MOVING TO THE BEAT IMPROVES TIMEKEEPING IN A RHYTHM PERCEPTION TASK

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1. INTRODUCTION

The relationship between perception and action is of recent interest in psychological research (Hommel, Musseler, Aschersleben, & Prinz, 2001), and particularly in music perception (Phillips-Silver & Trainor, 2005; Repp & Knoblich, 2007; Zatorre, Chen, & Penhune, 2007). We explored this issue through a novel paradigm designed to measure the effect of "moving to the beat" when listening to an auditory rhythm. Specifically, we investigated the effect of tapping on participants' sensitivity to changes in the temporal location of a probe tone. In doing so, we have documented a novel perception-action link by showing the importance of moving when timekeeping while performing an objective task, using participants selected without regard for musical training.

2. EXPERIMENT 1

2.1 Method

The experiment was conducted using a customized program design by the MAPLE lab at McMaster University. Tones were presented to participants through headphones and participants tapped on an electronic drum pad. Each trial consisted of fourteen tones divided into groups of four, occurring in a repeating pattern (Figure 1). The first tone of each grouped pattern was "accented" using a higher relative pitch (C5; ~523Hz) than the unaccented tones (G4; ~392Hz). In the last group, the 2nd, 3rd and 4th tones were silent. The four groups were followed by a final probe tone. In half of the trials the probe tone was consistent with the pattern (offset = 0ms), and in the other half of the trials the probe tone was inconsistent with the pattern at one of four offset positions; 30% of the inter-onset interval (IOI) early or late, or 15% of the IOI early or late. The pattern of tones was presented at two different IOIs; 400ms and 600ms.

During the experiment, participants were presented with a total of 64 trials; eight blocks each containing eight trials. Half of the blocks employed an IOI of 400ms and the other half employed an IOI of 600ms. Within the four blocks of each IOI, participants were asked to tap along to two of the blocks ("tapping" condition) and asked to not tap during the other half of the blocks ("non-tapping" condition). Within each block, four of the trials included a final probe tone that occurred at the "correct" time (i.e., an offset of 0ms), and four of the trials the probe tone occurred at the "incorrect" time; 15% or 30% of the IOI early, or 15% or 30% of the IOI late. Participants were presented with each of the four IOI (400ms, 600ms) X Tap condition ("tapping" or "non-tapping") combinations twice to make a total of eight experimental blocks. The order of the experimental blocks and the order of the trials within each block of the experiment were also randomized for each participant.

During "tapping" blocks, participants tapped on a drum pad using a drumstick for all beats including the probe tone. During the "non-tapping" blocks, participants were instructed to remain as still as possible. For each block, participants were asked to judge whether the final probe tone was "on-time" (i.e., positioned on a down-beat).

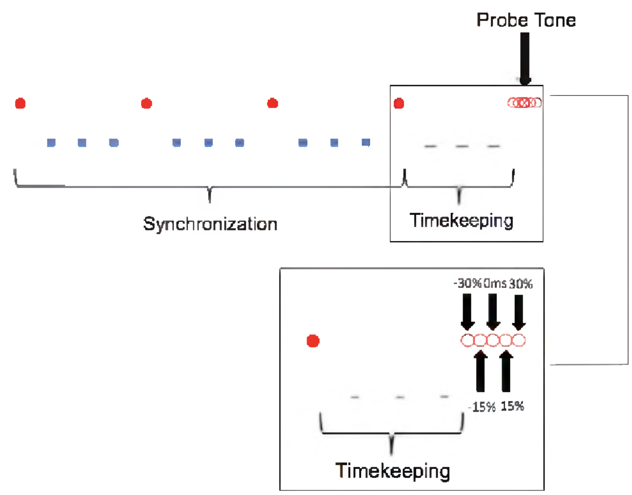

Figure 1. One trial with synchronization and timekeeping periods labeled.

Participants included 48 undergraduate students (32 females), ranging in age from 17 to 35 years (M = 18.6 years, SD = 2.65), from the undergraduate psychology participant pool. Participants reported normal hearing and normal or corrected-to-normal vision. All participants gave informed consent and were remunerated with course credit for their participation.

2.2 Results

The proportion of correct responses on perceptual timing judgments was generated by taking an average of the percentage of responses that were correct. These scores were assessed using a 2(IOI) X 5(offset) X 2(tap-instruction) repeated-measures ANOVA.

As expected, there was a main effect of offset ($F_{4,188}$ = 48.656, p < 0.0001), indicating that participants were sensitive to the timing of the probe-tone. However, the most important finding was a main effect of tapping ($F_{1,47}$ =

25.178, $p < 0.0001$), reflecting a difference in task performance between the with-tap and without-tap conditions. Additionally, a two-way interaction was observed between tap-instruction and offset ($F_{4,156} = 13.882$, $p < 0.0001$), indicating that tapping affected responses differently at different probe-tone locations (Figure 2).

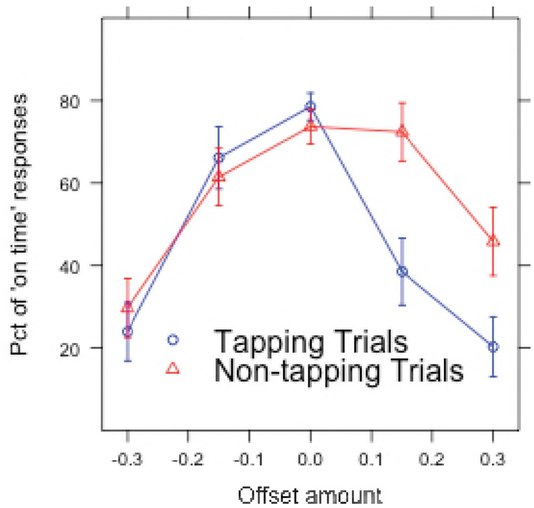

Figure 2. The proportion of responses indicating an "on-time" probe tone in experiment 1. Error bars indicate a 95% CI.

3. EXPERIMENT 2

Experiment 1 demonstrated a clear effect of tapping on task performance. Experiment 2 extended that work by exploring the segment of the tapping (i.e., synchronization vs. timekeeping) driving this effect.

3.1 Method

Experiment 2 differed from Experiment 1 only with respect to the instructions during the "tapping" blocks. Here, participants were instructed to tap for only the sounded beats (i.e., the synchronization measures and the probe tone) and to remain still for the "silent" beats – a.k.a. the timekeeping measure (see Figure 1 for details).

Participants included 49 undergraduate students (36 females), ranging in age from 17 to 24 years ($M = 18.7$ years, $SD = 1.15$), from the undergraduate psychology participant pool. Participants reported normal hearing and normal or corrected-to-normal vision.

3.2 Results

Once again, there was a main effect of offset ($F_{4,192} = 14.014$, $p < 0.0001$), participants were sensitive to the location of the probe tone. However, the most important finding was the lack of a main effect of tapping ($F_{1,48} = 1.799$, $p = 0.186$), indicating no significant difference between performance during the tapping and non-tapping trials. Therefore, movement appears to affect responses only when it occurs during the timekeeping phase.

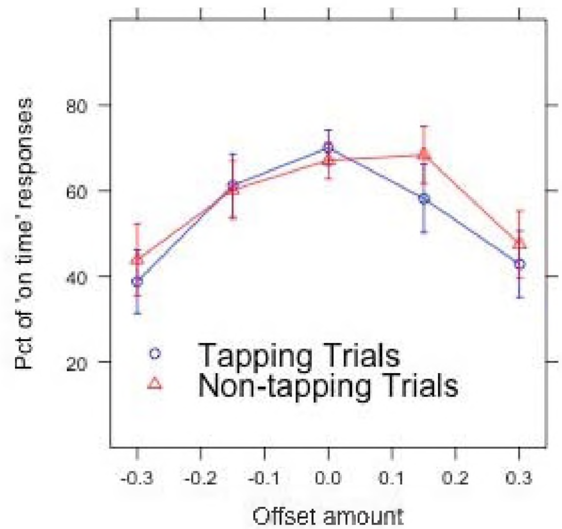

Figure 3. The proportion of responses indicating an "on-time" probe tone in experiment 2. Error bars indicate a 95% CI.

4. DISCUSSION

Experiment 1 demonstrates that tapping affects participants' ability to detect timing variations in the location of a final probe tone. This effect was eliminated when movement during the timekeeping (silent) measure was omitted in Experiment 2. Together, these experiments show that moving along to a perceived beat improves timekeeping in the absence of an external signal.

The effect of movement on rhythm perception is consistent with previous work showing that movement can affect the perception of metrically ambiguous stimuli (Phillips-Silver & Trainor, 2005). Therefore these results also add to the growing literature on the role of timing in perception (Repp, 2002), as well sensorimotor interactions in music perception and performance (Zatorre et al., 2007). Our data suggest that rhythmic movement may act as a surrogate for timekeeping in rhythmic music, an issue of great practical importance for music performers and listeners alike.

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