

# Memory for tactus and musical tempo: The effects of expertise and speed on keeping time

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The ability to keep time and remember speeds is important in musical performance. Eight musicians and eight non-musicians heard a metronomic beat at three musical speeds—35, 110, and 185 beats per minute (bpm)—and clapped in time to it as accurately as possible. They were then asked to recall the three speeds by clapping alone. After another set of trials clapping to the metronome, they recalled the three speeds once again. Results showed that the participants tended to clap too slowly for the 110 bpm and 185 bpm tempi and that the medium speed was less accurately remembered than the slow or fast. There was no effect of musical experience, but there was a trend of better recall of speed on the second than the first recall trial.

*Keywords:* tactus; absolute; tempo; memory; clapping

One important aspect of much musical performance is the ability to keep a beat or tactus going generally at a fairly steady rate, expressive variations in tempo aside. In larger groups a conductor will often act as an external time-keeper by dictating a self-paced beat, trying to make it as steady and constant as possible. It is the responsibility of all players to follow the conductor's beat and play at the same tempo. Their behavior can be seen as a form of sensorimotor synchronization (SMS), where they synchronize their motor behavior, whatever that may be, to the conductor's visual beat. Thus both the conductor's internally paced beat and the players' synchronization behavior are forms of rhythmic time keeping. Research on SMS and self-pacing has shown that there are a number of factors that affect the accuracy and variability of the beat, and also that there are upper and lower tempo limits (e.g. Repp 2005, London 2004, Aschersleben 2002).

Keeping in time is clearly relevant to musical performance, and responding regularly (e.g. tapping or clapping) is a commonly used method of measuring SMS ability. The asynchrony between the given beat and the participant's response indicates their accuracy. Previous research has suggested this SMS accuracy is affected by various factors, including the tempo of the tactus and the participant's musical expertise (Repp 2005). Research when the beat disappears but the participant has to keep tapping at the same tempo has also been conducted. This is called continuation tapping, and typically appears to show an approximately 12 s period of maintained control (Chen *et al.* 2002).

Another important skill in performing music in most cultures is the ability to set and control the tempo: too fast and the piece may be unplayable and detail glossed over; too slow and perceptual and structural coherence and performers' breathing (if relevant) may suffer. Conductors and unconduted performers (often soloists) must be able to start a piece at the right tempo, and better performances tend to show less evidence of tempo drift or unplanned corrections or fluctuations in speed. Although there is much evidence concerning absolute pitch (AP), the ability to recall a will a pitch from long term memory (e.g. Ward 1999), there is less on "absolute tempo" (AT), the ability to remember a particular beat speed (i.e. tactus) and recall it when required for performance.

Previous research has tested tempo recall for pieces in long term memory. Levitin and Cook (1996) had participants sing popular songs with which they were familiar, and 72% of the productions were within 8% of the original tempo. Trainor *et al.* (2004) also showed that infants preferred a familiar piece provided the tempo was not changed by more than 25%, suggesting a long-term tempo memory, though probably less accurate than that of adults.

The aims were, therefore, twofold. First, we investigated the effect of musical expertise on people's accuracy for carrying a tactus and remembering a tempo in the absence of a specific piece of music, both measured by clapping in time. It was hypothesized that expert musicians would be more accurate both in their tapping accuracy and in their long term memory for tempo than non-musicians. Secondly, we investigated the effect of different speeds of a given tactus on tapping in time and, in particular, on tempo recall.

## METHOD

### Participants

There were 16 participants, split into two equal groups of expert musicians (professional, semi-professional, and student) and those whose professional

life did not involve music. The musicians (5 M, 3 F) were aged between 20 and 48 years (mean=30.8). Some were specialists either in conducting or in percussion playing. Non-musicians (6 M, 2 F) were aged between 23 and 74 years (mean=49.9), and had no musical training beyond school, though two had choral singing experience, and one was a self-taught drummer.

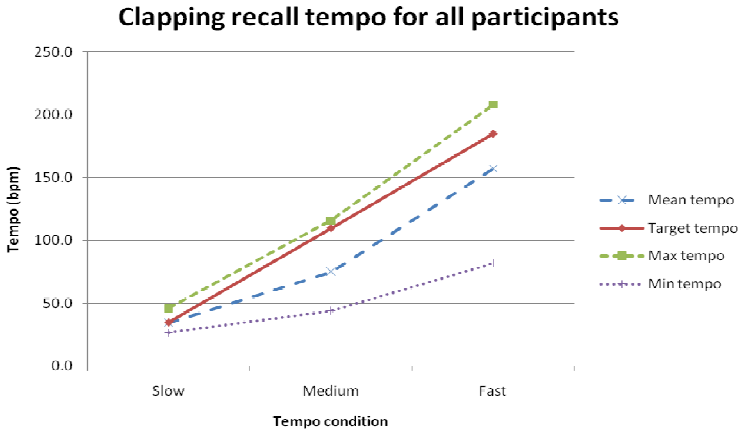
## Materials

Metronomic recordings of three different tempi: quarter note=35 bpm corresponding to interstimulus interval (ISI) of 1714 ms, quarter note=110 bpm corresponding to ISI of 545 ms, and quarter note=185 bpm corresponding to ISI of 324 ms, were made on a MacBook 4.1 (2.1 GHz processor) in the software *Finale*, using the sound of a woodblock. This was transferred to a CD, along with instructions, and the recordings were played to participants in various testing locations. Attention was given to minimizing ambient sound and to avoiding the presence of aural or visual rhythmic stimuli in the room. Participants' productions together with the metronomic stimuli were recorded on the same MacBook computer and converted to AIFF format files. These were then analyzed using the software program *Praat* (version 5.1.04) to measure times between claps (Boersma and Weenink 2009).

## Procedure

There were two tasks. First, participants were asked to clap, synchronizing as closely as possible with a recorded beat (the beats on the recording disappeared and reappeared, see below). In the second task, participants were asked to reproduce from memory the speeds of the original recording. The three speeds of 35, 110, and 185 bpm ("slow," "medium," and "fast," respectively) were chosen so as not to be related to each other by any simple proportion. Tempo order was counterbalanced between participants.

In the first section of each test, participants were asked to listen to the recording of beats, to join in after hearing the first four beats, and to continue clapping until told to stop. Some beats on the metronomic stimulus were absent and the participants were informed of this but asked to continue clapping nonetheless. In all tests, there were 8 beats present, 4 absent, 4 present, 4 absent, 8 present, 8 absent, 8 present, and 8 absent. Thus, clapping regularity in both the presence of a beat (SMS) and its absence (continuation) were tested. Participants performed the above test at the three speeds and then repeated them in the same order. A gap of about 30 s was left between tests. They were then asked to fill in a questionnaire covering age, gender, and musical experience. Approximately 4 mins were given for this.



*Figure 1.* Mean, minimum, and maximum recorded clapping tempi (bpm) as a function of the given tempo. The target tempo is shown by the solid line. (See full color version at [www.performancescience.org](http://www.performancescience.org).)

Next, participants' memory for the three speeds was tested. They were asked to clap at the slow, medium, and fast speed, in the same order they had already been tested on, both beginning and ending when indicated. A total of about 32 claps were recorded for each trial. After the recall test of each speed, the first test (clapping with the recorded beats) was repeated, followed, after a 1 min pause, by the test of memory once again. A complete testing session took approximately half an hour per participant.

## RESULTS

The present article focuses on the participants' tempo memory data. Overall, participants were fairly good at recalling the slow tempo but tended to underestimate both the medium and fast tempi (i.e. clapping too slowly) quite substantially (see Figure 1). However, their recall for these tempi was generally better on the second recall trial, underestimating less (see Table 1). When the musicians and non-musicians were analyzed separately, the musicians were generally found to recall the medium and fast tempos more accurately than the non-musicians, underestimating the speeds less (see Table 2). A 3-way Analysis of Variance (ANOVA) with tempo, trial, and musical experience as factors was conducted on the mean error as a percentage of the target tempo.

*Table 1.* Clapping tempo (bpm) in the recall tests (SD in brackets.)

<i>Tempo</i>	<i>Target tempo</i>	<i>Recall 1</i>	<i>Recall 2</i>
Slow	35	34.7 (4.86)	38.5 (13.36)
Medium	110	75.0 (23.06)	87.8 (28.52)
Fast	185	156.9 (35.02)	166.0 (23.75)

*Table 2.* Clapping recall tempo (bpm) as a function of musical training (SD in brackets).

<i>Target tempo</i>	<i>Musicians</i>		<i>Non-musicians</i>	
	<i>Recall 1</i>	<i>Recall 2</i>	<i>Recall 1</i>	<i>Recall 2</i>
Slow (35)	32.0 (3.24)	32.9 (3.02)	37.0 (5.01)	43.5 (17.05)
Medium (110)	74.5 (24.91)	97.5 (34.43)	75.4 (24.85)	80.5 (15.86)
Fast (185)	165.9 (21.46)	175.0 (22.95)	146.7 (45.90)	157.1 (23.75)

Tempo was highly significant ( $F_{2,22}=10.96$ ,  $p<0.01$ ): Bonferroni post-hoc tests showed that the medium tempo was recalled significantly more poorly than either the slow or fast tempi (as can be seen from the mean and target tempo lines in Figure 1). Trial showed a non-significant trend ( $F_{1,22}=4.14$ ,  $p<0.07$ ), in that the tempo error was smaller in the second trial than the first. Musical experience was not found to be a significant factor.

## DISCUSSION

Overall there was large variation in remembered tempo, particularly showing underestimation (see Figure 1), but the slow and fast tempi were recalled better than the medium tempo, at least in terms of percentage errors. It is unclear why fast speeds were better remembered than the medium speed, although future tests may study the relevance of remembering fewer tempi in a test. However, musical experience was not found to affect tempo recall, there being no difference between the two groups. This may be because three of the non-musicians in fact had some musical experience (see “Participants”), diluting the difference between groups. Tempo memory was generally better on the second trial, after the participants had carried out more SMS/continuation tasks. The continuation claps can be thought of as testing short-term memory, with in effect immediate feedback, so this was not surprising.

In future research, we intend to ask participants to clap to tempi identified by name (e.g. “quick march” and “slow dirge”) or bpm (e.g. quarter note=

65 or 140), rather than the terms “slow,” “medium,” and “fast”. We will vary the number of tempi included in tests and accurately control the time elapsing before participants are required to reproduce a tempo from memory. We also intend to include distracter tasks, which may affect mental rehearsal, and compare the use of a beat pad with clapping, to reveal the relevance of the “choreographic” element of clapping.

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