ISSN: 2083-389X
eISSN: 2084-3127
J Hear Sci, 2023; 13(4): 27–31
DOI: 10.17430/jhs/175323

COMPARING PITCH PATTERN TESTS BASED ON VOWELS AND TONES

Contributions:
A Study design/planning
B Data collection/entry
C Data analysis/statistics
D Data interpretation
E Preparation of manuscript
F Literature analysis/search
G Funds collection

Shrasti Gupta[B-F], Anuj Kumar Neupane[A-F]

School of Audiology and Speech Language Pathology, Bharati Vidyapeeth (Deemed to be University), Pune, India

Corresponding author: Anuj Kumar Neupane, School of Audiology and Speech Language Pathology, Bharati Vidyapeeth (Deemed to be University), Dhankawadi, 411043, Pune, India; email: anujkneupane@gmail.com

Abstract

Introduction: The pitch pattern test (PPT) is a test of temporal ordering in which a subject needs to correctly repeat a sequence of three auditory stimuli comprised of high and low frequencies. Traditionally, tones are used, but here the aim was to develop a PPT using vowels. The tests were done in young adults and a comparison was made between the two methods.

Material and methods: The study involved 40 young adults with normal hearing sensitivity and was done in two phases. Phase I involved the development of a PPT using the vowel /a/, and in Phase II the test was administered. A comparison was made with the PPT based on tones. In both tests, stimuli were delivered monaurally.

Results: All participants were able to do the PPT using either vowels or tones. No ear or gender effects were observed. However, the mean scores for PPT using tones were notably better than those obtained using vowels.

Conclusions: The present study has developed a PPT using the vowel /a/ and has compared scores with the tonal pitch pattern test. The absence of a ceiling effect in the PPT using a vowel gives it an advantage in terms of potential clinical utility. The strong positive correlation between the PPT using a vowel and the PPT using a tone shows a significant relationship between the two tests in the specific domain of temporal ordering.

Key words: adults • temporal • pitch • vowel • tone

PORÓWNANIE TESTÓW SEKWENCJI CZĘSTOTLIWOŚCI OPARTYCH NA SAMOGŁOSKACH I TONACH

Streszczenie

Wprowadzenie: Test sekwencji częstotliwości (ang. *pitch pattern test*, PPT) jest to test porządkowania czasowego, w którym osoba badana musi poprawnie powtórzyć sekwencję trzech bodźców akustycznych obejmujących wysokie i niskie częstotliwości. Tradycyjnie stosowanymi bodźcami są tony, ale celem obecnego badania było opracowanie testu PPT opartego na samogłoskach. Badanie przeprowadzone w grupie młodych dorosłych polegało na porównaniu obydwu metod.

Materiał i metody: W badaniu wzięło udział 40 młodych osób dorosłych z normalną czułością słuchu. Badanie przeprowadzono w dwóch fazach. Faza I obejmowała opracowanie testu PPT opartego na samogłosce /a/, faza II – przeprowadzenie testu. Dokonano porównania z testem PPT opartym na tonach. W obydwu testach bodźce były podawane do jednego ucha.

Wyniki: Wszyscy uczestnicy byli w stanie przejść test PPT z zastosowaniem samogłosek lub tonów. Nie zaobserwowano wpływu ucha ani płci osoby badanej. Jednak średnie wyniki uzyskane w teście PPT z użyciem tonów były zauważalnie lepsze niż w teście z użyciem samogłosek.

Wnioski: W prezentowanym badaniu opracowany został test PPT oparty na samogłosce /a/, następnie jego wyniki porównano z wynikami testu sekwencji częstotliwości z użyciem tonów. Brak efektu sufitu (ang. *ceiling effect*) w teście PPT opartym na samogłoskach daje mu przewagę pod względem potencjalnej użyteczności klinicznej. Silna pozytywna korelacja między testem PPT wykorzystującym samogłoskę i testem PPT wykorzystującym tony pokazuje obecność istotnego związku pomiędzy tymi dwoma testami w dziedzinie porządkowania czasowego.

Słowa kluczowe: dorośli • czasowy • częstotliwość • samogłoska • ton

Introduction

The pitch pattern test (PPT) is a test of temporal ordering that evaluates the ability of a subject to correctly repeat a sequence of three auditory stimuli comprised of high and low frequencies [1]. Initially developed by Pinheiro [2], the test uses a three-length sequence of two tones of 880 Hz (low) and 1122 Hz (high), resulting in six unique combinations. The tones have rise and fall times of 10 ms and a duration of 150 ms [3]. Participants can respond through humming, whistling, tapping, or pointing. The test provides information about interactions between the two hemispheres through the corpus callosum, wherein the right hemisphere decodes the pitch of the stimuli and recognises the auditory contour and the left hemisphere nominates the pattern [4,5]. The literature shows that the PPT remains effective even in cases of peripheral hearing loss, and is sensitive to detecting disorders in the cerebral hemispheres [6] or dysfunction of the corpus callosum [7].

Previously, the temporal ordering task has predominantly been explored using tonal stimuli, including in the duration pattern test [8,9]. However, a few researchers have also reported the use of verbal stimuli for ordering tasks [10–12]. Justras and Gagne reported a sequencing task using verbal stimuli (/ba/ and /da/) and tonal stimuli (1000 Hz pure tone and wideband noise) among individuals with and without hearing loss [10]. Their findings indicated that individuals with hearing loss encountered greater difficulty in recalling verbal sequences compared to non-verbal sequences. This difficulty in recalling verbal stimuli might be attributed to a phonological similarity effect, which arises when similar-sounding speech sounds are used, so that pattern recognition is impeded in comparison with dissimilar non-verbal sounds [13]. Thus, deficits in organisation of auditory sequences seem to be closely associated with auditory perceptual processing deficits. Similar findings have been reported by others [10,12].

Tests using verbal patterning [10,12,14–16] often require a certain level of linguistic proficiency. Although non-verbal stimuli are not constrained by the language of the subject, they are less easy to correlate with speech perception scores. Hence, the use of verbal blocks may offer a greater degree of naturalness in relation to speech sounds. That means it might be preferable to employ simpler verbal stimuli, such as vowels, for temporal ordering tasks. Vowels are less restricted by the language of the subject and can be easily administered even in individuals with limited speech output. Therefore, the present study aimed to develop a pitch pattern test using vowels and compare the performance of young adults to that of the traditional test using tones.

Material and methods

The current study utilised a within-group design and employed purposive sampling to gather the data sample. The study was approved by the Institutional Ethics Committee (BVDUMC/IEC/190 dated 17/08/2022). All the procedures involved in this study were explained to participants and were non-invasive. Informed written consent was obtained from all participants.

Participants

The sample size was calculated considering a standard deviation of 9.022 for the scores on a pitch pattern tests for adults from an earlier study [17], a confidence interval of 95%, and an allowable error of 3%. Hence, the data was collected from 40 young normal-hearing individuals which comprised a group of 20 males and 20 females between the ages of 18 and 35 years ($M = 26.4$ years, $SD = 1.7$). A detailed case history was taken first followed by a visual examination of the ear canal and the tympanic membrane of both ears using an otoscope. All had a bilateral pure tone average of < 15 dB HL and normal immittance. None had any known otological, neurological, or radiological history related to hearing, speech, language, or cognition. None had significant auditory processing difficulty or a vestibular condition. All were right-handed and had passed the Screening Checklist for Auditory Processing in Adults (SCAP-A) [18].

Instrumentation

Hearing evaluation was done using a calibrated 2-channel Madsen Orbiter 922 audiometer with RadioEar B-71 bone vibrator and TDH-39 headphones. Immittance evaluation was done using a calibrated Interacoustics AT235 device. SCAP-A [18] was used to screen for auditory processing difficulties. The pitch pattern tests were performed using a Hewlett-Packard 15-DAOxxx laptop and insert phones (Boat Bassheads 225) calibrated using the sound level meter.

Procedure

All behavioral and physiological test procedures were performed in a well-illuminated room with optimum temperature and permissible ambient noise (ANSI S3.1, 1999). The study was conducted in two phases. Phase I involved the development of a pitch pattern test using the vowel /a/. In Phase II, the test was administered to normal-hearing young adults and the performance was compared with a PPT using tones.

Phase I: Development of PPT using vowels

Praat software version 6.1.16 [19] was used to develop a pitch pattern test using the vowel /a/. A young adult female voice was recorded in a sound-treated room using a Lenovo ThinkPad E14 and insert phones (Boat Bassheads 225) at a sampling rate of 44.1 kHz. The original fundamental frequency of the recorded voice was 243 Hz, which was modified to 220 Hz for 'low /a/' and 261 Hz for 'high /a/' to correspond with the musical notes A3 and C4, respectively. Five normal-hearing young adults evaluated the recording and its modified stimuli on a three-point rating scale (1 – intelligible, 2 – intelligible but needs modification, 3 – not intelligible), and all stimuli received a score of 1.

To prepare the test items, Audacity software version 2.1.3 was employed. A total of 30 normalised test items were created using the high and low stimuli. Each test item consisted of three vowels, each lasting 150 ms, with an interstimulus duration of 200 ms and an inter-sequence duration of 6 seconds [2]. This resulted in six different combinations of three pitch contours: low low high, high high low, low high low, high low high, high low low, and low high high. In this way, a total of 6 practice items and 30 PPT sequences using vowels were developed. To compare the results of the PPT using vowels with the PPT using tones, a PPT test was also recorded using the same tonal stimuli as recommended by Musiek [3].

Table 1. Comparison of pitch pattern test (PPT) scores using either vowels or tones across ear and gender

Pitch pattern test	Sex	Ear	Mean	Percentage of correct responses	Standard deviation	Median	Interquartile range		Wilcoxon signed-rank test		Mann–Whitney *U*-test	
							Q1	Q3	*Z*	*p*	*Z*	*p*
PPT using vowels	male ($n = 20$)	right	18.38	61.26	7.78	15.00	12.00	28.00	1.19	0.23	731.50	0.21
		left	19.52	65.06	6.89	18.00	14.00	25.00				
	female ($n = 20$)	right	20.10	67.00	6.10	19.50	15.25	16.25	0.20	0.84		
		left	19.95	66.50	5.82	21.50	26.75	24.00				
PPT using tones	male ($n = 20$)	right	25.33	84.43	6.32	28.00	18.50	30.00	1.76	0.86	564.50	0.51
		left	25.10	83.66	6.34	29.00	20.50	30.00				
	female ($n = 20$)	right	23.55	78.50	5.08	23.00	20.25	21.25	1.34	0.18		
		left	24.50	81.66	4.76	25.50	28.75	28.75				

Phase II: Administration of the test

Phase II of the study involved administering the tests to the 40 individuals (20 males and 20 females). The tests were conducted through a laptop using headphones and calibrated using a sound level meter to ensure that the stimuli were presented at 60 dB SPL. Hence, a PPT using vowels and a PPT using tones were administered to all participants. Before every test the ear was selected randomly to eliminate bias. To familiarise the participants and ensure they understood the instructions, for both tests practice trials were provided initially. Following the practice trials, the 30 test stimuli were presented. The PPT using vowels and the PPT using tones were administered randomly to prevent potential learning biases. To prevent fatigue a 10-minute break was given after each session. Participants were instructed to listen to the pitch sequence of the vowels/tones and repeat them verbally in the same order. A score of '1' was assigned to each triad of stimuli if the correct sequence was repeated. Any other responses were assigned a score of '0'. In both tests, any omission or inversion of the order was considered incorrect. The responses were recorded in written form. In addition, one month after the initial assessment, the test–retest reliability of the PPTs using vowels and tones was assessed on a sample of 7 participants.

Statistical analysis

Statistical analysis was performed using Statistical Package for the Social Sciences version 26. The normality of the data was checked using a Shapiro–Wilk test and the data was found to have a non-normal distribution ($p < 0.05$). Therefore, descriptive statistics using the median and interquartile ranges were calculated. Further, a Mann–Whitney *U*-test was performed to check for the ear and gender effects. A Wilcoxon signed-rank test was performed to compare the scores between the PPT using vowels and the PPT using tones.

Results

All 40 participants were able to respond to the PPT using vowels and tones. Descriptive statistics were calculated to measure the central tendency which revealed relatively consistent mean scores across ears and genders for both tests, as shown in **Table 1**. It can be seen that the mean scores for the PPT using tones were notably higher compared to those obtained from the PPT using vowels. In four participants, the presence of a ceiling effect was observed in both ears when responding to the PPT using tones.

In order to analyse the inferential statistics, a Wilcoxon signed-rank test was employed to investigate the ear effect. The results indicated that there was no statistically significant difference observed between the ears for either the PPT using vowels and the PPT using tones ($p > 0.05$). Further, a Mann–Whitney *U*-test revealed no significant gender difference for either test ($p > 0.05$) as given in **Table 1**. As no ear or gender effect was observed, the total number of ears was combined for further statistical analysis. In this way, the Wilcoxon signed-rank test was used to compare the results between the PPT using vowels and the PPT using tones. It revealed a significant difference between the mean scores on the two tests ($Z = 136$, $p < 0.001$). Further, to understand the relationship between the mean scores of PPTs using vowels and tones, Kendall's τ coefficient was calculated, which revealed a strong positive correlation between the two tests and was statistically significant ($\tau\text{-}b = 0.436$, $p = 0.001$).

Test–retest reliability

Some 30 days from the initial assessment, a re-test of the PPT using vowels was conducted for 7 participants. Thus, the test–retest reliability of the scores could be calculated using the intra-class correlation coefficient, as presented in **Table 2**.

In **Table 2**, the central tendencies of PPT using vowel for seven normal hearing participants can be seen for both

Table 2. Descriptive statistics of PPT scores using vowels done in two sessions 1 month apart (based on 7 normal-hearing young adults)

Ear	Test session	Mean	Percentage of correct responses	Standard deviation (*SD*)	Median (*M*)	Interquartile range		Intraclass correlation coefficient
						Q1	Q3	
Right	first	19.54	65.13	6.68	16.00	11.00	27.00	0.92
	second	20.13	67.10	7.44	17.26	9.00	26.00	
Left	first	20.64	68.73	5.45	19.31	12.00	23.00	0.97
	second	19.73	65.70	6.34	18.14	11.00	28.00	

sessions. Calculations revealed excellent test–retest reliability (ICC > 0.9) for both ears.

Discussion

The present study focused on the development of a verbal pitch patterning test using the vowel /a/, and compared the responses with the traditional tonal pitch pattern test. Our study, based on 20 males and 20 females, looked for ear effects in both the PPT using vowels and that using tones. Despite minor variations in the mean scores, there was no significant difference observed in performance between the ears. These findings align with previous reports which also indicated no ear-specific dominance [3]. Additionally, the study looked for the effect of gender on both tests and again we saw no statistically significant differences in any of the test procedures. Similar findings have been reported in previous studies [3,20] as well. In contrast, some other studies have reported the need for longer interstimulus time intervals for females compared to males [21–23], which perhaps can be attributed to the unequal number of male and female participants in those studies. In the present study, an equal number of males and females were included, and based on our results, it can be concluded that separate gender-specific normative data are not necessary for the pitch patterning test using vowels.

However, the study did reveal significant differences in scores between the PPT using vowels and that using tones. The PPT scores using vowels were significantly lower than for the PPT using tones, and indeed all the participants achieved lower scores for PPT using vowels than tones. It addition, some participants reached a ceiling effect in the PPT using tones [24], a finding which was not observed in the PPT using vowels. These score differences might have been due to the large frequency difference of the stimuli used for the PPT based on tones (i.e., 880 Hz and 1122 Hz) compared to the PPT based on vowels (22029 Hz and 261 Hz). In addition, the difficulty was observed in a majority of the participants in decoding, understanding, and naming the verbal sequences, a skill which involved attention, memory, and learning effects. The added complexity in perceiving the phonological basis of verbal stimuli, discriminating their pitches, ordering the sequences, and labeling them could have resulted in relatively lower scores in PPT using vowels [8,12]. Furthermore, the task of verbal labeling becomes comparatively more intricate when it involves verbal sound stimuli [11,25]. The right hemisphere is largely involved in pitch discrimination as well as ordering. However, it is the left hemisphere that is crucial for decoding verbal stimuli and labeling the pitch patterns verbally [7,8,11,20]. Hence, it can be speculated that relatively more complex mechanisms are involved in verbal labeling of the PPT using vowels than in the PPT using tones. However, there was a significantly strong positive correlation between the two tests, indicating that there is a clear positive relationship when young adults with normal hearing assess temporal ordering ability.

For 7 participants, test–retest reliability between the two sessions of PPT using vowels was found to be excellent for both ears. These findings suggest that the measurement technique used for the PPT with vowels is reliable and provide consistent results. We conclude that the PPT using vowels is a reliable and valid method for evaluating the temporal ordering ability of young adults.

Conclusions

To the best of our knowledge, the present study is the first to develop a PPT using the vowel /a/ and compare the resulting scores with the tone-based pitch pattern test. We found no order or gender effects. The study demonstrated a significant relationship between the PPT using vowels and the traditional PPT using tones. The vowel-based PPT exhibited no ceiling effect compared to the traditional test, suggesting a potential clinical advantage in detecting subtle pitch pattern perception differences. The pitch pattern test using the vowel /a/ demonstrated excellent test–retest reliability, indicating consistency and dependability over time. Although the developed PPT using the vowel /a/ shows promise as a valuable tool for assessing temporal processing ability, particularly in clinical settings, additional investigations are required to explore the efficacy of the test across various clinical populations.

References

1. Shinn JB. Temporal processing: the basics. Hear J, 2003; 56(7): 52. https://doi.org/10.1097/01.HJ.0000292557.52409.67
2. Pinheiro ML. Tests of central auditory function in children with learning disabilities. In: Keith RW, editor, Central Auditory Dysfunction. New York: Grune and Stratton, 1977; 223–56.
3. Musiek FE. Frequency (pitch) and duration pattern tests. J Am Acad Audiol, 1994; 5(4): 265–8.
4. Bellis TJ. Assessment and Management of Central Auditory Processing Disorders in the Educational Setting: From science to practice. San Diego: Plural Publishing; 2011.

5. Elias KM, Santos MF, Ciasca SM, Moura-Ribeiro MV. Auditory processing in children with cerebrovascular disease. Pro Fono, 2007; 19: 393–400. https://doi.org/10.1590/s0104-56872007000400012
6. Musiek FE, Pinheiro ML. Frequency patterns in cochlear, brainstem, and cerebral lesions. Audiol, 1987; 26(2): 79–88. https://doi.org/10.3109/00206098709078409
7. Musiek FE, Pinheiro ML, Wilson DH. Auditory pattern perception in 'split brain' patients. Arch Otolaryngol, 1980; 106(10): 610–2. https://doi.org/10.1001/archotol.1980.00790340018004
8. Balen SA, Moore DR, Sameshima K. Pitch and duration pattern sequence tests in 7- to 11-year-old children: results depend on response mode. J Am Acad Audiol, 2019; 30(1): 6–15. https://doi.org//10.3766/jaaa.16132
9. Silva RD, Oliveira CM, Cardoso AC. Application of temporal pattern tests in children with persistent developmental stuttering. Rev CEFAC, 2011; 13: 902–8 [in Portuguese]. https://doi.org/10.1590/S1516-18462011005000045
10. Rowe EJ, Cake LJ. Retention of order information for sounds and words. Can J Psychol, 1977; 31(1): 14–23. https://doi.org/10.1037/h0081645
11. Jutras B, Gagné JP. Auditory sequential organization among children with and without a hearing loss. J Speech Lang Hear Res, 1999; 42(3): 553–67. https://doi.org/10.1044/jslhr.4203.553
12. Koravand A, Jutras B, Roumy N. Peripheral hearing loss and auditory temporal ordering ability in children. Int J Pediatr Otorhinolaryngol, 2010; 74(1): 50–5. https://doi.org/10.1016/j.ijporl.2009.10.009
13. Conrad R, Hull AJ. Information, acoustic confusion and memory span. Br J Psychol, 1964; 55(4): 429–32. https://doi.org/10.1111/j.2044-8295.1964.tb00928.x
14. Aaronson D. Temporal factors in perception and short-term memory. Psychol Bull, 1967; 67(2): 130–44. https://doi.org/10.1037/h0024123
15. Moore BC, Tyler LK, Marslen-Wilson W. Introduction. The perception of speech: from sound to meaning. Philos Trans R Soc B, 2008; 363(1493): 917–21. https://doi.org/10.1098/rstb.2007.2195
16. Norman DA, Rumelhart DE. A system for perception and memory. In: Norman DA, editor. Models of Human Memory. Elsevier Science; 1970: 19–64.
17. Tiwari, S. Maturational Effect of Pitch Pattern Sequence Test (Dissertation No IP441). Mysore: All India Institute of Speech and Hearing; 2003. Available from: http://203.129.241.86: 8080/xmlui/handle/123456789/4490 [Accessed: 10.10.2023].
18. Vaidyanath R, Yathiraj A. Screening checklist for auditory processing in adults (SCAP-A): development and preliminary findings. J Hear Science, 2014; 4(1): 33–43. https://doi.org/10.17430/890788
19. Boersma P, Weenink DJM. Praat: doing phonetics by computer (version 5.3.51). Available from: http://www.praat.org/ [Accessed: 10.10.2023].
20. Majak J, Zamysłowska-Szmytke E, Rajkowska E, Śliwińska-Kowalska M. Auditory temporal processing tests: normative data for Polish-speaking adults. Med Pr, 2015; 66(2): 145–52. https://doi.org/10.13075/mp.5893.00041
21. Fink M, Churan J, Wittmann M. Assessment of auditory temporal-order thresholds: a comparison of different measurement procedures and the influences of age and gender. Restor Neurol Neurosci, 2005; 23(5–6): 281–96.
22. Szymaszek A, Szelag E, Sliwowska M. Auditory perception of temporal order in humans: the effect of age, gender, listener practice and stimulus presentation mode. Neurosci Lett, 2006; 403(1–2): 190–4. https://doi.org/10.1016/j.neulet.2006.04.062
23. Lotze M, Wittmann M, von Steinbüchel N, Pöppel E, Roenneberg T. Daily rhythm of temporal resolution in the auditory system. Cortex, 1999; 35(1): 89–100. https://doi.org/10.1016/s0010-9452(08)70787-1
24. Fuente A, McPherson B. Auditory processing tests for Spanish--speaking adults: an initial study. Int J Audiol, 2006; 45(11): 645–59. https://doi.org/10.1080/14992020600937238
25. Frederigue-Lopes NB, Bevilacqua MC, Sameshima K, Costa OA. Performance of typical children in free field auditory temporal tests. Pro Fono, 2010; 22: 83–8. https://doi.org/10.1590/s0104-56872010000200003