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# Development and Evaluation of the Italian Version of the Dichotic Digit Test: Insights from 39 Normal-Hearing Children Aged 11 to 13 Years

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Data Interpretation D  
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**Background:** The dichotic digit test (DDT) is one of the tests for the behavioral assessment of central auditory processing. Dichotic listening tests are sensitive ways of assessing cortical structures, the corpus callosum, and binaural integration mechanisms, showing strong correlations with learning difficulties. The DDT is presently available in a number of languages, each appropriate for the subject's native language. However, there is presently no test in the Italian language. The goal of this study was to develop an Italian version of the one-pair dichotic digit test (DDT-IT) and analyze results in 39 normal-hearing Italian children 11 to 13 years old. We used 2 conditions of presentation: free recall and directed attention (left or right ear), and looked at possible effects of sex and ear side.





**Material/Methods:** This study involved 3 steps: creation of the stimuli, checking their quality with Italian speakers, and assessment of the DDT-IT in our subject pool. The study involved 39 children (26 girls and 13 boys), aged 11-13 years. All participants underwent basic audiological assessment, auditory brainstem response, and then DDT-IT.

**Results:** Results under free recall and directed attention conditions were similar for right and left ears, and there were no sex or age effects.

**Conclusions:** The Italian version of DDT (DDT-IT) has been developed and its performance on 39 normal-hearing Italian children was assessed. We found there were no age or sex effects for either the free recall condition or the directed attention condition.

**Keywords:** **Auditory Perceptual Disorders • Dichotic Listening Tests • Hearing Tests • Language Development Disorders • Speech Perception**

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## Introduction

Adequate functioning of the peripheral auditory system and the central auditory nervous system (CANS) are crucial for communication and learning. The American Speech-Language-Hearing Association [1] recommends that 6 underlying auditory mechanisms be evaluated in assessing central auditory processing (CAP). Among them, ability to separate competing acoustic signals is arguably the most important. The standard way to assess this is to present different acoustic stimuli to both ears simultaneously and ask the listener to repeat what they heard in each ear. This is the basis of the dichotic listening task. Such dichotic listening tests are sensitive ways of assessing cortical structures, the corpus callosum, and successful binaural integration. There is a strong correlation between poor dichotic performance and learning difficulties [2].

Since the 1960s there has been continuing interest in one specific test – the Dichotic Digit Test (DDT) – and its relationship with information processing and cortical structures. DDT has been widely used to assess binaural integration, the ability to process different stimuli presented to each ear at the same time [3]. Kimura [4] was one of its pioneers, and used DDT based on 3 pairs of digits in patients with unilateral lesions of the temporal lobe. Kimura found that there was a deterioration in the recognition of digits in the left ear when stimuli were presented simultaneously. Recent research has shown that central auditory processing disorder (CAPD) can be identified in subjects with traumatic brain injury [5].

Research has demonstrated that individuals with damage to the left temporal lobe have a higher percentage of correct responses in the right ear during dichotic listening tasks, even more so than normal individuals without auditory processing deficits, indicating a right ear advantage (REA). These findings prove the superiority of the right ear, which has more numerous contralateral than ipsilateral pathways, reflecting the fact that the left cerebral hemisphere plays a more important role in the perception of verbal stimuli [4].

DDT has also been mentioned as a possible screening protocol for auditory ability. The advantage of using DDT is that it is easy to perform, it is relatively quick, and it is a test model that reduces memory dependency [6-9]. This test revealed inferior binaural integration in mouth breathers with abnormal polysomnography [10], attention deficit disorder, hyperactivity (ADHD), dyslexia [11,12], phonological disorders [13], stroke [5,14], and school difficulties [15,16].

The research potential of dichotic tests, especially the DDT, derives from the fact that changes in the DDT may be associated with impairments in learning, academic performance, reading and writing skills, difficulties in classroom behavior,

and others [16-19]. It can be applied from the age of 5 years, enabling assessment from the earliest school years [20-21]. Because of these features, it is widely recommended and is considered the most valuable of the CAPD tests. The DDT is recommended in children, since if any alteration is found an auditory training program can be developed to improve communication [22-24].

DDT is capable of monitoring interaural asymmetry, which can be impaired, particularly in elderly adults who have difficulty understanding speech [25]. In a literature review and meta-analysis of subjects with dementia who underwent the dichotic digit test, the authors found that, in terms of REA, participants with dementia had an increased REA. After 1.5 years of follow-up, such subjects also had more of an REA than did controls, and this was due to a decrease in the DDT score for the left ear. These findings suggest a possibly higher rate of corpus callosum atrophy in patients with Alzheimer disease [26].

There are different modes of implementing DDT. For example, the primary stimuli on which it is based can involve digits or syllables, and the stimuli can be presented in a single pair or multiple pairs. However, tests with 1 or 2 pairs are the most used [27]. Other more cognitively challenging variations of DDTs were also used in previous research to avoid the ceiling effects found in 2-digit pairs test paradigms [28] such as using 3-digit pairs [29] or randomly presented 1-, 2-, and 3-pair dichotic digit stimuli [30].

The DDT test is available in different languages and should be applied in the child's native language [20,31-34]. However, until now the test has not been available in Italian. The goal of the present study was to develop an Italian version of the 1-pair dichotic digit test (DDT-IT). We aimed to evaluate the performance of typically hearing Italian children aged 11 to 13 years old under 2 conditions: free recall and directed attention (to the left or right ear). Specifically, we focused on examining the influence of sex and ear side.

## Material and Methods

### Ethics

This study was approved by the University of Ferrara's Ethics in Research Committee (protocol number 160387). Written informed consent was obtained from the parents of all the participating children prior to data collection.

### Participants

The sample size was calculated based on the sample mean estimator, with an error of  $\pm 0.3$  on average, a significance level

of 5%, and considering the standard deviation of a previous study related to the same measure in this study. The result was a target sample size of 25 individuals. In practice, however, this study recruited 39 children, comprising 26 girls and 13 boys, with ages between 11 and 13 years (mean 11.9,  $SD=0.9$ ). The children were categorized into 3 age cohorts: 11, 12, and 13 years old. The children were recruited from state public schools by invitations sent to their parents. They were all native Italian speakers, were right-handed, without professional music experience, and had normal hearing.

### **Inclusion and Exclusion Criteria**

All subjects passed the following inclusion criteria: a hearing threshold <15 dB HL (250 to 8000 Hz) [35]; type A tympanogram with presence of ipsilateral and contralateral acoustic reflexes (500 to 4000 Hz) in both ears [36]; otorhinolaryngological evaluation showing no anatomical changes or presence of earwax; and values within the limits of normality for click auditory brainstem responses (ABRs) for waves I, III, and V and inter-peak intervals I-III, III-V, and I-V for both ears [37].

### **Exclusion Criteria**

Exclusion criteria were a diagnosis of neurodevelopmental disorder (ADHD, dyslexia, or others), hearing loss, history of otitis media, and history of other neurological or psychiatric condition. In addition, the pedagogical coordinator of the school provided a profile of the child's academic performance via a questionnaire.

### **Procedures**

#### **Peripheral Auditory System**

Tympanometry and acoustic reflexes were measured with an Interacoustic AT235 audiometer and a 226 Hz probe. Acoustic reflexes had a maximum compliance near 0 da Pa and an equivalent volume of 0.3 to 1.3 ml according to Jerger's proposal [36]. Pure tone audiometry (PTA) was performed using an Interacoustic AC40 audiometer and TDH39 earphones following the normality criterion from the World Health Organization classification for children [35]. The speech audiometry involved speech recognition threshold (list of disyllables with 50% accuracy score) and speech recognition index (list of monosyllabic words 40 dB above the average tonal threshold and an accuracy score between 88% and 100%).

#### **Auditory Brainstem Responses (ABRs)**

The integrity of the auditory pathway was checked using the Navigator Pro equipment from Biologic/Natus. The active electrode (Fz) was placed on the forehead and the reference

electrodes were on the right (M2) and left (M1) mastoids, with the ground electrode on Fpz [38]. Stimuli were 0.1 ms rarefaction clicks delivered at 19.3 clicks/sec, low/high pass filter 0.1-3 kHz, analysis window of 12 ms, 2000 stimuli, 80 dB HL. Measurements were made of the amplitude of waves I, III, and V and the inter-peak latencies of I-III, I-V, and III-V. To check reproducibility, 2 recordings were made on each side and the criteria values were from Gorga et al [37].

### **Development of DDT-IT**

The development of DDT-IT was based in previous studies where single-pair stimuli were used [20-32]. The individual steps were as listed below.

#### **Step 1: Creation of Stimulus**

Audacity software was used to create pairs of Italian spoken digits. The digits were spoken by an Italian native male, aged 36 years old, in a normal clear voice and recorded in an anechoic chamber. Five Italian disyllables (quattro, cinque, sette, otto, and nove) were chosen and these numbers were randomly combined 2 by 2, eliminating cases of equal numbers.

The digits were edited to remove noise or excessive silence between them. The onsets of each pair of digits coincided to within 70 ms, which is the normal range of onset times critical for maintaining dichotic perception. Similarly, the offset times did not differ by more than 70 ms, and a 0.5-sec silent interval between each pair of dichotic digits was added. An inter-stimulus interval of 5 sec was inserted between each pair to allow an adequate response time [20]. The digits were then dichotically presented over 2 separate channels. The ordering of the pairs was random, creating a list of 20 pairs of digits. The one-pair DDT-IT has 2 lists (see [Table 1](#)).

#### **Step 2: Preparatory Check by Italian Speakers**

After the auditory material had been produced, a quality control check was made by playing the digits to 20 native Italians to confirm that all the digits could be clearly heard and identified. The participants in this stage of the study were professionals who are part of the Audiology and ENT team at our university. It should be noted that no type of adjustment was necessary in the test. An Italian version of the one-pair DDT-IT can be downloaded as Supplementary Material. Additionally, the file is available in an open-source database such as Zenodo ([Supplementary File](#)).

#### **Step 3: Presentation of the Actual DDT-IT**

The DDT-IT test involves presenting list 1 to the left ear and list 2 to the right ear ([Table 1](#)). That is, the subject hears 2 digits in

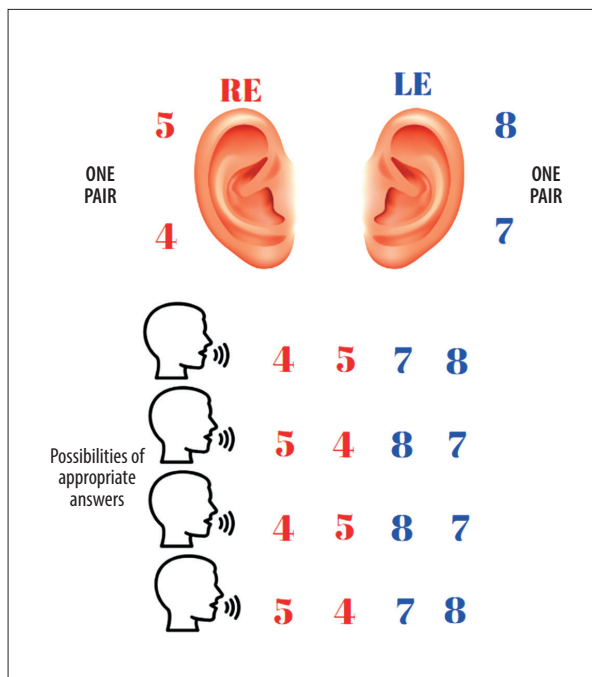
**Table 1.** Lists of the Italian version Dichotic Test of Digits and a schematic representation of the presentation of the digits.

List 1		List 2	
PAIR		PAIR	
5	4	8	7
4	8	9	7
5	9	8	4
7	4	5	9
9	8	7	5
5	7	9	5
5	8	9	4
4	5	8	9
4	9	7	8
9	5	4	8
4	7	8	5
8	5	4	7
8	9	7	4
7	9	5	8
9	7	4	5
7	8	5	4
7	5	9	8
8	7	4	9
9	4	5	9
8	4	7	9

one ear and 2 in the other, amounting to 4 in total. The pairs are presented through 2 channels of the Interacoustic AC40 audiometer and TDH39 earphones at an intensity of 50 dB SL (average of 500, 1000, and 2000 Hz). The test is administered 4 times. The test is also done in 2 different ways: a free recall task and a directed attention task.

**Free recall (FR):** This procedure tests for binaural integration. The list of 20 pairs of digits is presented dichotically and individuals are asked to repeat all the digits heard (Figure 1). Before each presentation of 4 digits, the subject hears the word “repeat”, reinforcing the message that they need to repeat all the digits heard (in any order).

**Directed attention (DA):** This procedure tests the subject’s ability to selectively attend to 1 ear. A list of 20 pairs of digits is presented dichotically and individuals are instructed to repeat only the digits presented to the specified ear. Before each presentation, the individual hears the word “repeat” to reinforce the message that they need to repeat the stimuli heard. There are 2 possible conditions: directed attention to the right ear



**Figure 1.** Diagram of the free recall condition and possible answers. The digits can be repeated in any order.

(DARE) (Figure 2) and directed attention to the left ear (DALE) (Figure 3), and both were part of the stimulus protocol.

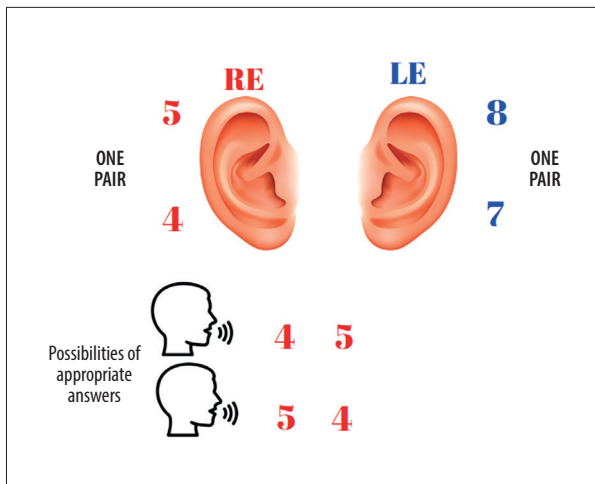
The answers were recorded by placing a circle around the identified digit by researcher. Each correctly identified number was considered a success and each omitted or wrongly identified number was considered an error. The total number of errors made was computed.

To calculate the DDT-IT score, it was considered that a total of 20 sequences of 4 digits are presented, 2 digits to each ear, for a total of 80 digits (40 to ear). The participant is instructed to repeat all 4 digits they heard. The score is calculated for each ear separately. Each correctly repeated digit represents 2.5% of the total score (2.5×40=100%). Therefore, the maximum score for each ear in the free recall protocol is 100%.

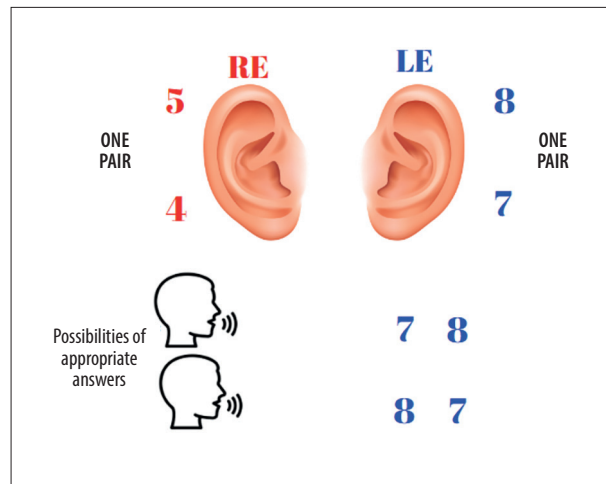
For the directed attention protocol, we assumed that a total of 20 sequences of 4 digits are presented, 2 digits to each ear, for a total of 40 digits in each ear. The participant is instructed to repeat only the digits presented to the specific ear being tested (eg, left ear only). Each correctly repeated digit in the designated ear represents 2.5% of the total score (2.5×40=100%). The maximum score for each ear in the directed attention protocol is also 100%.

**Statistical Analyses**

Descriptive statistics were calculated for quantitative variables and a Shapiro-Wilk test was used to check the assumption of



**Figure 2.** Diagram of directing attention only to the right ear (DARE) and possible answers.



**Figure 3.** Diagram of directing attention to the left ear (DALE) and possible answers.

**Table 2.** Descriptive statistics for 1-pair DDT-IT results ( $n=39$ ).

Assessment condition	Min	Max	Me	M	SD
	Percentage of correct answers (%)				
Free recall					
Right ear	85	100	95	95.38	4.78
Left ear	85	100	95	95.51	5.10
Directed attention to					
Right ear	85	100	95	96.15	4.05
Left ear	85	100	95	95.25	4.86

$n$  – number of cases; Min – minimum; Max – maximum; Me – median; M – mean; SD – standard deviation.

normality. A Wilcoxon test for paired samples (the result of this test is denoted by the symbol  $Z$ ), and a Mann-Whitney  $U$  test (the symbol is  $U$ ) or a Kruskal-Wallis test (the symbol is  $H$ ), were also applied. Statistical analysis was performed using IBM SPSS Statistics (v.24);  $P < 0.05$  was considered to be statistically significant.

## Results

The mean age of the 39 children was 11.9 years ( $SD=0.9$ ). Girls and boys had a similar age – in girls,  $M=11.9$  with  $SD=0.8$ ; in boys  $M=11.9$  with  $SD=0.9$ . Descriptive statistics for free recall and directed attention are shown in **Table 2**.

Results obtained in the free recall condition were not significantly different for the right ( $M=95.38$ ;  $SD=4.78$ ) and left ear ( $M=95.51$ ;  $SD=5.10$ ), with a  $Z$ -score of  $Z=0.05$ ;  $P=0.962$ . The same was true for the directed attention condition: results were similar for the right ( $M=96.15$ ;  $SD=4.05$ ) and left

ear ( $M=95.25$ ;  $SD=4.86$ ) and they did not differ significantly ( $Z=1.13$ ;  $P=0.260$ ).

DDT-IT results obtained for the same ear under both conditions (free recall and directed attention) were also about the same: for the right ear the results were not statistically different ( $Z=0.79$ ;  $P=0.432$ ) and the same was true for the left ear ( $Z=0.18$ ;  $P=0.855$ ).

### DDT-IT Results by Gender and Age

In terms of sex, 1-pair DDT-IT results obtained by girls and boys were similar, and this is shown in **Figure 4**.

DDT results in girls and boys did not differ significantly for any of the conditions: free recall right ear,  $U=168.0$ ;  $P=0.975$  (for girls,  $M=95.38$ ;  $SD=4.88$ ; for boys:  $M=95.38$ ;  $SD=4.77$ ); free recall left ear,  $U=151.0$ ;  $P=0.566$  (for girls,  $M=95.00$ ;  $SD=5.66$ ; for boys,  $M=96.54$ ;  $SD=3.76$ ); directed attention right ear,  $U=152.5$ ;  $P=0.595$  (for girls,  $M=96.35$ ;  $SD=4.14$ ; for boys,  $M=95.77$ ;

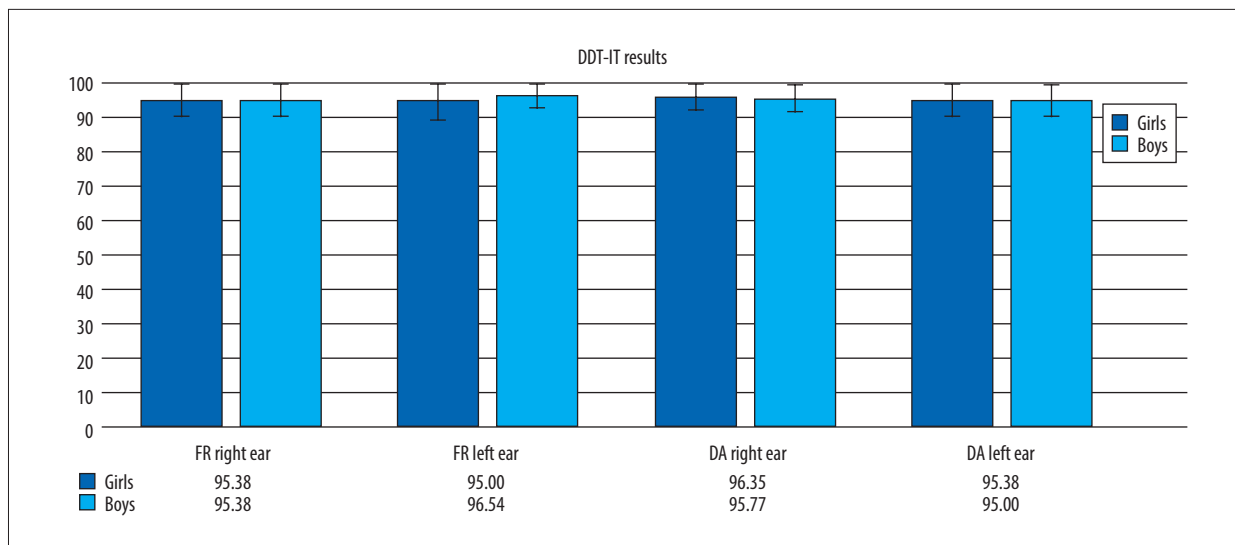


Figure 4. One-pair DDT-IV results in girls and boys.

Table 3. Descriptive statistics for 1-pair DDT-IV results by age.

Assessment condition	11 years (n=15)		12 years (n=11)		13 years (n=13)	
	M	SD	M	SD	M	SD
Percentage of correct answers (%)						
Free recall						
Right ear	95.33	3.99	95.91	4.91	95.00	5.77
Left ear	95.67	5.30	95.45	6.11	95.38	4.31
Directed attention to						
Right ear	95.00	4.63	96.36	3.93	97.31	3.30
Left ear	94.33	4.58	96.37	5.05	95.38	5.19

n – number of cases; Min – minimum; Max – maximum; Me – median; M – mean, SD – standard deviation.

SD=4.00); directed attention left ear,  $U=158.0$ ;  $P=0.727$  (for girls,  $M=95.38$ ;  $SD=5.08$ ; for boys,  $M=95.00$ ;  $SD=4.56$ ).

Table 3 shows the mean scores and standard deviations calculated for groups of children of different ages. There were no statistically significant differences in DDT-IT results between the age groups. Children in different age groups did not differ in terms of results obtained in the free recall condition for the right ear ( $H=0.21$ ;  $P=0.900$ ), nor for the left ear ( $H=0.19$ ;  $P=0.910$ ). They had similar results in the directed attention condition for the right ear ( $H=1.91$ ;  $P=0.384$ ), and for the left ear ( $H=1.40$ ;  $P=0.497$ ).

## Discussion

Understanding how a subject can deal with sound information is important in all age groups. Audiological tests, including the

dichotic listening test, aim to rate this ability numerically. In the dichotic listening test, when 2 different sounds are presented to each ear simultaneously, the subject's performance allows us to gauge how well they can hear in the presence of background noise and in activities that require processing of signals from both ears [1,2,20,33].

Assessing dichotic listening makes it possible to test the functioning of the cerebral hemispheres, the corpus callosum (which exchanges information between the hemispheres), and the maturity of the CANS. Dichotic ability is extremely useful in diagnosing auditory dysfunction [1,2,7,20,31,33]. The translation and adaptation of DDT into different languages contributes to the advancement of CAP research and the understanding of intercultural differences in auditory processing [39,40].

The translation and adaptation DDT are crucial for cross-linguistic and cross-cultural assessments of CAP. Studies have shown improved performance with age and a right-ear advantage in various adapted versions. Jutras et al [41] reported this trend in their newly developed French DDT for children aged 6, 9, and 12 years. Similarly, Liu et al [42] adapted the DDT for Mandarin Chinese, demonstrating good internal consistency and reliability, while Castro et al [43] observed the same right-ear advantage in their Spanish adaptation, along with a curvilinear relationship between age and performance, suggesting a decline after a peak period. Furthermore, a Brazilian Portuguese DDT translation allows analysis of auditory figure-ground through dichotic presentation of verbal stimuli [32]. Additionally, research by Mukari et al [44] applying the Malay language DDT suggests that the dichotic format can reveal greater differences in performance between age groups and a right-ear advantage.

The exact age of maturation for dichotic listening is still being researched, but there is universal agreement that it grows significantly during infancy and matures by late adolescence or early adulthood. The REA grows increasingly prominent between the ages of 6 and 12. According to studies, dichotic tasks improve accuracy and lateralization. Dichotic listening performance often peaks in adolescence, reaching levels equivalent to adults. Several factors can influence the development of dichotic listening skills, including brain development and exposure to complex auditory settings. Some people may have a stronger REA or attain maturity earlier than others [2,3,20,25].

Most dichotic assessments use 1-pair DDT or 2-pair DDT [15,20,25-27,32,44]. So far, there has been no DDT in Italian, and so this is the first such study to have been done. We have chosen to create the test based on just a single pair of digits, but later we hope to develop more complex tools.

Here we have developed a 1-pair DDT-IT and tested it on normal-hearing, native Italian-speaking children under free recall (FR) and directed attention (DA) conditions. We considered the variables of sex and ear side.

We found no statistically significant difference in the performance of boys and girls. However, some studies have reported differences in responses between the sexes in dichotic listening skills up to around 6 years of age, with boys showing poorer responses than girls [45]. The current study was carried out with children aged 11 to 13, so we expected to see no difference between the sexes, and our findings confirm this.

The groups in the present study were homogeneous between the sexes and ages. We evaluated responses under 2 conditions, FR and DA, and these will now be discussed separately.

### Free Recall (FR)

Dichotic tests are essentially binaural integration tasks and employ the performance of the corpus callosum and the right and left cerebral hemispheres. The lack of difference in performance as a function of age of our subjects may be explained by the maturation and myelination of these structures. We did not see an advantage of the right ear over the left, as observed in other studies carried out in younger children (<9 years). The DDT in the FR condition assesses selective attention and figure-ground separation ability [2,7,9,10,18,32,39,46].

Children diagnosed with central auditory processing disorder, cognitive disabilities, trauma, or brain injuries may benefit from the DDT evaluation, as their performance was lower than that of their peers without abnormalities. The observed inefficiency in dichotic information processing could potentially be linked to challenges encountered during sustained attention, impaired hemispheric integration of auditory information, or difficulty recognizing verbal sounds [47]. Performance in children seems to depend very much on attention and memory, and so we expected that performance might be impaired in children lacking these abilities [2,3,5,7-9,11,12,14-20]. Auditory skills that require the interaction of the 2 hemispheres, such as tested with the dichotic listening task, depend on the integrity of the corpus callosum. Any changes in the corpus callosum can lead to major impairments in auditory skills and, consequently, in speech, oral language, written language, and learning skills [48-52].

The values we have calculated for the FR condition are similar to those described in the literature [15,20,32,33,44]. Our study corroborates the findings of other research which has employed one-pair DDT: typically, children over 11 years of age and without hearing disorders achieve scores around 100% and have no (or only subtle) differences between the ears [32,33,44]. In our comparison of the different age groups in the FR task, the scores were very similar in those aged 11, 12, or 13. This finding agrees with Keith (2000), who found that children of this age display similar values to those of adults. A performance ceiling seems to be reached at about 11 years of age [53].

### Directed Attention (DA)

In the DA condition, the DDT evaluates figure-ground ability for verbal sounds and the effects of sustained attention and selective attention [7,15,18,46]. In the literature, normative values differ depending on age. We found that at ages 11 to 13 years values for both DARE and DALE are like those found in previous studies [15,20,32]. In this context, the literature reports that from the age of 11 onwards, children's responses are similar to those found in adults [41,43,44,54].

In dichotic tests the right ear always presents an advantage, and this has been reported in multiple studies. The advantage of the right ear is called REA and is probably due to the greater involvement of the left hemisphere in the processing of verbal stimuli. The effective participation of the corpus callosum is also important [55,56]. REA is more pronounced in young children and fades away with advancing age [41,57,58].

Although we found no statistically significant differences, our data (Table 3) show a better DA response in the right ear at 11 and 13 years old, while at 12 years old the DARE and DALE are about the same. These findings may be related to the degree of difficulty, or rather the lack thereof, in the 1-pair DDT. Experiments based on 1-pair DDT, that is, using a pair of digits in each ear, show that such digits can be easily identified [59-62]. Furthermore, individuals use digits constantly in their daily lives, meaning there could be no need for involvement of the dominant hemisphere, particularly in older children and adults [63].

Prior research conducted on children has demonstrated that REA is not evident in children who have articulation disorders and learning disabilities [12,64-66]. Children who experienced challenges in reading and writing exhibited changes in their left auditory performance [54,63]. People who have a stutter tend to exhibit reduced RE, particularly in children, compared to adults with the same condition [67]. Finally, researchers demonstrated that hemispheric lesions caused altered outcomes in the contralateral ear, but the altered results in both ears indicate alterations in the left hemisphere. Particularly in children, it can serve as a useful screening method for identifying central auditory dysfunctions [15,17,39].

The more difficult the task to be performed, the greater the difference between the ears; however, attentional and cognitive aspects can also influence the responses. A study comparing literate and non-literate subjects showed that a right-ear advantage was only observed in the non-literate [68], which suggests that learning a language stimulates both hemispheres – that is, activity in the corpus callosum tends to even out left and right ear responses.

In future studies, it may help to make the test more difficult by increasing the number of pairs of digits and/or randomizing the presentation of numbers. This might lead to a greater difference in responses between the ears [43,69,70]. It appears that the 1-pair DDT is not an effective way of measuring REA, even though it has been shown to be a sensitive instrument for monitoring general changes in the CANS [21].

### Final Considerations

Dichotic digit test protocols are an audiological part of diagnostic batteries. The DDT has been shown to be very effective

in identifying neurological disorders in the main central auditory relay stations, such as the brainstem, cortex, and corpus callosum [1,2,20]. DDT has also been mentioned as a possible screening protocol for auditory abilities. The advantage of the DDT is that the test is easy to perform, relatively quick, and requires a low level of linguistic ability [7,8].

The DDT evaluation under both assessment situations (FR and DA) will provide relevant information regarding dichotic listening ability and can be utilized to analyze the integrity of the central auditory nervous system [1,4,6,7,15,20]. Evaluators have the option to select a single evaluation condition, but this decision will be influenced by the patient's cognitive condition and the desire to obtain more detailed information about the auditory system, such as the analysis of binaural separation (DA) or binaural integration (FR) [1,2,7-9,20,25,30,39,46,62].

By analyzing the current literature, it is possible to find other behavioral tests that can evaluate dichotic listening (eg, dichotic sentences test). The inclusion of a comparative test could strengthen the application of DDT-IT. However, finding another test that taps into these exact aspects can be difficult because existing tests might focus on different aspects of CAP altogether (eg, sound localization), specific auditory processing skills not directly related to dichotic listening (eg, speech comprehension), and suffer from different influences (eg, short-term auditory memory), which could make this comparison less direct and less meaningful [1,4,9,11,15,19].

### Limitations and the Future

One of the limitations of the present study is that the individuals were close in age and there were no younger children. Nevertheless, the current research has allowed an Italian version of a 1-pair dichotic digit test (DDT-IT) to be developed. Nevertheless, further investigation is required, and normative data must be acquired. Additionally, we suggest that the assessment be implemented for children who, among other conditions, suffer from learning disabilities and auditory processing disorders. Exploring age effects in a broader age range, including either a group of elderly participants or young children, could be an interesting avenue for future research. Examining populations with potentially immature corpus callosum development could provide valuable insights into the development of dichotic listening abilities.

### Conclusion

An Italian version of the DDT (DDT-IT) has been developed and the responses of a small group of Italian normal children tested. Analysis has shown that, for both the free recall and directed attention condition, there are no statistically significant differences for age or sex.



## Declaration of Figures' Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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## Supplementary File

Italian Version of Dichotic Digit Test (DDT-IV).

<https://zenodo.org/records/10783638>

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