SUBJECTIVE RHYTHMIZATION: A REPLICATION AND AN EXTENSION

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ABSTRACT

Subjective rhythmization (SR) is the phenomena that the sounds of a monotone metronome sequence are experienced as having different intensity and that these differences follow a regular pattern. The present study aimed to replicate and extend the two studies that have employed the original SR experimental paradigm (Bolton, 1984; Vos, 1973). The extensions included using a wider range of tempi and a large number of participants. The result of the current study was in accordance these two earlier studies. In addition to the original SR task, a novel task was administered where the participants were not explicitly told about the existence of the phenomena. The responses of the participants were in agreement with that subjective rhythmization was experienced. The result indicates that SR is a robust phenomena that can be experience even without it being primed by verbal instructions.

1. INTRODUCTION

When listening to a piece of music a common response is to move one's body with a perceived periodic pulse (Snyder and Krumhansl, 2001). That pulse is the *beat* of the corresponding piece of music, a series of subjectively isochronous (equally spaced in time) events that are felt as being pronounced or accented. The beat is established by the rhythm of the musical events and in a piece of music the beat and musical events tend to coincide. It is not necessary that every beat is marked by a musical event, however, and the perception of a beat can be sustained even if there are conflicting musical events (Large and Palmer, 2002).

It is not common that all beats in a piece of music are perceived as being equally accented (Palmer and Krumhansl, 1987) and a periodically recurring pattern of strong and weak accents is called a meter. For example, a duple meter would imply that every second beat is perceived as having a stronger accent while every third beat is perceived as having a stronger accent in the case of a triple meter. Perceiving the beat and meter of a piece of music often comes natural and it does not require the listener to actively attend to the music. It has even been shown that some form of beat induction is functional in newborn infants (Honing et al., 2009).

One perceptual phenomena that shows our tendency to experience metrical structures is subjective rhythmization (SR), a phenomena which occurs when one listens to a sequence of isochronous, identical sounds. A pattern of accents will emerge that has a metrical structure and causes the impression that there are groups of sounds. Even though the sounds are objectively identical they sound subjectively different. This phenomena was described already in the 18th century (Kirnberger, 1776) but was first investigated by Bolton (1894) who systematically played monotone metronome sequences of different tempi to a number of participants and recorded their reactions. That study was later partially replicated by Vos (1973)[1], and both studies agree on some characteristics of SR. The most common groupings participants experience are two and four, the groupings of common meters of western music. Group size and tempo interacts as participants tend to perceive smaller groupings at slower tempi and larger groupings at faster tempi, though no groupings larger than eight have been reported (Bolton, 1894; Vos, 1973). There is a limit to the range of tempi where SR can be experienced. Bolton found that participants' experience of SR ceased when the interstimuli interval (ISI) between consecutive sound onsets was above 1500 ms. After reviewing the literature Fraisse (1982) proposed that the limit was around an ISI of 1800 ms. Here is a connection to rhythm production as this limit is in the same range as when sensorimotor synchronization (e.g. finger tapping) begins to feel laborious (Repp, 2006; Bååth and Madison, 2012).

The present study aim to replicate the result of Bolton (1894) and Vos (1973) using a wide range of tempi and a larger number of participants than in the earlier studies. Such a replication is presented in Experiment 1. A second aim was to verify the existence of the SR phenomena. In previous studies SR has been investigated by explicitly asking what groupings participants experience when listening to a metronome sequence. By explicitly asking participants about grouping it is possible that participants get primed to experience SR. In Experiment 2 we used a novel task where the response of a participant depends on whether he or she experiences SR but where SR is not mentioned in the task instructions.

2. EXPERIMENT 1

2.1 Method

Participants were recruited, and the experiment administered, using the on-line service Amazon Mechanical Turk (Buhrmester et al., 2011). Out of the 132 participants 111 reported having experience playing a musical instrument. The task instruction given to the participants were as follows:

“This task requires your full attention. Below are six sound sequences of clicks. You should listen to each sound sequence and rate if you feel any grouping or subdivision of the clicks, however weak or subtle. For example, if you hear "TICK-tick-TICK-tick-TICK-tick" that would be groups of two,

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1 Vos (1973) has not be translated into English, but the data from that thesis has been reanalyzed by van Noorden and Moelants (1999).

while if you hear "TICK-tick-tick-tick-TICK-tick-tick-tick" that would be groups of four. This task **is not** about whether there are groups in the sequences, it is about if you **feel** any grouping. Now listen to and rate the sequences one at a time in the order they are displayed."

The participants were then given six monotone metronome sequences with ISIs of 200 ms, 300 ms, 400 ms, 600 ms, 800 ms and 1500 ms in a randomized order. Each sequence was 15 s long and consisted of 10 ms long, 440 Hz sine wave sounds. After listening to a sequence the participant indicated what grouping he or she felt by using a list with the alternatives "no group" and "groups of 2" up to "groups of 8".

2.2 Result

The result replicated many of the findings of Bolton (1894) and Vos (1973) and Figure 1 shows the reported experienced grouping from six participants. In general participants reported larger groupings at faster tempi, as can be seen in participant C or F. Some participants were consistent, like participants A and B, while some were less consistent, like participant C and E. There was a tendency that some participants (for example, participant D) answered "no grouping" on the faster tempi (200 ms and 300 ms).

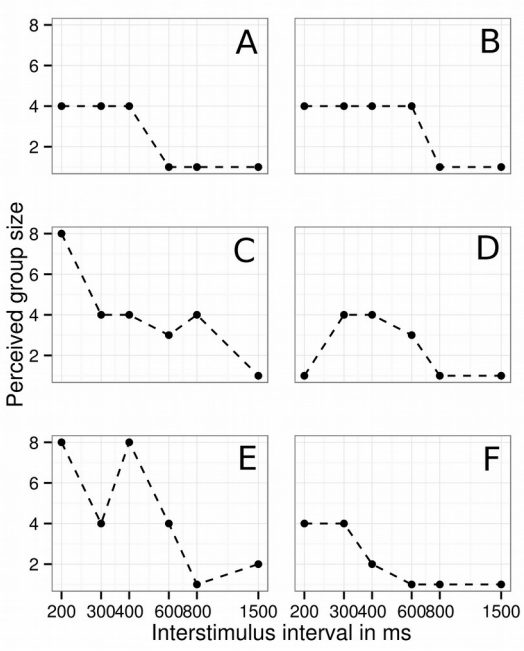

Figure 1: The reported perceived group size for six of the 132 participants in Experiment 1. Note that a group size of one corresponds to the participant having reported "no grouping".

The most reported groupings were two, four and eight with five and seven being rarely reported at all. Table 1 show how often the participants reported each possible grouping. Figure 2 show for each ISI level the proportion of participants that reported each grouping. The slower limit of SR was estimated to an ISI of 1500 by Bolton. In the current study no such sharp limit was found, however, a majority of the participants (81 %) reported experiencing no grouping at an ISI of 1500 ms.

Grouping	Peak ISI	% of responses
1 (No grouping)	1500	34 %
2	600	23 %
3	300	7 %
4	300	27 %
5	200	< 1 %
6	300	1 %
7	200	< 1 %
8	200	6 %

Table 1: Summary of the reported groupings in Experiment 1.

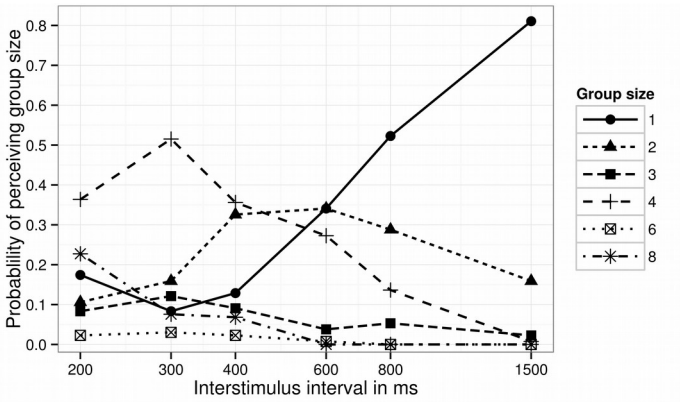

Figure 2: Percentage of reported groupings as a function of ISI. A group size of 1 corresponds to "no grouping".

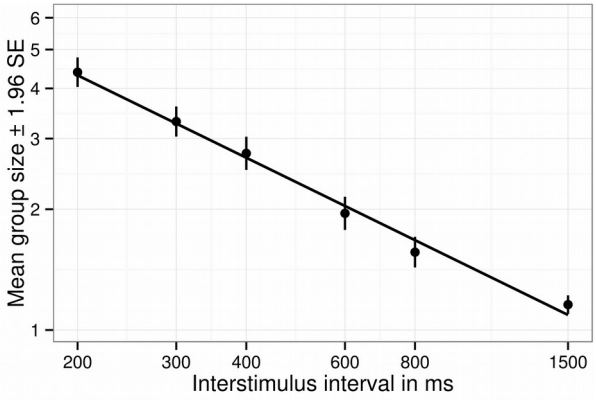

Figure 3: Log-log plot of mean group size as a function of ISI. The line show the best fitting regression line.

Figure 3 shows the mean group size reported for each ISI level with both axes being on the log scale. This relation appears highly linear, a result not previously reported in the literature. A linear regression with $\log_2$ group size as the dependent variable and and $\log_2$ ISI level as the independent variable gave an intercept of 8.1 (95% bootstrap[1] confidence interval [5.8, 10.5]), a slope of -0.77 (95% CI [-1.0, -0.53]) and an R^2 of 0.50 (95% CI [0.23, 0.77]).

3. EXPERIMENT 2

3.1 Method

The purpose of Experiment 2 was to investigate whether the phenomena of SR would influence participants responses even though SR was not mentioned in the instructions nor suggested in any way. Amazon Mechanical Turk was again used to recruit and administer the task to 120 participants, 60 in each of two conditions, where the only difference between the conditions were whether the following task instructions used the word *second* or *fourth*:

"In this task we are interested in if it is possible to feel very small differences in loudness. Below are 14 click sequences, in some of them all clicks are equally loud and in some of them every [*second, fourth*] click is a little bit louder. The difference in loudness will be **very** small. Listen to the sequences, in the order they are given, and for each sequence try to feel if the clicks are equally loud or if every [*second, fourth*] click is louder."

The 14 click sequences were the same as in Experiment 1, with the addition of a 2000 ms ISI sequence, each given twice in a randomized order. That is, despite the task instructions, all clicks were actually equally loud. After having listened to each sequence the participant was asked whether they perceived a difference in loudness or not. If the participant, without knowing it, experienced SR when listening to the sound sequence we would expect her to be more likely to report a difference in loudness. If a participant was given the *second*-instructions, to listen for a difference on every second click, we hypothesized that she or he would direct attention towards SR with a grouping of two and therefore be most likely to report a difference at an ISI of around 600 ms (cf. Figure 2). Similarly, if a participant was given the *fourth*-instructions and was listening for a difference on every fourth click, we would expect him or her to be most likely to report a difference around an ISI of 300 ms.

3.2 Result

There was a tendency for the participants given the *second*-instructions to report hearing a difference around an ISI of 600 ms while the participants given the *fourth*-instructions were more likely to report a grouping at the ISIs of 300 ms and 400 ms. Figure 4 show the probability of reporting hearing a difference for each ISI level, where there is a clear peak around 600 ms for the *second*-condition and around 300 ms and 400 ms for the *fourth*-condition. At the ISI levels of 1500 ms and 2000 ms, where the participants in Experiment 1 largely reported hearing no grouping, there is an increase in reporting hearing a difference for the *fourth*-condition. A reason for this could be that at such slow tempi some participants find it difficult to compare every fourth click and therefore approach the chance level of 50%.

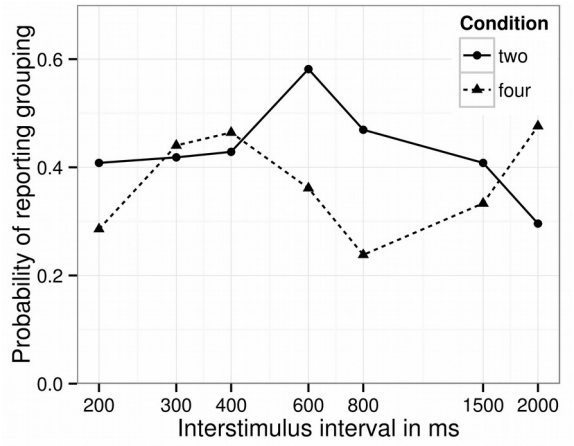

Figure 3: The probability of reporting hearing a grouping for the two instruction conditions in experiment 2.

4. CONCLUSION

Experiment 1 replicated the main findings of Bolton (1894) and Vos (1973):

- Subjective Rhythmization is a robust phenomena that seems to be experienced by most participants.
- The reported experienced grouping is most often two, four or eight, common meters of western music.
- What grouping that is reported is highly dependent on the tempo with larger groupings being reported at faster tempi.
- Most participants do not reporting hearing a grouping when the ISI is as slow as 1500 ms.

Experiment 2 confirmed the robustness of SR and showed that SR influence participants' responses in a task that is quite different from the original SR task.

It should be noted that as both experiments used Amazon Mechanical Turk, both experiments were administered on-line without the usual control of a perceptual experiment. This can be viewed both as a weakness and as a strength, a weakness because there was no control over what environment the participants were in when doing the experiment, a strength because despite the lack of control the result is well in agreement with the earlier studies of Bolton (1894) and Vos (1973).

1 The bootstrap confidence intervals (CI) were calculated using 10,000 resamples.

5. ACKNOWLEDGEMENT

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