BEAT PERCEPTION IN A NON-VOCAL LEARNER: RATS CAN IDENTIFY ISOCHRONOUS BEATS

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The origins of rhythm in music and language seem to be intertwined and may share evolutionary pathways (Fitch, 2006, 2013; Patel, 2006, 2010; Ravignani and Madison, 2017). The development of song in birds and speech in humans follows similar sensorimotor phases and parallel periods of vocal learning (Marler, 1970, 1976), an ability that allows animals to imitate and modify the vocalizations learned from other individuals thanks to specific neural connections (Jarvis, 2006, 2007). For the last decade, the vocal learning beat perception and synchronization hypothesis (Patel, 2006; Patel, Iversen, Bregman, and Schulz, 2009; Schachner, Brady, Pepperberg and Hauser, 2009) has been widely accepted among researchers, proposing that only vocal learners can extract and entrain to a periodic pulse. However, current animal studies reported beat entrainment (Cook, Rouse, Wilson and Reichmuth, 2013) and auditory synchronization (Hattori, Tomonaga and Matsuzawa, 2013) in not classically classified vocal learners, and non-human primates display some rhythmic behaviors in social interactions (see Merchant and Honing, 2013; Ravignani, Gingras, Asano, Sonnweber, Matellán and Fitch, 2013).

To explore to what extent beat perception appears in non-vocal learners, we tested rats (Rattus norvegicus) in a go–no go paradigm. Several studies on comparative research have successfully used this paradigm with rats to discern what components of music and language are actually shared with other species (Crespo-Bojorque and Toro, 2015; de la Mora, Nespor and Toro, 2013). In the current study, thirty-two rats were trained to distinguish between isochronous and non-isochronous beats at four different tempi (Inter Onset Interval of 300, 400, 500 and 600 ms). Forty sequences of twelve pure tones were presented to the rats in each session, and those sequences that were isochronous were reinforced with pellets. For each reinforced isochronous stimulus there was a unique non-isochronous stimulus lasting the same time and comprising the same number of beats in an irregular pseudorandom pattern (see Figure 1). The

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deviant stimuli were never reinforced. Each standard-deviant couple had always the same temporal lapse between the first beat of the sequence and the last one.

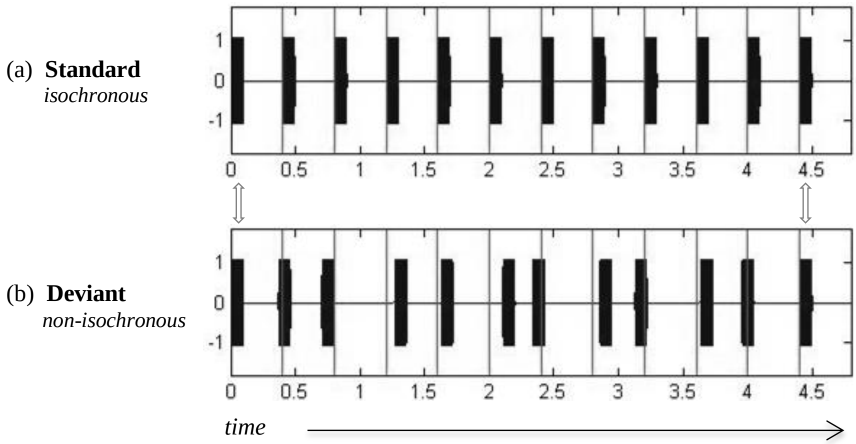

Figure 1. An example of (a) an isochronous stimulus and (b) its non-isochronous counterpart.

After the training sessions, rats were tested three times with ten isochronous stimuli at two new tempi (IOI of 350 and 550 ms) and their non-isochronous counterparts. During the tests sessions, rats never received reward for the new isochronous and non-isochronous stimuli. A 2-way repeated measures ANOVA with the within-factors Test (T1, T2, T3) and Stimulus (Standard, Deviant) revealed two significant main effects: the nose-poking behavior of rats increased at each test and was significantly higher for the standard stimuli. In other words, rats insisted more on receiving the pellets over time and succeeded in distinguishing the isochronous beats from the non-isochronous ones.

This first approach to beat perception suggests that the perceptual timing mechanisms underlying isochrony detection are not limited to vocal learners. This is in line with studies on regularity detection in birds (Spierings and ten Cate, 2016; ten Cate, Spierings, Hubert and Honing, 2016) and the neural responses to the beat found in anaesthetized gerbils (Rajendran, Harper, Garcia-Lazaro, Lesica and Schnupp, 2017). Next studies will focus on more complex metrical rhythms, similar to those used with the mimicking starlings (Hulse, Humpal and Cynx, 1984), to see whether rats are able to deal with beat perception and meter induction beyond the level of isochrony.

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