

SHORT-TERM MEMORY FOR PITCH INVESTIGATED WITH VOCAL MATCHINGS

A. RAKOWSKI (WARSZAWA)

Chopin Academy of Music
(00-368 Okólnik 2, Warszawa)

Three musicians not possessing absolute pitch repeated vocally five standard tones played on the guitar. The repetition was completed over various periods of delay ranging from 10 seconds to 6 minutes. Periods of delay were: a) silent, b) filled with cognitive activity (counting backward in threes) or c) filled with interfering tonal stimuli (an endless, ascending chromatic scale). The frequencies of tones sung by the subjects were measured and compared to those of standard tones. Standard deviations of the sets of frequency differences were taken as measures of the inaccuracy of pitch memory trace. The obtained "forgetting curves" show that at concentrated attention subjects could retain the memory for pitch of a standard with accuracy better than a quartertone for three minutes. With cognitive interference the same was possible for two minutes, and with tonal interference for thirty seconds. Conclusions may be drawn concerning the hypothetical time constant for short-term auditory memory.

1. Introduction

Pitch is that attribute of sound sensation which enables the ordering of sounds into a scale from low to high. Distances between discrete values of pitch form the most important part of the code used in music: the set of musical intervals. Musical intervals can be taught and permanently remembered, in particular as elements constituting melodies. However this is not so with absolute values of pitch. A limited number of such discrete absolute values can be fixed in the memory of only a limited number of people: those having the so-called "absolute pitch" (RAKOWSKI and MORAWSKA-BUNGELER [7]). People not having absolute pitch cannot remember the exact values of pitch permanently and recognize only broad pitch registers (POLLACK [4]). However most people can easily and very accurately remember absolute values of pitch for short time periods, e.g. repeating vocally a given note or performing tests of frequency discrimination (RAKOWSKI [5]). A question arises whether there exists a constant time value limiting the operation of exact memory for pitch.

The notion of pitch should be specified more exactly before an answer to the above question can be given. It was found by music psychologists, in reference to music, that the sensation of pitch has two separate components: tone height and tone chroma

(REVESZ [8]). Tone chroma refers to twelve within-octave categories or localized pitch classes having the musical names C, C sharp, D, etc. Tone height refers to a non-categorized sensation which may be used for ordering sounds from very low to very high and which changes continuously. The present investigation concerns exclusively this second aspect of pitch sensation, namely tone height.

The transition between the "very exact" (at short time distance) and "very inaccurate" (at longer time delays) mode of memory for pitch has much to do with one of the most important problems within the theory of human memory. It concerns the controversy between the unitary and dualistic theories of memory. The proponents of dualistic theory, like HEBB [3] tried to find the evidence for the existence of two qualitatively different types of memory in various sensory modalities. The existence of a specific sensory mode of auditory memory, a "precategory" one, was propounded by CROWDER and MORTON [1] and several others. DEUTSCH [2] summarised comprehensive studies on the short-term memory of categorized pitch classes. However very few investigators turned their attention towards the memory of the uncategorized form of pitch: the tone height.

Investigating short-term memory for tone height, as specified by RAKOWSKI [6], may be fruitful for two reasons. Firstly, this form of memory is not loaded with verbal descriptions. Second, the sensation is unidimensional and strength of its memory trace can be easily measured.

In the present experiment sensory memory for tone height is investigated with the use of vocal emission. Three musicians, a man and two women not possessing absolute pitch, participated as subjects.

2. Preliminary experiment

2.1. Training the Subjects

Each subject was given two-hour training in according to the following experimental design. One of the tones of the equally tempered chromatic scale within the subject's convenient vocal range was played on a guitar. The guitar was very accurately tuned and tone frequencies controlled with the automatic tuner ZEN-ON, Chromatina 331, with the accuracy of 1 cent (one hundredth part of a semitone). Subjects tried to repeat the tone as accurately as possible. The sequence was repeated until the matching was within the error of ± 2 cents. The tones were sung at a moderately low level, using any vowel that the subject wanted to chose. The training lasted 2 hours altogether and was performed within 3 or (in the case of one subject) 4 days.

2.2. Measuring Precision of Vocal Intonation

In all the subsequent parts of the experiment five standard tones were used: F \sharp G, G \sharp A and A \sharp . For the male subject these tones were taken from the third octave and

had the frequencies: 185.0; 195.9; 207.7; 220.0; and 233.1 Hz. For the female subjects the tones were taken from the fourth octave and had the frequencies: 370.0; 391.9; 415.3; 440.0; and 466.2 Hz.

Each subject's task was to listen to a tone played on the guitar, to sing a note with the same pitch and, if not correct, keep repeating until its accuracy was within ± 2 cents of a standard. After that, responding to a signal, the subject repeated the note once again trying to make it exactly the same. The difference in cents between frequencies of these two last tones was noted as raw data. After that, next tone chosen randomly from the set of remaining tones was played and the procedure repeated until each of the five standard tones had been worked on 12 times. The whole task was usually completed within 2 to 3 sessions. Standard deviations were taken as measures of inaccuracy. They were computed for each tone and averaged for each subject. The results for the man and two women were: 0.07, 0.08 and 0.10 semitones.

2.3. Measuring accuracy of Long-Term Memory

At the beginning of each experimental session, or as a separate measurement performed at least 15 minutes after any other singing activity, listeners were asked to sing one randomly chosen note from the set of 5 notes used in the experiment. The frequency of this note was measured. After 12 results for each note had been collected, the mean value for all standard deviations was computed and presented in Fig. 1 over the sign LTM.

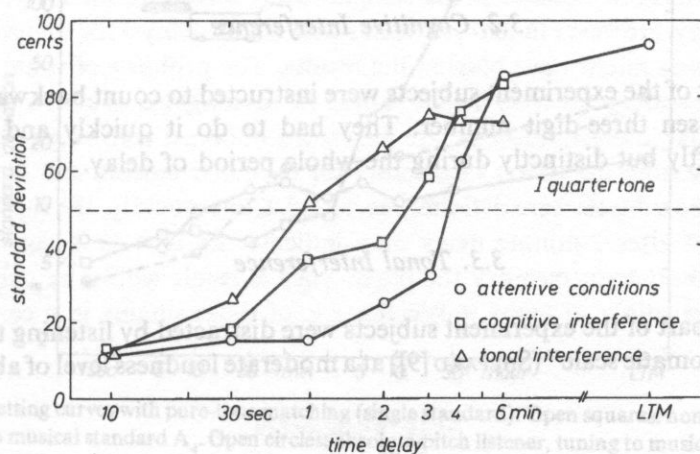


Fig. 1. Pitch forgetting curves with vocal matching. (Averaged results for tuning to five standards: F \sharp G, G \sharp A and A \sharp).

3. The main experiment

The procedure adopted in the main experiment was as follows: Subjects listened to a single note played two times on a very exactly tuned guitar and repeated the note by singing it twice under the control of an automatic tuner. The frequency of this second repetition was taken as the standard for the delayed matching. After a randomly chosen delay of 10, 30, 60 seconds and 2, 3, 4 or 6 minutes subjects repeated the standard note as exactly as possible. The frequency level difference between the standard and the matched tone was noted and the next matching started. The order of matchings was randomized within five standard pitches and seven times of delay.

For each one of the three listening conditions specified below subjects performed the same number of matchings. Two of the subjects (a man and a woman) performed 12 matchings and the third subject performed 6 matchings at every pitch and at each delay. Measurements were performed in a sound-isolated room, during individual sessions lasting no more than one hour with several short intermissions. Subjects were allowed to control timing and were warned just before the end of each delay time.

3.1. Attentive Conditions

In the first part of the main experiment subjects were instructed to concentrate their full attention on the standard pitch. However they were not allowed to hum the remembered tone and were told not to keep the larynx muscles in tension.

3.2. Cognitive Interference

In this part of the experiment subjects were instructed to count backward in threes from any chosen three-digit number. They had to do it quickly and accurately, whispering softly but distinctly during the whole period of delay.

3.3. Tonal Interference

In the last part of the experiment subjects were distracted by listening to the rising "unending chromatic scale" (SHEPARD [9]) at a moderate loudness level of about 60 dB.

4. Results

The results of the experiment are presented in Fig. 1 as "pitch forgetting curves". They show averaged values of standard deviations calculated under each experimental condition. Each measuring point represents data from 150 individual matchings.

Pitch forgetting curves show the growth of dispersion within sets of matchings performed at consecutively increasing time delays. The dispersion, represented by numerical value of the standard deviation may be taken as a measure of inaccuracy of the memory trace of a standard.

5. Discussion

There may be some doubts concerning the credibility of the method used in the present investigations. It may be argued that in spite of the instruction subjects tried to use a non-specific kind of memory (memory for muscular tension in the throat) to solve the auditory tasks. However, even if such an effect existed in some isolated cases, it must have been excluded in the conditions of cognitive interference when subjects had to whisper numbers.

The pitch forgetting curve for the attentive conditions shows a rapid increase in forgetting after a time delay of 3 minutes. This is in full agreement with the results of similar investigation with subjects who tuned the pure-tone oscillator to a standard pitch 440 Hz after varying time delays (RAKOWSKI, MORAWSKA-BUNGELER [7]). The results obtained in that experiment are shown in Fig. 2. They represent the pitch-forgetting curves produced by two subjects. One of subjects had the so-called "absolute pitch", or the ability to preserve in a long-term memory the set of standard musical pitches. The other one did not possess this ability.

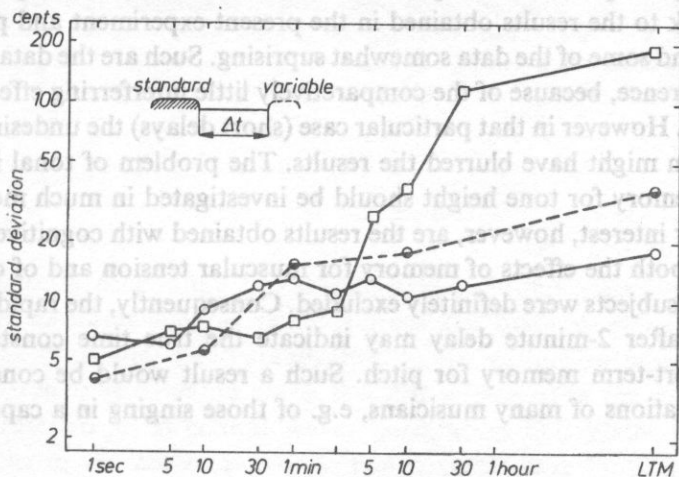


Fig. 2. Pitch forgetting curves with pure-tone matching (single standard). Open squares: non-absolute-pitch listener, tuning to musical standard A_4 . Open circles: absolute-pitch listener, tuning to musical standard A_4 . Semi-filled circles: absolute-pitch listener, tuning to non-musical standard $A_4 + 66$ cents.

The results of the second listener, a non-possessor of absolute pitch, are shown in Fig. 2 as open squares (standard deviations of twenty frequency settings at delayed tunings to the standard tone $A_4 = 440$ Hz). The conditions of performing that

experiment were very similar to the "attentive conditions" of the present investigation. The listener was placed in a sound-proof booth in silence and had to concentrate his whole attention on the pitch of the standard exposed at the beginning of each trial. No humming was allowed. After the delay time the variable-tone oscillator was heard, producing a very high or very low tone. The subject's task was to regulate its frequency to obtain equal pitch with the remembered standard. That tuning process lasted on average about three seconds.

As can be seen in Fig. 2 the results obtained by the non-absolute-pitch listener of RAKOWSKI and MORAWSKA-BUNGELER [7] are very similar to those obtained in the present investigation at attentive conditions. It seems that in both experiments the time delay of about 3 minutes marked a significant change in the salience of a preserved memory trace of a standard. The generally better accuracy of tuning obtained with the oscillator may be partly due to the fact that standard frequency there was always the same — 440 Hz.

Interesting comparisons may be made while looking at the results obtained by the absolute-pitch listener. In Fig. 2 those results are marked by circles. The open circles represent tuning to the exact musical standard 440 Hz (A_4). The semi-filled circles concern tuning to a non-musical standard 457 Hz ($A_4 + 66$ cents). At longer time delays tuning to the musical standard is superior to that performed with the non-musical standard. However at longer time delays in both cases, the performance of the absolute-pitch possessor is superior to that of the non-absolute-pitch listener.

Coming back to the results obtained in the present experiment and presented in Fig. 1 we may find some of the data somewhat suprising. Such are the data concerning the tonal interference, because of the comparatively little interfering effect up to the 30-second delay. However in that particular case (short delays) the undesired effect of muscular tension might have blurred the results. The problem of tonal interference with sensory memory for tone height should be investigated in much more detail.

Of particular interest, however, are the results obtained with cognitive interference. In this case both the effects of memory for muscular tension and of covert pitch rehearsal by the subjects were definitely excluded. Consequently, the rapid increase of forgetting rate after 2-minute delay may indicate the true time constant for the existence of short-term memory for pitch. Such a result would be consistent with everyday observations of many musicians, e.g. of those singing in a capella choirs.

Acknowledgments

This paper was sponsored by grant No 441609102 from the State Committee for Scientific Research. Parts of the material were presented at the International Seminar on Music Acoustics, Tokyo, August 1992, and at the 39th Polish Open Seminar on Acoustics, Cracow, September 1992.

References

- [1] R.G. CROWDER, J. MORTON, *Precategorical acoustic storage (PAS)*, Perception and Psychophysics, **5**, 365–373 (1969).
- [2] D. DEUTSCH, *The organization of short-term memory for a single acoustic attribute*, In: D. Deutsch and J.A. Deutsch (Eds.), *Short-Term Memory*, Academic Press, New York–San Francisco–London 1975, pp. 107–151.
- [3] D.O. HEBB, *The organisation of behaviour*, Wiley, New York (1948).
- [4] I. POLLACK, *The information of elementary auditory displays*, J. Acoust. Soc. Am. **24**, 245–249 (1952).
- [5] A. RAKOWSKI, *Pitch discrimination at the threshold of hearing*, Proc. 7th International Congress on Acoustics, Budapest, 20–H–6 (1971).
- [6] A. RAKOWSKI, *Memory for pitch in music*, Proc. of the First International Conference on Music Perception and Cognition, Kyoto, pp. 137–140 (1989).
- [7] A. RAKOWSKI, M. MORAWSKA-BUNGELER, *In search for the criteria of absolute pitch*, Archives of Acoustics, **12**, 75–87 (1987).
- [8] G. REVESZ, *Zur Grundlagen der Tonpsychologie*, Veit, Leipzig 1913.
- [9] R.N. SHEPARD, *Circularity in judgments of relative pitch*, J. Acoust. Soc. Am. **36**, 2346–53 (1964).