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Research Report

Evidence of beat perception via purely tactile stimulation

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ABSTRACT

Humans can easily tap in synchrony with an auditory beat but not with an equivalent visual rhythmic sequence, suggesting that the sensation of meter (i.e. of an underlying regular pulse) may be inherently auditory. We assessed whether the perception of meter could also be felt with tactile sensory inputs. We found that, when participants were presented with identical rhythmic sequences filled with either short tones or hand stimulations, they could more efficiently tap in synchrony with strongly rather than weakly metric sequences. These observations suggest that non-musician adults can extract the metric structure of purely tactile rhythms and use it to tap regularly with the beat induced by such sequences. This finding represents a challenge for present models of rhythm processing.

1. Introduction

From a very young age, most human beings will spontaneously tap their feet or move their bodies in synchrony with music (Trehub and Hannon, 2006; Drake et al., 2000a,b). This kind of motor behavior, described in all human cultures, reflects the processing of meter, which is regarded as a universal property of music and, more importantly, as a specific trait of human cognition (Drake, 1998; see London (2004) for a review). No other animal species seems to display this rhythmic ability, although many are able to produce regular movements (Patel, 2006). Perceptually, meter is experienced as the alternation of strong and weak beats according to an underlying regular pulse. More precisely, certain time positions within a metric musical sequence seem to be accented (strong beats) at regular time intervals. One accent every two beats leads to the sensation of a binary (or duple) meter, whereas one accent every three beats leads to a ternary (or triple) meter. Metric expectancies are automatically superimposed on any rhythmic sequence, depending on the meter inferred from the structure of the first events of the sequence (Keller and Repp, 2005; Repp, 2005). Metric accents may arise from differences in the physical attributes of the adjacent sounding events (longer, higher or louder tones). However, as the accenting process is subjective in essence, it also occurs if all the sounds of a regular sequence are physically identical (Povel and Okkerman, 1981; Brochard et al., 2003), as well as in the absence of certain sounding events (leading to the sensation of syncopation, Snyder and Large, 2004; Jongsma et al., 2005). The cerebral response to perceptual changes, occurring on stronger beats, is greater than that to weaker metric positions (Abecasis et al., 2005; Zanto et al., 2006; Potter et al., in press).

Recently, Patel et al. (2005) showed that it was almost impossible for human participants to extract the metric structure within the visual modality. When presented with sequences composed of short tones, participants had no difficulty synchronizing finger taps with clearly binary sound sequences, but they could not do so when presented with equivalent visual stimuli (flashes). These findings indicated that the processing of metric information may originate in the close and specific relationships between the auditory and sensorimotor

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systems. Similar relationships between the visual and sensorimotor systems, however, were not apparent, at least in the time domain. The human inability to infer meter from visual information was recently confirmed in adult participants presented with short ambiguous rhythmic sequences whose components could potentially be subjectively accented in a binary or ternary way (Phillips-Silver and Trainor, 2007). When preceded by an auditory sequence strongly stating a specific meter (either binary or ternary), grouping accents could be disambiguated according to the meter of this auditory primer. This effect was also observed when participants were asked to bounce their legs to a specific meter. However watching people move according to a binary or ternary meter had no effect on auditory accenting in motionless participants. Similar conclusions could be drawn from 7-month old infants (Phillips-Silver and Trainor, 2005).

It is unclear, however, if the ability to process meter is restricted to the auditory modality or if humans can feel the beat (i.e. the metric structure) outside the sound domain, for example through a different sensory modality. To answer this question, we compared auditory with tactile stimulations using an adaptation of the experimental procedure described by Patel et al. (2005). Participants were asked to tap with their right index finger as regularly as possible in synchrony with strongly metric patterns (Strongly Metric Sequences or SMS, see Figs. 1 and 2), in which the beat was easy to follow, or with weakly metric patterns (Weakly Metric Sequences or WMS), in which the beat was hard to extract from the temporal structure of all the rhythmic events. These rhythmic sequences were composed of identical short tones (auditory stimuli) or quick tickling of the tip of their left finger (tactile stimuli). If participants were able to extract metric information from a purely tactile stimulation, we expected their tapping to parallel the pattern of motor responses measured with auditory stimuli.

In addition, two other types of sequences served as controls. The first (I-800 condition in Patel et al. (2005)) consisted of the presentation of a sequence of the same length as that of the rhythmic sequences but completely isochronous (Inter-Onset Interval = 800 ms). This condition was designed to compare sensorimotor performance with regular sequences in the auditory and tactile domains since the relative superiority of sensorimotor coordination with an isochronous pace made of tactile and auditory inputs is unclear (see for example Al-Attar et al. (1998); or Müller et al. (2008)). The second control condition (absent from Patel et al. (2005)) consisted of an inducer segment composed of only 9 initial isochronous beats (IOI = 800 ms) followed by a period of silence during which participants were asked to continue tapping with the same pace as that of the inducer (see Fig. 1). This condition was designed to estimate how participants would keep a steady pace in the absence of any sensory stimulation. Pacing performance in silence was thus expected to be the poorest of all conditions since the to-be-produced interval (800 ms) was delineated by existing onsets of events in the three other conditions.

2. Results

We performed an ANOVA on inter-tap variability (Standard Deviation of inter-tap intervals), with the type of sequence (isochronous, SMS, WMS, silence) and the sensory modality (auditory vs. tactile) as within-subject factors (Fig. 3). This analysis showed that only the type of sequence had a significant main effect ($F(3, 27) = 26.053$, $p < 0.001$), whereas sensory modality did not ($F(3, 27) = 0.37$, $p = 0.78$), and the interaction between the two factors was not statistically significant ($F(1, 9) = 3.12$, $p = 0.11$), these findings are in good agreement with values of tapping accuracy measured under equivalent auditory conditions (Patel et al., 2005). However, results using visual stimuli did not resemble auditory stimulation (Patel et al., 2005). Whereas tapping with the beat was more accurate with auditory SMS compared to WMS, no statistical difference was found between the visual SMS and WMS. In our experiment, the motor performance measured with tactile stimulation parallels very

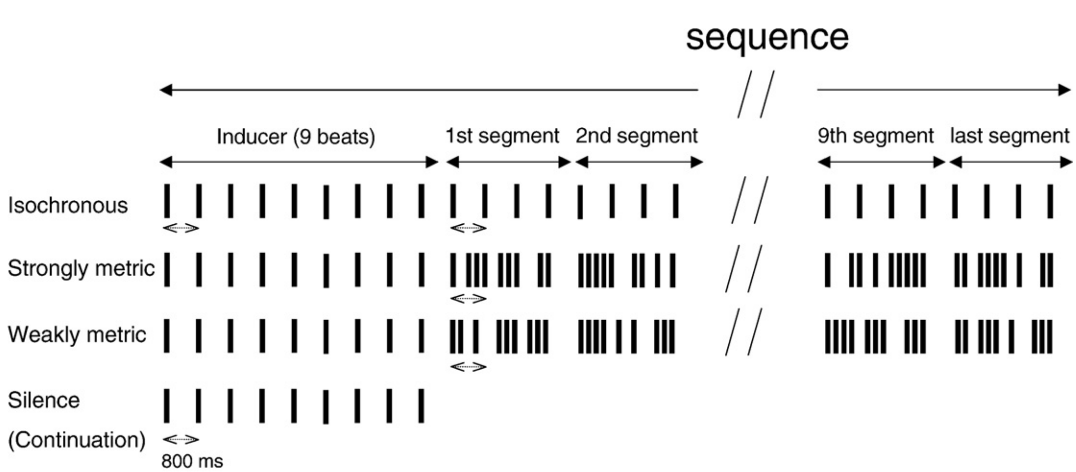

Fig. 1 – Representation of the four experimental conditions. Each vertical bar represents one sensory event (auditory or tactile stimuli). The dotted arrows represent the time interval between two beats (Inter-Onset Interval = 800 ms). For strongly and weakly metric sequences, the 10 segments following the inducer were randomly selected from two sets of 15 segments (see Fig. 2).