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Musicians and Non-musicians Adapting to Tempo Differences in Cooperative Tapping Tasks

Neta Spiro,*[1] Tommi Himberg#[2]
*Nordoff Robbins Music Therapy Centre, London, UK
#Finnish Centre of Excellence in Interdisciplinary Music Research, Department of Music, University of Jyväskylä, Finland
[1]neta.spiro@nordoff.robbins.org.uk, [2]tommi.himberg@gmail.com

ABSTRACT

A number of factors, including musical training, affect our entrainment to each other. Personality traits seem to correlate with some musical behaviours but it is not known whether this extends to entrainment. We observe patterns of interaction in tapping tasks in which people entrain or resist entrainment, and investigate whether these patterns relate to musical training or personality traits of the participants.

Seventy-four musicians and non-musicians were finger-tapping in pairs under 3 conditions; solo, duet in the same tempo, and duet in different tempi. Participants completed questionnaires about their musical experience, the Big Five Inventory and the Interpersonal Reactivity Index.

In duet tasks, entraining with the partner was often a yes-no question: the pair either locked in sync or stayed apart. Participants did not entrain in all same tempo trials, but often did so even in trials with maximum tempo difference (33 BPM). In general, participants kept their own tempo better in solo than in duet trials. Musicians were found to be more self-consistent than non-musicians in all conditions. No clear effects of personality were found, even though in the second half of the study participants were paired based on their personality scores. There was a considerable variability in performance even when the same pairs repeated tasks.

I. INTRODUCTION

From a very young age we quickly and automatically entrain and adapt to other people's beats (Kirschner and Tomasello, 2009). This is a socially contingent phenomenon with children and adults entraining to each other better than to a metronome (Kirschner and Tomasello, 2009, Himberg, 2006). Entrainment has been associated with socially beneficial outcomes in various contexts; in adults, children, care-giver infant interactions, conversation as well as music. (Bispham, 2006; Kirschner and Tomasello, 2009; Sebanz, Bekkering, & Knoblich, 2006; Tomasello & Carpenter, 2007; Oullier, de Guzman, Jantzen, Lagarde & Kelso, 2008; McNeill, 1995; Hove & Risen, 2009; Malloch, 1999; Trehub, 2003; Trevarthen, 1999; Cowley, Moodley & Fiori-Cowley, 2004; Macrae, Duffy, Miles & Lawrence, 2008; Wiltermuth & Heath, 2009).

Our ability to entrain to and hold a metronomic pulse has been extensively studied, mostly in solo conditions, participants synchronising with computer metronomes (see Repp, 2005 for a review), but the psychological and musical factors that are important for these effects are unclear. Also, only a few studies have also looked at entrainment in dyads and groups, or in actual musical contexts (Himberg, 2006, Himberg & Thompson, 2011; Konvalinka, Vuust, Roepstorff & Frith, 2010; Lucas, Clayton & Leante, 2011). Given that we can automatically entrain with music and the "ceiling effect" that this tends to have on entrainment measures, we opted to study *resisting* entrainment with the goal of beginning to explore the limits of entrainment and the contributing factors. This is done in order to observe a wider range of behavioural patterns than is usually possible in studies of entrainment and to shed light on the higher level psychological processes and factors involved. Currently, it remains unclear whether there is a link between the participants' social traits and their musical behaviour – for instance, do personality traits such as conscientiousness or empathy affect entrainment?

In this study, two people are given two different, unrelated pulses and are asked to play at the same time while maintaining their own pulse. In the light of previous studies (Himberg 2006; Himberg, forthcoming), the participants are expected to entrain to each other's pulse at least occasionally regardless of the tempo difference; the patterns of these interactions will be of interest. Psychological factors, such as leadership, conscientiousness and the tendency to adopt the partner's point of view (empathy) might have an effect on these "negotiation processes".

In unpublished student projects supervised by the second author, some indications of these links have been found. In music students, extroversion as assessed with the Big Five Inventory (John & Srivastava, 1999) was somewhat correlated with the synchronisation accuracy in finger tapping tasks, while those scoring high in neuroticism had lower tapping stability. However, these effects have been small and in another project, assertiveness scores and co-operative tapping performance showed no correlation. These studies have had a small number of participants, and they have been music students, with the task to entrain to the metronome and/or to each other. In order to determine whether personality factors have an effect or not, a larger sample is needed. Also, music students might have "overlearned" the beat-tracking and tempo-keeping skills needed to perform these kinds of tasks, which might not only lead to a ceiling effect (and low interpersonal variance) in terms of their synchronisation accuracy, but their training may overshadow any personality effects. Indeed, previous studies have shown that musicians outperform non-musicians in these kinds of tasks; they have greater attunement abilities, more accurate synchronisation and less variability in their tapping rates (Drake, Jones & Bharuch, 2000).

Repp (2003) has studied how a distractor beat affects participants who are synchronising with a metronome. Although Repp's experiment is different from ours, his results help us to predict the outcomes of this study. In Repp's study, tappers distracted with an unrelated beat got faster, their beat was more variable, and they lost the inter-tap interval microstructure that is typical for synchronisation tasks (negative lag 1 autocorrelation). Repp's participants would occasionally but only intermittently synchronise with the distractor rather than the pulse they were supposed to follow. Our experiment differs from Repp's in two key aspects. First, the participants will not have a metronome to guide them, and in this case the "distractor" is another human, who can also adapt their tapping. As mutual entrainment has been shown to be more engaging than one-sided synchronisation with a non-responsive metronome (Himberg, 2006), we expect our participants to entrain with each other more often and for longer segments than the participants in Repp's study.

The aims of this study are thus (1) to explore the beat patterns and entrainment in cooperative tapping, when participants are asked to play and sustain their own tempo against the other participant whose tempo is either same or different and (2) to explore whether there is a relationship between these patterns and musical experiences and personality traits.

II. METHODS

A. Participants

There were two experiments. In *Experiment 1*, 36 participants (average age 20.8 years, SD 2.95; 16 women) were recruited from the extended community of the University of Cambridge. Twenty of the participants had extensive musical training, while 16 were non-musicians with less than two years of formal musical training. They performed the experiment in pairs, matching in musical experience and age (age difference < 2 years, except 3 years in one pair and 18 in another).

In *Experiment 2*, 38 non-musicians (average age 24.4 years, SD 6.46; 30 women), all students in the University of Jyväskylä, took part. Participants were mostly non-musicians with less than 5 years of formal musical training; one pair had 10-13 years of musical training / activity, but none had the extensive, professional training levels as the musicians in Experiment 1. They were paired together based on their cognitive empathy scores (IRI, perspective taking subscale (Davis, 1980)), forming pairs with matching high, matching low, and mixing high and low scores.

B. Stimuli, materials and Apparatus

In both experiments, the isochronous metronome click tracks that started the trial were generated and presented by a digital audio workstation. The participants heard the metronome, feedback of their own tapping performance, and in duet tasks the other participant's tapping (see next section) through headphones. The participants' tapping performance was recorded in MIDI format using Roland MIDI drum pads and the DAW.

Personality traits of the participants were assessed using the Big Five Inventory (BFI) (John & Srivastava, 1999). In the second experiment, this was complemented by the Interpersonal Reactivity Index (Davis, 1980). Further information about the musical background of the participants was obtained using a brief, custom-made questionnaire.

C. Tasks and procedure

In both experiments, all pairs of participants took part in three conditions:

(1) *Solo synchronisation-continuation*: Participants were asked to listen to a metronome beat through headphones and synchronise to it (synchronisation), and continue tapping the beat in the original tempo after the metronome stopped (continuation). They were instructed to maintain the original tempo as accurately as possible and keep tapping until they heard a jingle.

(2) *Duet - same tempo*: Participants began in the same way as in (1). Four seconds after the continuation section started, the audio settings automatically changed so that the participants could hear the other tapper in addition to themselves (we will call this the chaos section, as this often led to some confusion, although the term "chaos" in a literal sense would be exaggerating it). The participants were asked to try to keep tapping their original beat and resist entrainment with the other participant. Both participants had been presented with the same metronome in the synchronisation section.

(3) *Duet - different tempo*: Participants began the same way as in (2). This time the participants had been presented with different metronome beats in the synchronisation section. In *Experiment 1*, there were two versions of this condition: (a) the participants had heard metronomes with similar tempi (105.5 beats per minute (BPM) and 115.5 BPM) and (b) they had heard metronomes with very different tempi (93.5 BPM and 126.5 BPM). In *Experiment 2*, they had three kinds of tempo differences, small (e.g. 93.5 BPM and 105.5 BPM), medium (e.g. 93.5 BPM and 115.5 BPM) and large ones (93.5 BPM and 126.5 BPM).

All trials were 45 seconds long. Participants were finger-tapping on a Roland MIDI drum with their preferred hand. Participants could only hear each other's tapping through the headphones and they could not see each other during the experiment.

Participants also completed questionnaires about musical experience, their experience of the tasks and personality questions. In *Experiment 1*, the forms were filled after the tapping trials, but in *Experiment 2* they were filled in online prior to the tapping trials, so that participants could be paired based on their empathy scores.

D. Analysis methods

The tapping data was processed in MATLAB, with additional statistical analysis performed in SPSS. A stability measure and synchronisation measure were calculated using circular statistics (Fisher, 1993). For the former, onset times were converted to phase angles using the participant's previous inter-tap intervals (ITI) as referents, essentially comparing each ITI to the participant's previous one. The stability measure is an index of the concentration of the circular distribution (R-bar) of the phase values obtained through this comparison. For the synchronisation measure, the ITI's were compared across participants, and the R-bar index was calculated from this distribution (R-bar can get values from 0 to 1, with high values indicating high concentration, or a high degree of phase-locking).

Rayleigh test (Fisher, 1993, 69) is a statistical test for comparing a unimodal circular distribution to a uniform distribution, providing one objective method for setting a threshold of synchronisation (see e.g. Patel et al., 2009) for situations where it is only needed to know if a pair is synchronised or not. We used Rayleigh test in this way to gain an overview of the amount of trials where the participants were entrained. The R-bar statistics were then used in more detailed analyses.

In addition to these circular measures, a tempo change measure was calculated by comparing the average inter-onset intervals of the first and the last ten taps of the continuation stage in solo tasks or the chaos stage of the duet tasks.

III. RESULTS

The analysis of the results is ongoing. Here are some preliminary results based on analyses looking at the two experiments separately. In the final analysis, presented at the conference, data from the two experiments will be combined.

A. Experiment 1

In Experiment 1, participants performed the set of 13 trials (8 duets, 5 solo) twice. Most were considered successful, only 18 trials (1.9%) were discarded due to having more than 10 missing beats or gaps that were longer than three beats. Data and results from the first experiment have been previously presented at the SACCoM conference in 2011 (Himberg, Braithwaite, Snape & Spiro, 2011).

1) Tempo change. Tempo change was measured by comparing the average inter-tap interval (ITI) in the first and the last 10 beats in the chaos section, and dividing this by the inter-onset interval (IOI) of the metronome in the beginning of the trial. This tells us the proportional tempo change or tempo drift during the chaos section, which can be used to check how well people kept the original tempo. Tempo drifts were observed in most trials and in all conditions, and typically the tempo accelerated towards the end (in 66% of the trials). In average, the tempo changed by 3.7%, however the maximum change in an acceptable trial was 23.7%.

To look at the effects of the initial tempo difference and musical training, a repeated measures ANOVA was performed, with the type of trial as a within subjects factor, musical training as a between subjects factor, and tempo drift as the dependent measure. A significant main effect of type of trial was observed ($F_{(3,210)} = 29.821$, $p < 0.0005$, $\eta^2 = 0.299$), but there was no difference between the musicians and non-musicians, and no interaction between the two factors. Tempo drift was largest in the trials with large initial tempo difference, and smallest in the solo trials, with the small tempo difference and same tempo trials in the middle. The pairwise contrasts between the extremes and the two conditions in the middle were statistically very significant (p<0.005) (see Figure 1). Musicians tend to keep their tempo better than non-musicians in the solo tasks, but this difference is not statistically significant.

2) Stability. The *stability measure* quantifies how isochronously the participants tap, how consistent their ITI's are from one to the next. With this stability measure as the dependent variable, we looked at the effects of trial type and musical training. The repeated measures ANOVA revealed that musicians were significantly more stable in their tapping than the non-musicians ($F_{(1,70)} = 9.200$, p= 0.003, $\eta^2 = 0.116$). This held for all conditions, and the main effect of trial type was not significant (see Figure 2).

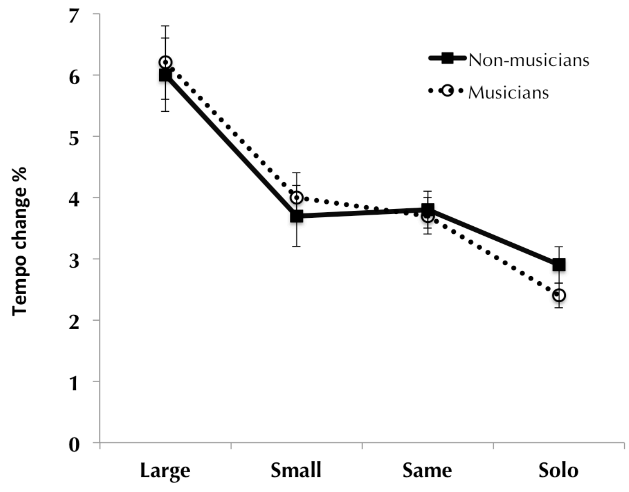

Figure 1. Mean tempo change in trials with large or small tempo difference, no difference, and solo trials. The error bars represent standard error.

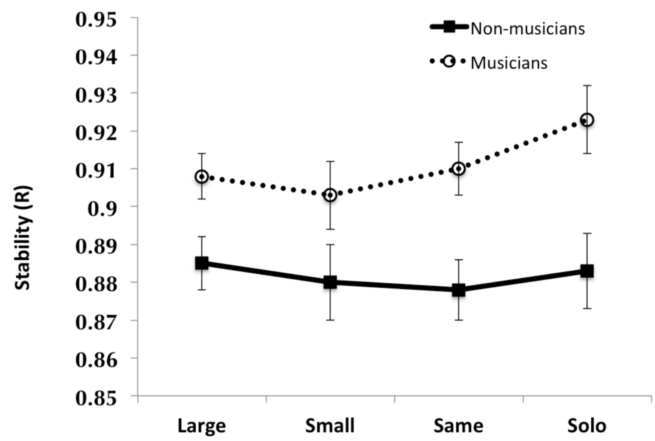

Figure 2. Stability measure. Bars represent standard errors.

3) Synchronisation. Synchronisation was analysed first at a yes-or-no -level, and then in more detail using the synchronisation measure explained above. First, we needed to anchor our results somehow, to see how to interpret the results. For this, we conducted Rayleigh tests for all trials. We used the Rayleigh test for unspecified direction, meaning that we just tested if the distribution of relative phase angles in the trial differs from a uniform distribution, which we could expect from an unsynchronised trial. Since this test is prone to type 1 errors, instead of trusting the test results as such, we only wanted to use it to compare our conditions to each other.

We used our solo trials as a baseline - pairing them together for each pair, so that we could calculate the relative phase angles of the two unrelated but tempo-matched performances. We expected that according to the Rayleigh test, some pairs would look synchronous due to this period-matching, and if this proportion would be larger in the actual duet trials, we could say that it would stem from the interaction and that some additional period- and phase-locking has occurred.

In these baseline pseudo-duets, the proportion of trials where the phase distribution was significantly non-uniform was 48.3%, when using a Rayleigh test p-value of 0.05 as a threshold. In the trials with different tempi, this proportion was smaller, 38.9%, but much higher in the trials with the same tempo (88.2%). According to t-tests, these differences between trial groups are statistically very significant. This suggests that in the same-tempo trials, participants were indeed entraining beyond what would be expected from just having a clustering of phases as an effect of starting in the same tempo, and similarly, in the trials with a tempo difference, they were successful in resisting entrainment.

The synchronisation measure captures how consistent the participants are in their relationship. This measure does therefore not make a difference between in-phase tapping (simultaneous taps) or anti-phase tapping (syncopation), just whether they are entrained to the same tempo, and are period and phase-locked to each other. In the absence of such locking, their relative phase varies randomly, resulting in an non-concentrated distribution of phase angles and thus a lower R-bar. R-bar gives us a higher resolution view on synchronisation than the Rayleigh test.

Figure 3 is a histogram of the synchronisation measures in all trials. This shows a bimodal distribution, which suggests that entrainment is a yes-or-no affair. 1:1 entrainment and phase relation is a “strong attractor”, so unless you can fully maintain independence, you fall into full synchrony. The trials in the middle of the distribution are the ones with intermittent entrainment, and are much more rare.

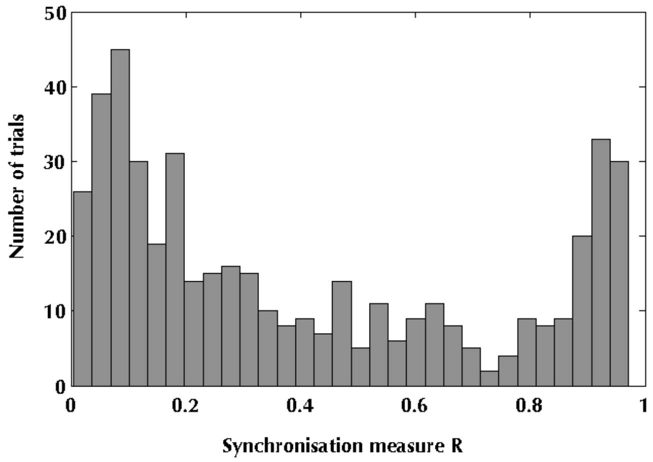

Figure 3. Histogram of synchronisation measure R-bar shows a bimodal distribution.

4) Patterns. Figure 4 depicts some of the different patterns of interaction observed in the experiment. The ITIs of a pair in the chaos section are plotted on the y-axis, with x-axis representing time (tap number). The dashed lines represent the original metronome tempo of the participant.

These data come from one pair (musicians), and the different patterns illustrate the individual variability of how the chaos was negotiated in these trials. Panels A and B depict trials with different tempi, and panels C and D trials with same tempo. The pair resists entrainment in two (A and D), while entraining in the two others. Comparing panels A and B, we can see that it made a difference which participant had the faster tempo. While the blue participant managed to maintain her slower tempo in A, the red player did not, and sped up to the partner’s tempo in B. To illustrate how the synchronisation measure captures this, the R-bar is just 0.05 in A, 0.18 for B, but 0.86 for the last 20 taps of B.

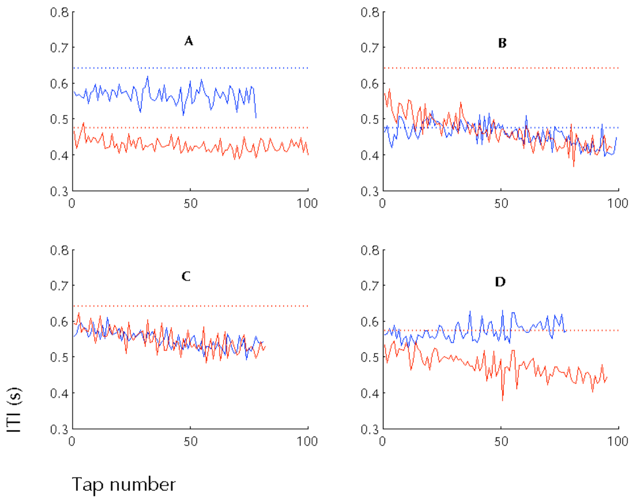

Figure 4. Examples of different patterns of entrainment. Inter-tap intervals of a pair of participants (musicians), for two trials with large tempo difference (A and B) and two trials with the same initial tempo (C and D).

Examining the asynchronies (onset time differences at each tap) for the trial in panel B reveals an attempt to resist synchronisation, with the two maintaining the tempo difference at the start, with fluctuating phase relationship, but then succumbing to intermittent synchrony at first, before locking to each others’ beats in the end; there was a transition to anti-phase synchronisation first, followed by finally succumbing in-phase synchrony.

The same-tempo trial in panel C was synchronised all through (R-bar = 0.94); both participants have a slight tempo drift toward a faster tempo, but they drift together. As mentioned, the R-bar will not take the tempo into account, just the consistency of the relationship of the pair. In panel D, despite of the same initial tempo, the two drift apart and resist entrainment successfully until the end of the trial (R-bar = 0.10).

5) Individual differences. The analysis regarding the possible effects of personality traits to pair performance is on-going. Preliminary results from correlating the stability measure with the Big 5 scores has revealed no statistically significant correlations. It seems that the relatively small variance in stability in this study is not due to personality factors as much as they are linked to trial type or the amount of musical training.

B. Experiment 2

The purpose for *Experiment 2* was to focus on the role of personality, and thus a few changes were made to the design. Most importantly, the participants were not paired randomly, but according to their IRI perspective taking subscale that measures their cognitive empathy. Also, we added a tempo combination so that we would get a more uniform distribution of *actual tempo differences* in the beginning of the chaos section. We noticed in *Experiment 1* that people had drifted slightly out of their initial tempi already during the four seconds of continuation, and thus categorising trials based on the tempo of the initial metronome was not always satisfactory from the chaos section analysis point of view. Having a more uniform distribution of actual tempo differences would perhaps help in discovering if there is a threshold in tempo differences, the other side of which pairs would be very likely to entrain, while on the other side they would entrain very rarely. Also, as musical training turned out to be a significant factor in *Experiment 1*, we wanted to focus on non-musicians in *Experiment 2*, still thinking that perhaps the lack of effect of personality has to do with the unifying (and improving) effect of performance that musical training has.

1. Entrainment threshold. To see if there was a tempo difference threshold that would divide trials as more or less likely to be entrained, the actual tempo differences in the trials were plotted against the synchronisation measures. This scatterplot is in Figure 5, with the distributions of tempo differences and synchronisation measures in panels B and C. A cubic curve was the best fit for the data, with $R^2 = 0.568$. This shows that while trials with a large tempo difference are very likely to remain un-entrained, and those with a very small tempo difference are almost always entrained, there is a very wide middle ground with trials as likely to be either or indeed fall in between. Thus defining a clear threshold is very difficult.

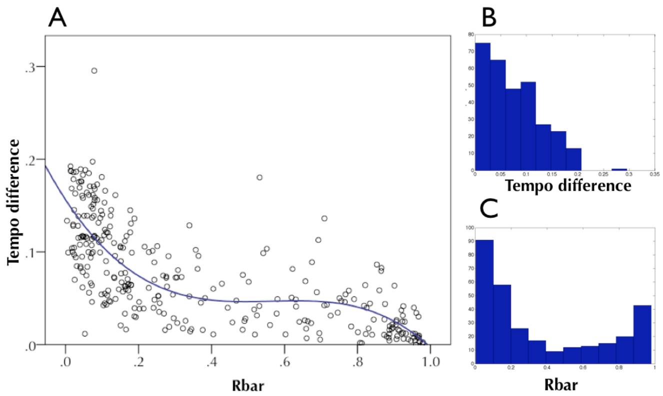

Figure 5. The distributions of actual tempo differences between the participants, as measured at the start of the chaos-section (panel B), and the R-bar synchronisation measure (panel C), and their scatterplot with a fitted cubic line.

2. Individual differences - effects of personality. The distribution of trials according to the synchronisation measure is again clearly bimodal as in Experiment 1 (see figure 5, panel C). The trials were therefore divided into two bins, synchronised and not synchronised, using the median value (R-bar = 0.215) as a cutoff point. A logistic regression analysis was then performed with tempo difference of the trial, the combined PT score of the pair, the difference in PT scores in the pair, and whether the pair was in the high-high, low-low, or high-low group as predictors. Significant models emerged ($\chi^2 = 171.027$, $p< 0.0005$), classifying up to 79.9% of the trials correctly. In these models, the main contributor was the tempo difference of the trial, with personality measures giving smaller contributions to the classification rate of the model. Attempts to build models with only personality factors in them were not successful. However, before concluding that personality has no effect on how people interact rhythmically in (pseudo)musical contexts, further analyses are necessary. A more detailed analysis with data combined from *Experiments 1* and *2* will be presented in the conference with particular focus on the patterns of interaction between partners in getting in and out of synchrony.

IV. CONCLUSIONS

Even in the context where maintaining one's own initial tempo is the priority, people tend to entrain with each other even when their initial tempi are very different. Entrainment is often a yes-or-no question, a bimodal rather than a normal distribution. Differences between individuals but also within individuals from one trial to another were observed.

Regarding our first aim, to study the interaction patterns, we found that participants keep their tempo better in solo than in duet tasks, regardless of musical training. In contrast, beat-to-beat consistency (stability) is not dependent on the trial type, but instead musicians are more stable than non-musicians. Various patterns of resisting entrainment, intermittent synchrony and very good entrainment were observed. Entrainment is dependent on the initial tempo difference, but we see no clear cut-off point.

As to our second aim, investigating the role of personality traits in these behaviours, the analysis is not yet completed, but the initial results indicate that at least the role is not very big or very clear. Personality traits may make a contribution, but compared to the effects that musical training or the differences in trial characteristics (solo vs. duet, size of the tempo difference), they are small and harder to characterise.

Our results are in line with those obtained by Repp in his studies on distracting tappers (2003, 2004). The variability of tapping increases (although in our Experiment 1 not significantly) and tappers speed up. Unlike Repp, we found many trials with consistent phase locking, even though the initial tempi had been different. Repp had only witnessed intermittent synchronisation. Perhaps this is due to the human partner being a more engaging "distractor" than a computer.

Our novel approach to cooperative tapping revealed a lot about the interaction patterns themselves, while at least so far, has revealed less about the psychological and personality factors underlying these behaviours.

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