ISSN: 2757-6817

Unika Sağlık Bilimleri Dergisi
Unika Journal of Health Sciences

Araştırma Makalesi/Research Article

Normative Data of Auditory Temporal Processing Tests For Turkish-Speaking Individuals

Türkçe Konuşan Bireyler İçin İşitsel Zamansal İşleme Testlerinin Normatif Verileri

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Abstract: Objective: Frequency pattern test (FPT), Duration pattern test (DPT) and Gap-in-Noise (GIN) test can be easily applied to different societies, regardless of language, due to their non-verbal structures. However, although these tests are non-verbal, they can be affected by the linguistic characteristics of cultures. This study aims to evaluate the normative value range of DPT, FPT and GIN in Turkish-speaking individuals with normal hearing. Methods: Sixty-one individuals with normal hearing, according to the hearing handicap inventory, were included in the study. For individuals who met the inclusion criteria, FPT, DPT and GIN were applied monoaurally to both ears with subaural headphones. Results: Forty-two of the participants were women, and 19 were men. There was no difference between genders in terms of age, FPT, DPT and GIN (p>0.05). Participants' average FRT score was 75.22%, average DPT score was 91.25%, and average GIN score was 67.96%. The average GIN threshold was 5.52 msec. There was no relationship between age and FPT, DPT and GIN (p>0.05). Conclusion: FPT, DPT and GIN can be easily applied to Turkish-speaking individuals. Our study's datas can be used to interpret these tests more accurately in Turkish-speaking individuals.
Keywords: Auditory Processing, Audiology, Frequency Pattern, Duration Pattern, Gap-in-noise.

Öz: Amaç: Frekans patern testi (FPT), Süre patern testi (SPT) ve Gap-in-Noise (GIN) testi sözel olmayan yapıları nedeniyle dilden bağımsız olarak farklı toplumlara kolaylıkla uygulanabilmektedir. Ancak, bu testler sözel olmasa da toplumların dil özelliklerinden etkilenebilmektedir. Bu çalışmanın amacı, Türkçe konuşan ve normal işiten bireylerde SPT, FPT ve GIN'in referans değer aralığını değerlendirmektir. Gereç ve Yöntem: İşitme engellilik ölçeğine göre normal işitmeye sahip 61 birey çalışmaya dahil edildi. Dahil edilme kriterlerini karşılayan bireylere FPT, SPT ve GIN subraaural kulaklık ile monoaural olarak her iki kulağa da uygulandı. Bulgular: Katılımcıların 42'i kadın, 19'u erkekti. Cinsiyetler arasında yaş, FPT, SPT ve GIN açısından bir fark yoktu (p>0,05). Katılımcıların ortalama FRT skoru %75,22, ortalama DPT skoru %91,25 ve ortalama GIN skoru %67,96 idi. Ortalama GIN eşiği 5,52 msn idi. Yaş ile FPT, SPT ve GIN arasında bir ilişki yoktu (p>0,05). Sonuç: FPT, SPT ve GIN Türkçe konuşan bireylere rahatlıkla uygulanabilmektedir. Çalışmamızda sunduğumuz veriler Türkçe konuşan bireylerde bu testlerin daha doğru biçimde yorumlanmasında kullanılabilir.
Anahtar Kelimeler: İşitsel İşlemleme, Odyoloji, Frekans Patern, Süre Patern, Gap-in-noise.

Introduction

Central auditory processing disorder (CAPD) is characterised by various auditory symptoms and observed in individuals with normal or near-normal pure-tone hearing thresholds. The disorder may occur in any of the central auditory system structures, such as the

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Makale Gönderim:30.05.2024 Makale Kabul:11.10.2024 Makale Yayın:23.12.2024

cochlear nucleus, superior olivary complex, lateral lemniscus, inferior colliculus, medial geniculate body and auditory cortex (Zhang et al., 2018). According to the American Speech-Language-Hearing Association (ASHA), CAPD encompasses the auditory mechanisms that underlie several abilities and skills, including auditory discrimination, temporal aspects of audition, sound localization and lateralization, auditory performance in the presence of competing acoustic signals, and auditory performance with degraded acoustic signals. Poor performance in one or more of these skills may be a marker of CAPD (Majak et al., 2015). However, these auditory difficulties are not specific to CAPD and can also occur in other disorders, such as attention deficit hyperactivity disorder or cognitive disorders (Bamiou and Murphy, 2018). Therefore, it is necessary to make differential diagnosis and evaluation with various audiological tests.

The central auditory system is quite complex and there was no single test to evaluate it. Therefore, it is necessary to select the appropriate test for the patient. Auditory temporal processing tests are frequently used because they are accessible and easy to apply. There are four subprocesses of auditory temporal processing (Chowsilpa et al., 2021): temporal ordering or sequencing, temporal resolution or discrimination, temporal integration, and temporal masking. Temporal ordering and temporal resolution tests are more established in clinics in order to evaluate the central auditory processing function of patients, since there are no available tests of temporal masking and temporal integration (Shinn, 2014).

The frequency pattern and duration pattern tests are among the most commonly employed assessments for evaluating temporal sequencing, while the gap-in-noise test is widely used for assessing temporal resolution. These tests have gained popularity due to their non-verbal nature, making them independent of language and applicable across different cultures and societies (Majak et al., 2015; Emanuel, 2002). However, even though these tests are non-verbal, it is important to consider that language characteristics can influence individuals' performance in these tests (Majak et al., 2015). Consequently, the interpretation of these tests relies significantly on the normative values specific to different languages, which are essential for accurate assessment.

This study aims to evaluate the range of reference values of DPT, FPT and GIN in individuals with normal hearing. Additionally, in our study, the effects of gender, age and ears on these tests will be investigated.

Methods

Permission was obtained from the ethics committee of XXX University for this study (2023/02 desicion no:16). Written and verbal consent was obtained from all participants included in the study**.**

This study was conducted on Karabük University students and staff. Sixty-one healthy individuals were included in the study. Hearing handicap inventory (HHI) was applied to these individuals. The study did not include individuals who reported hearing problems according to HHI (HHI score>0), tinnitus, and neurological disorders.

Evaluation of Auditory Temporal Precessing

FPT, DPT and GIN were applied to all individuals included in the study. The tests were performed in a quiet room, with Sennheiser HDA300 headphones used to the right ear first and then to the left ear, at an intensity level where the participants could comfortably hear the sounds. Yeral et al.,'s (2021) study was used for the reference values of FPT, DPT and GIN tests in Turkish-speaking individuals.

For FPT, patients were presented with three signals. 2 of these signals were at the same frequency, and one was at a different frequency. The duration of each tone was 200 ms, and the interstimulus interval was 150 ms. The frequencies of the tones were 880 Hz and 1122 Hz. There are 60 patterns of these sounds in rows of three. Individuals were asked to describe the patterns' sounds according to their order of occurrence in terms of thinness and thickness in the space between the patterns (such as thin-thin-bold). When the individual said the sequence correctly, it was recorded as correct. The first ten patterns were given to the patients as practice and were not included in the score calculation. The total score was calculated from 50 patterns, and the test was applied to both ears sequentially.

DPT consists of 3 tones with a frequency of 1000 Hz. Tones consist of two sounds of 250 ms (short) and 500 ms (long) duration. There are 66 patterns with long and short sounds in three rows. In the space between the patterns, the patients were asked to pronounce the sounds in the pattern in the order they appeared in terms of length and shortness (such as long-long-short). The first six patterns were given to the patients as practice and were not included in the score calculation. The total score was calculated from 60 patterns, and the test was applied to both ears sequentially.

There are 30 white band noises in GIN with a length of 6 seconds. This noise has gaps with sizes varying between 2 and 20 ms (2, 3, 4, 5, 6, 8, 10, 12, 15 and 20 ms). There are 60 gaps in total, six from each gap. Individuals were asked to listen carefully to the noise and to say these gaps when they felt them. At the end of the test, the GIN threshold and correct gap detection rate were calculated for each ear. The four correct in 6 gap rule was applied to determine the GIN threshold.

Statistical Analysis

IBM SPSS 21 software was used for statistical analysis. Descriptive statistics were presented as percentage, n, mean±SD and median (min-max). Normality distribution was performed with Shappiro-Wilk test. Normality distribution was evaluated with the Shapiro-Wilk test. Normally distributed data were presented as mean+SD, and non-normally distributed data were presented as median (min-max). T-Test, or Mann Whitney-U test was used to compare groups according to normality distribution. One sample T-test was used to compare the reference data with the data in our study. In all statistical analyses, $p<0.05$ was accepted as the level of statistical significance.

Results

Forty-two participants were female, 19 were male, and the average age was 28.03±11.63 (18-55). There was no difference between genders in terms of age, FPT, DPT and GIN ($p>0.05$, Table 1).

Table 1: Age, FPT, DPT and GIN Scores Between Genders

	Female n:42	**Male** n:19	**p**
Age, *median (min-max)*	20 (18-55)	29 (18-52)	0.070[a]
FPT (122 ears), *median (min-max)*	80 (16-100)	88 (24-100)	0.081[a]
DPT (122 ears), *median (min-max)*	93.33 (66.67-100)	100 (60-100)	0.190[a]
GIN (122 ears), *mean±SD*	67.97±7.67	67.93±8.60	0.981[b]

FPT: Frequency pattern test, DPT: Duration pattern test, GIN: Gap-in-Noise, a: Mann Whitney-U test, b: T-test

The mean FRT was 75.22±20.67, the mean DPT was 91.25±9.27, and the mean GIN was 67.96±7.94. There was no relationship between age and FRT, DPT and GIN (p: 0.519, 0.833, 0.290, respectively). The right ear GIN threshold was 5.45±1.25 (4-8), and the left ear GIN threshold was 5.59±1.25 (4-8). Our study's right and left ear GIN thresholds were better than the 6 ms in the reference article (7) (p: 0.001, 0.013, respectively). There was no difference in FPT, DPT and GIN scores between the right and left ears ($p>0.05$, Table 2).

Table 2: FPT, DPT and GIN Scores Between Ears

	Right Ear	Left Ear	p
FPT, *mean±SD*	74.39±20.83	76.06±20.65	0.895[a]
DPT, *median (min-max)*	93.33 (66.67-100)	93.33 (60-100)	0.727[a]
GIN, *median (min-max)*	80 (24-100)	82 (16-100)	0.585[b]

FPT: Frequency pattern test, DPT: Duration pattern test, GIN: Gap-in-Noise, a: Mann Whitney-U test, b: T-test

There was no difference between the reference data and the FPT and DPT scores in our study (p>0.05). However, the GIN score in our study was better than that of the reference article. The reference data stated by Yeral et al., (2021) and the FPT, DPT and GIN scores in our study are presented in Figure 1.

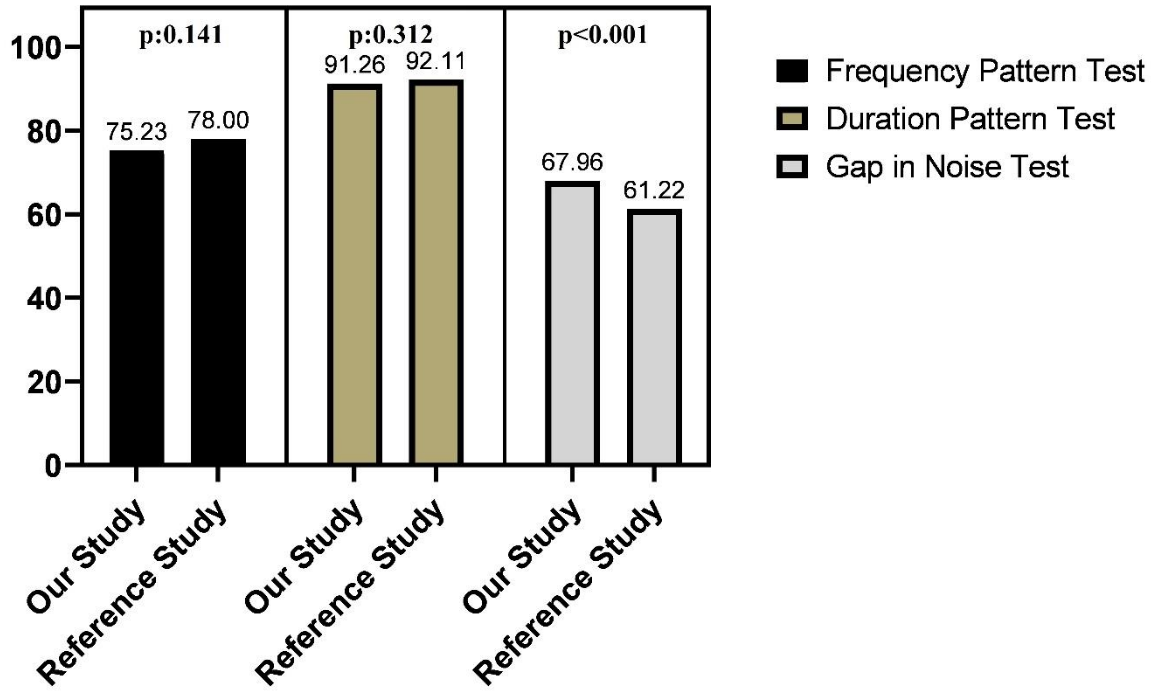

Figure 1. FPT, DPT and GIN Scores in Our Study With The Reference Data stated by Yeral et al., (2021).

Discussion

Auditory temporal processing is essential for detecting and discriminating syllables, phonemes, stress patterns, and phonological awareness. This study aims to determine the reference value range of DPT, FPT and GIN, which are temporal auditory processing tests, in individuals with normal hearing. Our study found no relationship between age and DPT, FPT and GIN. Additionally, there was no difference between ears in terms of DPT, FPT and GIN. When the scores in our study were compared with the reference data, there was no difference between DPT and FPT, and the GIN success and GIN threshold of the individuals in our study were better than the reference data.

DPT was first introduced by Musiek et al., (1990) and FPT was introduced by Pinheiro and Ptacek (1971). DPT and FPT demonstrate strong sensitivity, specificity, and test-retest reliability when assessing patients with cerebral lesions (Musiek et al., 1990; Paulovicks and Musiek, 2008; Musiek and Pinheiro, 1987 Musiek, 2020). However, it is worth noting that FPT has a lower sensitivity of 45% in detecting brainstem lesions compared to its higher sensitivity of 83% for cerebral lesions.[11] On the other hand, DPT shows a higher likelihood of detecting abnormalities in brainstem lesions.[12] Despite both tests being temporal ordering assessments, there is no significant correlation between DPT and FPT, (Marshall and Jones, 2017) which means they cannot be used interchangeably.

GIN test gained popularity due to its applicability in subjects with cognitive impairments or peripheral hearing loss at specific frequencies. GIN test could be a reliable tool for detecting abnormalities in central auditory processing, particularly at the level of the auditory cortex. However, test has certain limitations, including its time-consuming nature and its potential lack of sensitivity in detecting lesions at the brainstem level (Musiek et al., 2005).

Yeral et al., (2020) investigated FPT, DPT and GIN values in Turkish-speaking individuals. The authors determined the success rates of FPT, DPT and GIN as 78%, 92.11%, and 61.22%, respectively. The authors stated the GIN threshold as 6.34. Majak et al., (2015) noted that the FPT and DPT success rates in Polish individuals were 56.7% and 55.3%, respectively, and the GIN threshold was 6 msec. The authors also noted no relationship between the tests and age or gender. Neijenhuis et al., (2001) reported that the DPT score of 28 Dutch adults with normal hearing was 90%, and the FPT score was 89%.

It is known that the language factor can affect auditory temporal processes (Majak et al., 2015) For this reason, the data in our study were compared with the data of Yeral et al., (2021) a study conducted on other Turkish-speaking individuals. There was no difference between FPT and DPT scores in our study and the reference study. However, in our study, the GIN score and threshold were better than the reference article's. While high attention and motivation increase auditory temporal performance, fatigue and inattention can reduce performance. Therefore, the good GIN performance in our study may be due to attention and motivation. On the other hand, it is interesting that there is no difference between the reference study and our study in terms of FPT and DPT scores, but only in terms of GIN. This difference may be due to cognitive abilities that may affect temporal skills. However, the participants in both studies were academics and university students. Therefore, the better GIN scores of the participants in our study cannot be explained by their educational level. Another factor may be the way the tests are administered. Yeral et al., (2021) performed the tests using free-field. In our study, we applied the tests monothermally using headphones. It has been stated in the literature that using free-field or headphones does not affect FPR and DPT (Frederigue-Lopes et al., 2010). However, how the sounds are presented may have affected the temporal resolution (GIN score).

In our study, similar to Majak et al.'s study, there was no relationship between gender and age and auditory temporal tests. Also, other studies in the literature show that there is no difference between genders in terms of FPT, DPT and GIN (Musiek, 1994). On the other hand, Helfer and Vargo documented a difference in GIN results in younger and middle-aged women (Helfer and Vargo, 2009). This difference between studies may be related to high-frequency hearing loss in elderly individuals (Majak et al., 2021).

Conclusion

Since FPT, DPT, and GIN tests are non-verbal, they can be applied to any society, regardless of language. Our study's data can be used to interpret these tests more accurately in Turkish-speaking individuals.

Ethical Statement: Ethical permission was received for the study from Karabuk University Social and Human Sciences Ethics Committee (2023/02 Decision No:16).

Conflict of Interest: None.

Author Contributions: Idea: ES; Design: ES, MG; Check: NY; Sources: ES; Ingredients: ES, MG; Data collecting: ES; Analysis: ES; Literature Review: ES, MG; Posted by: NY; Critical Review: NY

Peer Review: Internal/External independent.

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