

# **Dichotic Interaural Intensity Difference (DIID) Training: A Review of Existing Research and Future Directions**

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Dichotic Interaural Intensity Difference (DIID) training was designed to address deficits in dichotic processing. The present review describes the theoretical and physiologic bases for this procedure, highlighting the available efficacy data that are currently available. Additionally, a new approach to the DIID (i.e., DIID II) is presented in which interaural timing deficits are utilized during training instead of interaural intensity differences (IIDs). The DIID II is considered in light of available research present on the dichotic lag effect and potential advantages it may provide, over the classic DIID protocol, in cases of peripheral hearing loss.

## **A REVIEW: DICHOTIC INTERAURAL INTENSITY DIFFERENCE (DIID) TRAINING**

### ***Theoretical Foundations***

The DIID is an auditory training paradigm which is emerging as a form of rehabilitation in cases of central auditory processing disorder (Baran, Shinn, & Musiek, 2006; Musiek & Schochat, 1998; Musiek, Shinn, & Hare, 2002). The

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current application of the DIID is built upon what is known of both auditory plasticity and dichotic processing. Plasticity has been defined by Musiek and Berge (1998) as the “alteration of nerve cells to better conform to immediate environmental influences, with this alteration often associated with behavioral change” (p. 18). The anatomy of plasticity has often been considered a change in synaptic density and dendritic sprouting which can enhance neurotransmission efficiency by enhancing neural connectivity (see Bear, Connors, & Paradiso, 2001). However, there are reports that demonstrate plastic changes that are simply too rapid for these morphological changes to be considered the underlying mechanism. These rapid plasticity changes may be related to increased neurotransmitters, neural reorganization, and/or a disinhibition of previously inhibited (or suppressed) neural circuits (Robertson & Irvine, 1989; Wang, Salvi, & Powers, 1996).

A dichotically presented stimulus is one in which a different signal is presented to each ear simultaneously. In these paradigms, a patient is asked to recall one or both of the auditory signals being presented. If both stimuli are to be recalled, then the task is one of binaural integration. If only a single signal is to be recalled, and the other ignored, then the task is one of binaural separation (Musiek, 1999; Musiek & Pinheiro, 1985; Musiek et al., 2002). A dichotic deficit will usually most typically present as a unilateral deficit on these tasks, although bilateral deficits can also be encountered. The goal of the DIID is to bring performance of the ear which performs more poorly in dichotic tasks into the normal range while ensuring that the ear which performs better on these tasks continues to do so.

### *The DIID and Relevant Underlying Physiologic Mechanisms*

To better understand how the DIID works, it becomes necessary to describe the physiology of dichotic processing. There are two main pathways in the central auditory nervous system which lead from the peripheral organs to the auditory cortex. The stronger of these two pathways are the contralateral connections, which connect the left periphery to the right hemisphere and the right periphery to the left hemisphere. However, weaker ipsilateral connections which connect, for instance, the left periphery to the left hemisphere also exist (Pickles, 1982). Animal models have shown that the ipsilateral connections may be weaker because there are more contralateral connections in the central nervous system (Rosenzweig, 1951; Tunturi, 1946).

The auditory pathway may recruit the contralateral pathways or both the ipsilateral and contralateral pathways depending on how it is stimulated across channels. When a stimulus is presented monotically or diotically (i.e., single signal to one ear or the same signal to both ears, respectively), both the contralateral and ipsilateral pathways are used to some extent to bring the neural signal to the cerebrum. The situation changes, however, when stimuli are presented dichotically at

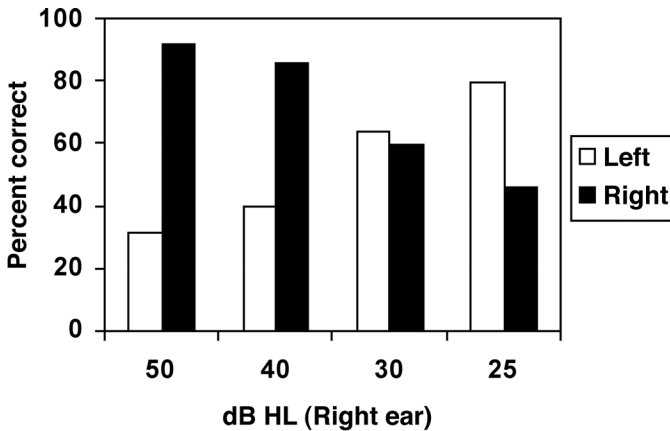
equal sensation levels. The contralateral connections will still carry the signal, but the ipsilateral connections will now be suppressed to some degree (Hall & Goldstein, 1968; Rosenzweig, 1951). This indicates that the pathways contributing to dichotic auditory processing are mainly the stronger contralateral connections. It is possible that this suppression of the ipsilateral connections occurs because of overlap between the two pathways at some point along the ascending route and because the two pathways compete for critical neural substrate (Kimura, 1961).

Consider the scenario where stimuli are presented dichotically and the patient is asked to repeat both signals back. These signals are presented at equal sensation levels and need to reach the language areas in the left hemisphere in order for the listener to identify verbally what they heard. Although the right ear stimulus can reach this area directly along the contralateral pathway, the left ear cannot directly reach the left hemisphere because the ipsilateral pathway is being suppressed. As a consequence, the left ear signal must first go to the right hemisphere via the contralateral connections, and then travel to the left hemisphere via the interhemispheric connections (i.e., corpus callosum).

Thus, for the right ear, the contralateral pathway and language areas in the left hemisphere need to be healthy. For the left ear, the contralateral pathway, the right hemisphere, the corpus callosum, and the language areas in the left hemisphere need to be healthy. If both of these routes are able to function appropriately, then both signals in the dichotic task should be able to be repeated verbally by the patient.

Function of this normal route will change, however, if any of the aforementioned pathways are compromised. Consider the case of callosotomy, which consists of a partial or complete ablation of the callosal fibers. Ablation of the auditory (posterior) region of the corpus callosum often yields drastic decreases in performance on tests which require interhemispheric interaction (Milner, Taylor, & Sperry, 1968; Sparks & Geschwind, 1968). Specifically, the patient has considerable difficulty repeating back stimuli that are presented to the left ear. This has been shown using a variety of stimuli: dichotic digits and/or words (Damasio & Damasio, 1979; Damasio, Damasio, Castro-Caldas, & Ferro, 1976; Musiek, Wilson, & Pinheiro, 1979), the dichotic rhyme test (Musiek et al., 1989), the staggered spondaic words test (Musiek & Wilson, 1979; Musiek, Wilson, & Reeves, 1981), competing sentences tests (Musiek et al., 1979; Musiek et al., 1981), and the frequency patterns test (Musiek, Pinheiro, & Wilson, 1980).

If the corpus callosum has been damaged in some way or has been prevented from transmitting the neural signal optimally, then performance on dichotic tasks will reflect central auditory pathology. Specifically, in most patients that show left hemisphere dominance for language, obstruction of the left ear signal will occur during dichotic tasks. The signal will travel from the left ear to the right hemisphere via the contralateral connections. However, upon reaching the right



*Figure 1.* Schematic representation of beneficial interaural intensity differences (IIDs). The left ear (poorer ear) is maintained at 50 dB HL, while the right ear intensity is decreased. At some level, in this case 30 dB HL in the right ear, the poorer ear will out-perform the better ear.

hemisphere, the signal can no longer be transmitted to the left hemisphere language areas. This is because the route of transmission, the corpus callosum, is no longer functioning properly. Therefore, the callosotomy patient will be able to say the right ear stimulus but not the left ear stimulus when the stimuli are presented dichotically.

Of interest is that this dichotic deficit can be overcome if the dichotic stimuli are presented at unequal sensation levels. Specifically, when the intensity level in the better ear is decreased while the level in the poorer ear is kept constant, the patient can respond more easily to poorer ear stimuli, until at some interaural intensity difference (IID) the original “poorer ear” outperforms the original “better ear” (see Figure 1). This was observed by Musiek et al. (1979), who reported that patients with callosal lesions could correctly identify more left ear stimuli when the right ear presentation level was decreased. It is not entirely clear what the mechanism is behind this change. However, it is thought that decreasing the better ear presentation level releases some of the other neural pathways, including the left ear ipsilateral pathway, from suppression. This occurs in part because the greater the intensity of a stimulus, the greater the amount of neural substrate that is activated (Lasota et al., 2003). As a result, utilization of this ipsilateral pathway allows the left ear signal to reach the left hemisphere language areas with greater ease. It is this IID phenomenon upon which the DIID is based.

The DIID rehabilitation protocol makes use of the physiologic principles defined above to allow the central auditory nervous system to perform more efficient dichotic processing. Patients involved in DIID training participate in a va-

riety of dichotic tasks which are presented at various IIDs. The purpose of the procedure is to, first, reduce the amount that the weaker connections are suppressed by the stronger connections and, second, to strengthen the weaker connections under progressively more challenging listening conditions. To reduce the amount of suppression, the presentation level in the better ear is decreased until the left ear performs normally. To then strengthen the weaker connections under challenging conditions, the presentation level in the better ear is gradually increased over time. The ultimate goal of DIID training is to have the poorer ear perform normally when the IID is zero.

In reaching this goal, speech stimuli are presented dichotically and the patient is asked to repeat stimuli verbally in a binaural integration or binaural separation task. Speech stimuli from the following media are typically utilized: Qualitone (Q/MASS) – Speech Audiometry Volume 1, Department of Veterans Affairs – Speech Recognition and Identification Materials, Department of Veterans Affairs – Tonal and Speech Materials, and Auditec – Extended Dichotic Digits.

### *Applications in the Learning Disabled Population*

Callosal dysfunction is also encountered in the learning disabled population, potentially making the DIID a useful rehabilitation protocol in these cases. In some instances of learning disability, it has been theorized that interhemispheric transfer along the corpus callosum may be interrupted because of a maturational delay in myelin development (Musiek, Gollegly, & Baran, 1984). The greater the amount of myelin surrounding an axon, the faster the signal can travel within the cerebrum and the more efficient auditory processing may become. The corpus callosum is especially highly myelinated and requires this myelin in order to perform ideally (Bear, Connors, & Paradiso, 2007; Musiek et al., 1984). Additionally, myelin is not completely developed at birth and takes some time to fully mature. For instance, it may take some auditory regions of the cerebrum 12 to 14 years of age or more to become fully myelinated (Salamy, 1978; Yakovlev & LeCours, 1967).

It should be noted, however, that this maturational milestone for myelin development is not a time course which applies to all children. There is considerable variability in myelin development across individuals (Bamiou, Sisodiya, Musiek, & Luzon, 2007; Salamy, 1978). It is for those children who are at the high end of the distribution, who exhibit these delays, that a reduction in callosal efficiency becomes noteworthy (Musiek et al., 1984).

Research has indicated that there does appear to be some tendency for the corpus callosum to appear different in the learning disabled child, suggesting that they may be more prone to these maturational delays. Some studies have used magnetic resonance imaging (MRI) to compare the structure of the corpus callosum in children with learning disabilities and/or attention deficit disorder (ADD) to normal controls (Hynd et al., 1991; Semrud-Clikeman et al., 1994). It was

found in both cases that the auditory region of the corpus callosum was significantly smaller in the experimental group than in the control group. The researchers suggested that the smaller posterior region may negatively affect modulation of cerebral activity in the experimental group (Hynd et al., 1991). Additionally, the number of fibers in the posterior region may be smaller in the experimental group (Semrud-Clikeman et al., 1994). There is also evidence to suggest that the smaller the corpus callosum, the bigger the difference between ears in performance on dichotic listening (Benavidez et al., 1999).

Basic research with non-human animals has also provided some additional evidence for callosal involvement in cases of learning disabilities. Sechzer, Folstein, Geiger, and Mervis (1977) completely sectioned the corpus callosum and compared behavioral development to normal controls. It was found that the experimental group tended to be more hyperactive and have more memory issues than the control group. Both of these behaviors are often exhibited by children with learning disabilities and suggest a possible link between structure and behavior.

### *Efficacy of the DIID*

Several studies have shown the DIID training protocol to provide benefits to the individuals with central auditory processing disorders and normal peripheral hearing. Behaviorally, improvements are witnessed on dichotic processing tasks. Investigating children with confirmed auditory processing disorder, Weihing and Musiek (2007) recorded left (poorer) ear improvement on the dichotic digits ( $N = 11$ ) and the competing sentences ( $N = 10$ ) tests and compared this improvement to a control group ( $N = 7$ ). Following DIID training, the left ear improvement observed in the experimental groups was between 10-15% on the two tests, whereas the control group only improved approximately 6%. Moncrieff and Wertz (2008) conducted a similar study, comparing the improvement on the dichotic digits in two pediatric samples with established dichotic deficits ( $N = 8$  and 13, respectively). Improvement on dichotic tasks was again observed following training. It should be noted that in both of these investigations (Moncrieff & Wertz, 2008; Weihing & Musiek, 2007), failure to include a sham group in the protocol (e.g., a group with established dichotic deficits that received a non-auditory based intervention) somewhat limits the validity of the results.

Case studies which incorporate behavioral measures have also evidence of DIID training benefits in individuals with central auditory processing disorder and normal peripheral hearing. Musiek and Schochat (1998) administered the DIID as part of an auditory training battery to a 15-year-old boy with learning disabilities. Pre-training, the patient showed a bilateral deficit on the dichotic digits with worse performance in the left ear. Following 6 weeks of training, performance on this measure returned to normal limits in both ears. Benefits were also witnessed on speech-language measures and in academic performance; however

it is unclear whether these secondary benefits can be attributed to the DIID (Musiek & Schochat, 1998). Musiek, Baran, and Shinn (2004) also administered an informal auditory training protocol (e.g., patient performed DIID type tasks at home) for an adult who had suffered a closed head injury. Prior to beginning the training protocol, the patient showed a left ear deficit on the dichotic digits and the competing sentences tests. At the end of training, the left ear performance on the dichotic digits was within normal limits and on the competing sentences it was borderline normal. This patient also reported that she was now able to engage in activities she previously had not been able to do (e.g., listen on the phone with her left ear), although her ability to complete these activities had still not returned to their initial state.

Effects of the DIID have also been investigated electrophysiologically. Schochat, Musiek, Alonso, and Ogata (in press) administered an auditory training protocol, in which the DIID was a component, to 30 children with auditory processing disorder and a control group. Results showed that the middle latency response Na-Pa amplitude at the C3 electrode (i.e., electrode over the left hemisphere) was greater in the auditory processing group following training, but not in a control group. These results demonstrate that changes induced by an auditory training protocol which includes the DIID may be measured electrophysiologically as well as behaviorally.

Taken as a whole, the research investigating the efficacy of the DIID is encouraging. However, the evidence behind this procedure is still emerging. Though promising, more research is needed to demonstrate its value in intervention.

## CONSIDERATION OF POTENTIAL FUTURE TRENDS: DIID II

### *Dichotic Lag Phenomenon*

The classic DIID procedure demonstrates considerable potential as a useful clinical tool. It does, however, present some limitations in cases of peripheral hearing loss. Since the audibility of the training stimulus is being modified in the DIID, some portions of the acoustic signal may be eliminated from the patient's perception. Thus, where peripheral hearing loss is present, manipulation of DIIDs may introduce unwanted variability into DIID performance.

A possible remedy to this issue is to manipulate interaural timing differences (ITDs) instead of utilizing intensity differences. These manipulations realign the respective onset of the stimulus presented to one ear relative to the other, such that one lags the other in time, and don't require that audibility of the signal be modified in any way. For reasons which will be discussed below, the ear which receives this lagging stimulus (i.e., lagged ear) can more easily process the signal than the ear which receives the leading stimulus (i.e., lead ear). In theory, this advantage can be utilized in a DIID-like protocol to obtain similar advantages to

those provided by manipulation of IIDs. Thus, just as decreasing the intensity of the stimulus in the better ear aided perception of stimuli in the poorer ear, so does lagging the onset of the stimulus in the poorer ear aid in the perception of the stimulus in that ear. This modification of the DIID, which utilizes ITDs, we have called the DIID II.

A considerable amount of audiologic research has examined this dichotic lag phenomenon. First noted by Studdert-Kennedy, Shankweiler, and Schulman (1970), it was reported that performance advantages for the lagged ear start to emerge in the vicinity of 30 ms ITD. The performance advantage that the lagged ear shows relative to the lead ear eventually reaches a maximum of 25%, occurring around 60 ms. This finding was expected when the right ear was lagged, since a right ear advantage is generally noted on dichotic tasks. However, observing a left ear advantage when the left ear was lagged was a new and unexpected finding. Berlin, Lowe-Belle, Cullen, Thompson, and Loovis (1973) also noted that around a 30 ms ITD was necessary to yield a lag effect and that maximal advantages were obtained at ITDs in the vicinity of 60 ms. When the right ear was lagged, their results were similar to Studdert-Kennedy et al., showing a right ear advantage over the left. However, contrary to Studdert-Kennedy et al., Berlin and colleagues observed that when the left ear was lagged it yielded an elimination of the right ear advantage, as opposed to demonstrating a considerable improvement of the left ear over the right. Thus, there was an advantage for lagging the left ear when compared to leading the right, but this advantage was not great enough to yield appreciably greater left ear performance over the right ear. This finding subsequently found support in the literature (Beiter & Sharf, 1976; Gelfand, Hoffman, Waltzman, & Piper, 1980; Mirabile, Porter, Hughes, & Berlin, 1978). The lag effect was also observed in cases of central auditory lesions (Berlin, Lowe-Bell, Jannetta, & Kline, 1972). Taken as a whole, these studies would seem to suggest that lagging either the right or left ear relative to the contralateral side will yield improved performance in the lagged ear, and this increase in performance may or may not be great enough to overcome ear advantages that are present at baseline. It should be noted that some studies have not been able to demonstrate a lag effect (Bingea & Raffin, 1986; Roeser, Millay, & Morrow, 1983). However, these studies seem to be in the minority and have a difficult time resolving this discrepancy.

### *Cognitive and Physiologic Explanations for the Lag Effect*

Several explanations have been provided for the lag effect phenomenon. In their original paper, Studdert-Kennedy et al. (1970) concluded that the lead stimulus cannot be properly represented at the central level because the listener is switching their attention to the contralateral ear just as crucial information is being presented on the ipsilateral side. The present authors also believe that the recency effect may be involved in this phenomenon. The recency effect is well



known in cognitive neuroscience. If one is asked to remember a string of items the last item heard will be most accurately recalled (Duncan & Murdock, 2000; Greene, 1986). The recency effect has been demonstrated under various study conditions for many years (Craik & Levy, 1970). This phenomenon may well play a role in regard to the lag effect which is important in using the DIID II. As discussed earlier, the ear which receives the lagged item yields better performance. A reason for this may be that the lagged stimulus occurs last and may best be recalled (i.e., the recency effect). This and some masking factors may explain why the trailing stimulus yields better scores than the leading stimulus. The masking factor is one that may interplay with the recency effect. When the two stimuli presented dichotically overlap in time, there is simultaneous masking which could yield a central masking effect (Zwislowski, 1953). This central masking effect would influence the middle and last part of the leading stimulus and potentially compromise optimal perception of these segments. However, for the latter part of the lagging stimulus, there would not be any central masking effect allowing the recency effect to work optimally. Therefore the recency effect will provide an advantage for recall to the lagging word, digit, or consonant-vowel syllable (CV).

Given that they yield similar degrees of benefits from manipulation of interaural differences, it would seem likely that the physiologic effects of manipulating the ITD are similar to manipulating the IID. It was noted earlier in this paper that reducing the intensity in the better ear would yield improved performance in the poorer ear because of decreased reliance on the compromised corpus callosum and increased reliance on the healthy ipsilateral pathways. A similar phenomenon is thought to happen with the lag effect. For instance, Berlin et al. (1973) speculated, based on similar paradigms in the somatosensory system, that reliance is less on the ipsilateral pathways and greater on the corpus callosum when the ITD is 30 ms or less. Therefore when onsets are staggered, key processes of each neural pathway can have nearly full access to the necessary neural substrate. This allows for better dichotic performance by permitting both ipsilateral and contralateral auditory pathways to contribute to hearing processes. An additional advantage may also be that a full complement of temporal, linguistic, attentional, and acoustic cues can operate in the period of time when dichotic stimuli don't overlap temporally. Therefore, temporal offsets related to these mechanisms can help explain the advantage of the lag effect.

### ***Is the Efficacy of the DIID II Comparable to That of the DIID?***

Although there are many reasons to expect that the DIID II is theoretically sound, it would be advantageous to demonstrate that this new variation on an existing procedure yields beneficial results in a population that would normally receive the DIID. To this end, a small pilot study was conducted by one author (C.L.) to determine if dichotic processing benefits were suggested when using the

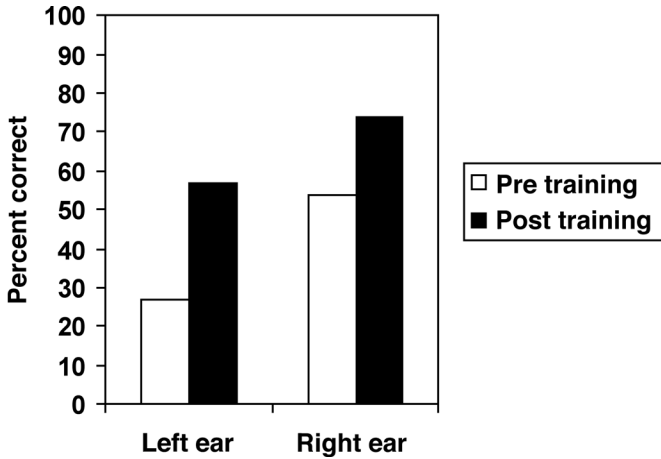


Figure 2. Case from a Dichotic Interaural Intensity Difference (DIID) II pilot study conducted by one author (C.L.) showing improvement of dichotic processing following training. The subject is a 10-year-old boy with normal peripheral hearing who was trained for 5 months.

DIID II in a population that would be normally administered the DIID. Although not a substitute for a complete investigation of this procedure, a pilot study of this type would provide some tentative evidence for benefits offered by DIID II training.

In this pilot study, children with confirmed dichotic processing issues and normal peripheral hearing were enrolled in the DIID II for a period of 10 weeks ( $N = 14$ ). A case result from this sample is shown in Figure 2. Stimuli were selected randomly from the NU-6 (Tillman & Carhart, 1966), CID W-22 (Hirsch et al., 1952), and the PBK-50 (Haskins, 1949), and dichotic stimuli arranged so that they had 150 ms of overlap, 250 ms of overlap, or simultaneous presentation. These particular conditions were selected to ensure increasing difficulty of the task. Dependent measures included pre versus post training dichotic digit scores. Results indicated that, following training, the ear which performed more poorly on dichotic tasks now performed significantly better,  $t(13) = 6.41$ ,  $p < .001$ . The numerical magnitude of this improvement on average was approximately 30%. This result demonstrates, at least tentatively, that the DIID II may be used as an alternative to the classic DIID procedure and obtain similar effects. This assertion is based on the finding that both paradigms yield improvements in dichotic processing.

The pilot study also revealed some evidence which suggested that DIID II training may translate into benefits in natural listening situations. Parents and teachers were asked to rate children's improvement on an informal, subjective communication-education questionnaire following DIID II training. Some of the

topics covered on this questionnaire included: ability to follow directions, communication ability, academic performance, attention, and ability to hear in noise. Each area was rated from 0 to 5, with 0 indicating no improvement and 5 indicating a 100% improvement, and 3 being the average. The findings showed average or above average improvement (i.e., 3 or greater) on the topic areas assessed. This suggests that benefits obtained from DIID II training may generalize to real-world situations, beyond tests administered in the sound booth, at least as judged by parent's and teacher's perception of the child's performance.

### *The Future of the DIID II*

For the DIID II to be incorporated clinically, there would appear to be at least two criteria that need to be met. First, it must at least provide clinical value equal to the benefits yielded by the classic DIID. If it does not, then there would be no reason to select the DIID II for training over the classic DIID, the latter of which has been investigated in more detail in the laboratory. This first criterion would appear to be met, at least tentatively, as indicated by the pilot study reported in the present paper which investigated the DIID II in a sample of children with dichotic processing deficits. However, a more controlled study needs to verify this conclusion. Second, assuming the DIID II provides benefits equal to the classic DIID, then it must also offer something new to the area of rehabilitation. As it has been mentioned already, the DIID II may find practical application in cases of peripheral loss in which the IID introduced by the DIID procedure raises concerns over how much of the signal is audible.

Given this goal, the most obvious population in which the DIID II might find application are patients with presbycusis. It is well known that age related changes in the central auditory nervous system can lead to degradation of the corpus callosum and an increasing prevalence of dichotic deficits (Bellis & Wilbur, 2001). Although this would initially suggest that this older population is a good candidate for the DIID procedure, the use of IIDs in this training protocol may be difficult to introduce with the co-occurrence of age related peripheral hearing loss. If the DIID II is less susceptible to these peripheral effects, however, then it might find tremendous application in this older adult group. One might expect that it would be less susceptible to peripheral effects because the DIID II does not manipulate audibility, only time. Additionally, the DIID II need not be restricted to peripheral hearing loss in cases of presbycusis, as there would be no reason to expect that dichotic deficits could not be comorbid in some cases of peripheral hearing loss in school aged children.

There are several limitations, however, to the application of the DIID II in cases of peripheral hearing loss that need to be addressed prior to its introduction in the clinic. The first is perhaps the most obvious: there needs to be at least some degree of residual hearing so that the CVs can be perceived. This would likely eliminate a percentage of peripheral hearing loss cases from the DIID II proce-

ture, specifically mid to high frequency severe to profound losses. The second limitation is perhaps more important to address, and that is that in addition to poorer audibility, presbycusis also induces poorer temporal resolution as a result of wider auditory filters at the peripheral level and, in the cases of the older adult, degradation of the central auditory nervous system (Committee on Hearing, Bioacoustics, & Biomechanics [CHABA], 1988). It will have to be determined what is the individual impact of each of these factors on the DIID II protocol if it is to be used in the clinic. If the DIID II is as equally susceptible to these peripheral issues as the classic DIID, then there seems to be little advantage in using it as an alternative. However, it would seem likely that, in at least some if not a majority of cases, that temporal issues induced by peripheral hearing loss would be overshadowed by issues of audibility. Additionally, it may be possible to increase the lag slightly to overcome temporal processing issues.

A third limitation is revealed from research into the dichotic lag effect. Some studies have indicated that the dichotic lag effect becomes unpredictable in cases of sensorineural hearing loss. For instance, Cattey (1981) noted that patients with this type of hearing loss will sometimes show a lead effect instead of a lag effect in this dichotic paradigm. Additionally, Gelfand et al. (1980) found in older adults that lagging the right ear yields the expected result, while lagging the left ear improves left ear performance with no decrement in the right ear performance. This pattern was notably different from what they encountered in younger adults, in which there was a considerably reduced lead effect for the right ear. Although both of these studies have some limitations of their own, they at least suggest that the dichotic lag effect in cases of peripheral hearing loss and presbycusis needs to be investigated further before a standardized DIID II protocol can be implemented. This does not lessen the potential impact of the DIID II in this population, but indicates that a more solid basic research base needs to be established before the training paradigm can gain acceptance.

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