). Hillsdale, NJ: Erlbaum.

Kraus, N., Micco, A., Koch, D., McGee, T., Carrell, T., Wiet, R., Wengarten, C., & Sharma, A. (1993). The mismatch negativity cortical evoked potential elicited by speech in cochlear implant users. *Hearing Research, 65*, 118-24.

Lederberg, A. R. (1991). Social interaction among deaf preschoolers: The effects of language ability and age. *American Annals of the Deaf, 136*, 53-59.

Lederberg, A. R., Chapin, S. L., Rosenblatt, V., & Vandell, D. L. (1986). Ethnic, gender, and age preferences among deaf and hearing preschool peers. *Child Development, 57*, 375-386.

Lederberg, A. R., & Everhart, V. (1998). Communication between deaf children and their hearing mothers: the role of language, gesture, and vocalization. *Journal of Speech, Language, and Hearing Research, 41*, 887-899.

Lederberg, A. R., & Mobley, C. E. (1990). The effect of hearing impairment on the quality of attachment and mother-toddler interaction. *Child Development, 61*, 1596-1604.

Lederberg, A. R., & Prezbindowski, A. K. (2000). Impact of child deafness on mother-toddler interaction: Strengths and weaknesses. In P. E. Spencer & C. J. Erting (Eds.), *Deaf child in the family and at school: Essays in honor of Kathryn P. Meadow-Orlans* (pp. 73-92) Hillsdale, NJ: Erlbaum.

Lederberg, A. R., Rosenblatt, V., Vandell, D. L., & Chapin, S. L. (1987). Temporary and long-term friendships in hearing and deaf preschoolers. *Merrill-Palmer Quarterly, 33*, 515-533.

Lewis, M., & Michalson, L. (1983). *Children's emotions and moods: Developmental theory and measurement*. New York: Plenum Press.

Lewis, T., Ellemberg, D., Maurer, D., & Brent, H. P. (2000). Changes in spatial vision during middle childhood in patients treated for bilateral congenital cataract. *Investigative Opthalmology and Visual Science, 41*(S756).

Lewkowicz, D. J. (2000). The development of intersensory temporal perception: An epigenetic systems/limitations view. *Psychological Bulletin, 126*, 281-308.

Liegeois-Chavel, C., Musolino, A., Badier, J. M, Marquis, P., & Chavel, P. (1994). Evoked potentials recorded from the auditory cortex in man: Evaluation and topography of the middle latency components. *Electroencephalography and Clinical Neurophysiology, 92*, 204-214.

Loots, G., & Devise, I. (2003). An intersubjective developmental perspective on interactions between deaf and hearing mothers and their deaf infants. *American Annals of the Deaf, 148*, 295-307.

MacDonald, J., & McGurk, H. (1978). Visual influences on speech perception processes. *Perception & Psychophysics, 24*, 253-257.

Maestas y Moores, J. (1980). Early linguistic environment: Interactions of deaf parents with their infants. *Sign Language Studies, 26*, 1-13.

Maher, T. F. (1989). The psychological development of prelinguistic deaf infants. *Clinical Social Work Journal, 17*, 209-222.

Mann, L. F. (1984, June). *Play Behaviors of Deaf and Hearing Children.* Paper presented at the International Symposium on Cognition, Education, and Deafness, Washington, DC.

Markham, R., & Adams, K. (1992). The effect of type of task on children's identification of facial expressions. *Journal of Nonverbal Behavior, 16*, 21-39.

Marschark, M. (1993). *Psychological development of deaf children*. New York: Oxford University Press.

Massaro, D. W., & Cohen, M. M. (1983). Evaluation and integration of visual and auditory information in speech perception. *Journal of Experimental Psychology, 9*, 753-771.

Maurer, D., & Lewis, T. L. (1993). Visual outcomes after infantile cataract. In K. Simons (Ed.), *Early visual development: Normal and abnormal* (pp. 454-484). New York: Oxford University Press.

Maurer, D., & Lewis, T. L. (2001). Visual acuity and spatial contrast sensitivity: Normal development and underlying mechanisms. In C. Nelson & M. Luciana (Eds.), *Handbook of developmental cognitive neuroscience* (pp. 237-250). Cambridge, MA: MIT Press.

Maurer, D., Lewis, T. L., Brent, H. P., & Levin, A. V. (1999). Rapid improvement in the acuity of infants after visual input. *Science, 286*, 108-110.

McCrone, W. P. (1979). Learned helplessness and level of underachievement among deaf adolescents. *Psychology in the Schools, 16*, 430-434.

McDermott, H. (2004). Music perception with cochlear implants: A review. *Trends in Amplification, 8*, 49-82.

McGinnis, M. D., Orr, C. D., & Freutel, J. M. (1980). *Becoming a social being*. Whittier, California: Oralingua School for the Hearing Impaired.

McGurk, H , & MacDonald, J.. (1976). Hearing lips and seeing voices. *Nature, 264*, 746-47.

Meadow, K. P. (1976). Behavioral problems in deaf children. In H. S. Schlesinger & K. P. Meadow (Eds.), *Studies of family interaction, language acquisition, and deafness* (pp. 257-293). San Francisco, CA: San Francisco Final Report, Office of Maternal and Child Health, Bureau of Community Health Services.

Meadow, K. P. (1980). *Deafness and child development.* Berkeley, CA: University of California Press.

Meadow, K. P. & Tybus, R. J. (1979). Behavioral and emotional problems of deaf children: An overview. In L.J. Bradford & W.G. Hardy (Eds.), *Hearing and hearing impairment*. New York: Grune & Stratton.

Messenheimer-Young, T., & Kretschmer, R. R., Jr. (1994). "Can I Play?" A hearing-impaired preschooler's requests to access maintained social interaction. *Volta Review, 96*, 5-18.

Meyer, T. A., Svirsky, M. A., Kirk, K. I., & Miyamoto, R. T. (1998). Improvements in speech perception by children with profound prelingual hearing loss: Effects of device, communication mode, and chronological age. *Journal of Speech, Language, and Hearing Research, 41*, 646-858.

Mitchell, R. E., & Karchmer, M. A. (2004). Chasing the mythical ten percent: Parental hearing status of deaf and hard of hearing students in the United States. *Sign Language Studies, 4*, 138-163.

Miyamoto, R. T., Houston, D. M., Kirk, K. I., Perdew, A. E., & Svirsky, M. A. (2003). Language development in deaf infants following cochlear implantation. *Acta Oto-Laryngologica, 123*, 241-245.

Miyamoto, R. T., Kirk, K. I., Robbins, A. M., Todd, S., & Riley, A. (1996). Speech perception and speech production skills of children with multichannel cochlear implants. *Acta Otolaryngolica, 116*, 240-243.

Mogford, K. (1988). Oral language acquisition in the prelinguistically deaf. In D. Bishop & K. Mogford (Eds.), *Language development in exceptional circumstances* (pp. 110-131). New York: Churchill Livingstone.

Mondain, M., Sillon, M., Vieu, A. Lanvin, M., Tobey, E., & Uziel, A. (1997). Speech perception skills and speech production skills in French children with prelingual deafness and cochlear implants. *Archives of Otolaryngology, Head and Neck Surgery, 123*, 181-184.

Moore, J. K., Niparko, J. K., Miller, M. R., & Linthicum, F. H. (1994). Effect of profound hearing loss on a central auditory nucleus. *American Journal of Otology, 15*, 588-95.

Mumme, D. L. (1993). Rethinking social referencing: The influence of facial and vocal affect on infant behavior. (Doctoral dissertation, Stanford University, 1993). *Dissertation Abstracts International, 54*, 1124.

Mumme, D. L., Fernald, A., & Herrera, C. (1996). Infants' responses to facial and vocal emotional signals in a social referencing paradigm. *Child Development, 67*, 3219-3237.

Myklebust, H. R. (1960). *The psychology of deafness*. New York: Grune & Stratton, Inc.

Naatanen, R., & Alho, K. (1995). Generators of electrical and magnetic responses in humans. *Brain Topography, 7*, 315-20.

Naatanen, R. & Picton, T. (1987). The N1 wave of the human electric and magnetic response to sound: A review and analysis of the component structure. *Psychophysiology, 24*, 375-425.

National Institutes of Deafness and Other Communication Disorders, (2002). *Cochlear implants* (NIH Publication No. 00-4798). Bethesda, MD: Author.

Naugle. R. I., Chelune, G. J., & Tucker, G. D. (1993). Validity of the *Kaufman Brief Intelligence Test. Psychological Assessment, 5*, 182-186.

Nelson, C. A., & deHaan, M. (1996). A neurobehavioral approach to the recognition of facial expressions in infancy. In J. A. Russell (Ed.), *The psychology of facial expression* (pp.176-204). Cambridge, MA: Cambridge University Press.

Nelson, K. (1973). Structure and strategy of learning to talk. *Monographs of Society for Research in Child Development, 149*.

Newcomer, P. L., & Hammill, D. D. (1997) *Test of Language Development – Primary (TOLD-P: 3rd ed.)*. Austin, TX: Pro-Ed.

Newport, E. (1977). Motherese: The speech of mothers to young children. In N. Castellan, D. B. Pisoni & G. Potts (Eds.), *Cognitive theory* (Vol. 2). Hillsdale, NJ: Erlbaum.

Neville, H. J. (1995). Developmental specificity in neurocognitive development in humans. In M.S. Gazzaniga (Ed.), *The cognitive neuroscience* (pp.219-231). Cambridge, MA: MIT Press.

Neville, H. (1990). Intermodal competition and compensation in development; Evidence from studies of the visual system in congenitally deaf adults. *Annals of New York Academy of Sciences, 608*, 71-91.

Neville, H. J., & Bavelier, D. (1998). Neural organization and plasticity of language. *Current Opinion in Neurobiology, 8*, 254-58.

Neville, H. J., Bavelier, D, Corina, D., Rauschecker, J., Karni, A., Lalwani, A., Braun, A., Clark, V., Jezzard, P., & Turner, R. (1998). Cerebral organization for language in deaf and hearing subjects: Biological constraints and effects of experience. *Proceedings of the National Academy of Sciences, 95*, 922-29.

Neville, H. J., & Bruer, J. T. (2001). Language processing: how experience affects brain organization. In D. B. Bailey Jr., J. T. Bruer, F. J. Symons, & J. W. Lichtman (Eds.), *Critical thinking about critical periods* (pp. 151-171). Baltimore: Paul H. Brooks.

Neville, H. J., Coffey, S. A., Lawson, D. S., Fischer, A., Emmorey, K., & Bellugi, U. (1997). Neural systems mediating American Sign Language: Effects of sensory experience and age of acquisition. *Brain and Language, 57*, 285-308.

Neville, H., & Mills, D. (1997). Epigenesis of language. *Mental Retardation and Developmental Disabilities Research Reviews, 3*, 282-292.

Nicholas, J. G. & Geers, A. E. (1997). Communication of oral deaf and normally hearing children at 36 months of age. *Journal of Speech, Language & Hearing Research, 40*, 1314-1327.

NIH Consens Statement Online (1995, May 15-17). Cochlear implants in Adults and Children. 13(2):1-30. Retrieved March 15, 2005 from http://consensus.nih.gov/cons/100/100_statement.htm.

Nikolopoulos, T. P., O'Donoghue, G. M., & Archbold, S. M., (1999). Age at implantation: Its importance in pediatric cochlear implantation. *Laryngoscope, 109*, 595-599.

O'Donoghue, G. M., Nikolopoulos, T. P., Archbold, S. M., & Tait, M., (1998). Speech perception in children after cochlear implantation. *American Journal of Otology, 19*, 762-767.

Odom, P. B., Blanton, R. I., & Laukhuf, C. (1973). Facial expressions and interpretation of emotion-arousing situations in deaf and hearing children. *Journal of Abnormal Child Psychology, 1*, 139-151.

Papousek, M., Bornstein, M. H., Nuzzo, C., & Papousek, H. (1990). Infant responses to prototypical melodic contours in parental speech. *Infant Behavior and Development, 13*, 539-545.

Papousek, H., & Papousek, M. (1992). Beyond emotional bonding: The role of preverbal communication in mental growth and health. *Infant Mental Health Journal, 13,* 43-53.

Pisoni, D. B., Cleary, M., Geers, A., & Tobey, E. (1999). Individual differences in effectiveness of cochlear implants in children who are prelingually deafened. *Volta Review, 101*, 111-165.

Pollak, S. D., Cicchetti, D., Klorman, R., & Brumaghim, J. T. (1997). Cognitive brain event-related potentials and emotion processing in maltreated children. *Child Development, 68*, 773-787.

Pollak, S. D., Cicchetti, D., Hornung, K., & Reed, A. (2000). Recognizing emotion in faces: Developmental effects of child abuse and neglect. *Developmental Psychology, 36*, 679-688.

Pollak, S. D., Holt, L. L., & Wismer Fries, A. B. (2004). Hemispheric asymmetries in children's perception of nonlinguistic human affective sounds. *Developmental Science, 7*, 10-18

Pollak, S. D. & Kistler, D. J. (2002). Early experience is associated with the development of categorical representations for facial expressions of emotion. *Proceedings of the National Academy of Sciences,* 99, 9072-9076.

Ponton, C. W., Don, M., Eggermont, J. J., Waring, M. D., & Masuda, A. (1996). Maturation of human cortical auditory function: differences between normal-hearing children and children with cochlear implants. *Ear & Hearing, 17*, 430-437.

Ponton, C. W., Don, M., Eggermont, J. J., Waring, M. D., Kwong, B., & Masuda, A. (1996). Auditory system plasticity in children after long periods of complete deafness. *Neuroreport, 8*, 61-65.

Ponton, C. W. & Eggermont, J. J. (2001). Of kittens and kids: Altered cortical maturation following profound deafness and cochlear implant use. *Audiology & Neuro-otology, 6*, 363-80.

Ponton, C. W. & Eggermont, J. J., Don, M., Waring, M. D., Kwong, B., Cunningham, J., & Trautwein, P. (2000). Maturation of the mismatch negativity: Effects of profound deafness and cochlear implant use. *Audiology & Neuro-otology, 5*, 167-85.

Ponton, C. W., Moore, J. K., & Eggermont, J. J. (1999) Prolonged deafness limits auditory system developmental plasticity: Evidence from an evoked potentials study in children with cochlear implants. *Scandinavian Audiology Supplementum, 51*, 13-22.

Prezbindowski, A. K., Adamson, L. B., & Lederberg, A. R. (1998). Joint attention in deaf and hearing 22-month old children and their hearing mothers. *Journal of Applied Developmental Psychology, 19*, 377-387.

Putallaz, M., & Gottman, J. M. (1981). An interactional model of children's entry into peer groups. *Child Development, 52,* 986-994.

Putallaz, M., & Wasserman, A. (1989). Children's naturalistic entry behavior and sociometric status: A developmental perspective. *Developmental Psychology, 25*, 297-305.

Putallaz, M., & Wasserman, A. (1990). Children's entry behavior. In S. R. Asher & J. D. Coie (Eds.), *Peer rejection in childhood* (pp. 60-89). Cambridge, MA: Cambridge University Press.

Ribordy, S. C., Camras, L. A., Stefani, R., & Spaccarelli, S. (1988). Vignettes for emotion recognition research and affective therapy with children. *Journal of Clinical Child Psychology, 17*, 322-325.

Rieffe, C., Terwogt, M. M., & Smit, C. (2003). Deaf children on the causes of emotions. *Educational Psychology, 23*, 159-168.

Roberts, S. B., Brown, P. M., & Rickards, F. W. (1995). Social pretend play entry behaviors of preschoolers with and without impaired hearing. *Journal of Early Intervention, 20*, 52-83.

Rodda, M., & Grove, C. (1987). *Language, cognition, and deafness*. Hillsdale, NJ: Erlbaum.

Ryugo, D. K., Pongstaporn, T., Huchton, D. M, & Niparko, J. K. (1997). Ultrastructural analysis of primary endings in deaf white cats: morphologic alterations in endbulbs of Held. *Journal of Comparative Neurology, 385*, 230-244.

Saarni, C., Mumme, D. L., & Campos, J. J. (1998). Emotional development: Action, communication, and understanding. In W. Damon & N. Eisenberg (Eds.), *Handbook of Child Psychology: 5th Edition Social, emotional, and personality development* (Vol. 3). New York: Wiley & Sons.

Scherer, K. R. (1986). Vocal affect expression: A review and a model for future research. *Psychological Bulletin, 99*, 143-165.

Schirmer, B. R. (1989). Relationship between imaginative play and language development in hearing-impaired children. *American Annals of the Deaf, 134,* 219-222.

Schwartz, R. M., & Trabasso, T. (1984). Children's understanding of emotions. In C. E. Izard, J. Kagan & R. Zajonc (Eds.), *Emotions, cognition, and behavior* (pp. 409-437). Cambridge, MA: Cambridge University Press.

Sharma, A., Dorman, M. F., & Spahr, A. J. (2002). A sensitive period for the development of the central auditory system in children with cochlear implants: Implications for age of implantation. *Ear & Hearing, 23*, 532-39.

Sharma, A., Spahr, A., Dorman, M., & Todd, N. W. (2002). Early childhood implantation in children allows normal development of central auditory pathways. *Annals of Otology, Rhinology, and Laryngology, 111*, 38-41.

Sobol, M. P., & Earn, B. M. (1985). Assessment of children's attributions for social experiences: Implications for social skills training. In K. H. Schneider, K. H.

Rubin, & J. E. Ledingham (Eds.), *Children's peer relations: issues in assessment and intervention* (pp. 93-110). New York: Springer-Verlag.

Snitzer Reilley, J., McIntire, M. L., & Bellugi, U. (1990). Faces: The relationship between language and affect. In V. Volterra & C. J. Erting (Eds.), *From gesture to language in hearing and deaf children* (pp. 128-141). Berlin: Springer-Verlag.

Spencer, P. E. (1993). The expressive communication of hearing mothers and deaf infants. *American Annals of the Deaf, 138*, 275-283.

Spencer, P. E., & Deyo, D. A. (1993). Cognitive and social aspects of deaf children's play. *Psychological perspectives on deafness* (pp.65-91). Hillsdale, NJ: Erlbaum.

Spencer, P. E., & Gutfreund, M. (1990). Characteristics of "dialogues" between mothers and prelinguistic hearing-impaired and normally-hearing infants. *Volta Review, 92*, 351-360.

Spencer, P. E., & Lederberg, A. R. (1997). *Different Modes, Different Models; Communication and Language of Young Deaf Children and Their Mothers*. Baltimore: Brookes.

Sumby, W.H., & Pollack, I. (1954). Visual contribution to speech intelligibility in noise. *Journal of the Acoustical Society of America, 26*, 212-215.

Svirsky, M. A., Stallings, L. M., Ying, E., Lento, C. L., & Leonard, L. B. (2002). Grammatical morphologic development in pediatric cochlear implant users may be affected by the perceptual prominence of the relevant markers. *Annals of Otology, Rhinology & Laryngology, 111*, 109-113.

Tomblin, J. B., Spencer, L., Flock, S., Tyler, R., & Gantz, B. (1999). A comparison of language achievement on children with cochlear implants and children using hearing aids. *Journal of Speech, Language and Hearing Research, 42*, 497-511.

Tos, M., Hedergaard Jensen, J., Salomon, G., Jonsson, M. H., Post, I., & Thomsen, J. C. (2000). Cochlear implantation in Danish prelingually deaf children. *Acta Otolaryngolica Supplementum, 543*, 92-94.

Traci, M., & Koester, L. S. (2003). Parent-infant interactions: A transactional approach to understanding the development of deaf infants. In M. Marschark (Ed.), *Oxford handbook of deaf studies, language, and education* (pp. 190-202). New York: Oxford University Press.

Tye-Murray, N., Spencer, L., & Woodworth, G. G. (1995). Acquisition of speech by children who have prolonged cochlear implant experience. *Journal of Speech and Hearing Research, 38*, 327-337.

Tyler, R. S., Fryauf-Bertschy, H., Kelsay, D. M. R., Gantz, B. J., Woodworth, G. P., & Parkinson, A. (1997). Speech perception by prelingually deaf children using cochlear implants. *Otolaryngology, Head and Neck Surgery, 117*, 180-187.

van Wassenhove, V., Grant, K.W., & Poeppel, D. (2005).Visual speech speeds up the neural processing of auditory speech. *Proceedings of the National Academy of Science, 102*, 1181-1186.

Van Naarden, K., Decoufle, P., & Caldwell, K. (1999). Prevalence and characteristics of children with serious hearing impairment in metropolitan Atlanta, 1991-1993. *Pediatrics, 103*, 570-575.

Vandell, D. L., & George, L. B. (1981). Social interaction in hearing and deaf preschoolers: Successes and failures in initiations. *Child Development, 52*, 627-635.

Vorster, J. (1975). Mommy linguist: The case for motherese. *Linguistics, 37*, 281-312.

Vygtosky, L. S. (1976). Play and its role in the mental development of the child. In J.S. Bruner, A. Jolly, & K. Sylva (Eds.), *Play* (pp.537-559). New York: Basic Books.

Walden, T. A., & Field, T. M. (1982). Discrimination of facial expressions by preschool children. *Child Development, 53*, 1312-1319.

Walker, E. (1981). Emotion recognition in disturbed and normal children: A research note. *Journal of Clinical Psychology and Psychiatry, 22*, 263-268.

Walker-Andrews, A. S. (1997). Infants' perception of expressive behaviors: differentiation of multimodal information. *Psychological Bulletin, 121*, 437-456.

Walker-Andrews, A. S., & Lennon, E. (1991). Infants' discrimination of vocal expressions: Contributions of auditory and visual information. *Infant Behavior and Development, 14*, 131-142.

Waxman, R. P., Spencer, P. E., & Poisson, S. S. (1996). Reciprocity, responsiveness, and timing in interactions between mothers and deaf and hearing children. *Journal of Early Intervention, 20*, 341-355.

Wedell-Monnig, J., & Lumley, J. M. (1980). Child deafness and mother-child interaction. *Child Development, 51*, 766-774.

White, S., & White, R. (1988). The deaf imperative: Characteristics of maternal input to hearing impaired children. *Topics in Language Disorders, 4*, 38-49.

Widen, S. C. & Russell, J. A. (2003). A closer look at preschooler' freely produced labels for facial expressions. *Developmental Psychology, 39*, 114-128.

Wiesel, T. N., & Hubel, D. H. (1965). Extent of recovery from the effects of visual deprivation in kittens. *Journal of Neurophysiology, 28*, 1060-1072.

Williams, K. T. (1997). *Expressive Vocabulary Test*. Circle Pines, MN: American Guidance Service, Inc.

Wood, D., Wood, H., Griffiths, A., & Howarth, I. (1986). *Teaching and talking with deaf children*. New York: Wiley.

Young, G. A., & Killen, D. H. (2002). Receptive and expressive language skills of children with five years of experience using a cochlear implant. *Annals of Otology, Rhinology & Laryngology, 111,* 802-810.

Zahn-Waxler, C., & Radke-Yarrow, M. (1982). The development of altruism: Alternative research strategies. In N. Eisenberg (Ed.), *The development of prosocial behavior*. San Diego, CA: Academic Press.

Zarbatany, L., & Lamb, M. E. (1985). Social referencing as a function of information source: mothers versus strangers. *Infant Behavior and Development, 8*, 25-33.

Zheng, W., & Knudsen, E. I. (1999). Functional selection of adaptive auditory space map by gaba (sub a)-mediated inhibition. *Science, 284,* 962-965.