Thresholds Are Not Enough: Understanding How Infants Process Speech Has a Role in How We Manage Hearing Loss

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Introduction

The most commonly used hearing aid fitting strategies are threshold-based procedures. Thus, audiometric thresholds are essential when making decisions about amplification. This is especially true for infants, with whom suprathreshold testing is not an option. However, threshold-based fitting procedures are really based, in theory and/or on empirical grounds, on an understanding of our ability to process speech in the presence of hearing loss. Our notions of the amount of gain necessary for given threshold values come from our understanding of speech acoustics, speech perception, sensorineural hearing loss and recruitment, clinical word recognition tests, and other psychoacoustic and audiologic information. So, although threshold-based systems are easy to apply, there is a great deal more behind such procedures than audiometric thresholds.

Most threshold prescriptive procedures are based on adult data. The measures of speech processing that have been used to develop and support our threshold-based fitting protocols cannot be obtained with infants, so we must be aware that simply applying such procedures to infants may be inappropriate. However, we do have considerable knowledge about how and when infants with normal hearing develop speech perception, and we have data that address the issue of the effects that hearing loss might have on that process. Threshold information alone, which itself has to be interpreted with care in infants, is not sufficient. Information from research on infant speech processing must be considered together with our knowledge of hearing threshold measures so that we can develop strategies for amplification and management that reflect the auditory needs, capabilities, and limitations of infants rather than those of older children and adults.

Miller and Jusczyk (1989) have stated that one goal in the study of speech perception is to develop a theory of “how the listener recovers the phonetic structure of an utterance from the acoustic signal during the course of language processing.” In the context of the infant, this is particularly important. Infants must recover the phonetic structure of an utterance from an acoustic signal that is varying rapidly in intensity and frequency, and that, when viewed as a purely acoustic event, is very difficult to segment into the components we hear as individual speech sounds, syllables and words. Infants do this to acquire language, not as a part of processes within a known language system, so the auditory demands must be much greater at this stage of speech and language development. Boothroyd (1978) suggested, with regard to the perception of speech, that those without language “do not have the internal knowledge or perceptual skills of the normal hearing adult and are therefore more dependent on accurate recognition of acoustic information” (p. 130).

To what extent is the infant with normal hearing in the first year of life able to recover the phonetic structure of an utterance? Or, stated more simply, how do infants perceive speech?

We know now that infants have remarkable speech perception skills from very early in life (cf. Jusczyk 1997; Kuhl 1987, 1992; Miller and Jusczyk 1989 for recent reviews). There is evidence that infants are universalists when it comes to phoneme discrimination. They can discriminate different phonemes, even when closely related acoustically, from just about any language from virtually the time they are born. They demonstrate perceptual constancy and categorical perception. Infants also have shown evidence of recognizing linguistically relevant segments of utterances, such as word boundaries, within the ongoing stream of acoustic events we know as speech. They can recognize suprasegmental aspects of speech, attending to linguistically relevant pitch contours in favor of others. Infants appear to recognize the difference between those speech sounds that are combined in ways
that are allowed in the language to which they are being exposed and those that are in violation of their native language phonotactic structure. Infants will show a preference for listening to the mother’s voice over others. The research on infant speech perception is plentiful and remarkable, and suggests that infants not only can recover the structure of speech but also are processing speech in linguistically relevant ways. In the many-faceted realm of infant speech perception, there is one line of research that bears particular relevance to the issues of amplification for infants: cross-language research.

Very young infants can tell the difference between virtually any pair of phonemes from any phonetic language, whether those phonemes are used for making a linguistic distinction in their own native language or not. However, we know that as adults we are not as sensitive to phonetic distinctions from a non-native language if those distinctions are not also found in our own native language. When trying to learn to speak a non-native language, adults often have difficulty discriminating among phonemes that are not also found in their own native language. One example of this is the difficulty that adult native speakers of Japanese have when trying to differentiate between /r/ and /l/. The interesting thing is that infants in an exclusively Japanese-speaking environment can tell the difference between the two phonemes but somehow become desensitized to that distinction through exposure to the Japanese language as they get older. Cross-language research gives us insight not only into developmental changes in the perception and organization of speech, but also into the timing of those phenomena. That is, it addresses not only the question of how well the infant recovers the phonetic structure, but also the timing of the development of phonetic perception as it relates to the native language.

Werker and her colleagues (Werker and Lalonde 1988; Werker and Tees 1984) have shown that infants by the age of about 10 months are beginning to lose sensitivity for phonetic contrasts that are not found in their native language. Kuhl, Williams, LaCera, Stevens, and Lindblom (1992), in a cross-language study using infants who were native speakers of English and infants who were native speakers of Swedish, have shown desensitization for perception of vowels that are not found in their native language by the age of 6 months.

Studies such as these are extremely relevant to our discussion of management of infants with hearing impairment. It appears that during the first 6 months of life, and certainly within the first 10 months, infants begin to change the way they perceive speech based on their exposure to their native language. The infant’s speech perceptual processes are modifiable and are being used very early in life to organize a phonetic inventory that will provide the foundation for verbal language. We don’t know how long that window remains open for sure, but we know that older children and adults have difficulty with those phonetic elements of a non-native language that are not found in the native language. This also is interesting in the light of intervention research such as reported by Bamford and Saunders (1991), Robinshaw (1995), and Yoshinaga-Itano, Sedey, Coulter, and Mehl (1998). The latter studies suggest that early intervention (by 6 months of age) produces a better language outcome in infants with hearing impairment than does intervention at later times.

Given that speech input early in life is directing the organization of a system upon which language will be built, it is important to determine what happens when the speech input is degraded or inconsistent. This has led us to two lines of inquiry. First, what is the effect on speech-sound discrimination performance of infants when speech stimuli are degraded in ways that simulate the effects of hearing loss? Second, what is the relationship between hearing sensitivity (i.e., thresholds) and the intensity level of speech that is necessary for an infant to perform a simple speech-sound discrimination task at some criterion level? Or, stated differently, is there a difference between infants and adults in the sensation level (SL) of speech sounds that is necessary for maximum performance on simple speech-processing tasks? We cannot simply apply our favorite threshold-based prescriptive procedure to the infant with a hearing impairment and hope for success. We must address these questions because they bear directly on the broad challenge of managing hearing impairment in infants and quite specifically on prescribing the best amplification.

Simulating Hearing Loss

Although phonetic discrimination studies place few demands on the infants in terms of language processing, demonstration of ability to discriminate must precede ability to perform more complex processes such as recognition and comprehension. If the ability of infants to make phonetic discriminations breaks down when speech sounds are degraded, then the more complex processes of speech perception that build upon simple phonetic discrimination must also be compromised.

In our research, three different approaches to addressing questions of the effects of hearing impairment on speech perception have been used. The three approaches all can be viewed as those that simulate
hearing loss in infants; they are all laboratory studies done with infants who are developing normally. First, simple reduction of the intensity of speech sounds was used to investigate the effects of attenuation of speech on ability to discriminate simple phonemes. Second, to simulate a mild-to-moderate high-frequency hearing loss, speech sounds were filtered to remove increasingly greater amounts of energy with increasing frequency. Third, we studied speech-sound discrimination in noise. Masking noise can be used in speech perception research as a means of simulating hearing loss, as a means of equating audibility across different subject groups, or as a means of assessing the listener’s ability to respond to speech stimuli under unfavorable listening conditions.

**Reduced Intensity of the Speech Signal**

The effects of reduced stimulus intensity, which can be considered a method of simulating a flat, conductive hearing loss because they both result in a simple attenuation of signal amplitude in the auditory system, were first reported by Nozza (1987a). In that study, infant ability to discriminate /ba/ from /da/ was measured at three different intensity levels, 70, 60, and 50 dB SPL (roughly 60, 50, and 40 dB HL). The two phonemes are quite similar acoustically and differ only in place of articulation. A head turn with visual reinforcement procedure was used in which the infant was taught to respond to a change from a repeating background speech sound (/ba/) to the discriminative speech sound (/da/). With one speech sound repeated continuously in the background, the infants learned to respond only when they detected a change to the alternate speech sound. All three intensity levels were well above the level at which adults reach maximum performance on a speech discrimination task. The highest level used in the study, about 60 dB HL, is considered to be in the range for normal conversational speech (55 to 65 dB HL). The lowest level, about 40 dB HL, would be considered lower than normal speech in the environment.

Mean performance versus intensity data of an infant group and an adult control group are shown in figure 1. Infants required considerably greater stimulus intensity to reach their maximum performance in the discrimination task than did the adults. For the infants, performance was good at the highest two intensities but was rather poor at the lowest intensity. The important feature of the two functions is their location with respect to the abscissa, or x-axis. That infant performance reaches maximum at only .82 proportion correct is typical for the procedure used, even when very easily distinguishable, acoustically dissimilar stimuli are used. The less than perfect performance probably relates to methodological limitations more than to limitations in infant speech perception. That is, the fact that adults can achieve nearly 1.0 and the infants achieve .82 proportion correct is not the significant finding in the present context. What is important is the fact that infants with normal hearing require so much greater signal intensity than do adults to reach their maximum performance.

Figure 1 includes a shaded area that represents the approximate long-term average intensity level of conversational speech under quiet conditions. Infant speech-sound discrimination performance is at its maximum in that region. We can estimate the effects of a mild hearing loss by shifting the performance-intensity functions of the two groups to the right by 15 or 20 dB, which is comparable to a mild shift in threshold. It then becomes obvious that conversational speech will be intersecting the performance-intensity function of the infants now considered hearing impaired at an intensity level for which discrimination performance is well below maximum. That is, speech-sound discrimination performance of infants with normal hearing, which is optimal at levels around normal conversational speech, is considerably reduced when the speech input is presented at intensity levels that simulate a hearing loss of only 15 to 20 dB. Adult discrimination remains at the maximum level, even with a shift of 20 dB.

![Speech-sound discrimination](image)

In another study (Nozza, Rossman, and Bond 1991), a speech-sound discrimination threshold procedure was used to estimate infant-adult differences in the intensity of speech that is required to achieve a given level of performance on a speech perception task. The discrimination threshold procedure is modeled after the traditional threshold procedure used in a detection task such as for estimating thresholds in audiometry. In this adaptation, the speech sounds are varied in intensity, depending on the subject’s response, in the same way that tones are varied in audiometry. An estimate of the intensity at which the infants can correctly discriminate the phonemes about 50% of the time is made with this technique. The speech-sound discrimination threshold procedure was shown to be reliable and valid in two studies of discrimination in noise (Nozza, Miller, Rossman, and Bond 1991; Nozza, Rossman, Bond, and Miller 1990), which will be discussed in the section on noise masking to simulate hearing loss. Using the threshold procedure is a more efficient means of determining differences between groups by estimating the intensity level that corresponds to a predetermined performance level, in this case, 50% correct, rather than trying to develop full psychometric functions.

In the discrimination-in-quiet threshold study (Nozza, Rossman, and Bond 1991), two speech sound contrasts were tested, /ba/-/ga/ and /ba/-/da/. The infant-adult differences in speech-sound discrimination thresholds were 25 and 28 dB, respectively (table 1). The results were consistent with the earlier study (Nozza 1987a) in demonstrating that infants require considerably greater signal intensity than adults to discriminate between simple phonemes.

The question that we needed to answer to interpret properly the results of the two studies on simulated hearing loss and to be able to apply them to questions of management of hearing impairment was related to audibility of the speech stimuli. Can a difference in hearing sensitivity between infants and adults explain the differences in the intensity levels of the speech signal that are needed to reach a criterion level of performance in a discrimination task? If so, then one could argue that for a given threshold value the same increase in speech-sound intensity, that is, gain, would be required by infants as is required by adults. However, if for a given threshold value, infants require speech to be at a greater intensity than adults to perform the discrimination task, then the notion that current adult-based threshold prescription procedures apply to infants should be questioned.

To address the question of whether differences in sensitivity could account for the differences between infants and adults in the two speech-sound discrimination studies (Nozza 1987a; Nozza, Rossman, and Bond 1991), detection thresholds for the /ba/ stimulus that was used in the two speech studies were compared. The thresholds for /ba/, which were obtained as part of another study using a separate group of infants, were 17 dB lower for the adults than for the infants (Nozza, Wagner, and Crandell 1988). This does not account completely for the 25 to 28 dB infant-adult difference in threshold for discrimination (Nozza, Rossman, and Bond 1991), and supports the notion that the more complex process of discrimination requires even greater signal intensity relative to detection threshold for the infants than for the adults. That is, the data suggest that infants require that speech be presented at a greater SL than is required by adults to perform optimally in a simple speech perception task. This has obvious implications for the application of threshold-based procedures for prescribing amplification that were developed using data from adults.

### Spectral Filtering of Speech

Filtering the speech signal is also a useful way of simulating hearing loss. In a doctoral dissertation done in my laboratory, Rossman (1992) examined the effects of a simulated sloping high-frequency hearing loss on infant speech perception by estimating speech-sound discrimination thresholds for two speech-sound contrast pairs, /ba/-/da/ and /da/-/ga/. Infants (7 to 10 months) and adults were tested under both filtered (i.e., simulated hearing loss, or SHL) and unfiltered (i.e., normal hearing, or NH) conditions. Separate groups of subjects at each age provided detection thresholds for stimuli in both the unfiltered and the filtered conditions so that the SL (re: detection threshold) that is required to achieve discrimination threshold for infants and adults could be estimated. Infant-adult differences in discrimination thresholds under NH and SHL conditions are provided in table 2. Again, it is apparent that there is a large difference between the groups in this speech perception task. In the context of amplification for infants, it is important to know whether the differences in detection thresholds account for the dif-


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<tr>
<td>Infants</td>
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<td>35.1</td>
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<tr>
<td>Adults</td>
<td>11.8</td>
<td>9.7</td>
</tr>
<tr>
<td>Infant-Adult Difference</td>
<td>27.5</td>
<td>25.4</td>
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</table>
should be noted. First, when comparing infant detection thresholds and discrimination thresholds, the same influences are present under both tasks. Aside from the discrimination between something and nothing (detection), and between one stimulus and another (discrimination), the tasks are identical, so any factors that affect response behavior in one will affect response behavior in the other. In other words, when looking at the discrimination thresholds in terms of SL, nonsensory factors have been accounted for. Second, even though the data can be normalized by taking the difference between detection and discrimination (i.e., using dB SL), we still must consider the intensity levels in absolute terms. When prescribing hearing aid gain, the amount of amplification depends on the thresholds, so a large nonsensory component that inflates the threshold estimates could translate into over-amplification when the prescription gain values are applied. Two studies were done to determine the magnitude of nonsensory influences on infant behavioral thresholds (Nozza 1995; Nozza and Henson 1999). The studies employed a method by which both unmasked thresholds and minimum masking levels were estimated for infants and adults, and then used to separate sensory from nonsensory contributions to threshold estimates of the infants as compared to the adults. The data revealed that infant thresholds, on the average, were elevated by less than 5 dB at each frequency (.5, 1, 2 kHz) by nonsensory factors. It appears that infant behavioral thresholds are a reasonably good reflection of the sensory process and do not necessarily overestimate hearing impairment by large amounts. Of course, the infants used in our studies are normally developing infants with normal hearing and, even as such, reveal greater intersubject variability than do adult control subjects. Relationships such as these for infants with hearing impairment have not been studied.

Noise Masking to Simulate

Table 2. Mean discrimination thresholds for two speech-sound contrasts, /ba/ versus /ga/ and /da/ versus /ga/, under two listening conditions [full cue, representing the “normal hearing” (NH) condition, and filtered stimuli, representing the “simulated hearing loss” (SHL) condition for infants and adults] (Rossman 1992). Reprinted by permission of author.

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<thead>
<tr>
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<th>/ba-ga/</th>
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<tr>
<td></td>
<td>NH</td>
<td>SHL</td>
<td>NH</td>
<td>SHL</td>
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<tr>
<td>Infants</td>
<td>49.1</td>
<td>65.6</td>
<td>65.0</td>
<td>90.8*</td>
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<tr>
<td>Adults</td>
<td>22.6</td>
<td>41.7</td>
<td>34.2</td>
<td>72.2</td>
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<tr>
<td>Infant-Adult Difference</td>
<td>26.5</td>
<td>23.9</td>
<td>30.8</td>
<td>18.6*</td>
</tr>
</tbody>
</table>

* The mean infant threshold (90.8 dB SPL) for /da/ versus /ga/ in the SHL condition is an underestimate because two infants could not provide a threshold with the intensity of the speech sounds at the highest permitted level. As a consequence, the infant-adult difference for /da/ versus /ga/ in the SHL condition (18.6 dB) is probably an underestimate as well.

Regarding infant thresholds in quiet, there is a question about the degree to which they are inflated by nonsensory factors, such as inattention to the task, use of a response criterion that is different from that used by adults, lack of motivation, and others. It is apparent that such factors affect infant thresholds, but two points should be noted. First, when comparing infant detection thresholds and discrimination thresholds, the same influences are present under both tasks. Aside from the discrimination between something and nothing (detection), and between one stimulus and another (discrimination), the tasks are identical, so any factors that affect response behavior in one will affect response behavior in the other. In other words, when looking at the discrimination thresholds in terms of SL, nonsensory factors have been accounted for. Second, even though the data can be normalized by taking the difference between detection and discrimination (i.e., using dB SL), we still must consider the intensity levels in absolute terms. When prescribing hearing aid gain, the amount of amplification depends on the thresholds, so a large nonsensory component that inflates the threshold estimates could translate into over-amplification when the prescription gain values are applied. Two studies were done to determine the magnitude of nonsensory influences on infant behavioral thresholds (Nozza 1995; Nozza and Henson 1999). The studies employed a method by which both unmasked thresholds and minimum masking levels were estimated for infants and adults, and then used to separate sensory from nonsensory contributions to threshold estimates of the infants as compared to the adults. The data revealed that infant thresholds, on the average, were elevated by less than 5 dB at each frequency (.5, 1, 2 kHz) by nonsensory factors. It appears that infant behavioral thresholds are a reasonably good reflection of the sensory process and do not necessarily overestimate hearing impairment by large amounts. Of course, the infants used in our studies are normally developing infants with normal hearing and, even as such, reveal greater intersubject variability than do adult control subjects. Relationships such as these for infants with hearing impairment have not been studied.

Noise Masking to Simulate

Table 3. Differences (in dB) between infants and adults (infant minus adult) in mean discrimination thresholds (row 1) and mean detection thresholds (row 2) for two speech-sound contrasts, /ba/ versus /ga/ and /da/ versus /ga/, under two listening conditions [full cue, representing the “normal hearing” (NH) condition and filtered stimuli, representing the “simulated hearing loss” (SHL) condition]. The differences (row 3) between values in row 1 and row 2 for each condition represent the differences in sensation level (SL) between the infants and the adults required to reach discrimination thresholds (Rossman 1992). The data reveal that speech sounds must be presented at greater SL for infants than for adults to achieve a given level of performance. Reprinted by permission of author.

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<th>/ba-/ga/</th>
<th>/da-/ga/</th>
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<tr>
<td></td>
<td>NH</td>
<td>SHL</td>
</tr>
<tr>
<td>Infant-Adult Difference in Mean Discrimination Threshold (dB)</td>
<td>26.5</td>
<td>23.9</td>
</tr>
<tr>
<td>Infant-Adult Difference in Mean Detection Threshold (dB)*</td>
<td>17.1</td>
<td>16.6</td>
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<tr>
<td>Infant-Adult Difference in Sensation Level (dB re: mean detection threshold) Required to Reach Discrimination Threshold</td>
<td>9.4</td>
<td>7.3</td>
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*Mean detection thresholds were estimated to be the average of the mean detection thresholds for the two stimuli (/ba/ and /ga/ for the /ba-/ga/ contrast and /da/ and /ga/ for the /da-/ga/ contrast) for each age group.
The use of masking noise has also added to our understanding of the effects of hearing loss on auditory capabilities (e.g., Fabry and van Tasell 1986). In two studies of infant discrimination of /ba/ versus /ga/ in noise, the results demonstrated that infants required greater signal-to-noise ratio (S/N) than adults to reach maximum possible performance (Nozza et al. 1990) or to reach speech-sound discrimination-in-noise thresholds (Nozza et al. 1991). Table 4 shows discrimination-in-noise thresholds (dB S/N) for speech-sound contrast /ba/ versus /ga/ for infants and adults (Nozza, Miller et al. 1991).

<table>
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<tr>
<th>S/N</th>
<th>Infants</th>
<th>Adults</th>
<th>Difference</th>
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<tr>
<td></td>
<td>–1.7 dB</td>
<td>–8.6 dB</td>
<td>6.9 dB</td>
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Figure 2. Performance (percent correct) versus signal-to-noise ratio (S/N) for discrimination of /ba/ from /ga/ in a background of noise for infants and adults (from Nozza et al. 1990). The two vertical dashed lines are placed on the x-axis at the discrimination thresholds obtained on separate groups of subjects (see table 4) to illustrate that the threshold values are found in the center of the rising portions of the functions for its respective age group and, thereby, agree quite well with the performance-S/N functions for each group (Nozza, Miller et al. 1991). Reprinted by permission of authors and American Speech-Language-Hearing Association. ©1991. Journal of Speech and Hearing Research 34:643-650.

**Hearing Loss**

The use of masking noise has also added to our understanding of the effects of hearing loss on auditory capabilities (e.g., Fabry and van Tasell 1986). In two studies of infant discrimination of /ba/ versus /ga/ in noise, the results demonstrated that infants required greater signal-to-noise ratio (S/N) than adults to reach maximum possible performance (Nozza et al. 1990) or to reach speech-sound discrimination-in-noise thresholds (Nozza et al. 1990; Nozza, Miller et al. 1991). Table 4 shows discrimination-in-noise thresholds (Nozza, Miller et al. 1991), and figure 2 shows the performance versus S/N functions for infants and adults in the discrimination task (Nozza et al. 1990). Superimposed on the S/N functions in figure 2 are two vertical lines representing the thresholds from table 4. By imposing the same masking noise on both infants and adults, we theoretically have not only imposed a “hearing impairment” on the subjects; we have imposed the same degree of hearing impairment on both groups. The infant-adult differences in performance versus S/N functions and in discrimination thresholds in noise, therefore, suggest that the infants are at a disadvantage relative to adults when performing the task of distinguishing one speech sound from another under conditions that simulate the same degree of peripheral hearing loss.

Stated differently, the data are consistent with the notion that infants require greater signal level relative to threshold to perform a speech-sound discrimination task at some criterion level of performance.

Of course, the masking noise in this kind of simulation could affect the infants in a different way. It is possible that the masking noise served as a distraction to the infants and caused a reduction in performance unrelated to sensory processes. However, the effects of unfavorable (i.e., noisy) environments on infant speech perception abilities is a limitation to consider in its own right. Consider the infant growing up in a noisy home environment. Our data suggest that noise causes greater interference with the process of phonetic discrimination in infants than would be predicted based on adult data. The need for greater S/N was determined when speech sounds were presented at intensity levels shown to be optimal for infants with normal hearing in a quiet environment. It is not difficult to speculate on the potential problems associated with an infant or young child who is hearing impaired wearing hearing aids in a noisy listening environment. Infants may be at an added disadvantage in noise because of limitations in binaural analysis. Infant binaural release from masking is not as well developed as that of adults (Nozza 1987b; Nozza et al. 1988).

The requirements for greater signal intensity and for greater S/N when a background noise is present indicate that infants cannot tolerate a degraded signal as well as adults when making simple speech-sound discriminations. Although a part of the explanation for the infants’ need for greater signal intensity in a speech-sound discrimination task relates to sensitivity, we cannot totally account for infant-adult differences in speech perception based on differences in audibility alone. We should note also that the need for greater signal intensity in speech perception tasks is found in studies of children older than the infants discussed in this chapter. Elliott and Katz (1980) reported that there was an age effect in the intensity level that was required to reach maximum performance using the NU-CHIPS test, even when the words were known to be in the vocabulary of all of the subjects. Also, Sanderson-Leepa and Rintelmann (1975) revealed variations in performance intensity (PI) functions across
age groups in young children for several different word recognition tests.

If differences in audibility cannot account for the differences between infants and adults in speech perception tasks, the differences may be related to the ability of infants to attend to the tasks, their level of motivation, or some other process that is unrelated to the processing of the auditory signal. If that were the case, would that mean that the infant, even though unable to respond at certain intensity levels, would still benefit in some passive way from the auditory signal at the same SL as an adult? Or must the infant process the signal in a meaningful way for it to provide the stimulus for language development? It is my contention that an infant who is under stimulus control in a behavioral task, such as speech-sound discrimination using the head-turn procedure, responds when the signal is processed in a meaningful way (e.g., when one speech sound is recognized as different from the other). Failure to respond is evidence that the signal was not processed and suggests that it could not be incorporated into the acquisition of language. Others may feel that a passive process drives the acquisition of language from speech input and that the stimulus attributes necessary to motivate a response in the infants may not be those that are necessary to inspire language development. Further research is needed to clarify this question.

**Implications for Pediatric Amplification**

The importance of quality speech input, very early in life, is not questioned. It is clear that infants use speech input for developing language from very early in life. Although it has been assumed by many, the belief that early intervention is necessary to minimize the effects of hearing loss during infancy is now supported by data. As we consider strategies for amplification for the very young, we must realize that infants, and young children as well, require speech to be at a greater SL, or a greater S/N in noise, than do adults to perform optimally in speech perception tasks. Given that most threshold-based prescriptive procedures are based on our understanding of hearing impairment in adults, we must consider that they may not serve infants and young children with hearing impairment as well as we would like.

There are many issues to consider. Estimating gain based on infant thresholds, whether they are behavioral or electrophysiologic, using current prescriptive formulas, has many possible pitfalls. There is more variability in the thresholds of young infants, so care must be taken when applying prescriptive gain values. If we decide that gain should be greater for infants with a given threshold than for adults, we must also consider the possibility of providing too much gain. What limitations must be imposed on the gain and output of a hearing aid for an infant with needs for greater signal intensity than an adult, with thresholds that may or may not be accurate, and with possible greater susceptibility to overamplification? This is clearly one of the more difficult problems we face as we fit younger and younger infants with hearing aids. Of course, we must also consider the consequences of providing amplification that is providing too little gain. Such underfitting may prevent adequate use of residual hearing and optimal development of language.

**Summary**

The importance of early intervention with infants with hearing impairment is no longer in doubt. However, using methods developed with and for adults to prescribe amplification for infants may be inappropriate. Research on the effects of simulated hearing loss on infant speech perception suggests that infants require greater signal intensity relative to behavioral threshold to perform optimally in speech perception tasks compared to adults. When noise is present and viewed as a means of elevating thresholds to simulate hearing loss, infants require greater S/N. Audiologists fitting hearing aids on infants must be aware of the fact that infants perform better in tasks of speech perception when signals are at greater SLs than would be predicted based on adult data. Further research is necessary to verify and clarify the relationships between infant thresholds and speech perception so that hearing aid prescriptive procedures specifically suited for infants can be developed. Clinicians must also participate by conducting appropriate outcome studies with infants with hearing impairment to determine the efficacy of the fitting strategies they favor.

**References**


