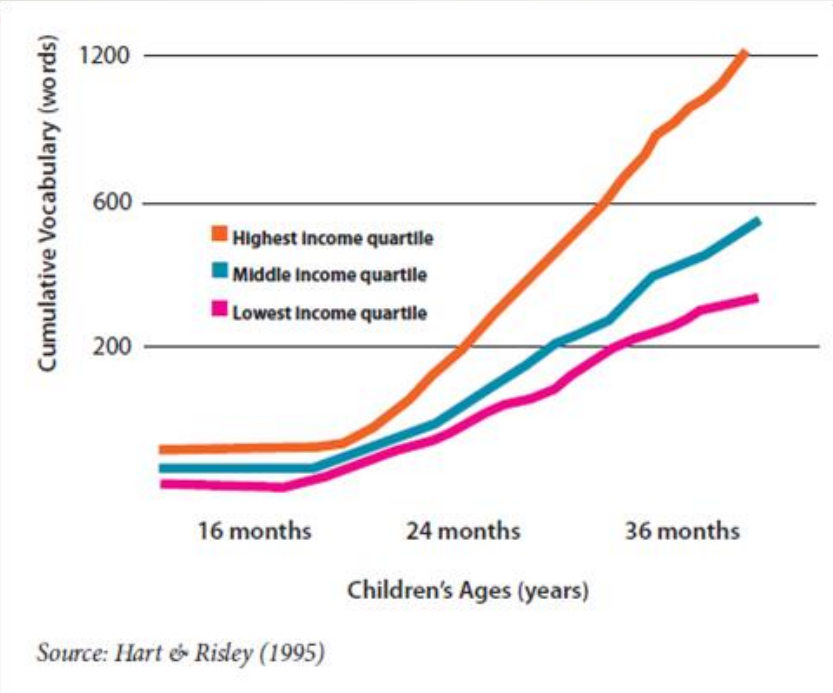
LECTURE 4

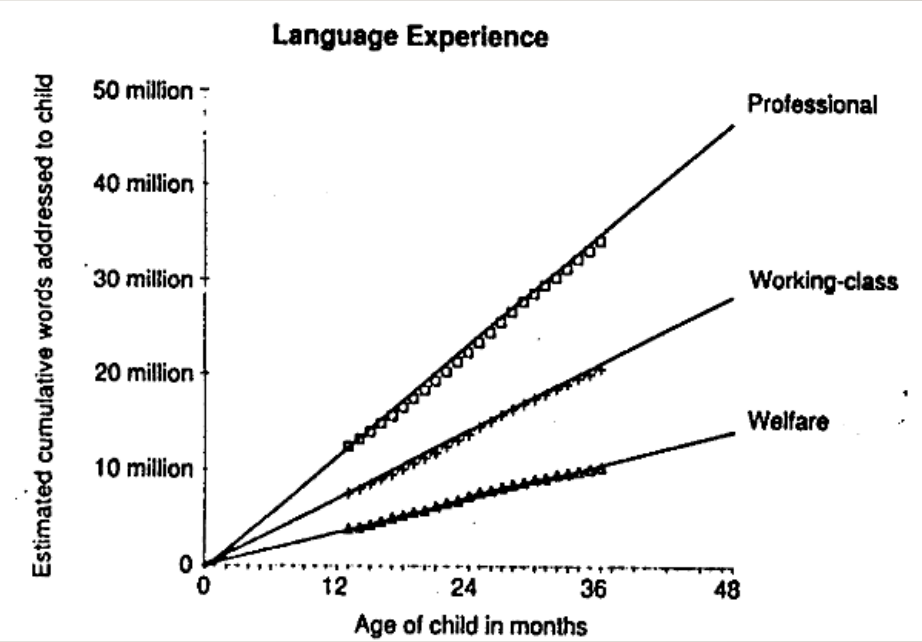
NEUROLOGICAL FOUNDATIONS: LISTENING AND TALKING

AUDITORY EXPERIENCE

VOCABULARY DEVELOPMENT



Source: Hart & Risley (1995)



TYPICAL INFANTS

- At birth, infants prefer their mother's speech and they even prefer songs and stories heard before birth.

- Infants are born with 20 weeks of listening experience.
  - Cochleae are formed and functional by the 20th week of gestation

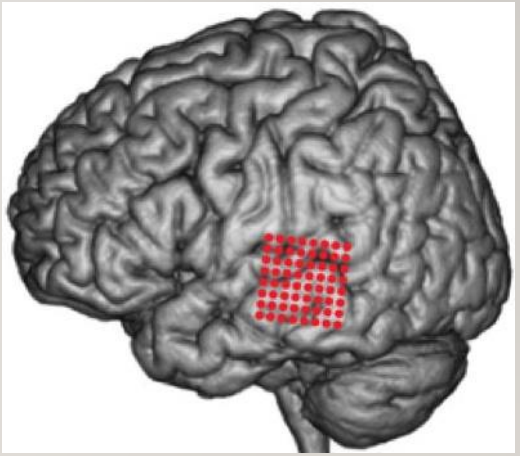
- So why do we care so much about early identification of hearing loss?
  - Experience with sound is available to the infant in utero
  - Newborns with hearing loss have already missed what?
    - **20 weeks of listening!**

"WE HAVE TIME, THE BABY IS ONLY 6 MONTHS OLD…"

- ***What do you think about that statement?***
- In the first 6 months of life, babies can discriminate many speech sounds, even those not heard in their home-spoken language(s).
- By the end of the first year, there is a functional reorganization of the brain to distinguish phonemes specific to language(s) heard daily.
- This neural reorganization improves and tunes the phonetic categories required for the infant's language and attenuates those phonemic distinctions not required for the infant's mother tongue.
- Infants use their phonetic categories as the foundation for learning new words. Phonetic distinctions guide new word learning by 17 months of age.
- What does that mean for listening experience in infancy?
    - It is critical for the development of both speech and language in young children, and a strong language base is essential for reading.

NEUROPLASTICITY

- Childhood hearing loss is a neurodevelopmental emergency!
  - Without early access to consistent intelligible speech, the auditory centers of the brain will not develop and normal intrahemispheric connections
- Auditory Access!
- Children hear 46 million words by age 4 years
  - Hear 46 million words by 4 years of age (Risley and Hart)
  - Listening 20,000 hours to learn to read…listening at least 12 hour days for 1,667 days (Dehaene)
  - Auditory exposure to learn new words and concepts increased up to 3 times necessary for children with hearing loss



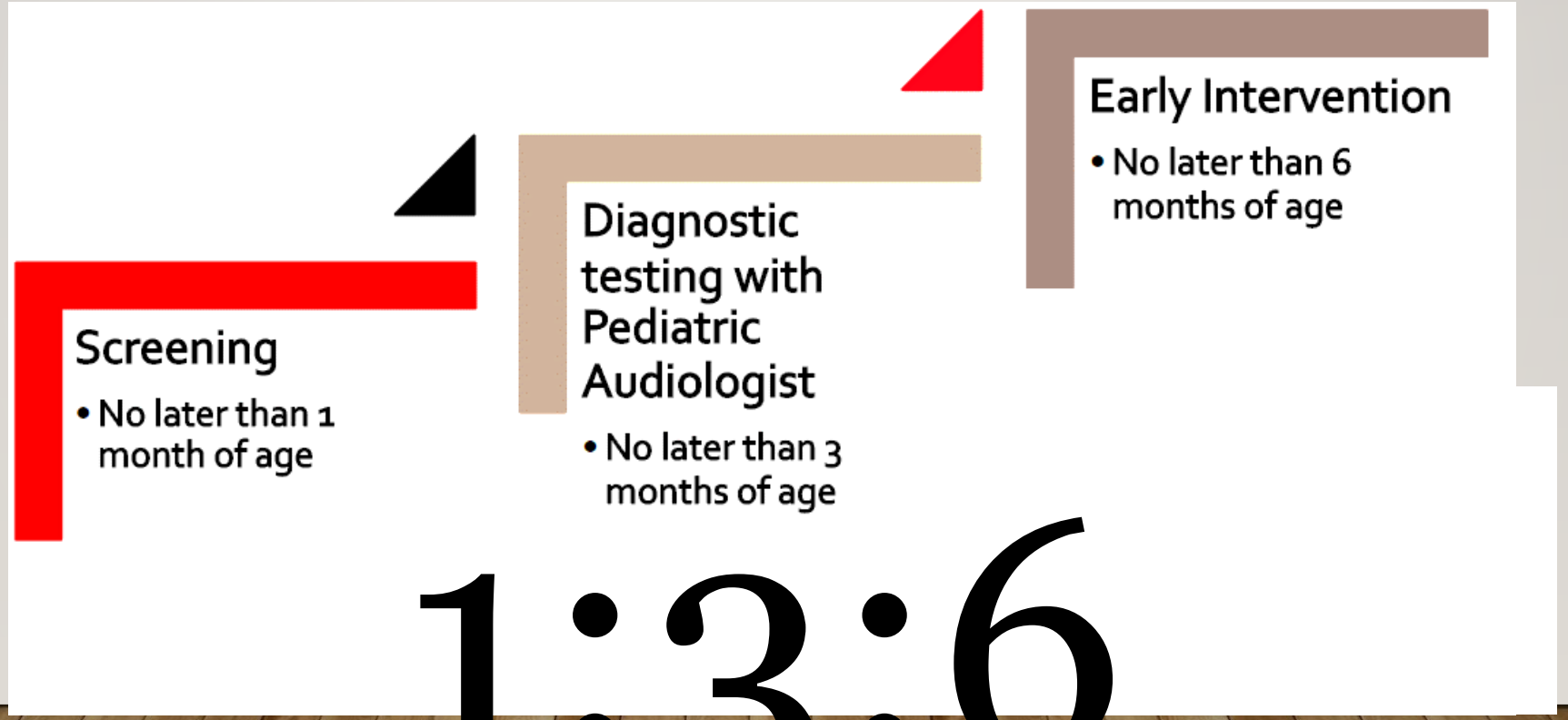
HOW MUCH IS NECESSARY?

- In order to obtain adequate language development, how much listening experience is necessary?
- The first three years of experience put in place a trajectory of vocabulary growth and the foundations of analytic and symbolic competencies that will make a lasting difference to how children perform in later years.
- ALL infants and children require a great deal of listening experience in order to develop age appropriate auditory and spoken language skills.

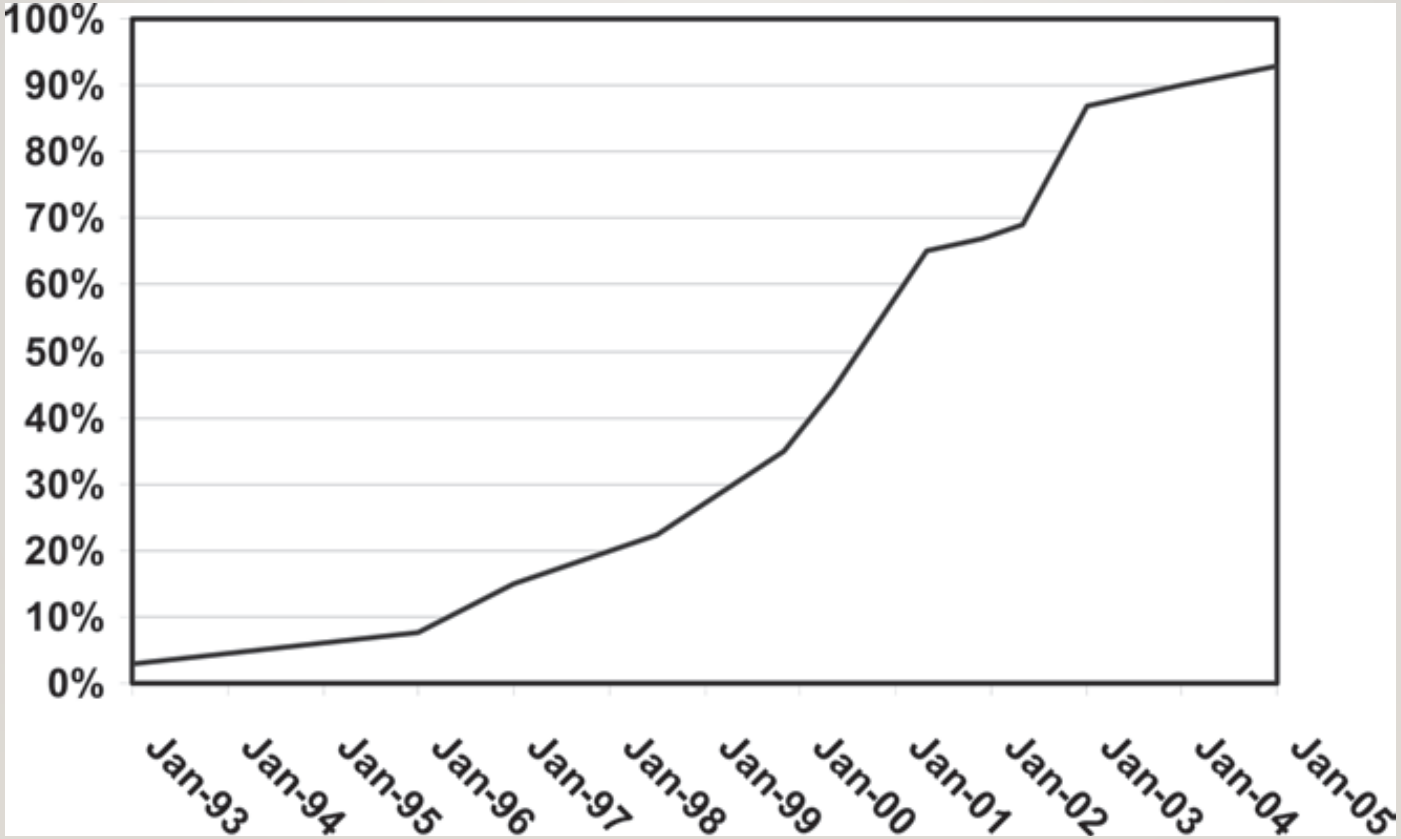
IMPORTANCE OF EARLY IDENTIFICATION

- Newborn infant screening programs and Newer technology
  - These both allow access to critical auditory brain centers during times of maximum neuroplasticity
  - Auditory language enrichment can be provided during critical periods of maximum brain neural plasticity – the first few years of life (Sharma, Dorman, & Spahr, 2002; Sharma et al., 2004; Sharma, Dorman, & Kral, 2005).

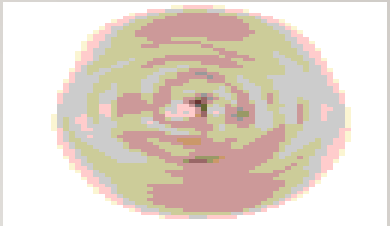
NATIONAL GOAL – EARLY HEARING DETECTION AND INTERVENTION (EHDI)



PERCENT OF NEWBORNS SCREENED FOR HEARING LOSS IN U.S.



NEUROPLASTICITY



- According to the theory of neuroplasticity, thinking and learning actually change both the brain's physical structure (anatomy) and functional organization (physiology).

- Neuroplasticity:
  - the capacity of the nervous system to modify its organization
  - changes in the structure and function of the brain as a result of experience

- To illustrate plasticity, imagine making an impression of a coin in a lump of clay. In order for the impression of the coin to appear in the clay, changes must occur in the clay. The shape of the clay changes as the coin is pressed into the clay. Similarly, the neural circuitry in the brain must reorganize in response to experience or sensory stimulation.

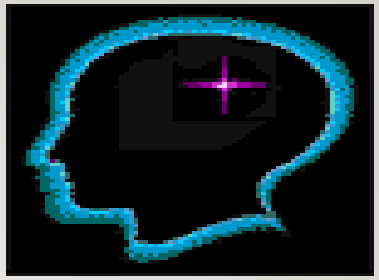
12 NEUROPLASTICITY

- It is a lifelong ability of the brain to reorganize neural pathways based on new experiences.

- Although plasticity occurs over an individual's lifetime, different types of plasticity dominate during certain periods of one's life and are less prevalent during other periods.

- Neuroplasticity does not consist of a single type of morphological change, but rather includes several different processes that occur throughout an individual's lifetime. Many types of brain cells are involved in neuroplasticity, including neurons, glia, and vascular cells.

13 NEUROPLASTICITY



- *Neuroplasticity occurs in the brain under two primary conditions:*

- 1. During normal brain development when the immature brain first begins to process sensory information through adulthood (developmental plasticity and plasticity of learning and memory).

- 2. As an adaptive mechanism to compensate for lost function and/or to maximize remaining functions in the event of brain injury.

1. PLASTICITY OF LEARNING AND MEMORY

- It was once believed that as we aged, the brain's networks became fixed. In the past two decades, however, an enormous amount of research has revealed that the brain never stops changing and adjusting.

- Learning, as defined by Tortora and Grabowski (1996), is "the ability to acquire new knowledge or skills through instruction or experience. Memory is the process by which that knowledge is retained over time."

- The capacity of the brain to change with learning is plasticity. So how does the brain change with learning?

- A change in the internal structure of the neurons, an increase in the number of synapses between neurons.

I. PLASTICITY OF LEARNING AND MEMORY

- Initially, newly learned data are "stored" in short-term memory, which is a temporary ability to recall a few pieces of information.

- Some evidence supports the concept that short-term memory depends upon electrical and chemical events in the brain as opposed to structural changes such as the formation of new synapses.

1. PLASTICITY OF LEARNING AND MEMORY

- One theory of short-term memory states that memories may be caused by "reverberating" neuronal circuits that is, an incoming nerve impulse stimulates the first neuron which stimulates the second, and so on, with branches from the second neuron synapsing with the first.

- After a period of time, information may be moved into a more permanent type of memory, long-term memory, which is the result of anatomical or biochemical changes that occur in the brain (Tortora and Grabowski, 1996).

2. INJURY-INDUCED PLASTICITY: PLASTICITY AND BRAIN REPAIR

- During brain repair following injury, plastic changes are geared towards maximizing function in spite of the damaged brain. In studies involving rats in which one area of the brain was damaged, brain cells surrounding the damaged area underwent changes in their function and shape that allowed them to take on the functions of the damaged cells.

- Although this phenomenon has not been widely studied in humans, data indicate that similar (though less effective) changes occur in human brains following injury.

2. INJURY-INDUCED PLASTICITY: PLASTICITY AND BRAIN REPAIR

- Deafness leads to extremely

  specific changes, the research

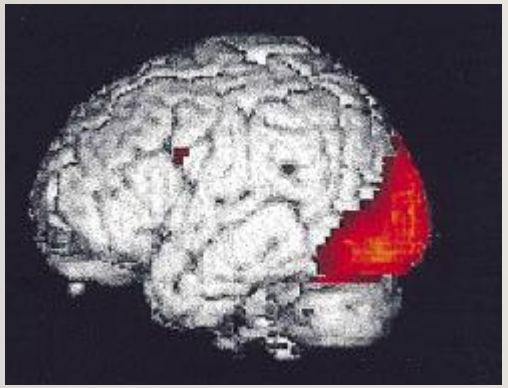
  supports the view that, in the

  absence of one modality, the remaining modalities take over multi-modal cortices, allowing for compensatory plasticity. clip

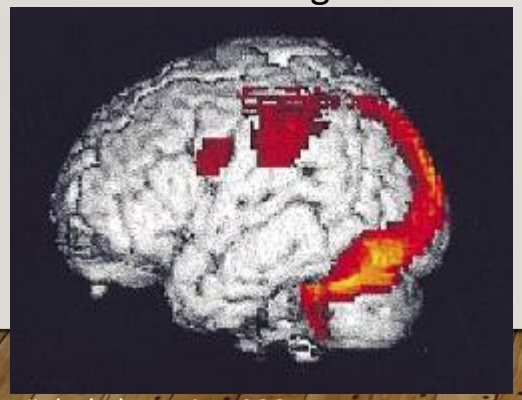
EXAMPLES OF NEUROPLASTICITY

- Sensory and motor representations – clinical aspects
  - Neural reorganization in sensory deprived people (blind, deaf)

Reading: sight

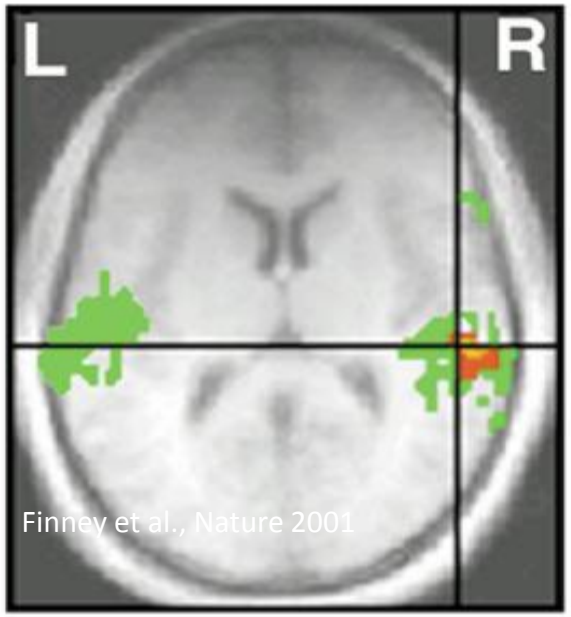


Braille reading: blind



Büchel al., Brain 1998

Visual activity in auditory cortex in deaf people



Finney et al., Nature 2001

Old Thinking	New Thinking
Early childhood experiences have little impact on later development	Early experiences have a decisive impact on the architecture of the brain & the nature and extent of adult capacities
Brain development is linear: the brain's capacity to learn and change grows steadily as an infant matures into adulthood	Brain development is non-linear: there are optimum times for acquiring different kinds of knowledge and skills
The genes that you are born with determine how your brain develops	Brain development is dependant on the interplay between the genes that you were born with and the experiences that you have.
A toddler's brain is much less active than the brain of a college student	By the age of three, their brains are twice as active as those of an adult. Activity drops off in adolescence.
A secure relationship with primary caregiver creates a favorable context for development and learning	Early interactions not only create the context, they directly affect the way the brain is "wired"
Brain growth and development lessens with age	The brain grows and continues development through death- provided the right conditions are met.

AUDITORY NEURAL DEVELOPMENT

- "We hear with the brain – the ears are just a way in."

- How do auditory pathways mature?
  - Full maturation of central auditory pathways is a precondition for the normal development of speech and language skills in children, whether or not they have a hearing loss

- Neuroplasticity
  - Brain's availability and malleability to grow, develop, and alter its structure as a function of external stimulation.
  - Why is neuroplasticity important?
    - Today's babies and young children who are born deaf or hard of hearing have incredible possibilities for achieving higher levels of spoken language, reading skills, and academic competencies than were available to most children in previous generations.
- Secondary Auditory Association Areas
  - Cortical level
  - Not fully developed until a child is about 15 years old

- Limited time period of optimal neural plasticity (greatest during the first 3 ½ years of life)
- Studies in brain development show that sensory stimulation of the auditory centers of the brain is critically important, and influences the actual organization of auditory brain pathways.
- Neural imaging has shown that the primary and secondary auditory areas are most active when a child listens and when a child reads.
- Phonological or phonemic awareness, which is the explicit awareness of the speech sound structure of language units, forms the basis for the development of literacy skills.

RAPID DEVELOPMENT IN INFANTS

- What is required to keep up with the rapid brain development in infants?
  - PROMPT intervention
  - …remember…not just identification, but INTERVENTION

- Early amplification or implantation stimulates a brain that is in the initial process of organizing itself, and is therefore more receptive to auditory input, resulting in greater auditory capacity.
  - *However,* this only provides the access to sound…

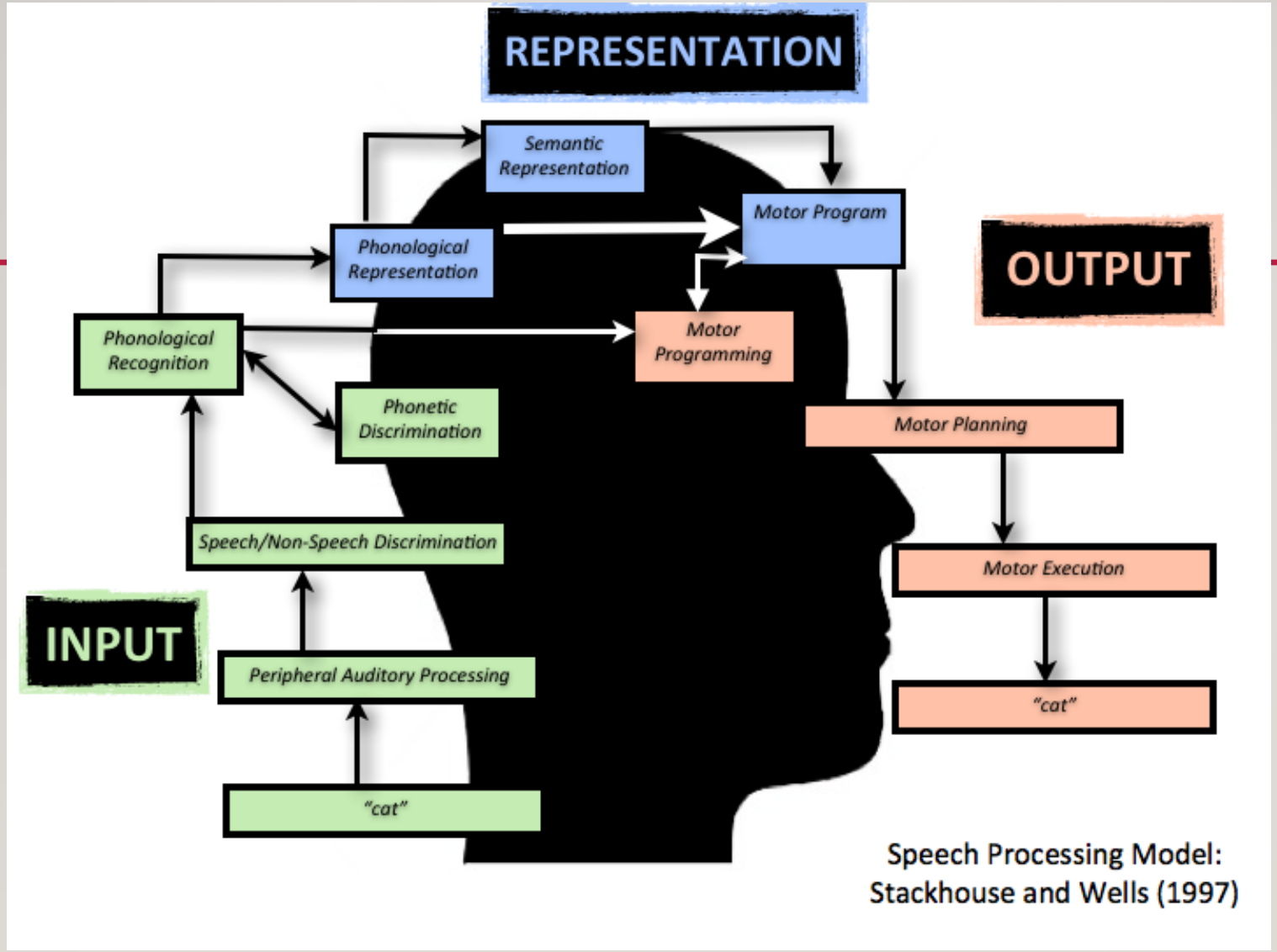
ACCESS, ACCESS, ACCESS

- Access will allow for experiences, which will allow for "programming" of those critical and powerful auditory centers of the brain with acoustic detail and will expand children's abilities to listen and learn spoken language.

- Early and ongoing intervention is essential. NOT JUST IDENTIFICATION. That is just the first step!

- Important neural deficits have been identified in the higher auditory centers of the brain due to prolonged lack of auditory stimulation.

- The auditory context is directly involved in speech perception and language processing in humans.



Speech Processing Model:
Stackhouse and Wells (1997)

NEURAL MATURATION

- In order for auditory pathways to mature, acoustic stimulation must occur early and often because normal maturation of central auditory pathways is a precondition for the normal development of speech and language skills in children.

- Audiologists are critical!
  - Fitting personal devices which allow for access
  - Fitting these devices appropriately
  - Direct, repetitive auditory skills instruction as part of an *effective* family-based early intervention program is critical
  - EXTRA auditory stimulation is necessary

“A BRAIN CAN ONLY ORGANIZE ITSELF AROUND THE SENSORY STIMULATION THAT IT RECEIVES.”

IMPACT OF THE ABSENCE OF SOUND

- The brain reorganizes itself to receive input from other senses, primarily vision.
  - *Cross-Model Reorganization*

- This process actually reduces auditory neural capacity.

IMPACT OF THE ABSENCE OF SOUND IN ADULTS

- People with mild, moderate and severe hearing loss are 2, 3 and 5 times more likely to develop dementia respectively than people with normal hearing. The findings are found in a study published in 2011 made by Frank Lin, otolaryngologist and epidemiologist at Johns Hopkins School of Medicine in the US.

- Another study, published in 2012 by Gallacher et al, has confirmed these findings. For every 10 dB (A) of increasing hearing loss, compared to normal hearing level for that age, the risk of developing dementia increased 2.7 fold.

IMPACT OF THE ABSENCE OF SOUND IN ADULTS

- A 2013 study by Lin and his colleagues suggested that hearing loss is linked to a 30-40% greater risk of cognitive decline than that faced by people without hearing loss.
- The researchers also showed that people who have hearing loss often strain to listen during conversation and everyday life, overtaxing parts of their brain and weakening their working memory.
- Brain scans published in 2014 have showed diminished grey matter in people with hearing loss over six years.
- Their brains had especially lost matter in a region associated with spoken language and semantic memory, which is the same region associated with early Alzheimer's.

IMPACT OF HEARING AIDS IN ADULTS

- Hearing loss accelerates cognitive decline in elderly adults, but the use of hearing aids counters this acceleration. A new scientific longitudinal study shows that those who use hearing aids have about the same cognitive level as those with no hearing loss.

- PAQUID is an extensive French study among 3,670 randomly selected individuals aged 65 and older. The study began in 1989-1990 and the participants have been evaluated regularly for 25 years. The study has been led by Professor Hélène Amieva, Université Victor Segalen Bordeaux 2, in France.

IMPACT OF HEARING AIDS IN ADULTS

- 80-93% of those who use hearing aids say that hearing aids improve their quality of life either regularly or occasionally. This is shown by studies from Germany, the United Kingdom, France and Switzerland.

- When asked about the positive impacts using hearing aids can have, the hearing aid users pointed to improvements in communication effectiveness, participating in group activities, relationships at home and sense of safety.

IMPACT OF HEARING AIDS IN ADULTS

- **Less depressed**

- The surveys show that the hearing aid users tend to be less depressed than the hearing impaired non-users.
- **Less exhausted in the evenings**
- Compared to hearing aid non-owners with significant hearing loss, hearing aid users in the surveys generally felt less exhausted in the evenings.
- **Hearing aid users tend to sleep better**
- The surveys also found that people who use hearing aids tend to sleep better than non-users. More hearing aid users answered "Yes" to the question "Are you generally satisfied with the quality of your sleep?" than the non-users in the survey with the most significant hearing losses.
- **Don't make fun of hearing aids**
- In the surveys, 89% of the hearing aid owners said that they don't think people make fun of them because of their hearing aids. This is compared to 35% of those with hearing loss who do not use hearing aids who felt people make fun of them because of their hearing loss.

WE CAN'T JUST STOP AT ACCESS!

- Hearing vs. Listening
- "We hear with the brain – the ears are just a way in."
- Hearing is acoustic access to the brain.
  - Improves the signal-to-noise ratio by managing the environment and utilizing hearing technology
- Listening is attending to acoustic events with intentionality.

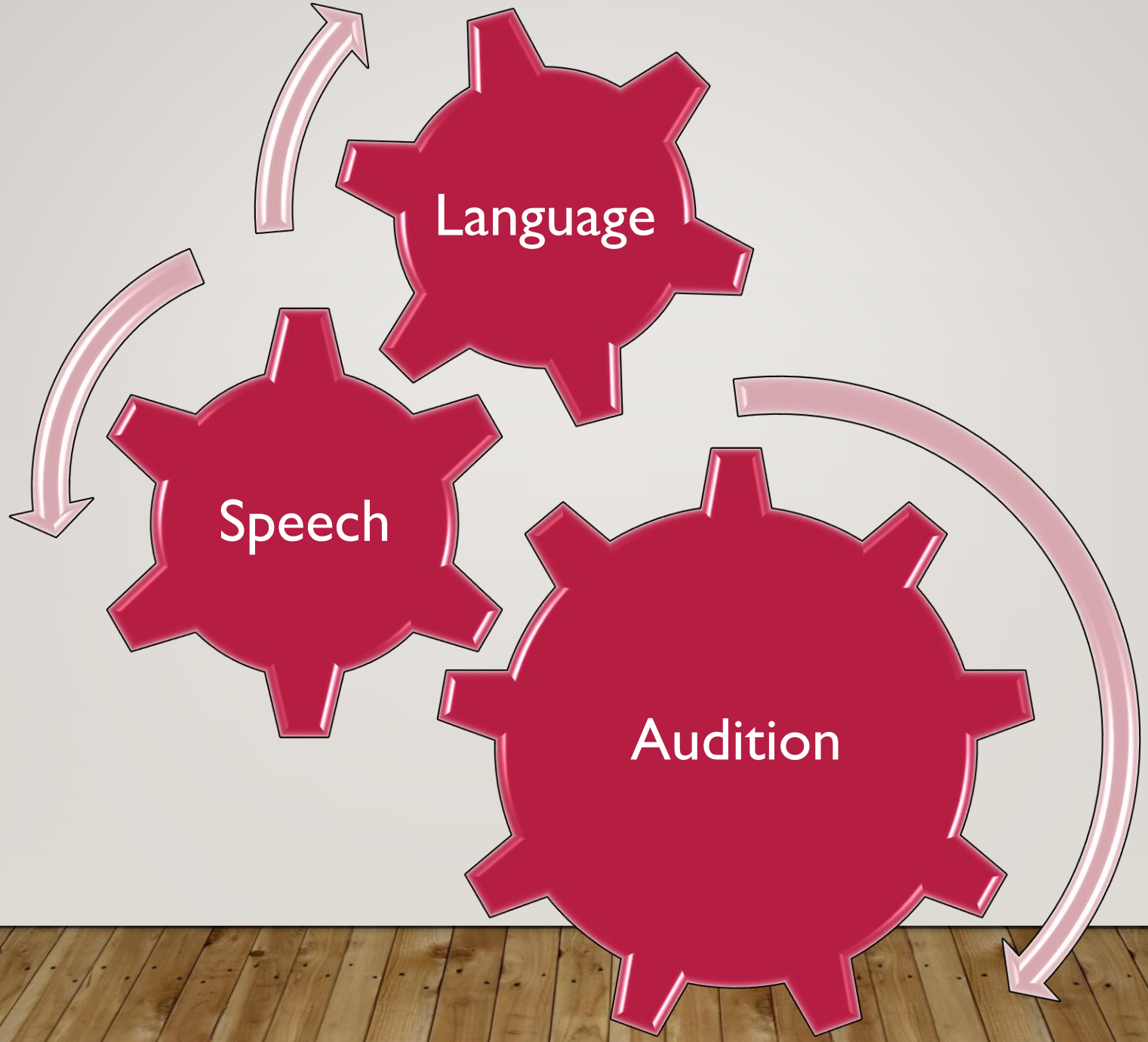
NORMAL DEVELOPMENT

- Based on the age by which *most* monolingual speaking children will accomplish identified milestones
- All items in a category are not typically mastered until reaching the upper age in the age ranges.
- Why important?
  - Not just so you know what abnormal development is…
  - To aid in counseling a family regarding progress
    - Other than… "Little Johnny is doing good!"

NORMAL DEVELOPMENT

Hearing, Understanding and Talking
Birth to 3 months
4-6 months
7 months to 1 year
1 year to 2 years
2 years to 3 years
3 years to 4 years
4 years to 5 years

(American Speech-Language-Hearing Association, 2012)


Language
Speech
Audition

BIRTH TO 3 MONTHS

Hearing & Understanding	Talking
Startles to loud sounds	Makes pleasure sounds (gooing, cooing)
Quiets or smiles when spoken to	Produces different cries for different needs
Seems to recognize caregivers voice and quiets if crying	Smiles when sees caregiver
Increases or decreases sucking behavior in response to sound	

(American Speech-Language-Hearing Association, 2012)

4 TO 6 MONTHS

Hearing & Understanding	Talking
Moves eyes in direction of sounds	Babbling sounds more like speech; many different sounds (p, b, and m)
Responds to changes in the tone of caregivers voice	Chuckles and laughs
Notices toys that make sounds	Vocalizes excitement and displeasure
Pays attention to music	Makes gurgling sounds when left alone and when playing with you

(American Speech-Language-Hearing Association, 2012)

7 MONTHS TO 1 YEAR

Hearing & Understanding	Talking
Enjoys games like peek-a-boo and pat-a-cake	Babbling has both long and short groups of sounds (tata upup bibibibi)
Turns head to look in the direction of sounds	Uses speech or other sounds (not only crying) to get and keep attention
Listens when spoken to	Uses gestures for communication (waving, holding arms to be picked up)
Recognizes words for common items (cup, book, juice, milk)	Imitates different speech sounds
Begins to respond to requests (Come here, want more?)	Has one or two words (hi, dog, dada, mama) around first birthday, although sounds may not be clear

(American Speech-Language-Hearing Association, 2012)

1 YEAR TO 2 YEARS

Hearing & Understanding	Talking
Points to some body parts when prompted	Produces more words every month
Follows simple directions and understand simple questions (Where's your shoe?)	Uses some one- or two- word questions (Where kitty? Go bye-bye?)
Listens to simple stories, songs, and rhymes	Puts two words together (more cookie, mommy juice)
Points to pictures in a book when named	Uses many different consonant sounds at the beginning of words

(American Speech-Language-Hearing Association, 2012)

2 YEARS TO 3 YEARS

Hearing & Understanding	Talking
Understands differences in meaning (go/stop, in/on, big/little, up/down)	Has a word for most everything
Follows two requests (Get the cup and put it on the table.)	Uses two- or three- words to talk about and ask for things
Listens to and enjoys hearing stories for longer time periods	Speech is understood by familiar listeners most of the time
	Often asks for or directs attention to objects by naming them

(American Speech-Language-Hearing Association, 2012)

3 YEARS TO 4 YEARS

Hearing & Understanding	Talking
Hears you when you call from another room	Talks about activities at school or at friends' homes
Hears television or radio at the same loudness level as other family members	People outside of the family usually understand the child's speech
Answers simple WH questions (who, what, where, and why)	Uses a lot of sentences that have 4 or more words
	Usually talks easily without repeating syllables or words

(American Speech-Language-Hearing Association, 2012)

4 YEARS TO 5 YEARS

Hearing & Understanding	Talking
Pays attention to a short story and answers simple questions about them	Uses sentences that give lots of details
Hears and understands most of what is said at home and in school	Tells stories and maintains topic
	Communicates easily with other children and adults
	Says most sounds correctly except a few like *l, s, r, v, z, ch, sh, th*
	Says rhyming words
	Names some letters and numbers
	Uses the same grammar as the rest of the family

(American Speech-Language-Hearing Association, 2012)

TYPICAL SPEECH INTELLIGIBILITY

Approximate Age	% Understood by Parents
18 months	A typical child is 25% intelligible
2 years	A typical child is 50-70% intelligible
3 years	A typical child is 80% intelligible
4 years	A typical child is 90% intelligible

(Talking Child, LLC, 2003)

AR

https://www.youtube.com/watch?v=AhJycJVLf-Y