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Rhythm implicitly affects temporal orienting of attention across modalities

Deirdre Bolger [a], Wiebke Trost [b], Daniele Schön [a,*]

[a] INS, INSERM & Aix-Marseille University, Marseille, France
[b] Laboratory for Behavioral Neurology and Imaging of Cognition, Department of Neuroscience, Medical School, University of Geneva, Switzerland

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ABSTRACT

Here we present two experiments investigating the implicit orienting of attention over time by entrainment to an auditory rhythmic stimulus. In the first experiment, participants carried out a detection and discrimination tasks with auditory and visual targets while listening to an isochronous, auditory sequence, which acted as the entraining stimulus. For the second experiment, we used musical extracts as entraining stimulus, and tested the resulting strength of entrainment with a visual discrimination task. Both experiments used reaction times as a dependent variable. By manipulating the appearance of targets across four selected metrical positions of the auditory entraining stimulus we were able to observe how entraining to a rhythm modulates behavioural responses. That our results were independent of modality gives a new insight into cross-modal interactions between auditory and visual modalities in the context of dynamic attending to auditory temporal structure.

1. Introduction

London (2004) described musical meter as an "emergent property…" that is characterised by multiple, hierarchically-related periodicities over several time scales (Lerdahl & Jackendoff, 1983) and whose basis element is the beat. Thus, beats are best understood as a psychological phenomenon relating to the subjective emphasis of certain events or pulses that are equally spaced in time. It is this phenomenon of beat induction that makes it possible for several people to tap along to a rhythm, all tapping on the same beats and, typically, tapping on those beats that are perceived as salient. Furthermore, given the hierarchical nature of metrical structure in musical rhythms, not all beats are perceived with the same salience, and this leads to the percept of stronger and weaker events within a meter.

The Dynamic Attending Theory (DAT) (Jones & Boltz, 1989; Jones, Boltz, & Kidd, 1982; Large & Jones, 1999) describes these behaviours. DAT focuses on the role of a metrical structure as an active listening strategy, a dynamic structure whose main function is to facilitate future oriented attending, to direct perception and to coordinate behaviour with external events. In conceiving of meter in this way, DAT goes beyond simply modelling meter as a parsing of rhythmic information. The periodicities at each hierarchical level of a metrical structure are described as entraining a listener's neural oscillations and facilitating beat induction (Drake, Penel, & Bigand, 2000; Large, 2000). A computational implementation of DAT (Large & Jones, 1999; Large & Kolen, 1994) models this process as the coupling of internal oscillator periodicities with the external periodicities of the metrical stimulus (entraining stimulus) and predicts the modulation of attentional resources over time in correspondence with the induced percept of strong and weak beats. Consequently, temporal events coinciding with strong beats are more highly anticipated than others and this leads to a focusing of attentional resources around those more anticipated points in time; this has been referred to as anticipatory attending (Jones, 2004).

There is a wealth of research supporting the role of meter in generating temporal expectations and in orienting attention, and thereafter in affecting pitch accuracy judgements (Klein & Jones, 1996; Jones et al., 2002) and temporal just-noticeable differences (Jones & Yee, 1997). The behavioural support for the rhythmic control of attentional orienting in time has been further strengthened by results from neurophysiological studies. Such studies (Snyder & Large, 2005) also provide evidence that an implicit manipulation of expectancy for certain points in time is an innate ability, present among newborn infants (Winkler, Haden, Ladinig, Sziller, & Honing, 2009).

Thus, while there is good support for the DAT, one aspect has, in our opinion, been largely overlooked. Indeed, because the DAT is a rather general theory of attending, it predicts that orienting of attention should not be modality dependent. In other words, attentional

* Corresponding author.
E-mail address: daniele.schon@univ-amu.fr (D. Schön).

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entrainment should be similar in the auditory and visual modalities, and most importantly for the purpose of the present work, it should be cross-modal. The evidence that attentional entrainment by an auditory meter can also modulate visual attention was only recently presented by Escoffier, Yeo, and Schirmer (2010). In their experiment, subjects performed a speeded response, visual discrimination task in the presence of an auditory four-beat meter; subjects were instructed not to attend to this background meter. The results strongly support a role of auditory meter in attentional modulation by showing that perceptual judgements were faster when the visual stimuli were presented in synchrony with the background auditory meter than when they were presented out of synchrony with it.

Within this context the aim of our investigation was, firstly, to compare the effect of auditory metrical entrainment on both auditory and visual modalities. Secondly, we wanted to study the extent to which entrainment is affected by the difficulty of the task and by changes in attentional demands. Indeed, because dynamic attending is a theory of how attention is directed in time and because attentional resources are limited, it is very possible that dynamic attending will be affected by task attentional demands. For instance, a more demanding task (here discrimination vs detection) may reduce somewhat the effects of a co-occurring entraining stimulus, because less resources can be allocated to attend to it, yielding to a reduction of the amplitude of the attentional oscillations. Thirdly, we wanted to compare the entrainment effect using a simple auditory sequence, such as a metronome, with a more ecological stimulus such as a real musical performance. Finally, rather than using two conditions (on-beat and off-beat) we wanted to have a more "parametric" approach, thus we test entrainment effects at four different metrical positions.

On the basis of these four aims we ran two reaction time experiments investigating the effect of meter on temporal orienting. In the first experiment, participants had to respond as quickly as possible to the presentation of a visual or auditory target in the presence of an isochronous rhythm, which we refer to as an auditory entraining rhythm. The first part of this experiment involved simple detection of target stimuli, while, in the second part, participants had to discriminate targets. In the second experiment the isochronous entraining rhythm was replaced by an excerpt of classical music and participants performed a discrimination task on visual targets. Both experiments were designed such that targets appeared randomly on one of four selected metrical positions (MP) of the auditory entraining rhythm: first beat (MP1), middle beat (MP5) right before the first beat (MP8), and right before the middle beat (MP4). Fig. 1 presents an oscillator model with four metrical levels: the fluctuation of attentional energy is depicted over time as a function of the metrical salience of temporal positions composing our entraining rhythm. Indeed, on the basis of previous models of DAT (Large and Palmer, 2002), it can be considered that the less salient the metrical position is within a given meter, the less attentional energy will be attributed to it. Thus, from this figure one would expect the following order of RTs to targets (ascending, from fastest to slowest): MP1, MP5, MP8, and MP4.

2. Methods

2.1. Experiment 1: isochronous entraining rhythm

2.1.1. Participants

Fourteen participants (mean age: 29, seven females) were recruited. Seven participants had no musical training experience. The other seven participants had between 5 and 30 years of musical practice, a mean of 18 years. Participants were paid 10 Euros.

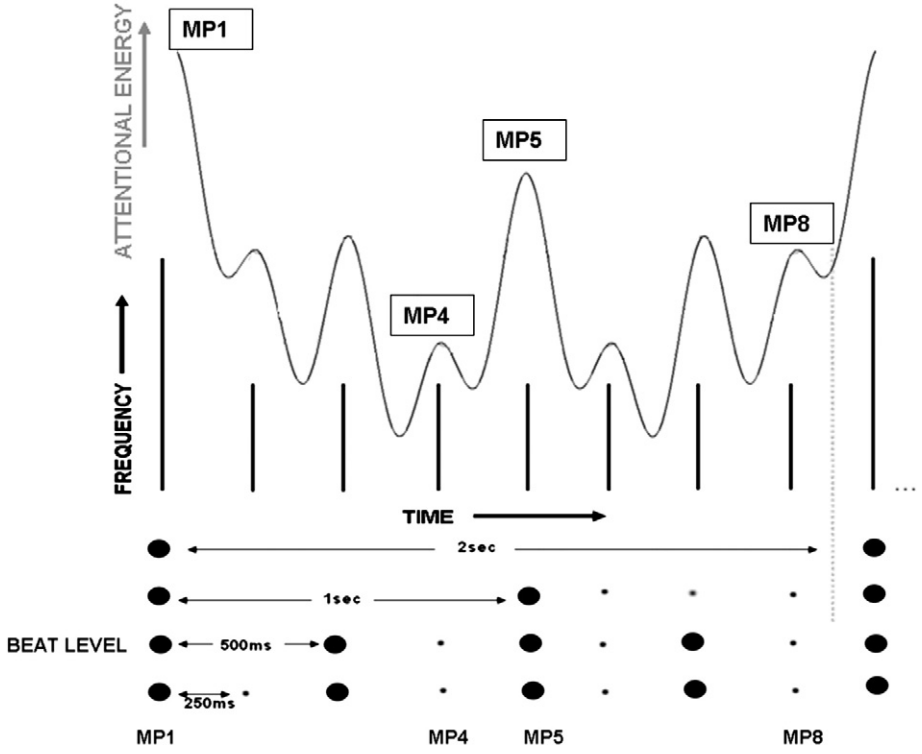

Fig. 1. Metrical structure of a single measure of the 8-tone isochronous entraining rhythm used in experiment 1. The sinusoidal tones composing the 8-tone pattern are represented by the black vertical lines, whose lengths indicate relative pitch level. Four levels of the rhythm's hierarchical, metrical structure are indicated by black circles. The assumed beat level, with an inter-beat interval of 500 ms, is indicated. Assuming this beat level, beat positions are marked by large black circles and non-beat positions by small dots. The four metrical positions (MPs) selected as the independent variables for both experiments are indicated below the tone and beat/non-beat position with which they coincide. The attentional curve, representing the variation of attention level as a function of the metrical structure is shown against the 8-tone measure. Based on the DAT, it represents the total output of a set of four oscillators whose periods are the 250 ms, 500 ms, 1000 ms and 2000 ms. For our purposes it illustrates hypotheses regarding the relative salience, in terms of attentional levels and expectancy, of each of our 4 MPs.