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What is the digits-in-noise test?

The digits-in-noise test (DIN) has become increasingly popular as a consumer-based method to screen for hearing loss. The DIN is a speech-in-noise test that uses digit triplets (e.g. 5-9-2), typically presented in steady speech-shaped noise, to measure the speech reception threshold (SRT), expressed in dB signal-to-noise ratio (dB SNR), where a listener can recognize 50% of the digit triplets correctly. Compared to pure tone audiometry or speech recognition in quiet, speech recognition in noise has the advantage of being more characteristic of a person's hearing ability in real-life situations. Furthermore, DIN assessment of sensorineural hearing loss (SNHL) correlates highly with pure tone audiometry and eliminates the need for a soundproof booth, calibrated equipment and a test administrator. The first smartphone-based hearing test was therefore released in South Africa in 2016 called *hearZA*. This was followed by the release of an American version in 2018 (*hearScreenUSA*) and in partnership with the World Health Organization, the *hearWHO* app in 2019.

The problem with previous test versions

Previous versions of all DINs either sequentially test each ear (monaurally) or present the test stimuli binaurally and identically to each ear (homophasic or diotic). This binaural DIN setup allows for rapid testing in approximately 3 minutes, whereas sequential testing of each ear doubles test time and may thus reduce uptake and completion. Using diotic presentation may, however, preclude detection of unilateral or asymmetric sensorineural hearing loss (SNHL). These listeners may pass the diotic DIN test because performance is largely based on the functionally better ear. Furthermore, both monaural and diotic testing is insensitive to the attenuation caused by conductive hearing loss (CHL) because most DINs are presented at suprathreshold intensities. To improve the sensitivity of the DIN, especially for listeners with unilateral, asymmetrical SNHL and CHL, we evaluated the use of a DIN test paradigm using digits that are phase inverted (antiphasic) between the ears, while leaving the masking noise interaurally in-phase. Such a configuration of stimuli (N_oS_π) was shown to improve DIN SRTs in normal hearing listeners.

Smits and colleagues (2016) examined SRTs in different listening conditions for the Dutch and American English DIN among normal hearing listeners. Results indicated that the threshold advantage over monotic presentation provided by diotic (N_oS_o) presentation was small ($\cong 1$ dB). However, the use of antiphasic digits (N_oS_π) provided a further $\cong 5$ dB advantage. Listeners with unilateral SNHL or CHL are not expected to have full access to the antiphasic advantage due to subtle timing irregularities caused by peripheral hearing loss, either sensorineural. In cases of symmetric hearing loss, the antiphasic advantage is expected to decrease as the degree of hearing loss increases because of increasing threshold and timing cue deterioration. These findings supported the idea that antiphasic digit presentation could sensitize the DIN for a wider range of hearing loss types while using a single binaural test. This would improve the function of current consumer-based DINs.

Results of antiphasic presentation

Antiphasic DIN was significantly more sensitive to all three forms of hearing loss than the diotic DIN. Area under the receiver operating characteristics (ROC) curve for detection of hearing loss (> 25 dB HL) was higher for antiphasic DIN (0.94) than for diotic DIN (0.77) presentation. After correcting for age, PTA of listeners with normal hearing or symmetric SNHL was more strongly correlated with antiphasic ($r_{\text{partial}[96]}=0.69$) than diotic ($r_{\text{partial}}=0.54$) SRTs. Slope of fitted regression lines predicting SRT from PTA was significantly steeper for antiphasic than diotic DIN. For listeners with normal hearing or CHL, antiphasic SRTs were more strongly correlated with PTA ($r_{\text{partial}[62]}=0.92$) than diotic SRTs ($r_{\text{partial}[62]}=0.64$). Slope of regression line with PTA was also significantly steeper for antiphasic than diotic DIN.

Antiphasic presentation improved the test characteristics of the smartphone DIN test with higher sensitivity and specificity to detect unilateral and bilateral symmetric SNHL, as well as CHL.

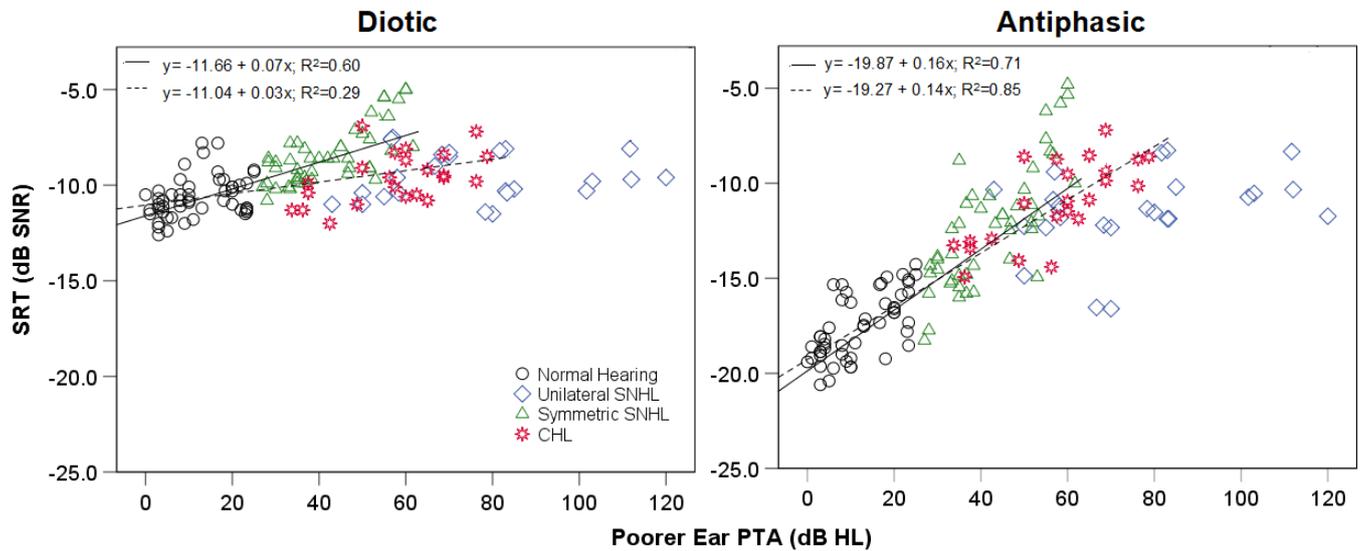


Figure 2. Correlations of the diotic and antiphase DIN to poorer ear PTA. Solid lines are regression lines fitted to normal hearing and symmetric SNHL group data. Dashed lines are regression lines fitted to normal hearing and CHL group data. SRT; speech reception threshold, dB; decibel, SNR; signal to noise ratio, PTA; pure tone average, HL; hearing level.

Full text version of the antiphase DIN test is available on BioRxiv:
<https://www.biorxiv.org/content/10.1101/677609v1.full>

What we want to do next

Based on the findings of the antiphase DIN test, we would like to compare the diotic and antiphase test versions on persons with diagnosed retrocochlear pathology. We hypothesize that the antiphase version should be a more sensitive measure, since antiphase processing is reliant on spatial processing, commonly affected in cases of retrocochlear pathology. Overall the DIN test could be a valuable tool in people with retrocochlear pathology because it would provide a way to measure their discrepant speech-in-noise performance in relation to their pure tone audiometric results.