SYNCHRONIZATION WITH BEATS IN DIFFERENT MODALITIES AND TEMPI

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Abstract

The current study compares synchronization with beats presented in various sensory modalities and tempi. Although beat perception and synchronization (BPS) has been studied extensively in auditory and visual modalities, relatively few have looked into and compared that in the tactile modality. We conducted an experiment in which participants had to tap in synchrony with fast (inter onset interval of 400 ms), middle (800 ms) and slow (1200 ms) beats that were presented either in single or in combinations of auditory, visual and tactile modalities. Preliminary results indicated that participants tended to fail in synchronizing with fast visual beats while they succeeded to synchronize with fast auditory and visual beats. This corresponds to the rate limits of visual BPS reported in previous studies. Although there was no significant difference between auditory and tactile BPS when beats were presented in a single modality, the tactile BPS performance was more influenced by the presence of visual inputs than the auditory BPS performance when beats were jointly presented in multiple modalities. Adding visual or tactile beats did not significantly influence the auditory BPS performance. These findings support the ideas that audition has a higher affinity for temporal information processing and that multimodal BPS tends to depend on inputs from the modality that is more efficient in dealing with temporal information.

The beat of a rhythm is a perceived pulse that marks equally spaced points in time (Large & Palmer, 2002). Synchronizing one's body movements to the beat of a musical rhythm seems very simple and easy because it requires little conscious effort (Patel, Iversen, Chen and Repp, 2005). However, it may not be that straightforward because it is a cognitive function that is believed to be unique to human (but see Patel, Iversen, Bregman, Schultz & Schultz, 2008). Mainly two cognitive functions, namely, beat perception and synchronization (BPS), allow us to realize this.

How do we integrate and process information of the beat obtained through different sensory organs, such as auditory, vision and tactile modalities? According to Patel et al. (2005), the rate limits for different sense organs reflect the precision with which temporal information is encoded in neural activity in the corresponding brain areas. Consequently, the efficacy of sensorimotor coupling, that is the degree of which temporal information is able to drive actions, is dependent on the sense organ to which the temporal information is presented. For example, it is more difficult to perform BPS to fast visual beats as compared to auditory beats (Dunlop, 1910). Repp (2003; 2006) reported that the coordination of motor activity with visual beats breaks down when the inter-onset interval (IOI) between the beats is shorter than around 460 ms. This rate limit is almost four times shorter for auditory beats, which suggests that audition has a higher affinity for temporal information processing than vision.

The current study compares BPS to tactile beats with that to auditory and visual beats. We also investigated how BPS performances with temporal beats presented in multiple sensory modalities (multimodal BPS) relate to that with beats presented in single sensory modality (unimodal BPS). Three hypotheses are considered. First, multimodal BPS performance is simply an additive function of the unimodal parts. According to this hypothesis, multimodal BPS performances should be better than the best unimodal BPS performance that is included. Second, the BPS performance is determined by a rate limit of the most efficient sensory modality and presenting additional information in less efficient sensory modalities does not influence the task performance. In this case, multimodal BPS performance should be equal to the best unimodal BSP performance that is included. Third, simultaneous presentation of additional information in other modalities hinders the BPS performance; presenting more information may cause an interaction in the processing. In this case, multimodal BPS performance should be worse than the best unimodal BSP performance that is included.

In the current study, we employed a tapping experiment in which participants tapped to beats provided in auditory, visual and tactile modalities as well as all possible combination of these modalities.

Method

Twelve college students of Radboud University Nijmegen participated in the study (4 male and 8 female). Their mean age was 23, ranging from 20 to 28. They received no payment.

Three different tempi were used: IOI of 400 ms (fast), 800 ms (medium), and 1200 ms (slow). A bright red filled circular flash with a diameter of 17 cm was used as the visual cue. A white noise click of 25 dB was used as the auditory cue. A tactile stimulator moving up and down all pins was used as the tactile cue. All cues lasted 10 ms. Participants were instructed to tap to the beat as accurately as possible. They were instructed to wait for two beats before start tapping in order to establish the sense of tempo. To begin with, participants practiced the task with 40 beats (IOI of 600 ms) that were cued by all three sensory modalities. After the practice session, the real experiment started, consisting of 21 trials of 40 beats.

The experiment yielded a within-subject design. The order of trials was counterbalanced with respect to three tempi and randomized with respect to sensory modalities (auditory, visual, tactile, audio-visual, visual-tactile, audio-tactile, and audio-visual-tactile). Between trials, participants had to tap once to continue. The total duration of the experiment was about 12 minutes.

Results

We analyzed the percentage of phase drifts in a trial. The phase drift was defined as a trial including taps with asynchrony larger than 2.5 times of the overall standard deviation. The first 10 taps in each trial were excluded from the analysis.

Fig. 1 presents the percentage of phase drifts. An overall tendency to drift away from the beat was very common (26%), especially in trials with IOI of 1200 ms (37%). Data was analyzed using a repeated measure ANOVA with sensory modality (audio, visual, tactile) and the combinations (audio-visual, audio-tactile, visual-tactile, audio-visual-tactile), hereafter termed simply as condition, as well as tempo (400 ms, 800 ms, 1200 ms) as nested within-participant factors. A significant effect of condition was observed ($p<.0005$, $\eta2=.407$). There was a significant interaction between condition and tempo ($p<.0005$, $\eta2=.205$). More detailed comparisons are provided in following sections.

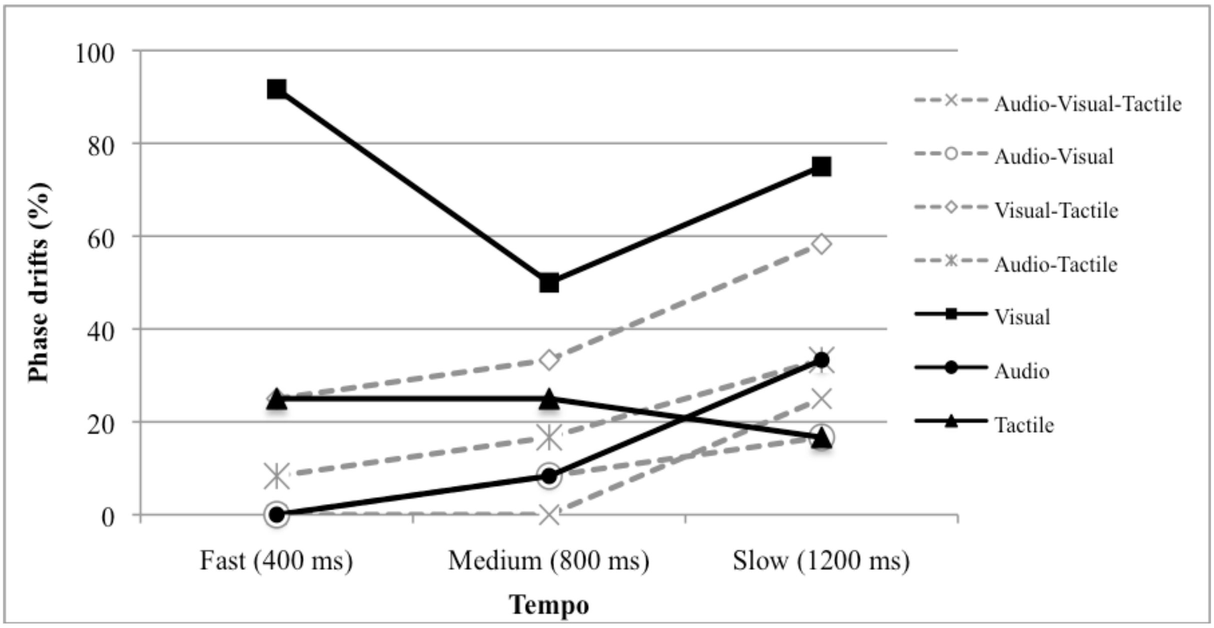

Fig. 1. The percentage of phase drifts for 7 conditions and 3 tempi. The maximum (100%) indicates that all 12 participants showed phase drift in their BPS performance.

Unimodal BPS

This section discusses the differences and similarities between unimodal BPS performances in auditory, visual and tactile conditions. In general, the percentage of drifts was much lower for the auditory and tactile BPS than for the visual BPS. The most striking effect was found for the visual BPS performance on the fast tempo; 91.7% of total observations (11 out of 12 participants) showed a tendency to drift. This replicates the previous finding that visual BPS performance breaks down at tempi faster than the IOI of 460 ms (Repp, 2006). The post-hoc comparison revealed that although the tactile BPS performance was significantly better than the visual BPS performance at slow and fast tempi (400ms $p<.01$, 800ms $p=.19$, 1200ms $p<.01$), it was not significantly different from the auditory BPS performance.

Multimodal BPS

Adding other modalities did not enhance the best unimodal BPS performance that was included. Thus, the first hypothesis, which states the multimodal BPS being an additive function of the unimodal parts, is rejected. Instead, the second hypothesis, which states the multimodal BPS performance being about as good as the best unimodal BPS performance that is included, seemed to be supported for all multimodal conditions including audio beats (audio-visual, audio-tactile and audio-visual-tactile conditions). Irrespective of the presence of the visual and tactile beats, BPS performance of these conditions remained at the level as the unimodal auditory BPS performance.

Interestingly, this may not be the whole story. The percentage of drifts representing visual-tactile condition at a tempo with IOI of 1200 ms was much higher than the line representing the unimodal tactile BPS performance. Thus, the tactile BPS performance became worse in the slow condition when visual cues were present. Therefore the third hypothesis, which predicts interference among information inputs in multimodal conditions, was true for this case. This may indicate that the tactile BPS performance is more distractible than the auditory BPS performance because this effect was not observed for any conditions including audio beat presentation.

Discussion

The current study replicated the previous finding that auditory BPS performance outperforms visual BPS performance. We further demonstrated that tactile BPS performance also outperforms visual BPS performance. When beats were presented in a single modality, there was no evidence for auditory BPS performance being better than tactile BPS performance. However, when beats were jointly presented in multiple sensory modalities, auditory BSP performance seemed to be more stable than the tactile BPS performance because the tactile BSP performance was influenced by the presence of visual beats. This extends the previous finding; hearing, as compared to vision and touch, has a higher affinity for temporal information processing. Repp and Penel (2004) reported that auditory distractors affect visual BPS much more than visual distracters affect auditory BPS. A similar approach could be taken to further investigate stability of auditory BPS and tactile BPS.

We found that multimodal BPS performance is roughly equal to performance of the best unimodal BPS that was included in many conditions (especially ones including auditory beat presentation). This may indicate that multimodal BSP tend to depend on the inputs from a modality that is more efficient in dealing with temporal information. Consequently, an additional presentation of information in a less efficient sensory modality may not contribute to enhance the performance and it may even hamper the performance in some cases.

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