Effects of Auditory Imagery on Movement Timing and Kinematics during Music-like Performance

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Introduction

Musicians engage in auditory imagery when planning their forthcoming actions during performance (Keller & Koch, 2008; Trusheim, 1993).

The manner in which such anticipatory auditory imagery is employed can influence several aspects of performance quality, including the degree to which precise temporal goals are met. Accordingly, Keller and Koch (2006) found that timing accuracy in a task that required short auditory sequences to be produced at a steady tempo was affected by whether upcoming (high vs. low) pitches were compatible or incompatible with planned (upward vs. downward) movements on the cross-modal 'height' dimension.

The current study further investigated the effects of anticipatory auditory imagery on music-like performance by examining movement kinematics in addition to timing accuracy. Our goal was to discover how auditory imagery affects timing accuracy through its effects upon the control parameters that govern movement trajectories.

Method

The experimental task, which was based on Keller and Koch's (2006) task, required musicians (N = 30) to respond to each of 4 colour-patch stimuli by producing a unique sequence of 3 finger taps on 3 vertically aligned keys (Fig. 1).

The colour-patch stimulus in each trial flashed 3 times with a 600 ms inter-onset interval, and participants tapped their responses as regularly as possible at this tempo after a further 3 flashes of a neutral 'lead-in' stimulus (Fig. 2).

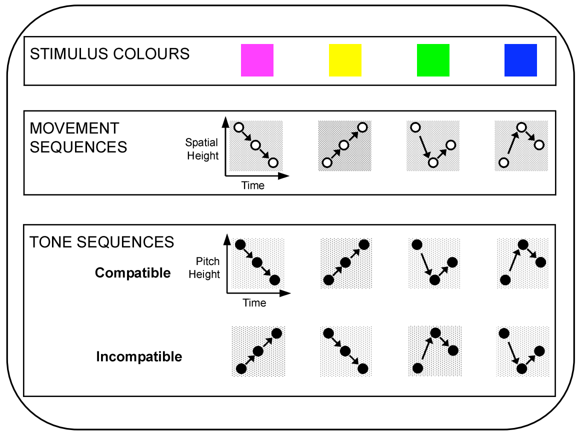

Fig. 1: Mappings between colour-patch stimuli, response sequences, and (compatible and incompatible) melodic contours.

Auditory feedback was manipulated (between counterbalanced experimental blocks) to yield three conditions:
(1) *Compatible* – taps triggered marimba tones with pitches F4, G4, and A4, resulting in melodic contours that were congruent with movement transitions (Fig. 1);
(2) *Incompatible* – the compatible key-to-tone mapping was reversed (Fig. 1);
(3) *Silent* – taps did not trigger feedback tones.

Assumption: Effects of the above feedback manipulations on the first movement of each sequence are attributable to the presence or absence of auditory imagery (while subsequent movements may be affected by both imagery and auditory perception).

Kinematic data collection: 3D finger position was sampled at 250 Hz by an Optotrak motion capture system.

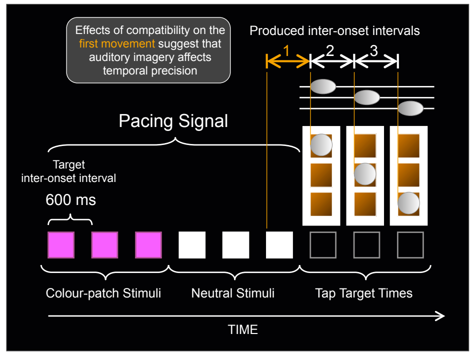

Fig. 2: Schematic representation of events from a single experimental trial.

Conclusion

Anticipatory auditory imagery plays a role in making movements direct and 'graceful', though not necessarily 'temporally precise' when the instructed goal is to be mechanically regular. This may reflect biomechanical efficiency, a restrained yet buoyant 'touch', or both of these qualities. In any case, the apparent favoring of gracefulness over precision is consistent with the claim that humans strive to produce movements that are "smooth and graceful" unless task demands (e.g., time pressure) make it impractical to do so (Hogan & Flash, 1987, p. 170).

The proposed relation between anticipatory auditory imagery and graceful movement may be mediated by a phenomenon known as anchoring. Anchoring occurs when cyclic movements are timed with reference to a discrete point within each cycle (Beek, 1989). In music performance, auditory images may serve as endogenous cross-modal anchors that provide a scaffold upon which continuous movement dynamics can hang. The specific (Compatible vs. Incompatible) effects of auditory imagery that we observed suggest that some anchors are more stable than others.

Results

Planned contrasts were used to test for nonspecific (Compatible and Incompatible combined vs. Silent) and specific (Compatible vs. Incompatible) effects of auditory imagery on movement timing and kinematics.

Timing accuracy
Interestingly, tap timing was more accurate in the Silent condition than in the Compatible and Incompatible conditions combined. However, as expected, timing accuracy was greater in the Compatible condition than in the Incompatible condition (Fig. 3).

Silent vs. (Compatible & Incompatible) Tones $p = .01$
Compatible vs. Incompatible $p < .05$

These effects were present for the first tap (i.e., before the onsets of tones in conditions with auditory feedback).

Silent vs. Tones $p < .05$
Compatible vs. Incompatible $p < .05$

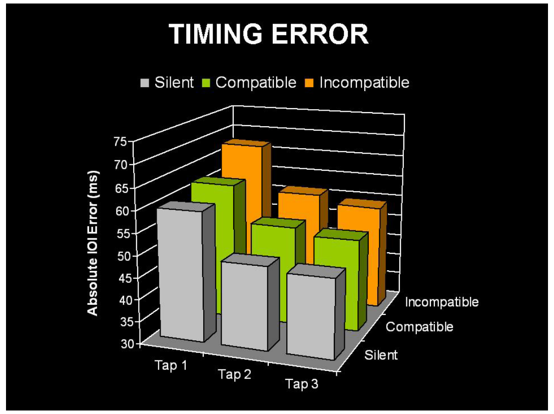

Fig. 3: Absolute timing error for the three taps in each condition.

Kinematics
Measures of distance traveled, velocity, and acceleration were computed from the 3D position data for movements associated with each tap for each sequence in each condition. Results for the first tap are reported here (similar effects were observed for all three taps).

Distance: Auditory imagery generally encouraged direct movement paths (Fig. 4).

Silent vs. Tones $p < .001$
Compatible vs. Incompatible $p = .34$

Velocity and acceleration: Auditory imagery encouraged a less forceful approach to key contact, especially when melodic contours and movement transitions were compatible (Figs 5 & 6).

Silent vs. Tones $ps < .001$
Compatible vs. Incompatible $ps < .01$

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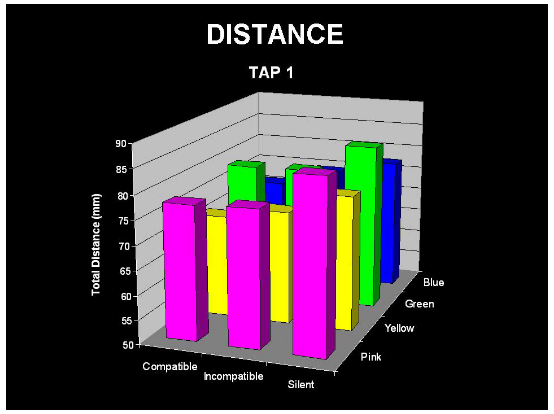

Fig. 4: Distance travelled for the first movement in each condition.

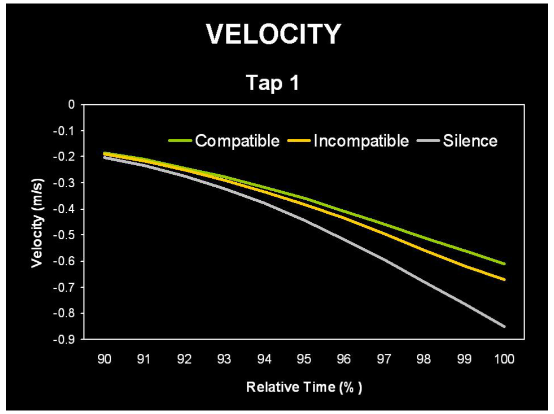

Fig. 5: Velocity during the final 10% of the first movement (collapsed across different responses).

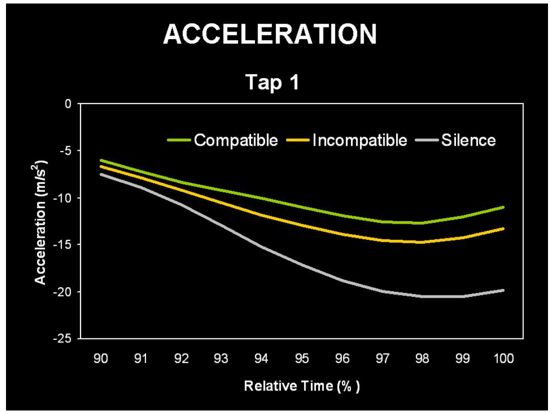

Fig. 6: Acceleration during the final 10% of the first movement (collapsed across different responses).