

Patterns of entrainment: Being out of sync, in sync, and in between

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In order to investigate a previously uncharted range of dyadic entrainment behaviors, we conducted a dyadic tapping study on resisting entrainment. Participants were asked to maintain their own tempo while interacting with their tapping partner. Different patterns of entrainment emerged, but trials were often either highly entrained or not at all. As expected, initial tempo difference between the participants was the main factor determining whether a trial was entrained or not, but a clear threshold was not found. Musical training, but not individual rhythmic skill or personality traits, had an effect. Surprisingly, participants with musical training were more likely to entrain even over a large tempo difference, perhaps owing to their training in playing together and learned aesthetic preferences.

Keywords: entrainment; interaction; synchronization; non-musician; tapping

Entrainment is often automatic and fundamental to human interaction and communication. Previous studies have explored unintentional and intentional entrainment (reviews in Repp 2005, Schmidt and Richardson 2008), while few studies have explored resistance to entrainment (Lucas *et al.* 2011). Previously, automatic phase attraction to distractors (Repp 2004), and preference of human partners over mechanical metronomes (Himberg 2006) have been demonstrated. Since the previous focus of tapping studies has been on extremely high synchronization, we performed an experiment on resisting entrainment to explore how people move in and out of sync. Participants were

asked to play and sustain their own tempo against the other participant, whose tempo was either same or different.

Our aims were to investigate (1) whether participants can maintain their own tempo or whether they entrain with their partner, (2) whether there is a threshold of tempo difference below which participants cannot help but entrain, and (3) the types of changes in the relationship between the tappers: are they gradual or sudden and are they symmetrical or asymmetrical?

In doing so, we explored which factors influence the extent to which participants can resist entrainment. We focused on two possibly highly correlated factors: musical training and the participants' solo tempo stability.

METHOD

Participants

In Experiment 1, 36 participants (20 musicians with an average 12.35 years of active musicianship and 16 non-musicians with <2 years of formal musical training) performed the experiment in pairs matching in musical experience and age. In Experiment 2, 38 non-musicians (<5 years of formal musical training) took part.

Procedure

Participants performed synchronization-continuation trials (45 seconds/trial, finger-tapping on a MIDI drum) at 5 tempi (93.5-126.5 bpm) in three conditions: solo, same tempo duet, and different tempo duet. In duet trials, participants did not hear each other until 4 seconds into the continuation part so that they had time to establish their own tempo. Their instruction was to maintain their original tempo as well as possible, regardless of the distraction of the other participant. In the different tempi duets the participants had smaller or larger tempo differences (5-33 bpm), depending on the combination of starting tempi.

RESULTS

Experiment 1

Our analysis focuses on the duet section of the trials. Relative phase of the participants' taps were calculated, and the concentration index of the phase angle distribution R was used as an entrainment measure (Fisher 1993). Trials seemed to be either highly entrained or not entrained at all—the histogram of R -values in the trials was bimodal with the extreme values dominat-

ing and fewer values in between (see Figure 1). Unsurprisingly, musicians were the better tappers and their tap-to-tap stability was better in all tasks. However, it is somewhat surprising that musicians were also more likely to entrain even when the initial tempo difference was large. This could reflect their ensemble training and preference for synchronized rhythms.

Figure 2 illustrates how, even within one pair (musicians in this case), performance could vary greatly between trials. Panels A and B show inter-tap interval data from experiments in which the initial tempo difference was large. In A, both participants sped up slightly relative to their metronome tempo (dashed straight lines mark the metronome IOI) but they did not entrain, instead maintaining their tempo difference to the end (they finished at the same time; the blue tapper had longer beat length so performed fewer taps). However, in B the red tapper quickly sped up and caught the blue one, and they became entrained for the rest of the trial (while having similar ITI's is not yet sufficient evidence for entrainment; this was confirmed in separate analysis).

In panels C and D the participants had the same metronome and started the duet section at a very similar tempo. However, only in C were they entrained, as in D they quickly separated. The blue tapper in particular behaved differently in these two trials, as in C s/he sped up with the red tapper, while in D s/he resisted not only entrainment, but also the natural tendency to speed up during the trial. Perhaps in an effort to resist entrainment, s/he actually slowed down slightly—a rare behavior in this study.

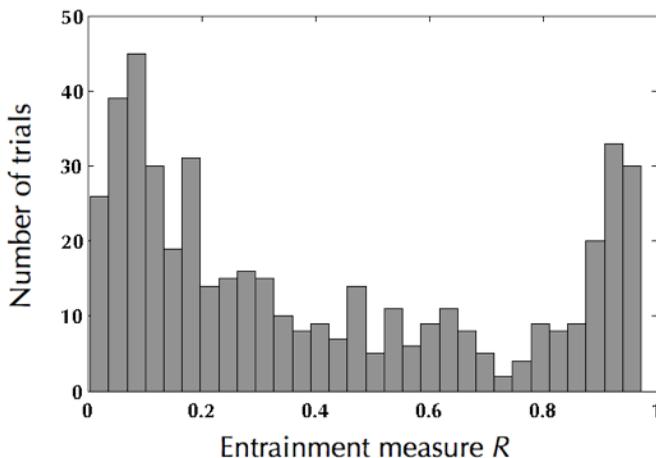


Figure 1. Histogram of the entrainment measure in the trials of Experiment 1.

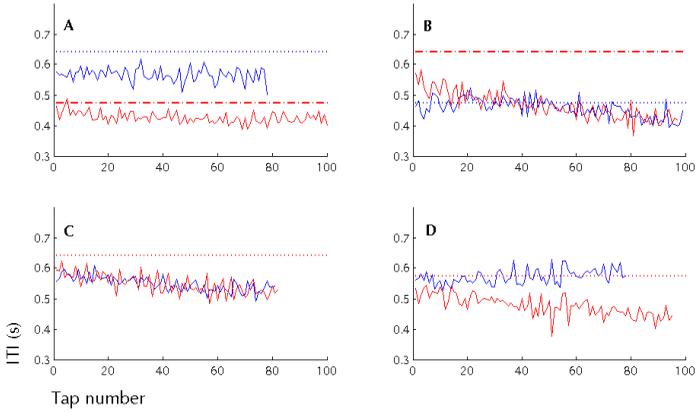


Figure 2. Inter-tap interval patterns for one pair (musicians) in four trials of Experiment 1. Dashed straight lines mark the original metronome tempi.

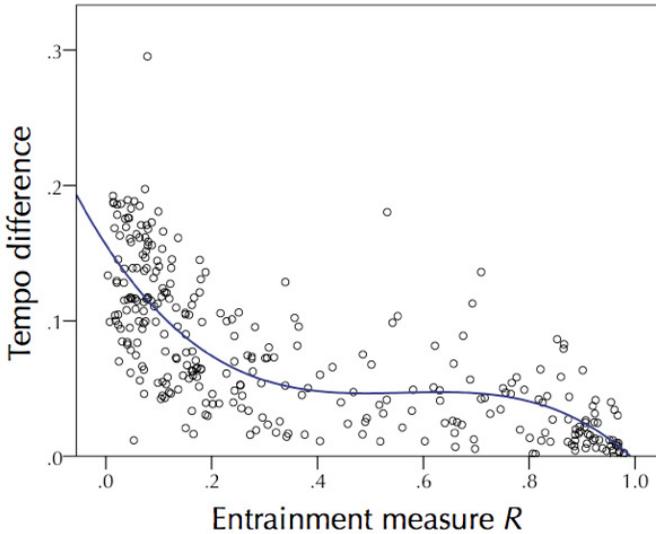


Figure 3. Cubic line fit for tempo difference versus entrainment in Experiment 2. (See full color versions at www.performance-science.org.)

Experiment 2

We made minor changes to the setup for the second experiment. The focus was changed to non-musicians only and tempo difference conditions were added so that we could formally investigate whether there is a threshold for resisting entrainment.

The example discussed above already suggests that it may not be possible to identify a clear threshold, as the same participants engaged in “opposite” behaviors when a trial was repeated. In Figure 3 the entrainment measure and tempo difference of the trials are plotted. A cubic line is fitted to the data, with a relatively good fit ($R^2=0.568$). It can be seen that trials are clearly clustered to the right bottom corner (high entrainment, small tempo difference) and towards the left top corner (low entrainment, large tempo difference). The long, horizontal middle part of the line illustrates that, for trials with small tempo differences, virtually any outcome was possible.

We also looked at entrainment patterns within the trials at this middle ground. About a quarter of these were trials where the participants started not entrained but entrained during the trial. This transition was usually very quick, but in some cases the shift was slightly more gradual and in others there were multiple transitions between the two extremes. There were also trials where the opposite transition occurred—from entrained to not entrained. Again, multiple transitions could occur, but these were rare.

Tempo drifts were observed in most trials. There was a general tendency to speed up, apart from the fastest tempo, but interestingly the amount of tempo drift did not affect the amount of entrainment in the trial—even in perfectly entrained trials large tempo drifts were observed and vice versa.

DISCUSSION

We conducted a dyadic tapping trial where participants were required to maintain their original tempi, in most cases resist entraining with their partner. We found that entrainment was often a yes/no affair, with fewer trials with mixed outcomes. Even of these mixed trials, most of the transitions between these two states were fast. The initial tempo difference was the main predictor of entrainment, but participants, and especially musicians, both resisted entraining even when in the same tempo and entrained even across a large tempo difference.

Our future research will apply these results to our work on entrainment and rhythmic behaviors in music therapy interactions. This involves exploring the links between entrainment and various psychological factors, such as

empathy, and analyzing therapist-client interactions in music therapy improvisations.

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