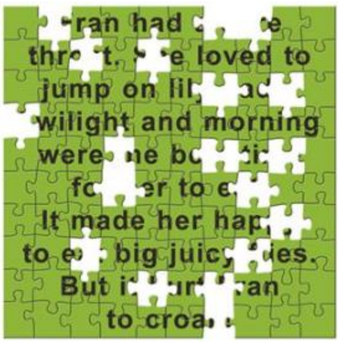
The Cascading Impact of Hearing Loss

Fragmented Hearing -> Effort -> Listening Comprehension -> Fatigue -> Pace of Learning

Hearing loss is invisible. Someone observing a student with hearing loss may believe that he or she has an attention problem or a learning disability as hearing loss can also impact perceiving, language processing, processing speed, memory and attention. Unlike ADHD or LD, learning issues caused by hearing loss are not due to a disorder (an issue with brain processes). Instead the learning issues are secondary to delays because the child has incomplete access to speech occurring around him or her, especially soft speech or completely understanding someone talking from a distance further than 3-6 feet.

Fragmented Hearing



Our educational system is based on the assumption that students in the classroom will perceive, and therefore understand, all of what the teacher is saying. **When much information received in school is fragmented because of hearing loss, learning consequences are likely. Even with the latest hearing technology, normal hearing ability is not restored by hearing devices**. Even aided thresholds of 20 dB HL will cause the soft speech, the high pitch speech sounds and unemphasized brief words to be undetected or too quiet to process. It is not unusual for children with hearing loss to have a 20% 'listening gap' as compared to class peers who may miss only 5% of information[1]. The image shows a story about Fran the frog who has a sore throat. As you can see, comprehending the meaning of the story is impacted when 20% of the information missing. **Even if a child is able to perform well in a quiet setting using hearing devices, a classroom setting is typically noisy, with fast-paced peer-to-peer conversations and teachers that move about the classroom, causing significant listening challenges.**

Increased Effort

Effort refers to the exertion of physical or mental power. Listening effort refers to the attention necessary to understand speech. Ease of listening is the perceive difficulty of the listening situation by the listener.

Research on persons with typical hearing[2-4] found that considerable listening effort is required when listening at noise levels typical of the school classroom. In low noise, being able to watch the speaker improves speech understanding and reduces listening effort. In high noise using both watching and listening results in greater effort to understand speech. Listeners who are better speechreaders benefit more from visual cues than those that are poor speechreaders, however, processing visual cues requires cognitive resources. Listeners with sufficient cognitive resources (like working memory capacity) can make use of speechreading to reduce listening effort. Without enough processing capacity listening effort increases and speech recognition is slower when a child is both listening and watching the speaker.

We can assume that children with hearing loss work harder to listen and use more cognitive resources to understand speech in the classroom when compared to class peers because even low noise in the environment will interfere with their speech understanding. **It has been assumed that speechreading will help children to compensate for what is missed due to fragmented hearing. These research results make it clear that this is only true IF a child is a good speechreader AND he has typical or better working memory capacity.** Working memory research[5] found that noise can impact both long- and short-term memory for children. Therefore it is important to assess speechreading ability (i.e., Functional Listening Evaluation) and the memory capacity (in quiet and noise) of students with hearing loss (i.e., Test of Auditory Processing Skills – TAPS-3). Read further for more information on working memory.

Additional research[6] found that extracting speech in the presence of high levels of background noise reduces the listener's ability to mentally rehearse material that was heard so it could be remembered. Use of hearing technology with a noise reduction algorithm can free up cognitive resources that would otherwise be involved in extracting speech from noise. When typically hearing children and children with hearing loss using hearing technology with noise reduction algorithms were compared[7], it was found that if the child with hearing loss was required to do any competing task that there was no improvement using the noise reduction technology. When so many cognitive resources are expended for listening, there is little capacity left to perform other tasks (i.e., notetaking) and digital noise reduction does not improve this ability. If a child has a higher cognitive aptitude, then managing listening plus other tasks would be more likely.

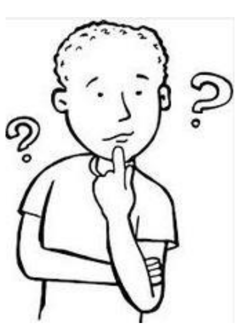
To summarize, digital noise reduction technology at this point may not provide any improvement in typical classroom listening situations. It *may*, however, improve performance in very noisy conditions such as a child listening in a simultaneous small group cooperative learning situations, a noisy lunch room or busy hallway passing times at school, as long as the only expectation is listening.

Decreased Listening Comprehension

It is assumed that when the teacher is speaking that the students will comprehend what they have heard. Listening comprehension abilities of children with hearing loss are typically lower than those of children with normal hearing due to the effort used to listen, which decreases the cognitive resources available to understand what was heard.

A study[8] of typically children's ability to follow instructions found that children perform better in noise than noise plus reverberation, which work together to impact the processing of listening to directions, even when students could see the face of the speaker. Smearing of the speech signal from a single person talking was no better than if multiple people were talking. When reverberation in the environment is at 0.6s or worse, it is likely impacting higher level cognitive processes as children with normal hearing try to understand the teacher, class discussion or peer communication. Children with hearing loss are even more sensitive to the impact of noise and reverberation in the environment. **Unless the acoustic conditions of the classroom are considered, it is likely that they will be impacting the ability of the child with hearing loss to follow directions.**

The Listening Comprehension Test 2 identifies skills in five areas, comparing the student tested to a group of typically hearing and typically developing children of the same age. One researcher[9] used this test to assess a group of children with typical hearing when they were listening in noise. It was found that excessive noise affects cognitive processing of information, even for children with typical hearing. Children had the greatest difficulty on the details, reasoning and understanding messages subtests. Identifying the main idea was resilient to interference from noise because the redundancy of language throughout the story informs the participant about the main idea. **Defining vocabulary**, especially unknown vocabulary, is dependent upon hearing the unknown word within the context of the story. At least half of the children had significant difficulty defining vocabulary. The greatest impact was on the subtests requiring higher-order comprehension with younger children performing more poorly than older children. **Detail recall** was impacted due to inaudibility of the entire passage and/or possible reduced short-term memory when listening in background noise. The **reasoning** subtest requires students to generate inferences and conclusions based on what they heard in the story. If details were missed or not remembered the reasoning subtest would be very impacted. Finally, the **understanding messages** subtest requires the child to repeat important information heard during the story; another skill that is impacted by listening in noise.



Due to fragmented hearing and extra listening effort, children with hearing loss are already more vulnerable than their peers to missing and comprehending information – with or without excess noise, even if they have age-appropriate language. Performing the Listening Comprehension Test 2 or the Listening Comprehension Test Adolescent will provide valuable information about how the student with hearing loss is performing. Using an FM while doing this test will provide the student's best possible listening comprehension performance on these higher cognitive tasks.

Another study[10] had typically hearing students answer comprehension questions about a story that was presented in a lecture format or when parts of the story were presented from locations around the student, to simulate listening to classroom discussion. The first finding was that accuracy when repeating sentences in quiet or noise (like on a Functional

Listening Evaluation) does not predict the true impact of classroom acoustics on listening comprehension for lecture or discussion. For example, children who would achieve a 95% accuracy repeating sentences in a typical classroom listening environment (+7 S/N noise, 0.6s reverberation) would perform more poorly under more typical listening activities. Average results for 11-year olds when listening to lecture was 80% accuracy and 75% for discussion, whereas for 8-year-olds it was 40% and 33% respectively. If the noise level was reduced (+10 S/N) the scores for understanding discussion improved from 33%/75% to 60%/90% for 8/11 year-olds respectively. **Students with hearing loss are more greatly impacted by noise and reverberation than their typically hearing peers. Even though an FM system will optimize listening to a lecture in the presence of excessive noise and reverberation, only a good acoustic classroom environment will allow the student with hearing loss to access classroom discussion.** This study further found that the younger participants (age 8) looked around more to aid their understanding during discussion. The surprising result was that most often they were unable to visually keep up as the discussion moved from student to student. Furthermore, **it appeared as though the act of trying to visually track class discussions could actually use up more cognitive resources, resulting in reduced comprehension, especially for younger students.**

Increased Fatigue from Listening/Processing

Another area related to effort is the fatigue experienced as a result of difficult listening situations. Fatigue refers to the weariness resulting from exertion. Mental fatigue relates to one's ability to attend or concentrate and refers to a general feeling of being tired. A fatigued child is a child who potentially isn't learning at the level he or she is capable of learning. A fatigued child has the potential of failing a grade. A fatigued child also has the potential to experience negative social and emotional consequences.

Fatigue and Learning:

- Often gives up easily as tasks become difficult
- Has poor frustration tolerance level
- Has difficulty concentrating on work and reduced productivity in many situations
- Makes careless mistakes
- Does not show creativity in solving problems
- Complains of feeling fatigued; falls asleep on the way home from school
- Does not seem to enjoy activities (especially social and/or in noisy conditions)

Students who expend more effort learning may decrease their potential to satisfy learning demands and thereby feel frustration when the expected rewards for learning as expected are not received.

Fatigue has been associated with poorer ability to maintain attention and concentration, slower mental processing, and impaired decision making. There is a connection between increased cognitive processing demands when listening to speech in noise and fatigue-related changes in cognitive processing ability. Because fatigue has an impact on cognitive processing, it is not surprising that recurrent fatigue (which can be caused by the added strain of listening with hearing loss) is associated with reduced academic performance in children.

Researchers[11-12] examined the question of fatigue in children with hearing loss as compared to age-matched typically hearing peers completing a standardized measure. Results indicated that even children with normal hearing subjectively report fatigue, but the group with hearing loss reported greater fatigue on all three subscales (general fatigue, sleep/rest fatigue, and cognitive fatigue). In a second study it was confirmed that children with hearing loss exert more effort on listening tasks than their typically hearing peers. This was found to NOT be related to difference in language ability nor was effort expended greater as the hearing loss level increased. Any degree of hearing loss, with or without amplification, resulted in greater effort. In the case of this study, the students with hearing loss did not rate their level of effort higher than their typically hearing peers, suggesting that subjectively asking students about effort may not accurately identify the actual level of effort as many of these students have never experienced a true easy listening situation.

Children with hearing loss expend more effort when listening than do children with typical hearing regardless of the noise condition. The fatigue experienced by children with hearing loss *is* substantial, even when compared to children with other chronic health conditions, such as cancer, diabetes, and rheumatoid arthritis. The findings supply the "ammunition" needed for convincing school administrators, teachers, and parents that the acoustical learning environments of our students need to be addressed.

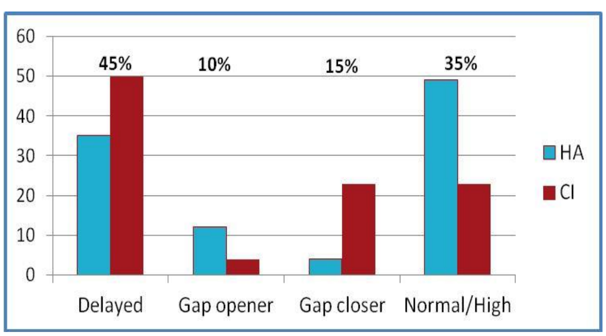
It is common for audiologists to test speech recognition in the presence of background noise in a test booth as a way to predict whether a child is in need of an FM system or other accommodations, in the classroom (i.e., Functional Listening Evaluation). The assumption is if a child maintains good speech-recognition performance under test conditions then an FM system is not needed. This assumption is lacking in that it does not take into account the excessive expenditure of effort and the resulting fatigue that exists for a child with hearing loss who is using listening to learn in a typical classroom. Clearly, research indicates that the issue of listening in a classroom with a hearing loss is more complicated than simple measures of speech-recognition ability.

In the world of business the impact of an effort-reward imbalance on fatigue and performance has been studied extensively. It has also been applied to school-children, resulting in a set of short questionnaires for those in grades 4-9. The resulting **Informal Assessment of Fatigue and Learning** can help to quantify if there is a learning effort-reward imbalance and overall level of fatigue.

Pace of Learning Decreases

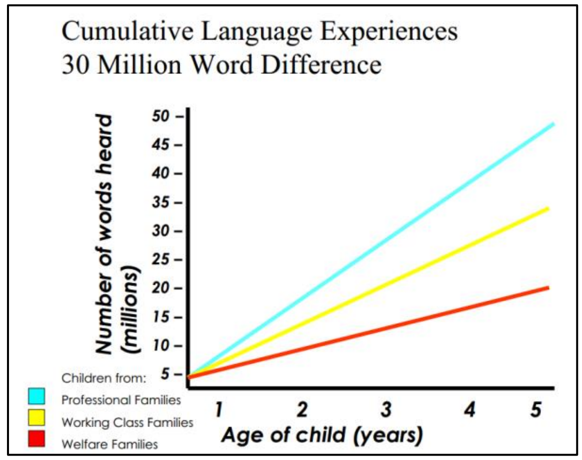
Hearing loss creates barriers to learning in the typical classroom environment and impacts social interactions. This *invisible* barrier typically causes CUMULATIVE learning gaps due to incidental learning/overhearing deficits.

Historically, most children with hearing loss experienced significant language delays in early childhood to prevent them from being ready for school, thus resulting in most being educated in restrictive school programs. The advent of newborn hearing screening and early identification of hearing loss has resulted in the families of many children with hearing loss receiving intensive early intervention services. A review of the collected post-universal newborn hearing screening research[14] revealed important outcomes including (1) parents expect that early identification and intervention will be sufficient to make their child like a hearing child, (2) children who are identified early and receive early intervention have been found to demonstrate language development in the "low average" level compared to hearing children, and (3) many if not most children with hearing loss who use listening and speaking for learning fail to keep pace with hearing peers (even those with cochlear implants). Although we live in a time when the potential of children with hearing loss is more likely to be reached than ever before, the reality is that the gains of early childhood are often eroded by the challenges of learning in a non-supportive auditory environment.



As a follow up to studies of language development of early identified children with hearing loss who received early intervention services, researchers[15] examined the continued trajectory of language learning once children entered school. Language was assessed every 6 months between ages 4 and throughout age 7 for 135 cognitively normal children with hearing loss of all degrees from English-speaking families. There were 49 cochlear implant users and 38 hearing aid users (mild-profound loss). As the table shows almost half (45%) of the children had delayed language at school entry and continued to have language delays at age 7. Only 15% of children who had language delays closed their gap in language learning by age 7. None of the children who had profound hearing loss and language delays at age 4 closed their gap in language learning. Over 1/3 had typical language at age 4 and continued to do so at age 7. Finally, of the children who entered school with 'normal' language development, but the time they were in second grade 10% had noticeable language gaps. Experience tells us that the percent of 'gap openers' only increases as the curriculum and new vocabulary is introduced at a faster pace. As the graph shows, more children with hearing aids were gap openers and more children with cochlear implants were gap closers.

We know from extensive studies[16] that it is not unusual for a child from a home in poverty to have heard 30 million fewer words by school age than the child of professional parents. This is a growing concern with increasing attention being given to educate families of young children, where the real difference can be made. Children from impoverished families can show language delays by 2 years of age. Pretty much, these are the same children with academic delays in kindergarten, grade 7 and in high school. So the fact that children with hearing loss who enter school with delays continue to experience delays is not a surprise. This is why there is so much emphasis on early intervention – quality early intervention by professionals trained in the impact of hearing loss on learning.



The concern for school-age children is that the effects of fragmented hearing on effort, listening comprehension and fatigue can be unrecognized by educators who erroneously assume that a good start to typical language learning inoculates a child from the learning challenges caused by being educated in a typical classroom environment.

References for the Cascading Impact of Hearing Loss

1. Bodkin, K., Madell, J., & Rosenfeld, R. (1999). Word recognition in quiet and noise for normally developing children. American Academy of Audiology Convention, Miami, FL, Poster session. Download *Speech in Noise Norms for Typical Children* from http://successforkidswithhearingloss.com/speech-perception
2. Picou, E. M., Ricketts, T. A, and Hornsby, B. W. Y. (2011). Visual cues and listening effort: Individual variability. *Journal of Speech. Language, and Hearing Research,* 54, pg 1416-1430.
3. Fraser, S., Gagne`, JP., Alepins, M., & Dubois, P. (2010). Evaluating the Effort Expended to Understand Speech in Noise Using a Dual-Task Paradigm: The Effects of Providing Visual Speech Cues. *Journal of Speech, Language, and Hearing Research*, 53, 18-33.
4. Howard, C. S., Munro, K. J., & Plack, C. J. (2010). Listening effort at signal-to-noise ratios that are typical of the school classroom. *International Journal of Audiology*, 49(12), 928-932.
5. Beaman, C.P. & Roer, J. P. (2009). Learning and failing to learn in immediate memory. In 31st Annual Meeting of the Cognitive Science Society, Austin, Texas, USA. http://www.academia.edu/2407326/Learning_and_failing_to_learn_in_immediate_memory
6. Sarampalis, A., Kalluri, S., Edwards, B., & Hafter, E. (2009). Objective measures of listening effort: Effects of background noise and noise reduction. *Journal of Speech, Language, and Hearing Research,* 52, pg 1230-1240.
7. Pittman, A., Children's performance in complex listening conditions: Effects of hearing loss and digital noise reduction. *Journal of Speech, Language, and Hearing Research,* 54, 1224-1239.
8. Lewis, D., Manninen, C.M., Valente, D. L, & Smith, N. A. (2014). Children's Understanding of Instructions Presented in Noise and Reverberation. *American Journal of Audiology*, 23(3), 326-336.
9. Schafer, E., Bryant, D., et. al, (2013). Listening comprehension in background noise in children with normal hearing. *Journal of Educational Audiology*, 19, 58-64.
10. Valente, D. L., Plevinsky, H. M., Franco, J. M., Heinrichs-Graham, E. C., & Lewis, D. (2012). Experimental investigation of the effects of the acoustical conditions in a simulated classroom on speech recognition and learning in children. *Journal of the Acoustical Society of America,* 131(1), 232-246.
11. Hornsby, B., Werfel, K., Camarata, S., & Bess, F. (2014), Subjective fatigue in children with hearing loss: Some preliminary findings. *American Journal of Audiology, 23,* 129-134.
12. Hicks, C. B., & Tharpe, A. M. (2002). Listening effort and fatigue in school-age children with and without hearing loss. *Journal of Speech, Language, and Hearing Research*, 45, 573-584.
13. Fukuda, S., et al (2010). Effort-reward imbalance for learning is associated with fatigue in school children. *Behavioral Medicine,* 36(2), 53-62.
14. Spencer, P. E. & Marschark, M. (2010). Evidence-Based Practice in Educating Deaf and Hard-of-Hearing Students. Oxford University Press, New York, NY.
15. Yoshinaga-Itano, C. (2010). The longitudinal language learning of infants and children with hearing loss. ASHA Virtual EHDI Conference, October.
16. For a comprehensive presentation go to: http://www2.ed.gov/programs/readingfirst/2008conferences/language.pdf
17. Read about pragmatic language and so the Pragmatics Checklist (ages 3-7) at http://successforkidswithhearingloss.com/pragmatics
18. Functional Listening Evaluation – find information at http://successforkidswithhearingloss.com/tests and http://successforkidswithhearingloss.com/fle-recorded
19. The following checklists can be found at http://successforkidswithhearingloss.com/tests : CHILD, Starting School LIFE, SIFTERs (Screening Instrument For Targeting Educational Risk), Informal Assessment of Fatigue and Learning
20. LIFE-R Teacher Appraisal can be found at http://successforkidswithhearingloss/tests/life-r