SHORT TERM PITCH MEMORY IN WESTERN vs. OTHER EQUAL TEMPERAMENT TUNING SYSTEMS

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ABSTRACT

This study investigates the use of short-term memory for pitch recognition in a Western (12-tone) vs. a 10-tone equal temperament context. 10 subjects with at least one year of formal music and theory training participated in an experiment that consisted of two identical music listening tests (one per tuning system) in which they were trained to recall a reference tone and count the number of times it recurred in various short monophonic melodies. In the parts of the experiment where subjects used their short-term memory to execute one-to-one comparisons between the given reference tone and the melody tones, the results were equivalent for both tuning modes. On the other hand, when subjects tried to recall the reference tone directly from long-term memory, the results were noticeably better for the Western tuning context.

1. INTRODUCTION

A considerable amount of research has been done over the past decades regarding the way human brains process, store and recall music pitch. It is clear, for example, that the way our brain responds to music is different from the way it handles visual reference. We are very good in treating colors in a discrete scale, easily distinguishing them, naming them, and recalling them from memory, while we seem to experience pitches in music as a continuum [9].

The population can be divided into groups, according to pitch processing capability; those who have absolute pitch abilities, those who have relative and those who have both. *Absolute pitch* is defined as the ability to either identify and name pitch classes of single tones, or to accurately reproduce a given pitch without any reference, while *Relative Pitch* describes the acquired ability by trained musicians to identify or produce musical intervals [9]. Absolute pitch is a very rare skill, occurring in 1 out of 10,000 people and can be divided into two different skills: *pitch memory*, and *pitch labeling* [10].

While pitch labeling is a unique characteristic of AP possessors, pitch memory is widespread among musically trained and untrained individuals. Schellenberg [12] has shown that adults will little musical training can distinguish the original versions of popular tunes from those pitch shifted by one or two semitones. Other experiments have revealed that listeners can not only identify familiar tunes when played back at different pitch transpositions and tempi, but also accurately reproduce them from memory within a two semitone range and an 8% deviation from the original tempo [9].

Extended research been done regarding characteristics of people that demonstrate absolute pitch abilities. Several theories have been developed based on different factors such as ethnicity, inheritance, age at which individuals began studying music, etc. [7]. Pamela Heaton [8] proposed that autistic musical savants are superior in long-term-memory music tasks, because their cognitive style biases processing of information on local rather than on global features.

Diana Deutsch has, over the years, developed an extended study on pitch memory. Some of her very interesting observations concern the variety of factors that can influence subjects' pitch memory accuracy. She has suggested that recognition precision decreases inversely with temporal separation between the reference and the test tone, if longer than 6 seconds. Furthermore, the presence of distractor pitches between the two tones can also affect subjects' performance. This variation can be considered a function of the pitch relationships and intervals between the distractor tones [3, 4, 5].

In this study we are investigating the use of short-term pitch memory in a 12-tone vs. a 10-tone equal temperament tuning system. To our knowledge, there are no other studies that have attempted a cross-comparison of pitch memory in different tuning systems. Yet, we can use an approach similar to the one employed by Deutsch [3], in which two tones that are either the same or up to a whole tone apart are compared

2. EXPERIMENT

The experiment consisted of two separate sessions (one per tuning system). Subjects were asked to recall a reference tone and count the number of times it appeared in various short, monophonic melodies.

2.1 Participants

Ten subjects (8 female and 2 male) between 23 and 39 years old (mean 29.2) successfully completed both of the listening tests. Two of them claimed to have absolute pitch, and two others claimed to have the ability to recognize certain pitches more easily, even without a reference tone. All subjects reported having at least one year of formal musical training on an instrument (minimum 1, maximum 24, mean 12.3 years) and at least one year of formal theory training (minimum 1, maximum 20, mean 7.3 years).

2.2 Stimuli

Two sets of 46 short monophonic melodies (averaging five measures in length) were composed, one for each of the two listening tests. The stimuli were written in various meters and tempi and had different tonal centers. The target tone could appear between one and five times in a single melody. The first set was composed in 12-tone equal temperament (Western tuning) and the second in 10-tone equal temperament. All melodies were rendered using MIDI piano sounds.

2.3 Procedure

The experiment consisted of two pitch-memory listening sessions. All 10 subjects successfully completed both of sessions in random order, and each session took part on separate days. The procedure and the task were identical for both sessions—the only difference was the set of stimuli used (either 10 or 12-tone equal temperament). The subjects were asked to identify and count the number of times a given reference tone was present in each of the short melodic examples they listened to.

Each session consisted of three parts—intro, training, and testing—and lasted for approximately 45 minutes, with a 10-minute break after the training part. The stimuli were presented to the subjects on a Macintosh computer via headphones, while the graphical interface was a stand-alone application programmed in Max 5.

Before the beginning of the experiment, all subjects had to read a detailed description of the task and the purpose of each part of the session. Subjects were then presented with 6 sample melodies in order to give them the opportunity to familiarize themselves with the interface and task, adjust the volume, and further clarify the test goals as needed. The training phase of the session consisted of 70 melodies (35 different melodies each played twice in a random order), each one preceded by the same reference note. For the 12-tone test the reference note was always the middle D (293.66 Hz), while for the 10-tone one the note was slightly higher in pitch (297.08 Hz). Subjects had to indicate how many times the reference tone appeared in the melodies by pressing the corresponding button. They were clearly advised to ignore all octave equivalent tones.

The training phase was followed by a short 10-minute break, during which subjects had the chance to rest and fill in a questionnaire regarding their music background and their experience with the test so far.

The last part of the session was the testing phase. It consisted of 5 short melodies, presented in random order. This time, no reference tone was given before the beginning of each melody. Subjects were asked, once again, to identify and count the number of times that the previous target tone was present in the melodies by recalling it from memory. Once again, the target tone appeared between 1 and 5 times in each example and subjects were expected to ignore any octave equivalencies.

3. RESULTS

3.1 12-tone equal temperament test

As it can be seen in **Figure 1** all subjects performed well above chance in both the training (minimum 27, maximum 70 correction responses, mean 49, [70%]) and the testing (minimum 1, maximum 5 correct responses, mean 3.7) phases of the 12-tone session.

In the training part, two subjects had a perfect score (one of whom reported having absolute pitch) and two more had more than 60 correct responses (87% accuracy). Three more subjects were clustered around the mean, having a score between 44 and 51 correct answers (62.9% and 72.9%), while the rest had a scores varying from 27 to 31 (38.6% to 44.3%).

In the testing phase, 4 out of the 10 subjects had a perfect score, managing to correctly recall from memory the right pitch all 5 times, while 2 other subjects made only a single error. The rest of the subjects scored below the mean. It is worth mentioning that one of the two subjects who had reported having absolute pitch scored below average in both the training and testing parts.

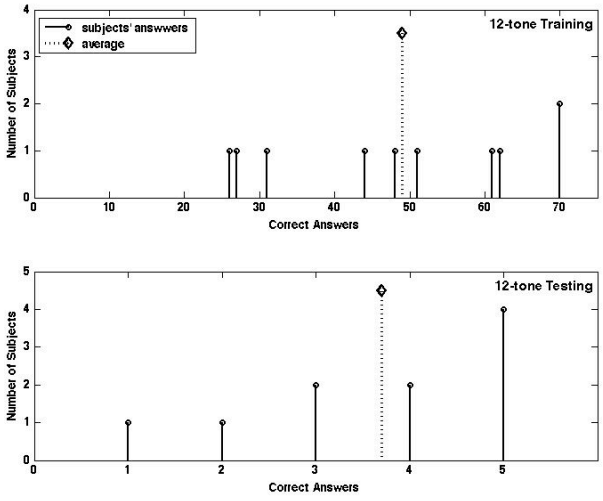

Figure 1. Cross subject evaluation in the 12-tone equal temperament test.

3.2 10-tone equal temperament test

The subjects' performance in the training part of the 10-tone session was nearly equivalent to that of the 12-tone session. The minimum score was 30 correct responses and the maximum 70 (mean 49.3, [70.4%]).

As we can see in **Figure 2**, the top four subjects had a score that ranged between 59 and 69 correct answers (84.3% and 98.6%). Two subject answered 69 out of the 70 questions successfully, one of whom reported having absolute pitch. The next three subjects, clustered around the mean, had scores between 41 and 52 out of 70 correct answers (58.7% and 75.7%), while the bottom three ranged between 30 and 35 (42.9% and 50%).

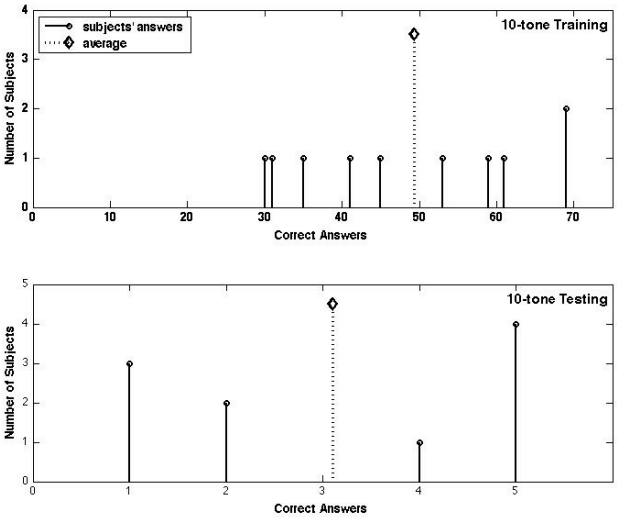

Figure 2. Cross-subject evaluation in the 10-tone equal temperament test.

In the testing phase, on the other hand, we can see differences in the performance of the subjects. Once again 4 subjects had a full score of 5 out of 5, and another had 4 out 5. Yet this time, more subjects scored below the average. As it can be seen in **Figure 2**, 2 subjects had 2 correct answers and 3 managed to recall the correct reference tone from memory only once. One of the subjects who had reported having absolute pitch scored below average in both the training and testing parts of the session.

3.3 Cross-test evaluation

When we initially started conducting the experiment, we expected that the subjects' performance in the 12-tone session would be considerably better than in the 10-tone session due to familiarity with the tonal context. Yet, it quickly became clear that, at least in the training portion of each session, subjects performed equally well in both tuning systems.

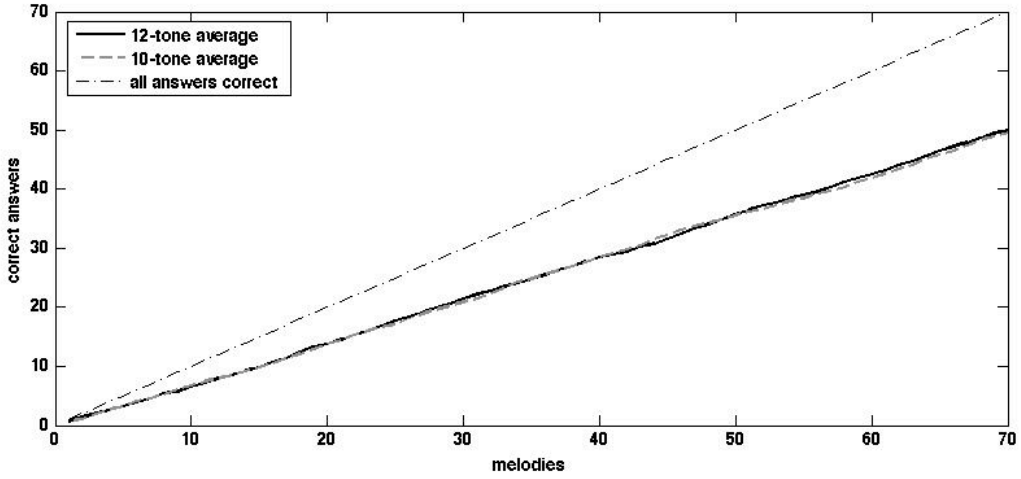

Figure 3. Average cross-session performance of all subjects.

In **Figure 3**, we can see the average progress of all subjects during both of the sessions, versus the perfect score. The horizontal axis corresponds to each new melody the subjects were being tested on during the training part, and the vertical one to the number of correct answers. Each time a subject gives a correct response, the line increases in height; the dashed diagonal, corresponds to perfect score (70/70).

Results show that for each session, the number or correct answers per subject is almost the same for both tuning modes in the training portion. A cross-session evaluation of the training part of the experiment for all subjects is summarized in **Figure 4**.

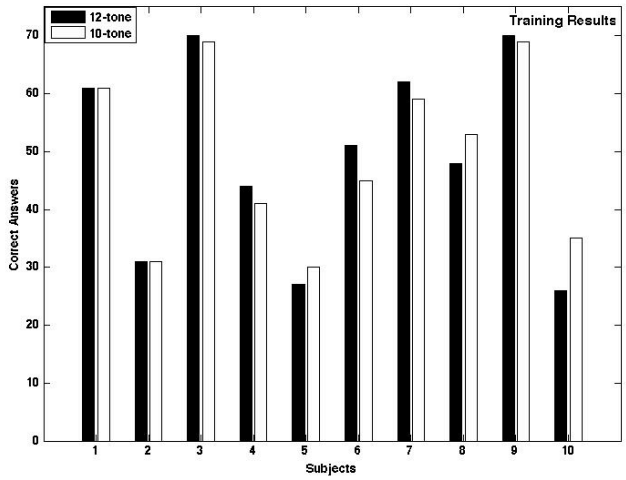

Figure 4. Cross-session performance per subject (Training).

Figure 4 indicates that there is very little difference in performance between the two sessions across all subjects, varying between 0 and 5 out of 70 answers. It may also be noted that while the majority of subjects (7 out of 10) performed a little better or equally well in the 12-tone equal temperament test, the biggest cross-session performance variation can be seen in subject 10, who actually performed better in the 10-tone equal temperament test mode.

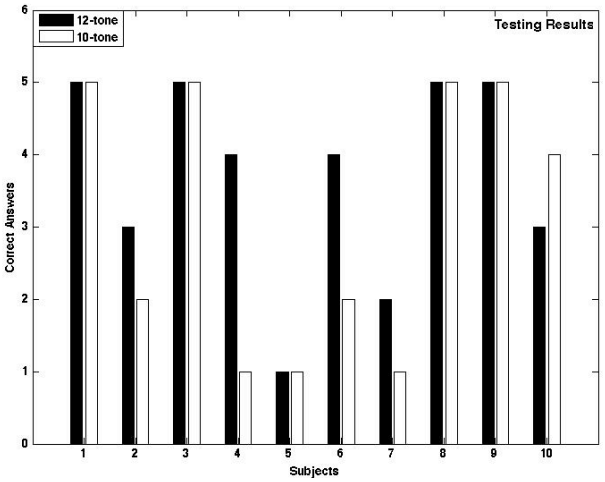

Figure 5. Cross-session performance per subject (testing phase).

The picture is slightly different when we attempt a cross-session performance comparison of the testing phase for all subjects (**Figure 5**). Here the variations in performance are evident (between 0 and 3 out of 5, 0% / 60%). Moreover, half of the subjects have less than 50% accuracy in the 10-tone tuning mode, while that holds true for only two subjects in the 12-tone session. Finally, in 9 out of 10 cases, subjects performed with equal or greater accuracy in the Western tuning testing phase.

4. DISCUSSION

After the completion of the second session, subjects were asked to evaluate the perceived difficulty of the task so far. All but one subject stated that the 12-tone temperament test was equally difficult or easier than the 10-tone one (**Table 1)**.

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}
12-tone	**8**	**6**	**3**	**6**	**5**	**4**	**4**	**5**	**1**	**3**
10-tone	**8**	**7**	**4**	**7**	**10**	**8**	**7**	**8**	**2**	**2**

Table 1. Evaluation of test difficulty by subjects.

This reaction coincides with our initial hypothesis that subjects would perform better in the 12-tone session due to extended exposure to the tuning system and familiarity with the tonal environment. This is also supported by the overall performance of all subjects in the testing phase of each session, where they had to recall from memory the reference tone that they were trained to identify. Here, as we mentioned before, subjects seemed to more successfully recall the 293.66 Hz reference tone, which corresponds to the middle D (D_4), than the 297.08 Hz tone.

The subjects' results in the testing phase were also in agreement with the information we collected from them, regarding their exposure to non-Western music idioms. Only three subjects responded positively to this question. Yet, even among those three, only one of them performed more accurately in 10-tone equal temperament session (**Figure 5).**

On the contrary, as we have seen in **Figure 4,** the subjects' cross-session performance during the training phase resulted in a highly similar level of accuracy. All subjects were successful in recalling the reference tone. This might be an indication that musically trained listeners can ignore the tonal environment of a certain melody when they are relying on short-term memory to perform one-to-one pitch comparisons between a reference tone, presented immediately before each stimulus and the tones in the following melody. The testing phase, on the other hand, was always preceded by a 10-minute break and no reference tone was explicitly provided. Subjects were thus forced to rely on their long-term memory of the reference tone. It is therefore easy to imagine that the reference tone of the 12-tone test (D_4), had a stronger encoding in the subjects' brains due to extended and repeated exposure to the pitch itself through regular listening of Western music, than that of the 10-tone pitch that was slightly higher in frequency.

It is also worth mentioning the subjects' consistency in the overall perceived difficulty of the experimental task in light of one specific subject's remark. This subject commented, "I find I recall pitch more purely in the microtonal/atonal test. The tonal test introduces interference of relative pitch relationships between notes." It appears that this subject found it easier to recognize the recalled target tone in a one-to-one direct comparison

manner than to establish tonal relationships between the target tone and the key of each test melody.

Three other subjects reported that they were able to develop relative tonal associations between the reference tones and the melodies in the 12-tone equal temperament tests, and felt more insecure in the 10-tone context where such associations were not an option. Finally, one of the two subjects who had reported having absolute pitch mentioned being surprised by the difficulty of the tests. The second one, who had a perfect score in both tests, wrote, "For the Western tuning test, I was able to just count how many times I would hear that D in the melodies. For the second test on the other hand, I was just trying to listen for the target tone and ignore the rest of the notes. After some time, I had memorized it and needed the reference no more." According to that comment, this particular subject had approached pitch comparisons in an absolute rather than a relative manner, in both the Western and the 10-tone tuning modes. Such an approach is fully justified, since, in the case of Western tuning, an absolute perception of frequency is trivial, given the AP listener's learned labels for pitches, while in the 10-tone case, the absence of relative associations make direct comparisons a necessity. These comments imply that a fast and efficient encoding of the reference tone allowed the AP possessor to quickly precede in the 10-tone case much in the same way as in the 12-tone case. It is likely that AP listeners have the ability to create faster, clearer, and stronger mappings of different frequencies that would allow them to continue functioning in an absolute rather than a relative manner. However, this question still remains to be answered.

As indicated by the results of this study, short-term pitch memory can function equally well for both 12-tone and 10-tone equal temperament systems. We would like to further investigate the point at which short-term memory and long-term memory interact or overlap in the case of pitch recall. Further work will include comparing extreme equal-temperament cases, such as 6-tone equal temperament, 12-tone and 16-tone ones, or even unequal temperament scales. We are also interested in expanding the present research to subjects with no formal musical training in order to get an idea of the effect of musical training on subjects' decision-making process in such experiments.

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