MEMORY FOR TEMPO: HOW PRECISE DO WE REMEMBER TEMPO OVER TIME?

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ABSTRACT

In studies published in 1994 and 1996, Levitin and Cook [1, 2] found an amazing precision in memory for tempo and pitch among students when they reproduced pop-songs they knew well.

The aim of the experiments reported here was to find out if a similar exactness in tempo and pitch would be found in other sorts of melodies, and also to examine the stability over a period of time. The effect of musical training by the participants was also examined.

10 persons listened to 10 melodies from a CD and were asked to remember the tempo of these melodies over a period of time. The melodies were classical melodies, pop-melodies and well-known songs. The participants reproduced the songs once a day for a week, and again one month later once a day over a week. Their singings were recorded digitally and analysed for tempo and pitch. In a follow up study two years later, five of the same persons again sang the same melodies once a day for a week, but this time they had no recording at the start giving the "target" tempo.

Findings indicate great stability in tempo. There are variances from person to person and from melody to melody. Often the stability is good even if the ability to hit the given tempo (given on the CD) is not very precise. The stability in pitch was also good, but often being stable in another key than the original.

The findings by Levitin and Cook are basically confirmed in this experiment. The findings seem to indicate that "ordinary people" do have an ability to remember tempo and pitch more precisely than formerly assumed.

1. INTRODUCTION

For a conductor and musician the ability to remember a tempo exactly is crucial. Stories are told of musicians demonstrating this ability to perfection. But how precise are "ordinary people" able to remember a tempo? Is the ability to remember tempo comparable to the ability to remember pitch (perfect pitch), and if so, is there a connection between these abilities?

In a studies published in 1994 and 1996, Levitin and Cook [1, 2] asked students to hum pop melodies that they knew well, trying to imagine the sound of the record. The result was an astonishing exactness both in pitch and tempo of the original record. 60% sang within 2 semitones of the original pitch. 33 out of 46 subjects (72%) performed within +/-4% of the actual tempo for the songs (calculated in beats pr minute), and 89% performed within +/- 8% of the actual tempo. It is worth mentioning here that the JND (just noticeable difference) for tempo is estimated to be between 5% and 8%. Consequently at tempo difference of 4% is hardly recognizable, and a tempo change of 8% will pass unnoticed by many listeners.

The melodies in Levitins experiment were pop and rock melodies of which only one version, the original, existed. These melodies are associated with one specific tempo and one specific key. Other kinds of music (classical, folk-music, songs and dance music) can be heard in different tempi and also different pitch. How is our ability to remember tempo and pitch for this kind of music? Will the results be different from what Levitin found or will we here too find an ability to remember tempo and pitch?

The purpose of the study reported here was to investigate a number of aspects of memory for tempo in the light of these considerations and to find out:

1. The ability to remember a given tempo over time
2. The stability of remembered tempo over time
3. The effect of different musical styles and original tempi on memory for tempo
4. The effect of musical background
5. The relation between tempo stability and pitch stability (not reported here)

2. METHOD

2.1. Materials

A limited number of subjects (n=10) were asked to sing 10 different melodies once a day over a period of one week, and again once a day one month later. The choice of melodies was constrained by a number of factors

1 Each melody must be familiar to all participant

2 Melodies should come from a range of styles (classical music, pop music, songs)

3 Melodies should demonstrate a range of tempi

The melodies fall into three categories: Pop music normally associated with one specific artist and performance (as in

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Levitin's experiment), and thus heard in one fixed tempo and pitch, classical melodies, all normally heard in one key, but the tempo /varying from one performance to another. The third group was familiar songs heard and sung in different tempi and keys. The melodies were:

1. Classical: a) Eine kleine Nachtmusik (beginning), b) Morgenstemning (Morning Mood) from Peer Gynt by Grieg, c) Wilhelm Tell overture by Rossini, d) Jesu Joy of Mans Desiring by Bach,

2. Traditional songs: a) Kongesangen (= God Save the Queen), b) Per Spelemann and c) Byssan Lull, all well known popular songs in Norway.

3. Pop melodies: a) Yellow Submarine by Beatles, b) Money, Money, Money by Abba, and c) Love me tender by Elvis Presley.

2.2. Procedure

The melodies were presented in the above given order. To check if the order influenced the tempo and pitch, the order of songs was changed for the last two performances

The melodies were first sung once by the subjects before listening to a recoded performance from CD. They were asked to try to remember the tempo and the pitch of these performances for reproduction by humming or whistling over the next days. Then there was an interval of one month before they again sang the melodies once a day for 3-4 days. Two years later they again sang the same melodies over a week, this time with no given tempo from CD.

2.3. Participants

The 10 participants were all volunteers who participated without payment. They were aged from 16 to 43. Roughly they fell into tree categories:

- Musically trained grownups n=3, 1 female 2 male, (P1, P2, P3)
- Music students n=3 aged 19 to 24, 1 female 2 male, (S1, S2, S3)
- Non musicians (music amateurs) n=4 aged 16, 18, 41, 44, 1 male 3 female (A1, A2, A3, A4)

2.4. Equipment

Each "performance" by the participants was digitally recorded to a minidisk. The tempo was later registered and analysed by tapping the tempo to a computer, using a program called DelTime to calculate the tempo.[1]

[1] The tempo was calculated as the average tempo for each performance. It was later control-checked by using the program Transcribe! In which wav-files and markers are analysed for tempo.

3. RESULTS

3.1 General remarks

When analysing the results, three main aspects were of primary importance

1. The accuracy of tempo of the performances in relation to the given (target) tempo.

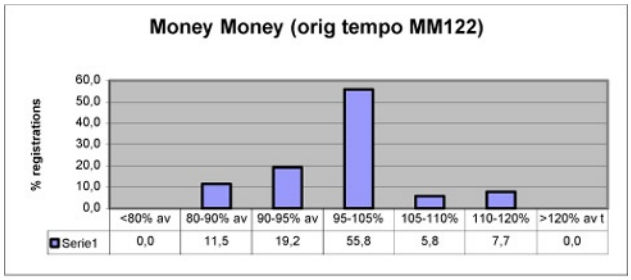
2. The stability of tempo in each song over time

3.2 Tempo accuracy

Regarding the total result of all registrations after listening to the originals, 32,5% of the reproductions had a tempo hit closer than +/-5% from the original tempo. 44,6% fell within +/-10% deviation. This is considerably weaker that Levitins findings. However, when looking more closely at the results, there are good reasons for this.

The songs with best tempo accuracy are two pop melodies, Yellow Submarine and Money, money. Both have more than 50% hits within +/-5% deviation (50,9 and 55,8 respectively). None of these had misses of more than 20%.

The other extremes are Kongesangen and Jesu Joy with only 9,6 and 5,7% of the "performances" within the +/-5% frame. For the other six songs the hits within the +/-5% frame varied between 26,4% and 41,5%



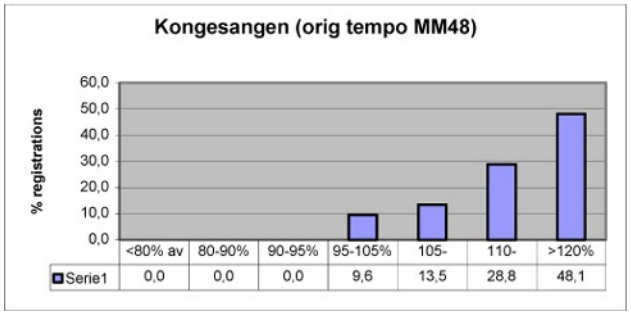


Figure 1 Tempo registrations for two of the songs

Kongesangen was deliberately chosen for its extremely slow tempo on the record (MM48). As seen from the graph, 48% reproduced this melody at a tempo more than 20% faster than played at the CD. Mean tempo for reproductions of this song was 59 BPM, which is 22.8% faster than the original. Even this is a

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very slow tempo, and when looking at the adaptation to the given tempo this is the song where the participants adapted best.

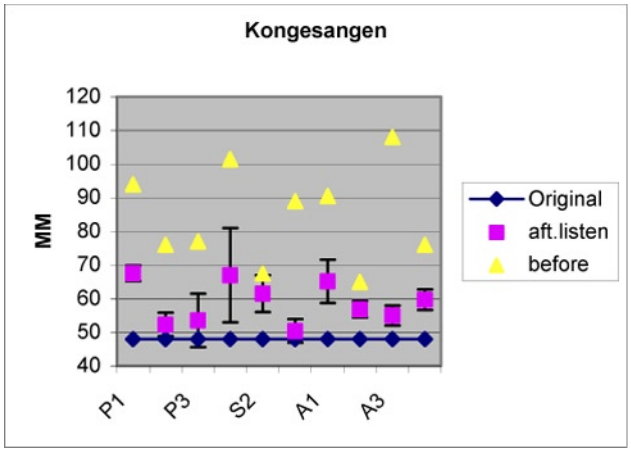

Figure 2 Adaptation to given tempo in Kongesangen

As seen in Fig 2 some (P2, P3, S3, A2 and A3) adapted the given tempo well, and also showed great stability (indicated by whiskers). Their "own" tempo before listening to the CD (indicated by triangles) was for most participants between 70 and 110.

Comparing the average tempo miss for each song (in %) shows a diversity between 4,0 (for Yellow Submarine) and 22,7% (kongesangen)

Songs	Eine kleine	Morn mood	Jesu Joy	W. Tell	Konge sang	Byss lull	Per spele	Yell sub	Mon ey	Love me
% miss	9,2	9,4	14,9	7,2	22,7	9,8	7,1	4,0	5,7	10,3
Mean groups	11,2				13,2			7,0		

Table 1 Average tempo miss for each song and groups

Splitting the songs into groups (classical melodies, songs, and pop-melodies) does show significant differences between groups. Average difference for groups are 11,2%, 13,2% and 7,0%. Grand mean 10,0%. As we see the "pop"-group is the best, significantly better than the other two ($F_{2,24}$=5.803; p=0,00879). This in spite of "Love me" which is no better than the grand mean for all songs.

There are differences between participants in the ability to hit tempo. Average mean miss for all the participants in all songs are as follows (in % from original tempo):

Participants	P1	P2	P3	S1	S2	S3	A1	A2	A3	A4
average tempo miss (in %)	12,7	5,0	12,3	11,4	7,7	8,1	12,2	14,9	10,2	10,9
means for groups	9,5			9,2			11,1			

Table 2 Average tempo miss for participants and groups

Comparing the groups of participants, professionals, students and amateurs, there is not a significant difference between the groups.

3.3. Tempo stability

As seen in fig. 2 the participants showed a remarkable stability in tempo over time even when they missed the original tempo considerably (see P1 and A4). The standard deviations for each song give an expression of this fact.

There is no correlation between means of tempo hit and mean std. deviation. Often the melodies with less stability in tempo are close to original tempo with its mean tempo. To take one person, A4 as an example (Fig 2), Morgenstemning and Money are very stable in tempo (st.d. just 2.2/2.2%), but she misses tempo by 12,2/12.4%. In Per spelemann the st.d. is 7,3 but the mean tempo is close to the original missing by just 1,1%.

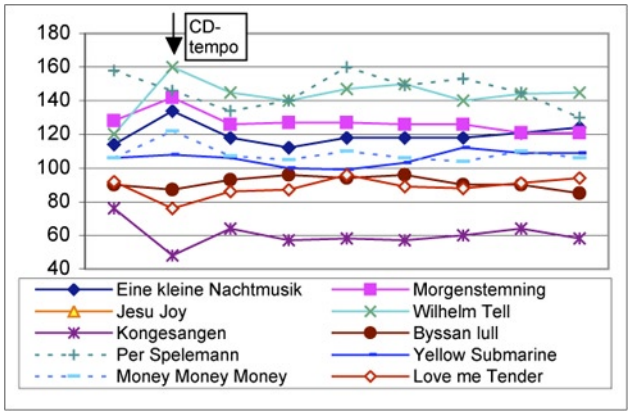

Figure 3 Tempos by participant A4

A curious feature is that all participants seem to have one or two melodies in which they show considerably less stability in tempo than for the other songs. These songs differ from person to person.

3.4. Stability over time

The first reproduction after listening was done immediately after hearing all the melodies, and then the subjects sang the melodies the four following days. For nine of the subjects, there then was a break of more than a month before the next singing. The result shows no difference in the tempo of the performances that can be explained by the distance in time from hearing the original. On the contrary, the variance from the original tempo and the dispersion is almost the same shortly after listening, as it is five weeks later.

3.5. Does the order of songs influence tempo?

For the two last performances, the order of songs was changed. Instead of normal order 1, 2, 3, …. 10, the order was 2, 5, 8, 1, 4, 7, 10, 3, 6, 9. This did not have any noticeable influence on the tempo of each song. In none of the songs there can be

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seen any salient tendency in tempo different from the previous performances. Neither do any of the subjects show any significant change in tempo for the last two performances that can be explained by the order of songs.

3.6. Stability in tempo with no target tempo

Two years after the referred test, the same participants were asked to sing the same songs once a day for a week, but this time no "target tempo" was given. The stability of tempo was significantly better this time than in the test reported above. The explanation for this is probably that they use different part of their memory capacities in the two tasks. In the test reported above they will have to use their episodic memory, remembering one specific tempo given on the CD. In the follow up test where no tempo is given, they refer to their semantic memory, tempos previously associated to the melody.

4 DISCUSSION

How close to a target tempo must a performance be for it to be regarded as "the same"? This will obviously vary according to the circumstances. Anecdotal evidence suggests that musicians are able to set the tempo so precisely that they can predict exactly the duration a piece of music. On the other hand we know that expert musicians can vary their tempo from one performance to the next as shown by (among others) Bowen on Beethovens 5. symphony [3] and Eric Grunin on Eroica (www.grunin.com/eroica).

The well-known Weber's law describes the degree of change in a given stimulus for a difference to be perceived. Weber's findings, and also later results, indicate a threshold of around 5% for perceiving a difference of intensity in a sensory stimulus. Drake and Botte [4] found the JND (Just Noticeable Difference) to be 6.2%-8.8% in a task in which they asked listeners to judge "which music is faster?" Halpern [5] came to similar results in a listening task. For tapping, either along with or continuing a rhythm, JNDs have been measured between 3.5% and 11% [2].

In a follow-up study (Reed, in preparation), subjects were asked to detect tempo changes in recorded music. They listened to different kinds of music, and at a given signal there was a sudden tempo change (faster or slower) of 0%, 3%, 5% or 10%. Listeners failed to identify tempo changes of 3%, performed somewhat better than chance for 5%, and with considerable success for changes of 10% (80% correct). This confirms the assumption that tempo changes of less than 5% will pass unnoticed, but it also shows that even tempo changes of 10% may pass unnoticed by as many as 20% of the listeners, even in a situation where they are specifically alerted to the possibility of a tempo change. These findings are congruent with findings by Geringer and Madsen [6].

This suggests that for the present study, deviations within +/- 5% of the original tempo should be regarded as "hits", and that a deviation within 10% must also be regarded as good,.

5 CONCLUSION

Levitin reports in his paper: "Specifically, we show that memory for music seems to preserve the absolute tempo for the musical performance" [2]. This is a strong claim, which, if true, would indicate that people have some kind of absolute tempo. The present study seems to confirm that people show a remarkable ability to remember and recall a tempo, even over a long span of time.

It seems appropriate to distinguish between two different aspects of remembering tempo, one being the stability of tempo from one performance to the next, the other the ability to "hit" a given tempo. Stable performance does not necessarily correspond to accuracy in relation to a target tempo. It also seems that a person's tempo stability varies considerably between songs. People with good overall stability for most songs, may nonetheless demonstrate considerable instability for particular songs, but with no apparent consistency from person to person. Why this is so is hard to explain. It may relate to familiarity with a style or to the characteristics of specific songs, or it could be connected with individual differences in the judged appropriateness of the target tempo for particular songs. There is insufficient data from this study to determine which, if any, of these possible explanations holds.

The results show no significant effect of musical background of the participants, and nor does the amount of elapsed time since hearing the target recording seem to influence the result. The level of achievement was just as good after five weeks as it was immediately after listening.

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