Absolute pitch: an unusual type of memory for standard musical scale

Słuch absolutny: Niezwykły rodzaj pamięci dotyczący standardowej skali muzycznej

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ABSTRACT

Absolute pitch (AP) is a rare phenomenon, which appears in some musicians, of long-term memory for the musical-pitch standard values. In the present experiment 63 music students were presented with 2 versions of the 'pitch-naming' test, differing in time-distances between the subsequent sounds – 4 seconds or 1 second. It appeared that only the 1-second version of the test was effective in selecting the genuine absolute pitch possessors from a group of musicians.

STRESZCZENIE

Słuch absolutny (ang. AP) jest rzadko spotykaną cechą pamięci długotrwałej muzyków dotyczącą standardowych wartości wysokości tonu w muzyce. W niniejszym eksperymencie 63 studentom muzyki zaprezentowano 2 wersje testu polegającego na „nazwaniu tonu", różniące się odległością czasową między dwoma następującymi po sobie dźwiękami – 4 sekundy lub 1 sekunda. Okazało się, że tylko jednosekundowa wersja testu pozwalała na efektywne wyłonienie spośród grupy muzyków osób posiadających słuch absolutny.

1. Introduction

The term 'absolute pitch' (AP) is used to define a particular, and as yet not wholly explained, feature of long-term auditory memory which occurs in some musicians. People with genuine, full absolute pitch are capable of recognizing in a natural way the twelve pitches of the chromatic musical scale and associating them with the names of twelve semitones of that scale, e.g. C, C sharp (or D flat, equally valid), etc. The musical pitch values of the same name are recognized as identical across all the octaves of the musical scale.

In the present paper it is intended to show absolute pitch as an auditory phenomenon of pitch and long-term memory, based on the complete musical interactions of these two elements. The practical aspect of these relations will be shown later in a simple experiment showing how to select the possessors of genuine absolute pitch from a group of musicians. Before discussing in more detail the unusual phenomenon of absolute pitch it seems reasonable to recall some selected notions of auditory psychophysics such as pitch and its relations, and to propose some refinements in their definitions.

In most dictionaries pitch is described simply as an auditory sensation which enables ordering sounds in a scale from ‘low’ to ‘high’. However, pitch, particularly in music, appears as a much more complex auditory phenomenon, whose various parts in various ways jointly overcome the limitations of auditory memory [1]. Most important here would be regarding the domain of pitch as divided into two symmetrical sub-domains, *pitch value* and *pitch distance*. These sub-domains in music divide further, each into two parts. Pitch value divides into *natural pitch* (earlier ‘tone height’ [2]) and into a series of strictly categorical *musical pitch classes* (‘tone chromas’). Similarly, pitch distance divides into the *natural pitch distance* and into a pitch phenomenon which is strictly categorical and most important in music, namely a set of *musical intervals* [3].

Apart from being important in ‘giving birth’ to various musically meaningful scales of pitch intervals, the pitch distance scale provides material to create another important sub system of human communication, namely that of speech intonation, so clearly shown by Wiktor Jassem [4]; a system with less strict standards but with creative rules and significant distances not much different from those in a system of musical intervals.

In light of the above consideration it seems reasonable to connect the notion of *absolute pitch* with the sub domain *pitch value*. Here the long term auditory memory shows its most strict performance. The values of pitch standards, usually acquired early in life in an absolute pitch possessor, remain stable and unchanged even when actual music performance (e.g. singing in an *a capella* choir) allows for some deviations.

2. The kinds of absolute pitch

The feature characteristic of genuine absolute pitch is fixing in one’s memory a specific number of chromas, that is, values of musical pitch, recognised with an accuracy of about one quarter-tone, repeated across the octaves, and each of them expressed through specific features of auditory impressions. Full genuine absolute pitch [2, 5] is the fixing in one’s memory of all the pitches of the within-octave, equally tempered chromatic scale. There is evidence to show that the permanent acquisition of all twelve standards of absolute pitch takes place gradually, and that usually the first to be mastered is the set of seven chromas of the diatonic ‘white keys’ scale. Such a clear differentiation of the regularities of the recognition of notes corresponding to black and white keys has been observed in young people who are most probably not yet in the final phase of forming their absolute pitch [6, 7]. But in the case of persons with fully-developed absolute pitch, there are usually no noticeable systematic differences in the accuracy of tuning the pitch of a test note to the internally-fixed standards of the diatonic and chromatic scale.

However, while the examples given above could, in principle, concern full absolute pitch in various stages of development, cases of the stable memorising of single notes must be subject to a different qualification. Such cases are quite frequent and result from the practical conditions in which music is learned or practised. One typical example is the memorising by many students of music schools in France of the pitch of the note ‘C’, caused by the use there of the ‘fixed *do* method’ of Jacques Dalcroze. The ‘fixed *do*’ method (in the solmisation system of names, do corresponds to the note C) involves the constant referring of all listening exercises to this pitch standard. Another typical example is the frequent memorising by some musicians playing string instruments of the note A4, to which they tune their instruments daily by means of a tuning device.

Two authors who have achieved a great deal in the study of absolute pitch, A. Bachem and W. D. Ward, qualify these cases as quasi-absolute pitch [2, 8, 9]. The way in which this category is often used has little in common with the normal way in which absolute pitch functions. A person with quasi-absolute pitch treats his memorised pitch standard as a tuning fork. He takes a long-term remembered value of pitch as a starting point in relation to which he can recognise or intone any note, making use of the permanently-acquired values of musical intervals. This strategy, aiming often to create the impression of possessing full absolute pitch, has its unquestionable virtues, as it leads to perfection in the use of relative pitch (musical intervals) – most important for a musician. However, a person with quasi-AP employing this strategy can be easily distinguished from someone who has full absolute pitch. The quasi-AP possessor needs always a much longer time to summon any musical pitch not belonging to his standards, while the reactions of a person with full AP are always spontaneous and immediate.

A similar situation appears in cases when the pitch model has not been fixed permanently in the auditory memory but is based on different phenomena, such as remembering the tension of the muscles of the larynx for performing the lowest note of one's own voice scale or the training of the recognition of a certain segment of the natural pitch scale. Any similarity of the results of these procedures to the effect of absolute pitch can at best be termed, pseudo-absolute pitch.

Genuine absolute pitch can be encountered, in two variants, namely as active and passive absolute pitch [10]. Active absolute pitch is the most perfect form of this phenomenon. It enables the individual to produce the required pitch, and to recognise musical pitch classes, generally irrespective of the kind of source and timbre of a given sound.

Passive absolute pitch does not allow one to produce required pitch, but only to recognise it. Although possessing the basic attributes of genuine absolute pitch (the recognition of individual chromas is spontaneous, and the reception of each of them is connected with an individual, specific auditory impression), passive absolute pitch has many limitations in relation to active absolute pitch. Besides the basic restriction, which is the inability to intone the required pitch, passive absolute pitch usually displays considerable sensitivity to the timbre of the notes used in the test. Often, the effect of the absolute recognition of a chroma is limited here to the sounds of one's own instrument, e.g. the piano or the violin.

3. How does absolute pitch arise?

Interest in the phenomenon of absolute pitch dates from the second half of the nineteenth century [11, 12], and almost from the very beginning there emerged two controversial theories accounting for its origins. Meyer [13] was the first psychologist who, in the belief that the acquisition of absolute pitch was a question of training, carried out exceptionally laborious training on himself and his colleague, ultimately achieving 60% and 64% of correct recognition of notes on the piano. This could have been regarded as a fairly good example of absolute pitch were it not for the fact that when the exercises were discontinued the memory of the pitches soon disappeared. Later efforts to learn absolute pitch undertaken by scholars such as Mull [14] and Wedell [15], and also by a great many nameless enthusiasts, were equally fruitless. The only case of an adult person acquiring, through several months of exercises, perfection in the recognition of notes on a piano that came close to full absolute pitch (65% correct recognitions) was described by Brady [16].

In the face of such evident defeats for the 'learning theory', a certain authority has been gained by the 'genetic theory', or the 'theory of innate factors', according to which the possession of absolute pitch is an inborn phenomenon, dependent in some unclear way on heredity. Supporters of this theory have been primarily individuals who themselves have possessed full genuine absolute pitch, including such eminent authors as Révész [17], Bachem [2], and Seashore [18].

However, even for the advocates of this theory, the drastic division of the human population and the isolation of a microscopic privileged minority has seemed a rather curious and incomprehensible fact. There soon also appeared data attesting a clearly positive correlation between possessing absolute pitch and beginning one's musical education at an early age [19, 6, 20–22]. It was shown that in order to acquire absolute pitch it is most crucial that a child's musical education, takes place as early as possible, ideally during the period 3–6 years of age. It was also noticed that in music schools in Japan, the percentage of children with absolute pitch was several times greater than in Europe. Some specialists advanced the assumption that this may be due to the fact that many children in Japan begin to learn music at the age of 3–4 years, thanks, among others, to the popularity of learning through the Suzuki and Yamaha schools [23], where music lessons begin several years before the regular school age.

And so the 'early learning theory' began to dominate in the opinions. However, its success began to display certain limitations. The early musical initiation of a child clearly increased the probability of forming absolute pitch, but it by no means gave certainty in this respect [9]. In addition, as has been demonstrated [24], there do occur people with absolute pitch who commenced their musical education above the age of nine, and even between their twelfth and fifteenth years. This prompted an assertion opposed to the theory of early learning: Perhaps, after all, it was innate genetic factors that were decisive [25]? Perhaps it is just such factors, creating in some children a physiologically privileged hearing ability, that cause their greater interest in music, as a result of which parents earlier organise for them the access to music. Nevertheless it should be mentioned that Japan has recently become the object of interest for specialists in genetics [21]. In Japan, where the number of people with absolute pitch is remarkably high, the cases of the inheritance of this trait also prove to be much more frequent than in other countries [26, 27].

4. The screening test for brief selection of full-absolute-pitch possessors

For practical reasons in music education and also for theoretical interest it may be necessary to know how many subjects have absolute pitch and what kind of AP it is. Also, in recent years problems of absolute pitch again attracted the attention of some researchers due to the possibility of using AP possessors as subjects in assessing the pitch salience ('pitch strength') of sounds like short pulses or high-pass-filtered harmonic tones [28–30]. As a result it was decided to perform a simple testing looking for the possibility of selecting the genuine AP-possessors from a group of students at the Chopin Academy of Music (now the Fryderyk Chopin University of Music).

The test was constructed from 24 piano tones selected 'quasi randomly' from a wide range of the piano scale (from first to seventh octave) with the limitation that neighbouring notes were separated by an interval of at least 14 semitones. The test was prepared in two variants differing with time distances separating the beginnings of subsequent tones. These distances of time were 4 and 1 second. The 1s test differed additionally from the 4s test with the order of appearance of three initial tones. Care was taken to ensure a very high quality of the piano tones; their duration was shortened in the most natural way possible to approx. 0.7 s. The two variants of the test were recorded monaurally onto CD and played back to the subjects in an acoustically adapted room from the high quality loudspeaker with loudness level of about 60–70 phons.

Sixty three students (including two former students) of the Chopin Academy of Music took part in the experiment. These were students of music theory, composition, sound engineering, and music education, who had completed a high-level course in ear training. The listenings were held in groups of about 10 participants. Before performing the test subjects were given a short training. When the proper testing had started, every sixth successive item was announced in a soft voice by the operator. The answers had to be entered in the relevant boxes on the answer sheet. In the first and second tests performance (test 4s and 1s) subjects' task was to recognize a given chroma and to enter a letter, e.g. D, F sharp or G flat (equally valid). In the third test performance (again test 4 s unchanged) the subjects' task was to recognize the octave where a piano tone belonged and to mark it on a draft of the piano keyboard.

The results of present research are presented in successive Figures. Figure 1 shows the combined results of the 4s and 1s tests. Marked on the x-axis are numbers allocated to the listeners, with number 1 given to the listener who achieved the best recognition of chromas in the 4s test, and number 63 to the listener who gave only wrong answers. (A blank box against a particular item was also considered as wrong). As can be seen, the distribution of the rising values of correct recognitions in the 4s test (black diamonds) has a continuous character among the subjects. This is typical of tests of this sort when the subjects are given a relatively long time for their responses [31, 25, 32].

When the time allotted for responses was shortened to one second, the distribution of responses altered significantly. Yet the change concerned, above all, the group of subjects scoring with not very high accuracy in the first 4s test. For this group the shortening of the response time to one second eliminated any possibility of manipulation with intervals (quasi-absolute pitch or pseudo-absolute pitch based on the non-auditory memory).

The results of the two tests present an almost total concordance in the case of listeners who obtained the highest percentage of correct responses in both tests. In observing the combined results of the two tests on Figure 1, it is possible to distinguish the group of listeners assigned the numbers 1–11 as quite clearly apart from the rest of the group in terms of the quality and stability of their answers (a result of over 70 correct answers in both tests). It seems that tests requiring a really great speed in giving answers from the subjects are the best in selecting subjects with true absolute pitch. For practical reasons the between-onset time of 1 second appears here as a proper solution.

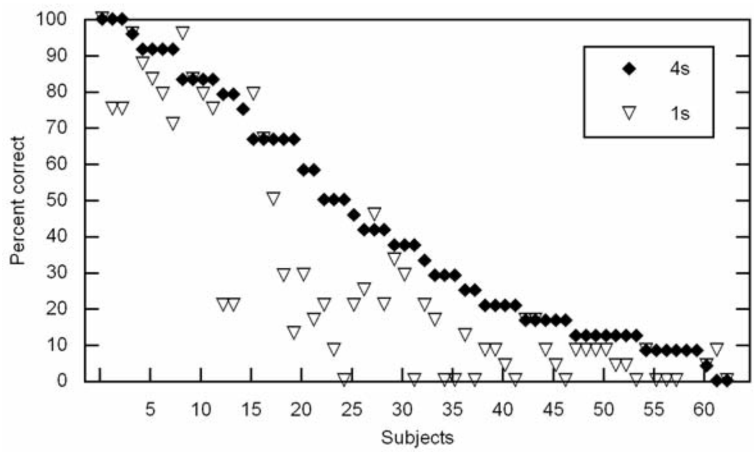

Figure 1: Proportion (percent) of correct chroma recognition in 24 piano tones by 63 students of the music academy. Black diamonds and white triangles correspond to the tests with 4-second and 1-second time distances between onsets of subsequent tones in the tests.

The third testing performed for the same group of listeners concerned their ability to recognise the octave in which a given note was played on the piano. The test 4s, used here for the second time, allowed a four-second response time. The results of testing on octave recognition are shown in Figure 2 together with the results of chroma recognition.

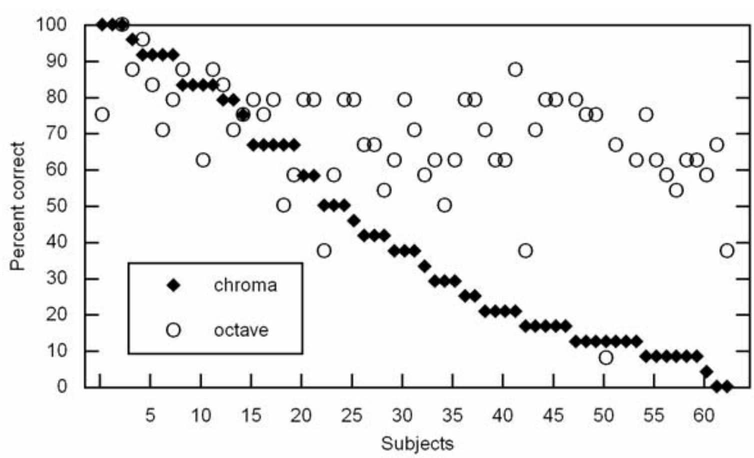

Figure 2: Percent of correct responses in the 4-second octave-recognition test presented with the results of the 4-second chroma recognition test.

The distribution of the results presented in Figure 2 shows a general lack of correlation between the compared percentages of correct recognition. It presents the division of the remembering mechanism into two separate cases: the memory for strictly categorized pitch chromas, and the memory for musical octaves, to some degree representing the ranges of natural pitch stored in memory. Nevertheless, the two distributions show a slight agreement as far as the results of best subjects are concerned. A quite similar result with an analogous group of student-musicians was obtained by Rogowski and Rakowski [31]. These observations lead to a reflection on whether the possession of full genuine absolute pitch is not, after all, in some way related to an increased general efficiency of auditory memory?

Acknowledgements

The author is indebted to Piotr Rogowski and Jihee Ryou for help in collecting the data.

References

[1] Rakowski, A. and P. Rogowski. 2007. Experiments on long-term and short-term memory for pitch in musicians. *Archives of Acoustics* 32, 813–826.

[2] Bachem, A. 1937. Various types of absolute pitch. *Journal of the Acoustical Society of America* 9, 146–151.

[3] Rakowski, A. 2009. The domain of pitch in music. *Archives of Acoustics* 34, 429–443.

[4] Jassem, W. 1973. *Fundamentals of Acoustical Phonetics*. (In Polish). Państwowe Wydawnictwo Naukowe.

[5] Miyazaki, K. 2007. Absolute pitch and its implications for music. *Archives of Acoustics* 32, 529–540.

[6] Miyazaki, K. 1988. Musical pitch identification by absolute pitch possessors. *Perception and Psychophysics* 44, 501–512.

[7] Miyazaki, K. and Ogava. 2006. Learning absolute pitch by children: A cross-sectional study. *Music Perception* 24, 63–78.

[8] Bachem, A. 1955. Absolute pitch. *Journal of the Acoustical Society of America* 27, 1180–1185.

[9] Ward, D. W. 1999. Absolute pitch. W: D. Deutsch(ed.), *The Psychology of Music*, 2nd Edition, Academic Press, New York.

[10] Teplov, B. M. 1947. *Psychology of musical talent* (in Russian). Editions of the Academy of Pedagogical Sciences RSFSR, Moscow-Leningrad. Polish translation: Nasza Księgarnia, Warszawa 1952.

[11] Stumpf, C. 1883. *Tonpsychologie*. Hirzel, Leipzig.

[12] Kries, J. 1892. Über das absolute Gehör. *Zeitschrift für Psychologie und Physiologie der Sinnesorgane* 3, 257–279.

[13] Meyer, M. 1899. Is the memory of absolute pitch capable of development by training. *Psychological Review*, 6, 514–516.

[14] Mull, H.K. 1925. The acquisition of absolute pitch. *American Journal of Psychology* 36, 469–493.

[15] Wedell, C. H. 1934. The nature of the absolute judgement of pitch. *Journal of Experimental Psychology* 17, 485–503.

[16] Brady, P.T. 1970. Fixed-scale mechanism of absolute pitch. *Journal of the Acoustical Society of America* 48, 883–887.

[17] Révész, G. 1913. *Zur Grundlagen der Tonpsychologie*. Veit, Leipzig.

[18] Seashore, C.E. 1938. *Psychology of music*. McGraw-Hill, New York.

[19] Sergeant, D. 1969. Experimental investigation of absolute pitch. *Journal of Research in Music Education* 17, 135–143.

[20] Miyazaki, K. 1988. Musical pitch identification by absolute pitch possessors. *Perception and Psychophysics* 44, 501–512.

[21] Takeuchi, A. H. and S. H. Hulse. 1993. Absolute pitch. *Psychological Bulletin* 113, 345–361.

[22] Gregersen, P. K., E. Kowalsky, N. Kohn and E. W. Marvin. 1999. Absolute pitch: prevalence, ethnic variation, and estimation of the genetic component. *American Journal of Human Genetics* 65, 911–913.

[23] Baharloo, S., S. K. Service, N. Risch, J. Gitschier, and N. B. Freimer. 2000. Familial aggregation of absolute pitch. *American Journal of Human Genetics* 67, 755–758.

[24] Miyazaki, K., and Y. Ogava. 2006. Learning absolute pitch by children: a cross-sectional study. *Music Perception* 24, 63–78.

[25] Baharloo, S., Johnston, P. A., Service S. K., Gitschier, J. and Freimer, N. B. 1998. Absolute pitch: an approach for identification of genetic and non-genetic components. *American Journal of Human Genetics* 62, 224–231.

[26] Brown, W.A., H. Zachs, K. Cammuso and S. E. Felstein. 2002. Early music training and absolute pitch. *Music Perception* 19, 594–597.

[27] Deutsch, D., T. Henthorn, E. Marvin and H. Hu. 2006. Absolute pitch among American and Chinese conservatory students: prevalence differences, and evidence for a speech-related critical period. *Journal of the Acoustical Society of America* 119, 719–722.

[28] Rakowski, A. and K. Miyazaki. 2007. Absolute pitch: Common traits in music and language. *Archives of Acoustics* 32, 5–16.

[29] Rakowski, A., P. Rogowski and S. Makomaska. 2008. Absolute pitch as a measuring device in psychoacoustic experiments. *Proc. 10th International Conference on Music Perception and Cognition, Sapporo, Japan*. 34–38.

[30] Hsieh, I. and K. Saberi. 2009. Virtual pitch extraction from harmonic structures by absolute-pitch musicians. *Acoust. Physics* 55, 232–239.

[31] Rogowski, P. and A. Rakowski. 2010. Pitch strength of residual sounds estimated through chroma recognition by absolute-pitch possessors. *Archives of Acoustics* 35 (3), 331–347.

[32] Rakowski, A. and M. Morawska-Büngeler. 1987. In search for the criteria of absolute pitch. *Archives of Acoustics* 12, 75–87.

[33] Miyazaki, K. and A. Rakowski. 2002. Recognition of notated melodies by possessors and non-possessors of absolute pitch. *Perception and Psychophysics* 64, 1337–1345.