Chapter 3
Cognitive Development

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It is well established that childhood hearing loss limits children's ability to hear the language in their auditory environment and has a negative impact on language acquisition. Without timely and appropriate intervention, children who are deaf or hard of hearing (D/HH) might have limited language proficiency that also impacts their ability to learn in school and engage in successful social interactions. Often, the focus of intervention is ensuring adequate access to the speech spectrum and promoting language development with the belief that once children have age-appropriate language skills, performance in all other domains will be age appropriate. However, research conducted in the last two decades indicates that children who are D/HH who experience early auditory deprivation and have delayed language development continue to demonstrate delays and deficits in certain areas of cognition. This chapter will provide an overview of the deficits that have been observed in cognitive development, factors that contribute to these deficits, and how teachers of the deaf might address these deficits in their classrooms.

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Cognition

The study of cognition is the study of how human beings receive, process, integrate, and respond to information. Attention, memory, executive function, convergent thinking, and divergent thinking are some of the cognitive processes that have been studied in children with and without disabilities. These cognitive processes are important for learning in and out of the classroom. In fact, the common core standards were designed to help students develop "critical-thinking, problem-solving, and analytical skills" necessary for higher education and employment (http://www.corestandards.org/). So in addition to teaching infants, toddlers, and children to listen and speak, teachers of the deaf are also responsible for teaching them to observe, describe, compare, classify, sequence, analyze, evaluate, interpret, predict, summarize, hypothesize, imagine, and create.

Cognitive development has been studied in the context of several theories of cognitive development. Piaget's development stage theory posited that a combination of maturation and nonlinguistic experiences during early childhood shape an individual's cognitive development. He proposed that children are organizing the world around them through mental operations that become more complex and adult-like by adolescence. Children progress from the sensorimotor stage of physical exploration to the preoperational stage of creating mental representations and engaging in role playing to the concrete and formal operational stages involving information organization, perspective taking, and reasoning.

Vygotsky proposed that children develop their thinking skills through social interactions with a tutor or guide who can model behaviors or strategies of organizing knowledge and information. He also proposed that children learn best when they are taught within their "zone of proximal development" with a focus on emerging skills rather than skills that are too advanced. His theory also emphasized language as a tool of sharing and organizing knowledge and thoughts. A deeper understanding of each of these theories and how they influence cognitive development in children is important but beyond the scope of this chapter. As readers of this chapter explore theories of cognitive development, they should examine how congenital hearing loss might impact cognitive development. For example, how might hearing loss impact the sensorimotor stage of development, or how might hearing loss impact the use of language as a tool for thinking? These reflections will be helpful when determining how you could teach a particular topic, behavior, or skill to your students.

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In this chapter, we will examine a few cognitive processes that have a significant impact on cognitive and language development of children who are deaf or hard of hearing. ***Executive function*** is a broad construct that is important for conscious control of thought and action (Zelazo & Müller, 2010) and is reflected in an individual's ability to attend to tasks, inhibit responses, create and follow rules, and solve problems. It is also associated with proficiency in reading, math (Blair & Razza, 2007), and social skills (Blakemore & Choudhury, 2006). The construct of working ***memory***—often included as a part of executive function—is the ability to receive and manipulate or "act on" the information that is provided. It has been observed that certain executive function and memory skills are "domain general" (i.e., apply to skills not just from the cognition domain but also from the motor domain and language domain, such as sequencing words, symbols, and actions; Pisoni, Conway, Kronenberger, Henning, & Anaya, 2010). Additionally, certain cognitive skills are also considered to be "language mediated" (i.e., individuals use language to implement the cognitive skills). One common example is a preschooler's self-talk during problem solving.

In addition to core cognitive constructs of executive function and memory, convergent and divergent thinking are critical for thinking and learning successfully. ***Convergent thinking*** is the exercise of processing multiple pieces of information to arrive at a single piece of information (i.e., answering the question, "*How are the sun, an orange, and a ball alike*?" with the response, "*They are round*"). ***Divergent thinking*** is the exercise of processing one prompt or piece of information to arrive at multiple exemplars or responses (i.e., answering the question, "*Name three things that are yellow,*" with the response, "*Sunflower, egg yolk, banana*").

Another aspect of cognition that is relevant for teachers is ***social cognition*** (i.e., applying cognitive skills to understand and participate in social situations). Theory of mind (i.e., an understanding of other's emotions, beliefs, and perspective) is an important aspect of social cognition (de Villiers & de Villiers, 2012; Garfield, Peterson, & Perry, 2001).

Cognitive psychologists have proposed theories to understand and explain cognitive development. Two that are often implemented in educational settings are Piaget's development stage theory and Vygotsky's theory of cognitive development.

Cognitive Development

In the first few years of life, typically developing children progress from basic cognitive skills, such as understanding cause and effect (e.g., the baby discovers that the toy lights up when Daddy pushes the button and reaches to push the button herself) and object permanence (e.g., the baby starts to learn that his favorite toy is still there even if he doesn't see it), to more complex skills, such as classification (e.g., separating indoor toys and outdoor toys), simple problem solving (e.g., fixing a ripped book with tape), and recalling sequences (e.g., remembering a set of instructions for an art project; see developmental milestones checklists available from CDC https://www.cdc.gov/ncbddd/actearly/milestones/). These skills develop naturally when children engage in age-appropriate play activities. Often very little direct instruction in these skills is required for typically-developing children.

It is important to note that cognitive skills are developing in the context of other skills and abilities. For example, a baby reaching out to push the button on a light-up toy is a combination of skills in the cognition domain (understanding cause and effect) and motor domain (reaching and pointing). If motor development is delayed or if severe visual impairment does not allow the baby to see the toy lighting up, development of the cognitive skill of understanding cause and effect in this context might be limited or delayed. Similarly, following instructions for an art activity might be limited by deficits in the language domain that affect understanding of vocabulary and concepts necessary to complete the activity.

Additionally, the experiences of the child and the input received from adults and peers can also influence cognitive development. For example, if a toddler has minimal contact with a caregiver or minimal exposure to developmentally appropriate activities, she might show delays or deficits in skill development. A deficit or delay in one domain caused by a sensory impairment (e.g., visual impairment, hearing loss) or developmental disorder (e.g., cerebral palsy, autism) can create a developmental dysynchrony across domains. This dysynchrony should be understood and addressed to minimize long-term impact.

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In the context of children who are D/HH, several factors might influence development of cognitive skills:

Child Factors

Characteristics related to the child's hearing loss, presence of other disabilities, overall development, and intervention.

Caregiver Factors

Characteristics of parental engagement as well as quality and quantity of input provided by parents, caregivers, and interventionists.

Environmental Factors

Includes situations, stresses, and supports present in the child's environment.

Research on the precise impact of these factors individually and in combination is ongoing. However, examining the contribution of each of these factors to overall development—and cognitive development in particular—is important for teachers of the deaf working with young children.

Hearing loss limits a child's access to her auditory environment, which negatively impacts the process of language acquisition. The extent to which hearing loss affects development might be dependent on how quickly and how well the hearing loss is managed. Researchers have discovered that lack of stimulation to the auditory cortex in the first few years of life can alter brain development (Gilley, Sharma, & Dorman, 2008; Kral & Sharma, 2012; Sharma, Nash, & Dorman, 2009). The differences in neural responses to sound in children with and without hearing loss have been attributed to lack of auditory input. If children who are D/HH receive auditory input (through a cochlear implant) before 3.5 years of age after a period of auditory input, their responses to the presence of sound become similar to children with normal hearing (Sharma et al., 2009).

Another fundamental process that might be disrupted by lack of early auditory input is audiovisual integration. Speech perception is an audiovisual activity that involves listening to speech and watching the talker's face to integrate auditory and visual cues present in a spoken language (Kuhl & Meltzoff, 1982; Lewkowicz, 2010; Sumby & Pollack, 1954). Infants who have normal hearing rely on auditory and visual cues when learning the home language(s). Individuals with hearing loss demonstrate differences in their ability to integrate auditory and visual cues in the context of speech and spoken language. It has been proposed that deficits in these fundamental developmental processes might have a long-term impact on language learning and processing.

Teachers of the deaf would benefit from understanding the underlying cognitive constructs, challenges that children who are D/HH might face, and how they manifest in their learning and behavior.

These developmental processes can be further impacted by the presence of other sensory or neurological deficits. The presence of visual impairment in addition to hearing loss can significantly affect development of audiovisual integration for speech perception and how the child engages with the environment in general. The presence of a neurological disorder, such as cerebral palsy in which motor deficits might impede cognitive and language development or autism spectrum disorder in which the desire to engage in social interaction is diminished, can further impact development.

In addition to the characteristics of the child, caregiver characteristics and environmental factors also influence cognitive development. Child development across domains is influenced by the child's experiences and inputs received. The quality and quantity of language input can have an impact on children's vocabulary development. Children who receive less and/or poor-quality input often have smaller vocabularies than their peers (Hart & Risley, 1995; Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002). Children who are D/HH typically receive less language input depending on how consistently they wear their hearing aids and/or cochlear implants.

Additionally, they might receive limited input for other reasons, such as caregivers' hesitance or lack of knowledge regarding providing rich input or living in an impoverished environment where exposure to developmentally-appropriate activities is limited. In other words, for a variety of reasons, many children who are D/HH might not have adequate opportunities for developing cognitive skills. For children who are D/HH, quality and quantity of input can sometimes be limited by the child's language proficiency. Often the focus of intervention might be learning words of objects and action. Certain types of activities or conversations might not be conducted, because the child doesn't have enough language to understand and respond. However, activities that promote cognition can also support language development. Strategies to target cognition and language development through age-appropriate activities will be discussed later in this chapter.

Impact of Hearing Loss on Cognitive Development

Over the last few decades, the impact of auditory and language deprivation on neurocognitive development and psychosocial development has been an area of growing research. It has been widely observed that having age-appropriate language skills does not guarantee age-appropriate skills in other domains. It has been proposed that deficits in cognitive skills might in fact be related to an earlier period of auditory and language deprivation and not the child's current language proficiency (Pisoni et al., 2010). Teachers of the deaf would benefit from understanding the underlying cognitive constructs, challenges that children who are D/HH might face, and how they manifest in their learning and behavior.

Researchers are interested in understanding if and how hearing loss impacts processes that do not rely on or require language and are applicable across multiple domains (domain-general skills) but are "executive-organizational-integrative" processes (Beer, Pisoni, & Kronenberger, 2009; Pisoni et al., 2010). For example, sequencing is a process that is present in verbal as well as nonverbal forms (e.g., repeating a series of words, executing a series of actions). In line with the hypothesis that early auditory and language deprivation might impact cognitive development, Conway and colleagues proposed the "auditory scaffolding hypothesis," which posited that early auditory experience of processing speech as a temporal and sequential signal contributes to learning sequence processing across verbal, nonverbal, and motor domains (Conway, Pisoni, & Kronenberger, 2009. Deficits in auditory, visual, and motor sequencing demonstrated by children who are D/HH suggest that early auditory deprivation disrupts development of sequence processing (Conway et al., 2009). This finding is important for teachers, because sequence processing is a prerequisite to learning a variety of skills, including learning the vocabulary and grammar of a language and motor planning for writing letters. Converging evidence indicates that children who are D/HH who use cochlear implants demonstrate deficits in working memory, fluency, and inhibition. Additionally, deficits in these skills can manifest as deficits in academic achievement as well as social competence. The ability to receive, retain, and recall information is important for learning.

Working memory and the ability to receive, retain, and *manipulate* information has been often evaluated using the digit span task in which children are asked to repeat sequences of numbers in the reverse order that they were presented. Multiple studies have demonstrated that cochlear implant users demonstrate deficits compared to their hearing peers (Houston et al., 2012; Kronenberger, Pisoni, Harris, et al., 2013; Pisoni, Kronenberger, Roman, & Geers, 2011). These deficits have been observed in long-term users who were early implanted, indicating that duration of deafness and duration of auditory experience might not contribute much to development of working memory skills. Additionally, there is a lot of variability in working memory abilities across children suggesting that some children have age-appropriate working memory skills—demonstrating that it is possible to develop age-appropriate working memory skills.

Responses of parent questionnaires, such as the Behavior Rating Inventory of Executive Function, are aligned with findings from experimental tasks and also indicate deficits in working memory (Beer, Kronenberger, & Pisoni, 2011). Given that hearing loss negatively impacts language development, some studies have examined memory for nonverbal stimuli, such as motor sequences (finger-tapping) and visual-spatial sequences (series of lights on a grid), and discovered that children who are D/HH were deficient—reinforcing the hypotheses that memory for sequences is impaired across domains for children who are D/HH, presumably due to limited exposure to auditory scaffolding (Conway et al., 2009).

Deficits in working memory and difficulty with learning sequences are correlated with poor speech and language outcomes (Conway et al., 2009; Houston et al., 2012). It is easy to imagine how a student who has difficulty with listening to and remembering information might struggle in the classroom with routine activities, such as listening comprehension, solving story problems using mental math, and following a set of complex directions. Research on evaluating interventions that might facilitate development of working memory are ongoing (Kronenberger, Pisoni, Henning, Colson, & Hazzard, 2011).

It is easy to imagine how a student who has difficulty with listening to and remembering information might struggle in the classroom with routine activities.

Another area that is examined is fluency and speed of processing information. Children who used cochlear implants were less proficient than their hearing peers when performing tasks requiring verbal fluency (naming words), visual fluency (identifying or matching pictures), and motor fluency (drawing symbols; Kronenberger, Pisoni, Henning, & Colson, 2013). Anecdotal data from parents and teachers often suggest that children who are D/HH need extra time to process a question or formulate an answer. We can speculate that these deficits in fluency might contribute to needing more time to process information.

A third area where deficits have been observed is executive function, especially inhibition, which is the ability to suppress automatic responses to follow a certain set of rules. The Stroop Word Color test is often used to examine the ability to substitute a familiar or over-rehearsed response, such as names of colors and numbers, with another response (Kronenberger, Pisoni, Henning, et al., 2013; Pisoni et al., 2010). Children who use cochlear implants demonstrate deficits in the ability to inhibit a response (i.e., override an automatic response). We can speculate that this deficit might be manifested in difficulty with learning new information that requires overriding previously learned information. Additionally, deficits in inhibition might negatively affect social interactions. (For additional readings on this topic, review the research report *The Ear is Connected to the Brain*; Houston et al., 2012.)

In summary, childhood hearing loss alters a child's sensory experience and can impact domain-specific skills, such as vocabulary and grammar development, but also domain-general skills, such as sequencing and memory. Deficits in executive function as well as deficits in integrating and processing information have been observed in children who are D/HH. These deficits often manifest as poor performance on academic tasks. The next step is to explore how teachers might facilitate cognitive development and address cognitive deficits.

Supporting Cognitive Development in Early Intervention & the Classroom

Teachers of the deaf work with a diverse group of children who are D/HH. Some children might have received timely and effective intervention and are "closing the gap," while others might have experienced setbacks, such as late diagnosis, minimal parental engagement, presence of additional disabilities, or delayed intervention. The cognitive development of each child in your care might be at a different stage based on the child's intervention so far. Unfortunately, there isn't a simple answer to how teachers can evaluate and facilitate development of cognitive skills. However, through a combination of strategies that will also support development of listening and spoken language skills, teachers can help their students develop cognitive skills or identify compensatory strategies (see *Table 1*).

Table 1
Strategies to Support Cognitive Skill Development

Strategy 1: Familiarize yourself with age-appropriate cognitive skills for your students.

Refer to developmental checklists and grade-level learning standards. However, do not base your expectations on chronological age or grade level alone. Take into account the child's hearing age as well as language proficiency. For example, even though by age 4, children are expected to engage in cooperative problem solving, a child with hearing loss who has the language skills of a 2-year-old will have difficulty achieving this goal—not because of her inability to problem solve but her inability to communicate with her peers about problem solving. Similarly, a fourth-grade student who reads and writes at a second-grade level might have trouble summarizing a story due to difficulties with the skill of summarizing as well as a limited proficiency with reading and writing. The Cottage Acquisition Scales for Listening, Language, and Speech (CASLLS) are a useful resource for monitoring a child's cognition, play, listening, and language development.

Strategy 2: Identify the cognitive skills required in the various activities your students participate in.

Age-appropriate play activities and routine classroom activities rely on particular language and cognitive skills (see chart below).

Subject	Activity	Cognitive Skills
Math	• Rote counting, math facts. • Learning about 2D & 3D shapes.	• Memory. • Observing shapes to identify features, classifying based on features.
Science	• Creating a chart of living & nonliving things. • Science experiment.	• Observing features, applying principles/rules, classifying. • Observing, planning, hypothesizing, analyzing.
History & Geography	• Creating a diorama. • Examining "what if" situations for historical events.	• Planning, executing a sequence of actions. • Analyzing, predicting.

Strategy 3: Observe your students and identify if any deficits are attributable to listening skills, limited language proficiency, and/or underdeveloped cognitive skills.

Identifying which skill needs to be addressed is not easy and requires some observation and analysis on the teacher's part. For example, a student who struggles with retelling a sequence-based story (e.g., Very Hungry Caterpillar, Little Red Hen) might have difficulty with remembering the sequence of events and/or formulating the sentences to retell the story. One way to further evaluate the student's skill would be to provide the student with visuals of the sequence and ask to retell. If the student retells the story successfully, it is indicative of his difficulty with remembering a sequence of events. If he doesn't benefit from the visuals, additional probing is required, such as asking him to retell a story or event that is less complicated or more familiar. Observing student performance on activities that do and don't require certain cognitive skills can provide insight into their language and cognitive abilities.

Strategy 4: Evaluate how your lessons and teaching strategies promote development of cognitive skills.

This exercise will help you see that there might be several skills you have been targeting all along! The next step is to be more mindful and explicit about those targets and ensure that you are addressing a wide variety of skills. For example, you might be working on making predictions—"What will happen next?"—every time you read a story but might not be targeting making deductions—"*Why do you think the boy's hair is wet?*" The following prompts might be useful in helping you evaluate your teaching:

Does the language I use promote thinking?

Often, there is an emphasis on teaching the labels for objects and actions. While that is most definitely the first step in acquiring a foundation for language, the next step should be using the language to promote thinking. Asking a variety of questions can be a useful technique.

Am I asking questions that provide opportunities to use a variety of cognitive skills?

In an effort to build vocabulary, it is easy to ask questions about the here and now. Questions about here and now can promote cognitive skills of observing—describing what is being seen. It is important to ask questions beyond what is observable, such as questions that prompt comparing—"*Did you have a yellow cake at your birthday party, like the girl in the story?*" While the answer might be a simple yes or no, the skills that are used here are that of understanding the question, recalling the birthday event, comparing personal experience with the one in the story, and coming to a conclusion. The chart below lists some cognitive skills and the prompts/question you can use to foster these skills.

Cognitive Skill	Prompts/Questions
Observing	What do you see?
Comparing	How are they alike? ■ How are they different? ■ Are these similar?
Classifying & Categorizing	Which ones go together? ■ How can we group these (objects)?
Organizing, Computing, & Analyzing Data	How many types of (supercategory) do you have? ■ Which one has the most? ■ Which one has the least? ■ Which ones are equal? ■ How many (objects) do you have that are greater/larger/heavier than?
Sequencing	What happened before? ■ What happened after? ■ What was first/second?
Deducing & Inferring	How does the girl feel? ■ Why? ■ How do you know? ■ Why is the boy's hair wet? ■ What does it tell us about the weather?
Predicting	What will happen next? ■ What would happen if?
Hypothesizing	We know that (principle). What would happen if?

Strategy 5: Develop activities that focus on specific cognitive skills while addressing listening and language targets.

Once you have identified the cognitive skills that are developmentally appropriate for your students and your students' current proficiency, you can incorporate cognitive skills into your auditory and language activities. The following are some sample activities for key cognitive skills.

Memory

Many children who are D/HH have deficits in memory. Working memory interventions haven't been particularly beneficial, and it is unknown if practicing strategies for remembering sequences or separate pieces of information is beneficial. However, implementing activities that incorporates memory practice in a natural manner can allow children to practice and develop compensatory strategies. Playing a simple game of "telephone" can help students practice attending to and retaining information. Learning an action song, like the *Macarena*, and doing the actions in a forwards then backwards sequence can provide practice with motor sequencing.

Observing

Children need to practice carefully observing various features using all of their senses. Observation activities can provide natural opportunities to talk about nouns and adjectives. The chart below lists activities that are appropriate for preschoolers.

Activity	Observation/Dialog
Present the students with a small plant.	***Teacher:*** What do you see? ***Student:*** I see hair. ***Teacher:*** Yes, those have a special name. They are called "roots." They help the plant get water from the dirt.
Pass the plant to the next student. This interaction can also promote social interactions.	***Student:*** I see green circles. ***Teacher:*** Yes, those are called "leaves." And look, this leaf is longer. The shape is like a circle but longer. It is an oval.
Also ask students to draw the plant and help them label.	This will promote cognition, fine motor, and language skills.
Each student's drawing can then be made into a puzzle.	This will help students practice part-to-whole concepts.
The teacher could further extend this as an auditory activity with language targets.	For example, "Find the roots," or "Find the part that helps the plant get water from the dirt."

Classifying Objects & Analyzing Data

Students are expected to be able to sort, categorize, compare, and compute data. These skills do not require very advanced language skills and can be incorporated in routine activities.

The purpose of the activity in the chart below is to categorize objects based on a feature—shape, color, function, etc. This activity, while focused on cognition, allows the teacher to target concepts and language important for math—sort, most, least, column, etc.

Activity	Observation/Dialog
During snack, give each student graph paper with large squares; then serve Frootloops or colored Goldfish.	***Teacher:*** Sort the snack into groups. "Sort" means make groups of things that go together.
If students do not have enough language to follow these directions, demonstrate and teach the target language. Allow students to work independently.	***Teacher:*** Student 1, tell me what groups you made. ***Student 1:*** I have red, yellow, blue, orange. ***Teacher:*** Great. You sorted by color. ***Student 2:*** I sorted by color too. ***Teacher:*** Great! Now can you organize it in a column?
Help with creating a bar graph.	***Teacher:*** Tell me which color do you have the most? ***Student 2:*** The red ones. ***Teacher:*** Student 3, which color do you have the most of and which color do you have the least of? ***Student 3:*** Most of my Frootloops are green; only a few are blue.
Once students are familiar with concept, make task harder by serving a snack with more features (i.e., Chex Mix), sorting by shape, texture, salty/not salty, solid/hole in middle, etc.	Such an activity can also provide opportunities for students to share their thinking (e.g., "I sorted based on texture").

Deducing & Inferring

Using information that has been provided to deduce or infer other information is important for academic tasks as well as social interactions. The activity in the chart below provides opportunities for practicing inferring a person's emotions and thoughts. As can be seen in the example, certain activities provide opportunities to target multiple cognitive skills and language structures, such as compound and complex sentences, and mental state verbs.

Activity	Observation/Dialog
Choose a picture book in which characters go through a series of emotions (e.g., *Flora's Surprise* by Debi Gliori).	***Teacher:*** What do you see on this page? *(Observation)* ***Student:*** Flora and her brothers and sisters. ***Teacher:*** How do you think they feel? *(Making an inference)* ***Student:*** Excited! ***Teacher:*** How do you know they are excited? *(Making a deduction)* ***Student:*** They have big smiles and big eyes. ***Teacher:*** What do you think they are excited about? Look for some clues on this page. ***Student:*** I see seeds. Maybe they are excited about planting their flowers. ***Teacher:*** *(Turn page)* You are right. They are planting flowers and vegetables. But look, Flora is planting a brick! She wants it to grow into a house. Do you think it will grow into a house? ***Student:*** No, bricks are nonliving things. They cannot grow. *(Predicting, applying principles)* ***Teacher:*** Look at this page. How does Flora feel now? ***Student:*** She is sad. ***Teacher:*** Why do you think she is sad? ***Student:*** Because the brick is not growing.

Strategy 6: Monitor progress in a systematic manner.

There aren't many tests that can be administered to children to evaluate specific cognitive abilities, but you might be able to create a set of tasks for your students. For example, when working with young children, it is important to evaluate their ability to sort objects based on features. You can have a box with multiple objects and tell the child to make two groups—maybe the child will sort by color, shapes, function, etc. For a child who has limited language abilities, it is important that the concept of sorting has been explored and demonstrated beforehand. To evaluate cognitive skills, you might use a picture of a scene from books, such as *1001 Things to Spot on the Farm*, and develop a set of questions that require students to observe, infer, predict, etc. Asking the same questions at the end of every grading period can provide insight into development of these cognitive skills, as well as the language skills required to respond to the questions.

However, it is possible that, even with extensive efforts to develop cognitive skills, children who are D/HH continue to demonstrate deficits. Identifying learning strategies that can compensate for these deficits will be important. For students who have difficulty remembering sequences or manipulating multiple pieces of information, providing visual strategies, such as counting the number of items on fingers or writing/drawing the information, could be beneficial. Using graphic organizers, such as webs or Venn diagrams, can help with practicing describing, categorizing, etc.

Summary

In this chapter, we have reviewed cognitive development of children who are D/HH and factors that contribute to this development. Even though cognitive development hasn't been extensively studied as language development of children who are D/HH, it is clear that deficits in cognition often go hand in hand with deficits in language. Teachers of the deaf have to take into account overall development and address needs of their students in all domains, because deficits in one domain often impact achievement in other domains. The strategies of identifying cognitive skills that are age-appropriate and teaching them through natural, language-rich activities could be beneficial for many students. Teachers might not be able to change their students' medical and educational history and prevent cognitive deficits from occurring, but they can certainly make a conscious effort to remediate and reduce the impact of any cognitive deficits.

Teachers of the deaf have to take into account overall development and address needs of their students in all domains, because deficits in one domain often impact achievement in other domains.

Suggested Readings

Pisoni, D. B., Conway, C. M., Kronenberger, W. G., Henning, S. C., & Anaya, E. M. *Executive function, cognitive control, and sequence learning in deaf children with cochlear implants.*

Houston, D. M., Beer, J., Bergeson, T. R., Chin, S. B., Pisoni, D. B., & Miyamoto, R. T. (2012, June). The ear is connected to the brain: Some new directions in the study of children with cochlear implants at Indiana University. *Journal of the American Academy of Audiology*, *6*, 446–463. doi: 10.3766/jaaa.23.6.7

Resources

These videos from the Association of American Medical Colleges and the Khan Academy provide overviews of the topics:

- Theories of language and cognition, https://www.youtube.com/watch?v=RgvmKfvCwps
- Piaget, https://www.youtube.com/watch?v=Jt3-PIC2nCs
- Vygotsky, https://www.youtube.com/watch?v=-p_-0n2f35o

References

Beer, J., Kronenberger, W. G., & Pisoni, D. B. (2011). Executive function in everyday life: Implications for young cochlear implant users. *Cochlear Implants International*, *12*, S89–S91. https://doi.org/10.1179/146701011X13001035752570

Beer, J., Pisoni, D. B., & Kronenberger, W. (2009). Executive function in children with cochlear implants: The role of organizational-integrative processes. *Volta Voices*, *16*(3), 18–23.

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development*, *78*(2), 647–663. https://doi.org/10.1111/j.1467-8624.2007.01019.x

Blakemore, S.-J., & Choudhury, S. (2006). Development of the adolescent brain: Implications for executive function and social cognition. *Journal of Child Psychology and Psychiatry*, *47*(3-4), 296–312. https://doi.org/10.1111/j.1469-7610.2006.01611.x

Conway, C. M., Pisoni, D. B., & Kronenberger, W. G. (2009). The importance of sound for cognitive sequencing abilities. *Current Directions in Psychological Science*, *18*(5), 275 –279. https://doi.org/10.1111/j.1467-8721.2009.01651.x

de Villiers, P. A., & de Villiers, J. G. (2012). Deception dissociates from false belief reasoning in deaf children: Implications for the implicit versus explicit theory of mind distinction. *British Journal of Developmental Psychology*, *30*(1), 188–209. https://doi.org/10.1111/j.2044-835X.2011.02072.x

Garfield, J. L., Peterson, C. C., & Perry, T. (2001). Social cognition, language acquisition, and the development of the theory of mind. *Mind & Language*, *16*(5), 494–541. https://doi.org/10.1111/1468-0017.00180

Gilley, P. M., Sharma, A., & Dorman, M. F. (2008). Cortical reorganization in children with cochlear implants. *Brain Research*, *1239*, 56–65.

Hart, B., & Risley, T. (1995). *Meaningful differences in the everyday experience of young American children*. Baltimore, MD: Brookes Publishing Company.

Houston, D. M., Beer, J., Bergeson, T. R., Chin, S. B., Pisoni, D. B., & Miyamoto, R. T. (2012). The ear is connected to the brain: Some new directions in the study of children with cochlear implants at Indiana University. *Journal of the American Academy of Audiology*, *23*(6), 446–463. https://doi.org/10.3766/jaaa.23.6.7

Huttenlocher, J., Vasilyeva, M., Cymerman, E., & Levine, S. (2002). Language input and child syntax. *Cognitive Psychology*, *45*(3), 337–374. https://doi.org/10.1016/S0010-0285(02)00500-5

Kral, A., & Sharma, A. (2012). Developmental neuroplasticity after cochlear implantation. *Trends in Neurosciences*, *35*(2), 111–122. https://doi.org/10.1016/j.tins.2011.09.004

Kronenberger, W. G., Pisoni, D. B., Harris, M. S., Hoen, H. M., Xu, H., & Miyamoto, R. T. (2013). Profiles of verbal working memory growth predict speech and language development in children with cochlear implants. *Journal of Speech, Language, and Hearing Research*, *56*(3), 805–825. https://doi.org/10.1044/1092-4388(2012/11-0356)

Kronenberger, W. G., Pisoni, D. B., Henning, S. C., & Colson, B. G. (2013). Executive functioning skills in long-term users of cochlear implants: A case control study. *Journal of Pediatric Psychology*, *38*(8), 902–914. https://doi.org/10.1093/jpepsy/jst034

Kronenberger, W. G., Pisoni, D. B., Henning, S. C., Colson, B. G., & Hazzard, L. M. (2011). Working memory training for children with cochlear implants: A pilot study. *Journal of Speech, Language, and Hearing Research*, *54*(4), 1182–1196. https://doi.org/10.1044/1092-4388(2010/10-0119)

Kuhl, P. K., & Meltzoff, A. N. (1982). The bimodal perception of speech in infancy. *Science*, *218*(4577), 1138–1141. https://doi.org/10.1126/science.7146899

Lewkowicz, D. J. (2010). Infant perception of audio-visual speech synchrony. *Developmental Psychology*, *46*(1), 66–77. https://doi.org/10.1037/a0015579

Pisoni, D. B., Conway, C. M., Kronenberger, W. G., Henning, S. C., & Anaya, E. M. (2010). Executive function, cognitive control, and sequence learning in deaf children with cochlear implants. In *Deaf Studies, Language, and Education* (pp. 439–457). New York, NY: Oxford University Press.

Pisoni, D. B., Kronenberger, W. G., Roman, A. S., & Geers, A. E. (2011). Measures of digit span and verbal rehearsal speed in deaf children after more than 10 years of cochlear implantation. *Ear and Hearing*, *32*, 60S–74S. https://doi.org/10.1097/AUD.0b013e3181ffd58e

Sharma, A., Nash, A. A., & Dorman, M. (2009). Cortical development, plasticity, and reorganization in children with cochlear implants. *Journal of Communication Disorders*, *42*(4), 272–279. https://doi.org/16/j.jcomdis.2009.03.003

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

Zelazo, P. D., & Müller, U. (2010). Executive function in typical and atypical development. In U. Goswami (Ed.), *The Wiley-Blackwell handbook of childhood cognitive development, second edition* (pp. 574–603). Wiley-Blackwell. Retrieved from http://onlinelibrary.wiley.com.proxy.library.vanderbilt.edu/doi/10.1002/9781444325485.ch22/summary.