The Subjective Difficulty of Tapping to a Slow Beat

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ABSTRACT

The current study investigates the slower limit of rhythm perception and participants subjective difficulty when tapping to a slow beat. Thirty participants were asked to tap to metronome beats ranging in tempo from 600 ms to 3000 ms between each beat. After each tapping trial the participants rated the difficulty of keeping the beat on a seven point scale ranging from "very easy" to "very difficult". The result strongly support the notion that subjective difficulty increased with slower tempo as this was the case for all participants. While rated difficulty increased monotonically as a function of tempo the largest increase was between the tempo of 1200 ms and 1800 ms. This is in line with earlier reports on where tapping starts to feel laborious and supports the notion that there is a qualitative difference between tapping at fast (< 1200 ms between each beat) and slow (> 2400 between each beat) tempi. A mixed model analysis showed that tempo, tapping error and percentage of reactive responses all affected the participants rating of difficulty. Of these, tempo was by far the most influential factor, still participants were, to some degree, sensitive to their own tapping errors which then influenced their subsequent difficulty rating.

I. INTRODUCTION

Music come at a wide range of different tempi. John Coltrane's *Giant Steps* is an example of a tune that clocks in at the faster end of the spectrum with a tempo of 285 beats per minute (bpm). An example of a piece of music at the slower end of the spectrum would be Bach's *Air* from suite No. 3 in D major which is sometimes played at a tempo below 60 bpm. There are more extreme examples, for example, John Cage's *As Slow as Possible* have months between each new note. It is, however, rare for popular music to have a tempo slower than 1500 ms and faster than 300 ms between each beat, with tempi around 500 ms being the norm (van Noorden and Moelants, 1999). This also shows in the tempo ranges of metronomes which generally do not go slower than 1500 ms or faster than 300 ms between each beat.

It is reasonable to believe that these limits of tempo in some way reflect the limits of rhythm perception. Both the slower and the faster limit of rhythm perception has been studied using rhythm production tasks, especially finger tapping (Repp, 2005). The faster limit of rhythm perception has been assessed using tapping tasks where participants are asked to tap to successively faster metronome sequences. In order to not be limited by motoric factors when the tempo is fast only every second tone in the metronome beat is tapped to. Using this method trained musicians are able to synchronize to sequences with an inter stimuli interval (ISI) of close to 100 ms (Repp, 2007).

The slower limit of rhythm perception has been more difficult to assess as there seems to exist no (within reason) upper limit to when tapping to a beat is no longer possible. When asked to freely tap a beat as slow as possible participants tend to tap at a tempo of around 2500 ms between each tap (McAuley et al., 2006). However, participants are able to tap at a much slower rates when paced by a metronome (Miyake et al., 2004). Two common observation are that as the tempo gets slower there is an increase both in tapping variability and in the number of reactive responses, that is, when the participant reacts to the sound rather than anticipates it (Repp and Doggett, 2007; Mates et al., 1994). Even though tapping variability increases with slower tempo there is at no point a sharp change in tapping variability. Nevertheless Repp (2006) argued for a slower limit around 1800 ms as it is around this tempo that participants start having difficulties anticipating the tones and reactive responses start to occur. He also noted that tapping is a rather effortless activity up to a tempo of 1500 ms, but when the tempo approaches 1800 ms it becomes a difficult task requiring cognitive effort. This observation was not supported by any experimental data, however, and the present study aims to investigate the relation between tempo, tapping error and subjective ratings of difficulty when tapping to a slow metronome sequence.

The study had three aims: (1) To establish the relation between subjective difficulty and tempo. (2) To test the hypothesis that there is a qualitative difference between tapping at fast and slow tempi and that this is reflected by a steep shift in subjective difficulty around an ISI of 1800 ms. (3) To test if subjective difficulty depends on the tempo, the trial-to-trial performance of the participants or a combination of these factors. (1) and (2) is motivated by the observation by Repp (2006) above. A participants experience of difficulty when tapping could be caused by many factors, both factors that made the task more difficult, here a slow tempo, and factors that was the result of the high difficulty, such as a large tapping error or a high percentage of reactive responses. It might be the case that participants are sensitive to their own performance. For example, a participant might notice that he or she produced many reactive responses during a trial and as a result experience that trial as more difficult. On the other hand, participants might not be influenced by their own performance but solely by the difficulty of tapping at a slow tempo. The motivation for (3) is to find what factors influences subjective difficulty when tapping at a slow tempo.

II. Method

A. Participants

Nine female and 21 male participants, ranging in age from 19 to 78 years (M=31.6 , SD=12.8) were recruited from the Lund community. All were unpaid volunteers. All participants reported being right handed. Twenty-six participants reported that they had experience playing an instrument and ten participants reported having regularly played or practiced an instrument for more than ten years. All participants gave informed consent according to the guidelines of the Swedish Research Council.

B. Material

A custom build tapping board was used in order to record the onsets and velocities of the participants' finger taps. For a technical report describing the tapping board see Bååth (2011). The stimuli for the tapping task consisted of isochronous sequences of 440 Hz square wave tones of 20 ms. Each sequence consisted of 31 tones and were presented at five tempi, corresponding to tone ISIs of 600, 1200, 1800, 2400 and 3000 ms. The ISI of 600 ms can not be regarded a slow tempo but was included as a baseline as participants tend to prefer tapping at an ISI of around 600 ms when being able to choose freely (McAuley et al., 2006). Both registration of taps and generation of sound was handled by an Arduino micro-controller, this was in order to avoid the timing uncertainties resulting from using a personal computer and to guarantee millisecond accuracy. The micro-controller was connected to a Dell Vostro 3700 computer that collected the timing information through a USB interface.

C. Procedure

During a session each participant performed a number of rhythm perception and production tasks, but only the data from the tapping and rating tasks are analyzed here. In the tapping task the participants sat in front of the tapping board wearing head phones. The task consisted of four blocks where each block contained five trials, one for each tone ISI. The order of the trials was randomized within each block. First the participants were asked to adjust the volume of the head phones to a comfortable level while a tone sequence was playing. After a short test trial the participants then started with the first block. They tapped using the index finger on their dominant hand which was the right hand for all participants. There was a scheduled one minute break after the second block, otherwise successive trials were started as soon as the participant indicated that he or she was ready.

A trial consisted of the participants tapping to a tone sequence on the tapping board. The instructions given were to try to tap along the given tone sequence, to try to start tapping as soon as the sequence started and to stop when the sequence stopped. The participants were especially asked not to subdivide the beat in any way, for example by covert counting or by movement of the body. After finishing each sequence the participants rated the difficulty of tapping on a seven point scale ranging from “very easy” to “very difficult”. More specific, the participants were asked to rate “How difficult did you find it to keep the beat?” (translated from the Swedish “Hur svårt tyckte du det var att hålla takten?”).

D. Analysis

The first four taps of every trial were discarded in order to use only those taps where the participants had had some time to synchronize to the sequence. For each tone in the sequence the tap-to-tone asynchrony was calculated as the difference between the tone onset and the corresponding tap so that a negative asynchrony indicated that a tap preceded the tone. Sometimes participants tapped as a reaction to the tone instead of tapping with the tone. This was especially common at the slow tempi. For each trial the percentage of reactive responses was calculated where a response was labeled as reactive if the corresponding asynchrony was larger that 100 ms. Statistical analysis was conducted using the R statistical environment Team (2010). Mixed-effects regression modeling was done using the lme4 package (http://cran.r-project.org/web/packages/lme4/) with p-values calculated using the pval.fnc function from the languageR package (http://cran.r-project.org/web/packages/languageR/) (Baayen et al., 2008).

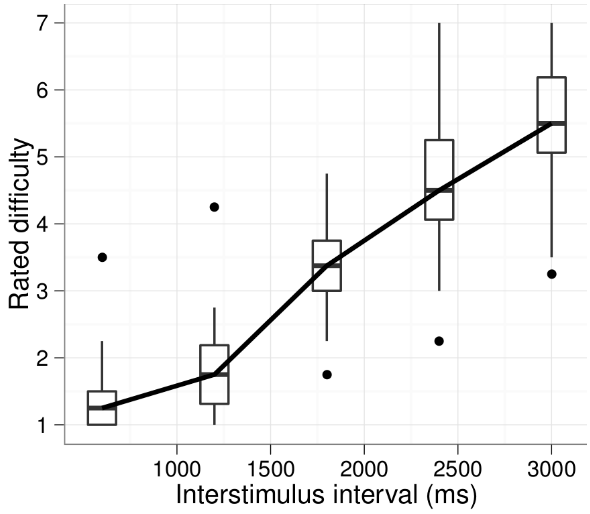

Figure 1. The distributions of difficulty ratings at the different tempi. The line connects the median ratings.

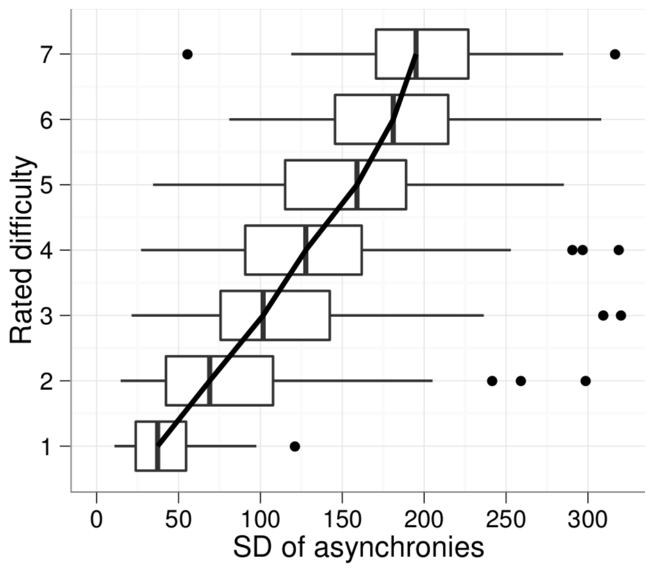

Figure 2. The distributions of tapping error as a function of rated difficulty. The line connects the median ratings.

III. Result

The participants generally used the whole rating scale and as expected there was a strong, significant correlation between tempo and the mean rated difficulty for each participant (Pearson's product moment correlation, r=0.89, n=150, p < 0.001). Figure 1 show the distributions of difficulty ratings at the different tempi. The smallest increase in rated difficulty was between tempi of 600 ms and 1200 ms (M = 0.5) which was significantly smaller than the differences between tempi of 1200 ms and 1800 ms (paired t-test, t(29)= -5.42, p < 0.001), 1800 ms and 2400 ms (t(29) = -5.63, p < 0.001), and 2400 ms and 3000 ms (t(29) = 2.69, p = 0.012). The largest increase in rated difficulty was between tempi of 1200 ms and 1800 ms (M=1.6) which was significantly larger than the difference between tempi of 600 ms and 1200 ms (t(29)= 5.42, p < 0.001) and 2400 ms and 3000 ms (t(29) = 3.47, p = 0.002). While the difference in rating between tempi of 1200 ms and 1800 ms was larger than the difference between tempi of 1800 ms and 2400 ms it was not significantly so (t(29) = 1.66, p = 0.11).

Tapping error, as measured by the standard deviation of the tap-to-tone asynchronies, was significantly correlated with rated difficulty (r=0.79, n=150, p < 0.001). The increase in rated difficulty as a function of tapping error is also visible in figure 2. This result is hard to interpret, however, as tapping error is known to increase linearly with tempo. As expected tapping error increase with larger ISIs (as shown in figure 3) and there was a significant correlation between tapping error and tempo (r=0.90, n=150, p < 0.001). There was a significant correlation between rated difficulty and percentage of reactive responses (r=0.68, n=150, p<0.001) but the number of reactive responses also increased with slower tempo (see figure 4).

A number of linear mixed-effects models were fitted to asses the influence of tempo, tapping error and percentage of reactive responses on rated difficulty. The models were fitted on the per-trial data, not data averaged over trials, and all models included participant as a random effect. As tempo had the highest correlation with rated difficulty a first model only included tempo as predictor. A second model also included tapping error and percentage and a likelihood ratio test showed that it it was justified to include those terms (chi-square = 37.8, p < 0.001). A third model added a term for tapping error relative to tempo, that is, the standard deviation of the asynchronies divided by ISI. This was the final model and the addition of the relative tapping error term was justified according to a likelihood ratio test (chi-square=5.99, p=0.014). All slopes in the final model deviated significantly from zero except for the slope for the tapping error, probably due to the inclusion of the relative tapping error term. The final model is summarized in table 1.

Predictor	B	β	p
ISI	0.0015	0.65	< 0.001
SD(asynchrony)/ISI	9.36	0.13	0.014
% reactive responses	1.76	0.11	< 0.001
SD(asynchrony)	0.0002	0.01	0.90

Table 1. A summary of the linear mixed-effects model predicting rated difficulty. Collumn B show the raw slopes of the predictors while collumn β show the standardized slopes.

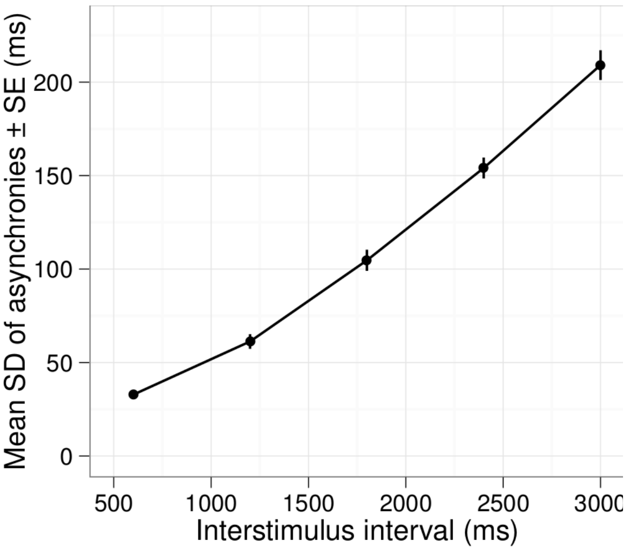

Figure 3. The tapping error as a function of tempo.

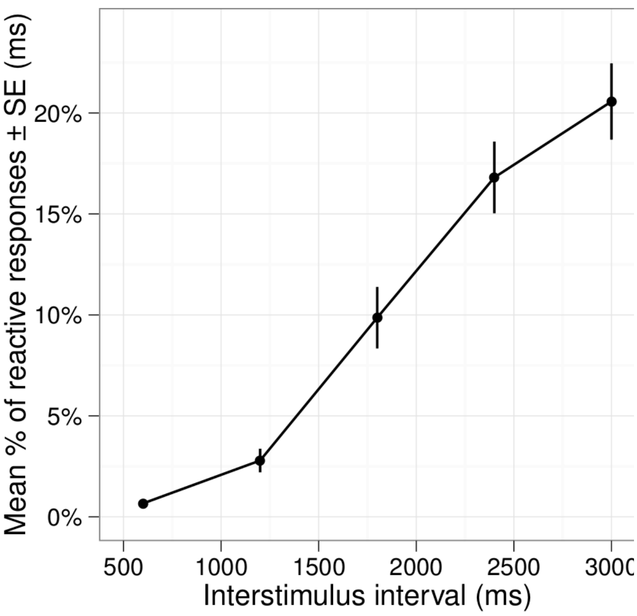

Figure 4. The percentage of reactive responses as a function of tempo. A reactive response was defined as a tap that struck more than 100 ms after the target sound.

IV. Discussion

The result strongly support the notion that subjective difficulty increased with slower tempo as this was the case for all participants. While difficulty increased monotonically as a function of tempo the largest increase was between the tempo of 1200 ms and 1800 ms. This agrees with Repp's (2006) description of a subjective slower limit were rhythm production goes from being effortless to being cognitively demanding. After having finished the session many of the participants also expressed that tapping to the slow tempi felt very taxing and that there was a great contrast between tapping at the slow tempi and at the fastest tempo. The mixed model analysis showed that tempo, tapping error and percentage of reactive responses all affected the participants rating of difficulty. Of these, tempo was by far the most influential factor as the standardized slopes in table 1 show.

Still participants are, to some degree, sensitive to their own tapping errors which then influences their subsequent difficulty rating.

In this study there was relatively few ISIs levels distributed over a quite wide range. In a future study it would be interesting to narrow down the range to around 600 to 2000 ms and try to pinpoint the exact point where subjective difficulty increases the most. Another question remains: Why is there an upper limit of rhythm perception at all? This is hard to answer without addressing the larger question: What is the neural mechanism behind rhythm perception? A promising framework for explaining this mechanism is the resonance theory of rhythm perception and production which postulates that rhythm is coded as a multifrequency pattern of oscillating neural circuits (Large, 2008). The oscillating circuits can only code for rhythms that are as slow as the slowest circuit which would then explain the existence of a slower limit of rhythm perception.

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