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CRNL

Thresholds of auditory-motor coupling measured with a simple task in musicians and non-musicians: Was the sound simultaneous to the key press?

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Introduction

Many motor actions have sensory consequences. For example, we see our hands displace when we move them, and our steps make sounds. The human brain is able to predict the sensory effects of its actions, enabling it to distinguish between self-generated and environment-generated sensory information (Aliu et al, 2009).
In this study, we investigate auditory-motor sensitivity and ask:
- **How precise are these predictions?**
- **Is precision dependent on expertise (musicianship)?**
- **How is this capacity related to other auditory or auditory-motor capacities?**

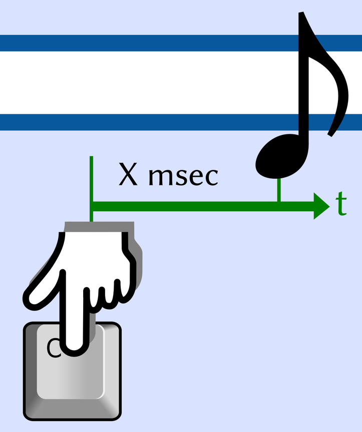
The present research proposes a new tool to measure thresholds for the perception of simultaneity of a simple action and a sound.

Aim

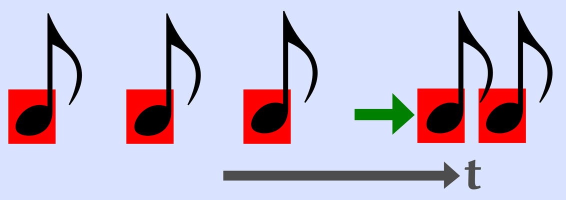
Hypothesis A	Musicians have lower auditory-motor delay thresholds than nonmusicians.
Hypothesis B	For pianists, finger movements are immediately coupled to sounds. Therefore, pianists have lower auditory-motor delay thresholds than brass players.
Hypothesis C	Performance in the delay detection task is explained as a combination of temporal accuracy (anisochrony), sensorimotor synchronisation accuracy and musicianship.

Tasks

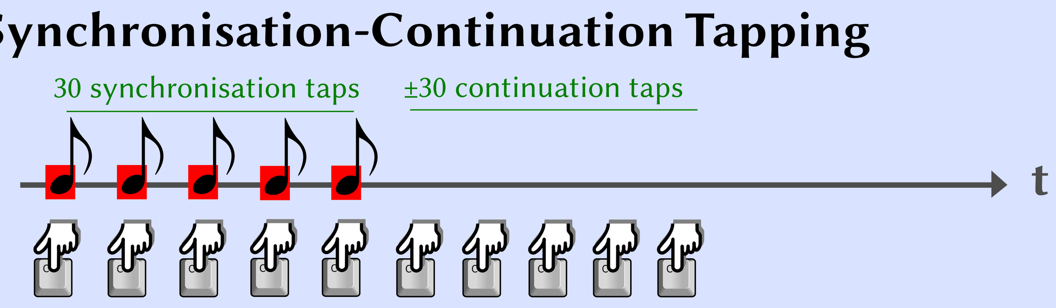
Auditory-motor delay detection
Was the sound simultaneous to the keypress?
response: simultaneous / delayed



Anisochrony (auditory only)
Was the fourth note delayed or on time?

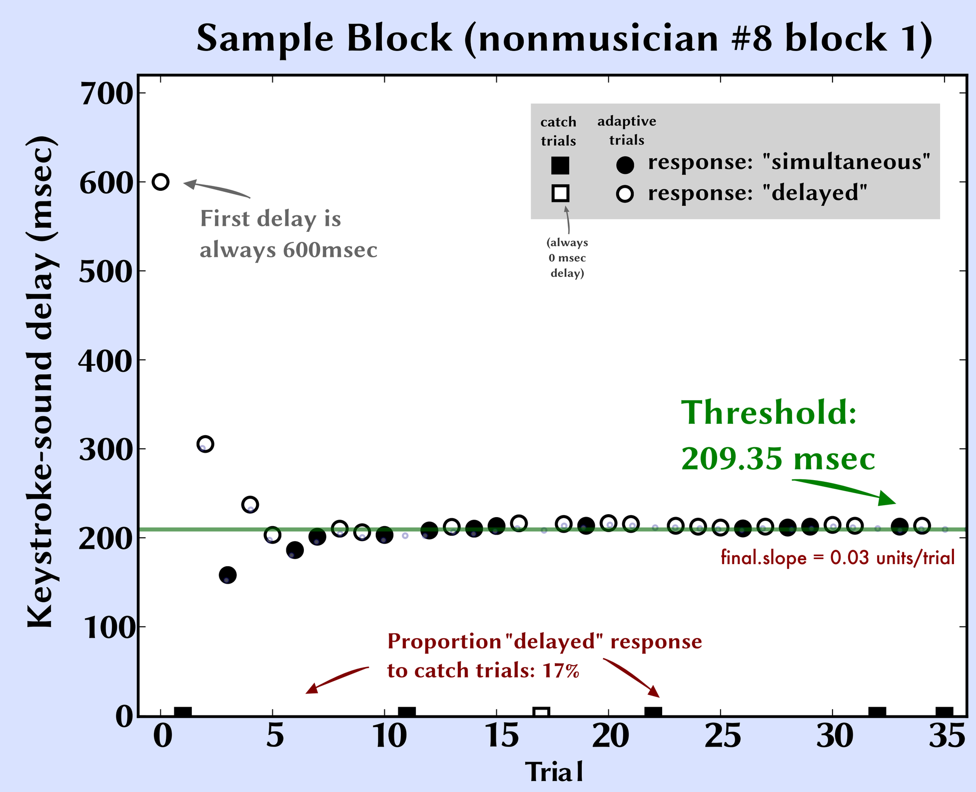


Synchronisation-Continuation Tapping

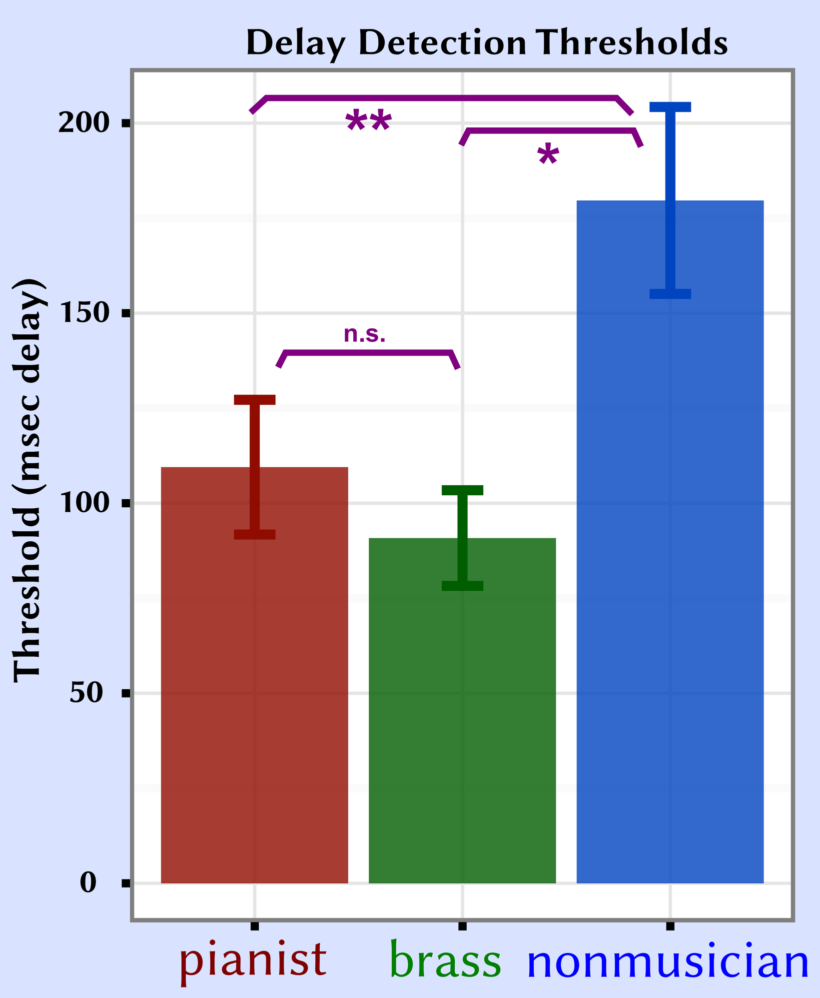


Maximum Likelihood Procedure

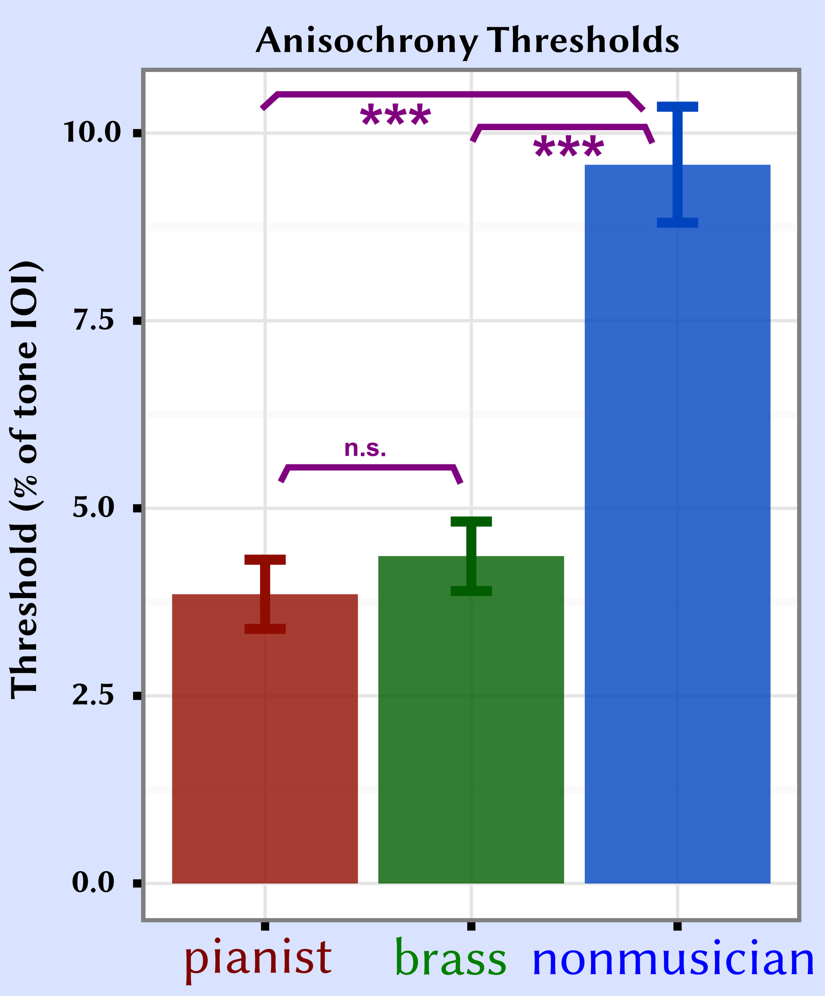
Thresholds are detected using the **Maximum Likelihood Procedure** (MLP; Green, 1993) as follows. We maintain a large set of possible psychometric curves, differing in curve midpoint (threshold) and vertical curve offset (false alarm rate). For each, we determine how likely it makes the set of all answers of the participants. The maximally likely curve is selected. Its sweetpoint determines the next asked stimulus level. MLP converges quickly to the participants' threshold.



Results



Musicians showed lower thresholds in delay detection (left) and anisochrony (right); but no differences appeared between pianists and brass players.



With anisochrony thresholds as a covariate, the musicianship effect on delay detection vanished (p=.47).

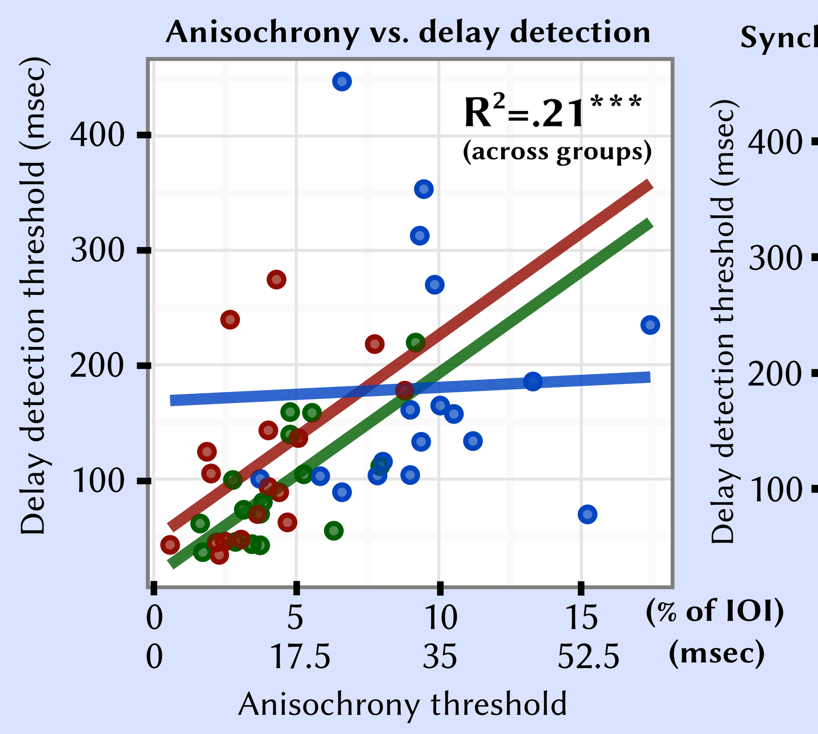
Participants

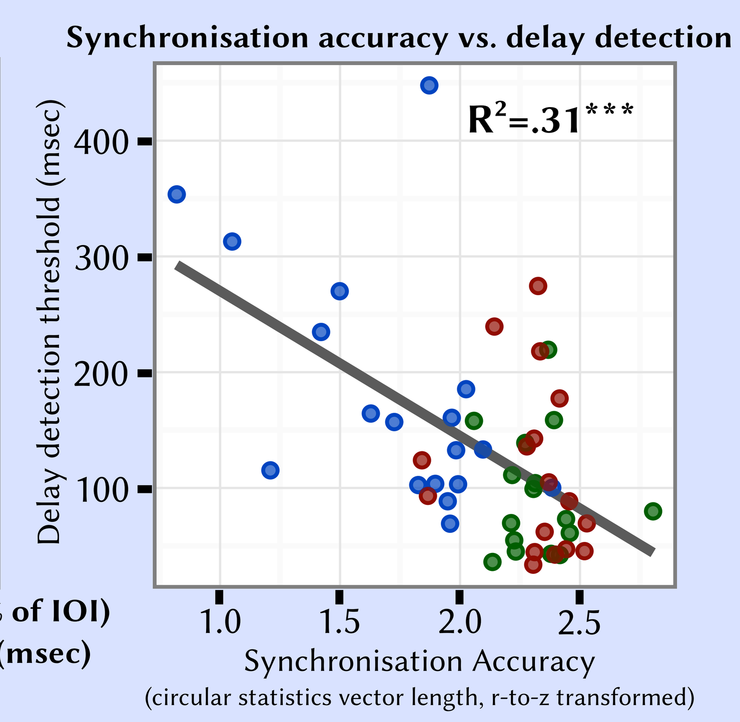
We recruited pianists and brass players (without substantial piano experience) from the student and young professional pool in the Hanover Music University. A nonmusician group of roughly the same age and gender distribution served as controls.

	pianist	brass	nonmusician	
N	20	18	18	
Gender (female/male)	10/10	7/11	8/10	$\chi^2(2)=.47$, p=.79
Age (years)	26.1 (5.7)	24.9 (3.5)	26.2 (4.7)	Kruskal-Wallis $\chi^2(2)=1.07$, p=.59
Handedness (Laterality Quotient in %)	73.4 (19.9)	75.3 (16.5)	78.1 (20.0)	Kruskal-Wallis $\chi^2(2)=1.10$, p=.58
Capable of blind typing (10 fingers/less than 10 fingers/none)	2/14/4	7/10/1	5/10/3	Kruskal-Wallis $\chi^2(2)=4.67$, p=.10
Video game use in hours per week (none / <1h / 1-7h / >7h)	16/3/1/0	10/7/1/0	13/1/3/1	Kruskal-Wallis $\chi^2(2)=2.09$, p=.35
Use of text messaging on cell phone in hours per week (none/ <1h / 1-7h / >7h)	7/9/4	4/12/2	10/4/4	Kruskal-Wallis $\chi^2(2)=1.42$, p=.49
Age of onset of musical training (years)	6.65 (2.2)	9.78 (3.1)	NA	t(30.5)=-3.56, p=.001**
Accumulated practice time on principal instrument (x10,000 hours)	22.6 (10.5)	13.1 (8.1)	NA	t(35.3)=3.15, p=.003**
Years of musical practice	19.5 (5.6)	15.1 (3.6)	NA	t(32.6)=2.90, p=.007**
Current daily practice time (hours)	3.7 (2.2)	3.3 (1.8)	NA	t(35.6)=0.68 p=.50
Absolute hearing (yes/no; self-reported)	7/13	0/19	NA	Fisher Exact Test p=.009**

*Table 1: Basic information about the three groups of participants. Data is reported as mean (SD) unless otherwise specified. Uncorrected significance is indicated: *p<.05, **p<.01, ***p<.001*

Comparing the tests





Combined ANCOVA with delay detection threshold as dependent variable:

Anisochrony threshold is significant predictor [F(1,46)=14.87, p=.0004]. Anisochrony **slopes** differ by group [F(2,44)=3.33, p=.045].

Synchronisation accuracy is a significant (additional) predictor [F(1,46)=9.29, p=.004]. Synchronisation **slopes** do not differ by group [F(2,44)=.86, p=.43].

Conclusion

These findings suggest that the brain has a relatively large window of integration (100-200 msec) within which an action and its resulting effect are judged as simultaneous. This stands in contrast to thresholds for judging two auditory events as asynchronous, which are usually of the order of milliseconds. However, visual and auditory events simultaneity thresholds are usually around 150msec, in line with our findings (Stevenson & Wallace, 2013).

Participants' capacity to judge simultaneity of movement and sound was explained as a combination of temporal perceptual accuracy (anisochrony) and sensorimotor synchronisation accuracy. Both of these varied with musicianship, which did not additionally explain thresholds for audio-motor synchrony judgements.

This novel paradigm provides a simple test to estimate the strength of auditory-motor action-effect coupling that can readily be incorporated in a variety of studies investigating both healthy and patient populations.

See **poster #40 (van der Steen et al)** for an application of this paradigm in a **Musician's Dystonia** population.

References
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