FOCALISATION ON THE TEMPORAL CONTEXT OF COMPLEX SEQUENCES

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ABSTRACT

Studies of the perception of sound sequences indicate the existence of an optimal processing rate [1]: sequences in which sound events occur at rates within this range are processed in more depth than events within faster or slower sequences. But what happens if two sequences occur simultaneously at different rates? We investigate whether or not listeners focus preferentially on (and process in more depth) the sequence which is closest to their optimal rate. We do this by measuring the way listeners hear and synchronise with complex sequences composed of two co-occurring subsequences. In a within-subjects design, participants completed four tasks, two perceptual and two motor. The results indicate in particular that: 1) irregularity detection was better within the sequences closest to each participant's optimal rate, 2) participants tended to synchronise with the same subsequence, and 3) a strong link between the optimal tempi was observed in all four tasks.

1. INTRODUCTION

Studies of the perception of sound sequences have demonstrated the existence of an optimal processing rate: sequences in which sound events occur at rates within this range are processed in more depth than events within faster or slower sequences. For example, when listeners were asked to say which of two isochronous sequences was the fastest, they were more accurate for intermediate sequences: 300-800 ms IOI (sequence rate or tempo is expressed in terms of the duration between the onset of successive tones: interonset interval, IOI, measured in milliseconds), than for faster or slower sequences [1]. Interestingly, this range of rates corresponds almost exactly to the range of spontaneous motor tempi, the rate at which people tap if they are asked to tap in a regular fashion at the rate that seems most natural to them [2]. Recent conjuncture postulates that these perceived and produced optimal rates both reflect a common functioning mode. Jones, in her Dynamic Attending Theory [3,4], suggests that this optimal processing rate would be specific to each individual, with listeners spontaneously focusing on events occurring at their own personal optimal rate or reference period.

But can these observations be extended to more realistic listening conditions? From a practical point of view, such findings would help the choice of rate during the design of auditory signals such as alarms where a rapid process is searched. In order to verify Jones' theory in more realistic conditions, we investigated participant's behaviour with complex sound sequences composed of two co-occurring isochronous sequences, each with a specific tempo and pitch. We predict that listeners should spontaneously focus on the sequence that occurs at the rate closest to their referent period.

In order to test this hypothesis, participants completed four tasks. We first obtain two measures of their individual referent period (spontaneous motor tempo). We then examined participants' behaviour in relation to complex sequences. First, they were asked to detect a temporal irregularity within one of the subsequences. Second, they were asked to tap in time in a regular fashion with the complex sequences at the rate that seems most natural to them. If the hypothesis of spontaneous focus on an optimal rate is correct, irregularity detection should be better for the sequence closest to the referent period, and similarly, participants should synchronise more frequently with the subsequence closest in tempo to their referent period. Strong correlation between performances on these tasks would provide support for the hypothesis of a common origin of these perceptual and motor phenomena.

2. EXPERIMENT

2.1. Procedure

Task 1: A measure of each individual's referent period was obtained by taking two spontaneous tempo measures (one at the beginning and one at the end of the session). Participants were asked to tap on a drum pad in a regular fashion at the rate that seemed most natural to them.

Task 2: A control condition verified that all the tempi used in Task 3 were equally easy, by asking participants to detect a 15% temporal irregularity within simple isochronous sequences at the same rate as used in Task 3 (where they were presented simultaneously with another subsequence)(108, 180, 300, 500, 833, 1388 ms IOI).

Task 3: The rate on which listeners spontaneous focus their attention was measured with an irregularity detection task within complex sequences composed of two co-occurring isochronous sequences. We created complex sequences composed of two isochronous subsequences, each with a specific tempo and pitch. A small temporal irregularity was introduced into one of the subsequences. Listeners indicated whether the irregularity occurred in the first or second complex sequence. The temporal irregularity was only detectable if the listener was focusing on that particular subsequence [5]. The assumption is that if the spontaneous focusing was unaffected by rate, detection of the temporal irregularity should not be influenced by the subsequent tempo.
Task 4: Another indication of the sequence on which listeners spontaneously focused attention was obtained by asking participants to tap in time with the complex sequences, in a regular fashion, at the rate that seemed most natural to them. It is assumed that they will synchronise with the sequence on which they spontaneously focus.

2.2. Subjects

All 19 subjects had normal hearing. They were all undergraduate psychology students at the University René Descartes.

2.3. Stimuli

In Tasks 3 and 4, each trial consisted of the successive presentation of two complex sequences composed of two subsequences of pure tones that were uniquely defined by tempo and frequency. Each complex sequence was composed of subsequences presented at two different frequencies (486 Hz or 1137 Hz), each presented at a different IOI (108, 180, 300, 500, 833, or 1388 ms). Sequence 1 was composed of 108ms-180ms subsequences with 108 ms the high rate subsequence and 180 ms the low one; Sequence 2 of 180ms-300ms subsequences with 180 ms the high rate subsequence and 300 ms the low one and so on. In Task 3, a temporal irregularity of 15% was created by advancing or delaying, in relation to regularity, the onset of one tone in one of the sequences, near the beginning, middle or end of the sequence (figure 1). Tones had a duration of 50 ms (including 5-ms onset and offset ramps) and were presented to both ears at 70 dB SPL.

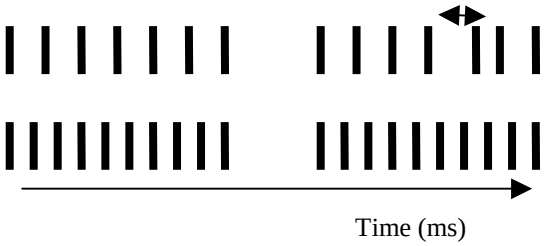

Figure 1. *Stimuli for one trial. Each bar represents one 50-ms, 70-dB tone. One example of a temporal irregularity is given (arrow).*

2.4. Apparatus

The sequences were generated by a synthesizer and controlled by a personal computer. Listeners sat in a soundproof room and listened to sequences through headphones. In Tasks 2 and 3, the subjects gave their responses by pressing the left/right button when they thought that the temporal irregularity was in the first/second sequence.

2.5. Results

Task 1: The mean *spontaneous motor tempo*, averaged over the first and second measures was 691 ms IOI (SD = 212 ms IOI).
Task 2: Individual *irregularity detection rates within simple isochronous sequences* were above 80%, confirming that all temporal irregularities used in Task 3 were easily detectable.
Task 3: *Irregularity detection within complex sequences* varied as a function of sequence tempo. More specifically, as predicted, detection was higher in each case for sequences of intermediate tempi (300-500 ms IOI). For instance, Figure 2 shows that for the fastest sequence (sequence 1 = 108 and 180 ms IOI) detection was better for 180 than 108 ms IOI. At the other extreme for the slowest sequence (Sequence 5 = 833 and 1388 ms IOI), detection was better at 833 ms IOI. For intermediate rate sequences (Sequence 3 = 300 and 500 ms IOI) detection was similar for the two sequences.

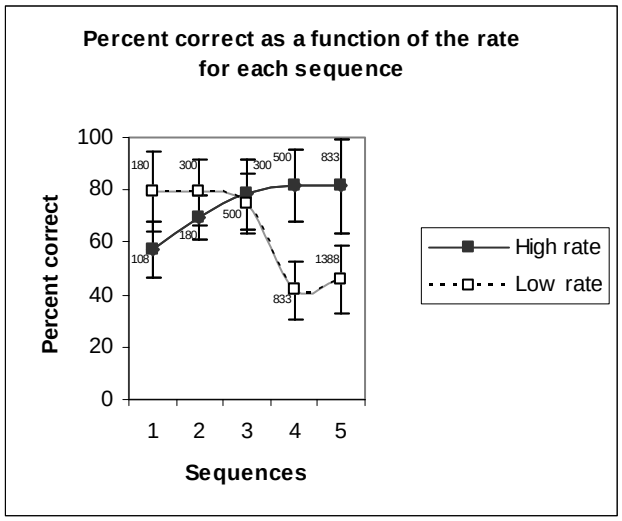

Figure 2. *Percentage correct detection of a temporal irregularity at each of the ten subsequence tempi, depending on the complex sequence within which the subsequence was embedded.*

Task 4: Figure 3 shows mean synchronisation rates with complex sequences: participants systematically synchronised with the rates for which they were better able to detect the temporal irregularities. The cross-over point in Task 3 is almost identical to the cross-over point in Task 4.
During Task 4 (figure 3), listeners synchronised with low rate subsequences considering sequences 1 and 2 and with high rate subsequences considering sequences 4 and 5.

Note that synchronisation at 108 ms was impossible, due to motor limits.

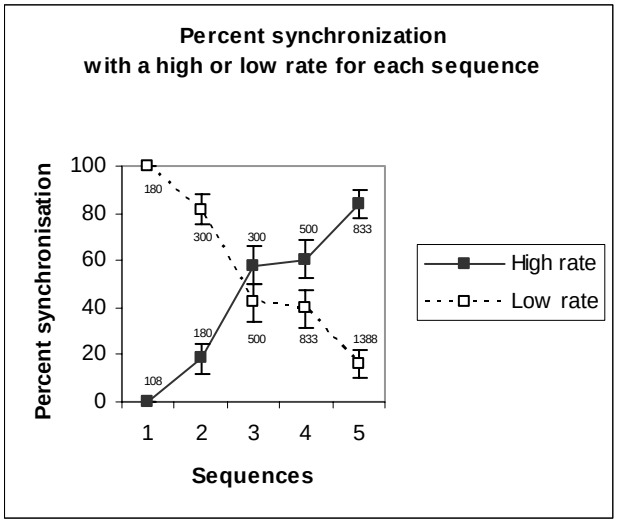

Figure 3. *Percentage synchronisation with one of the two subsequences composing the auditory complex sequences.*

3. DISCUSSION

The results argue in favor of the hypothesis that listeners spontaneously focus on events occurring at intermediate rates:

1) Detection was always better when the irregularity occurred in the subsequence closest to the intermediate tempo zone.
2) Synchronisation was more often with the subsequence closest to the intermediate tempo zone.

The zone of optimal processing appears to be at intermediate rates.

The cross-over point in both the detection and synchronisation tasks was around Sequence 3 (300 ms – 500 ms) while the mean spontaneous motor tempo was around 700 ms. This later rate may reflect a multiple of the cross-over point rate of the curves in Figures 2 and 3. It can be explained by the use of a higher hierarchical level during spontaneous motor tempo than during the detection and the synchronisation tasks.

4. CONCLUSION

A large body of research in time perception indicates that listeners are most sensitive to changes in pitch or timing of events in the range of intermediate rates. In order to test if listeners spontaneously focus on these intermediate rates, we have designed an experiment still in progress. The first results indicate that irregularity detection and synchronisation were better performed at intermediate rates. They are in favor of a spontaneous focus on intermediate rates.

5. REFERENCES

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