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Fine temporal deviations in scale playing reveal motor program chunking

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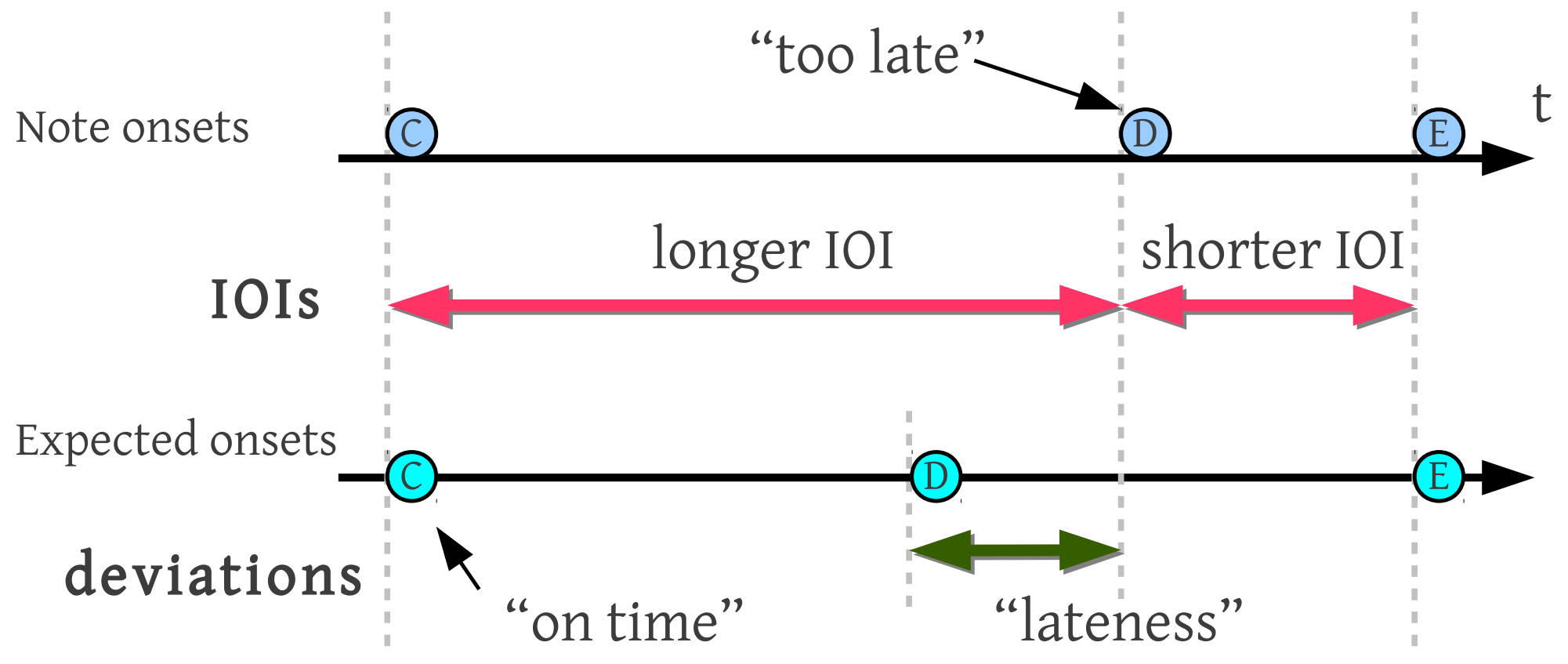
Factors that contribute to timing deviations in scale playing

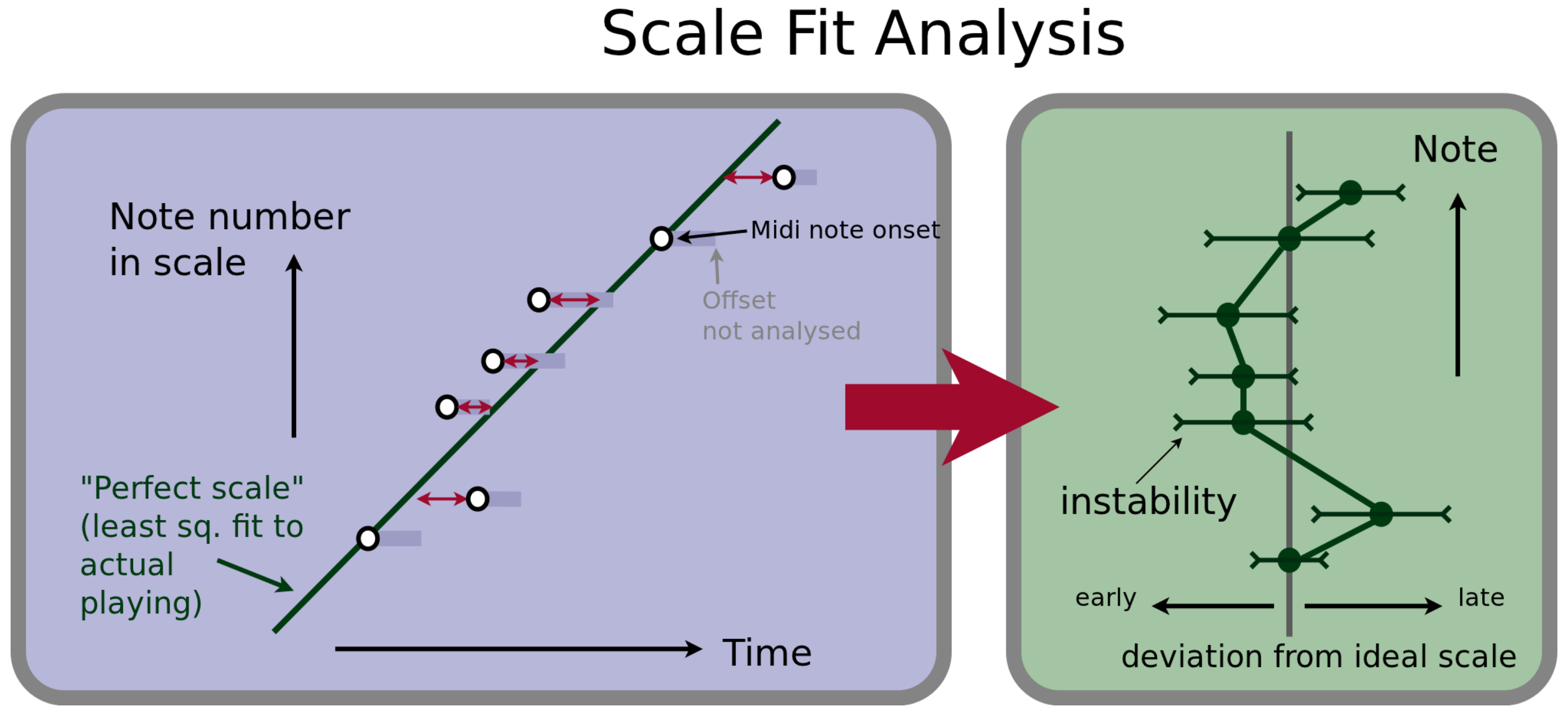
- Playing tempo (Wagner, 1971, MacKenzie & van Eerd, 1990)
- Accumulated playing time (Sloboda, 2000)
- Mechanical constraints in our body (Seashore, 1938)
- Warping of our perceptual space (Penel & Drake, 1998)
- Residuals of expressive timing (Repp, 1993)

Disentangling note timings – a new look at scales

- Previous studies have investigated inter–onset–intervals of scale playing. However, a delay in one note affects two adjacent IOIs, making it impossible to attribute timing deviations to single notes.



- To establish a temporal reference for each note in the scale, we compute a least square fit to the note onsets.



Experimental design

- N=25 advanced pianists were instructed to play two-octave C-major scales, upward and downward directions interleaved (2×15 times) with the right hand and normal fingering.
- As regular as possible ($5\frac{1}{3}$ notes/sec), accompanied by a metronome at $1\frac{1}{3}$ beats/sec.
- Playing on Wersi Digital Piano CT2 (Halsenbach, Germany); MIDI keypress events captured by PC and time points analysed offline.

Deviation and instability are independent

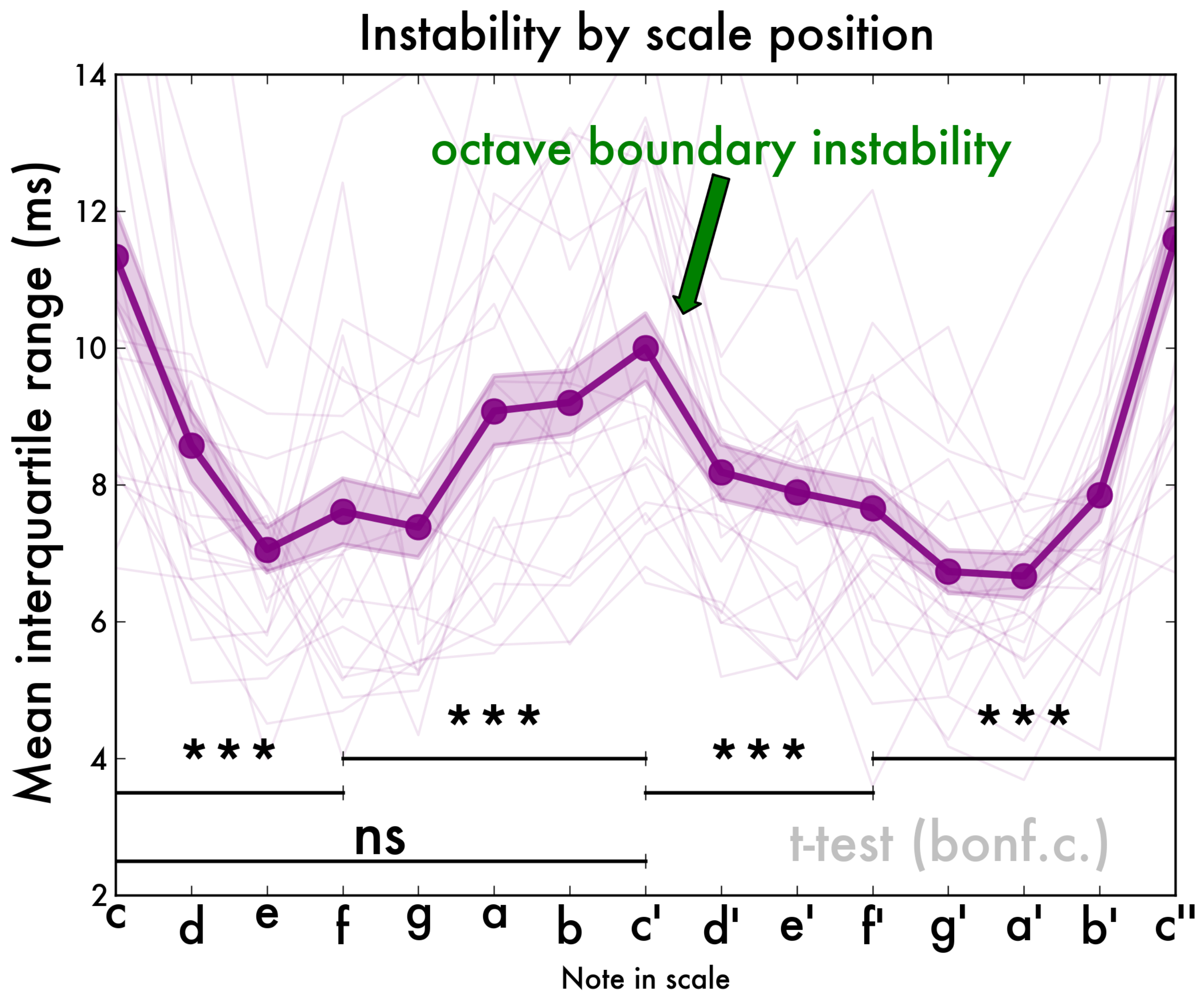
- For each subject we computed the median and interquartile range (spread) of the deviations.
- We found that **the deviations for each scale note did not correlate with the spread of its timings** (mean Spearman $r = 0.18$, $\mathrm{SD} = 0.41$, n.s.).
  - This is contrary to previous findings (e.g., Repp, 1997) that longer IOIs are associated with greater variability (Weber's law). Presumably Weber's law only obtains for notes that are not nominally of equal length (as they are in our experiment).
- We propose teasing apart two independent contributors to timing:
  - deviation (the median) represents residuals of expressive timing (Repp, 1993) and bio–mechanical constraints (Minetti, Ardigo, & McKee, 2007).
  - instability (the interquartile range) represents imprecision of the motor program, possibly influenced by perceptual factors (Penel & Drake, 1998), and is our main focus.

Main Question

How does the timing stability vary within the two scales?

Main finding: playing is more unstable at octave boundary

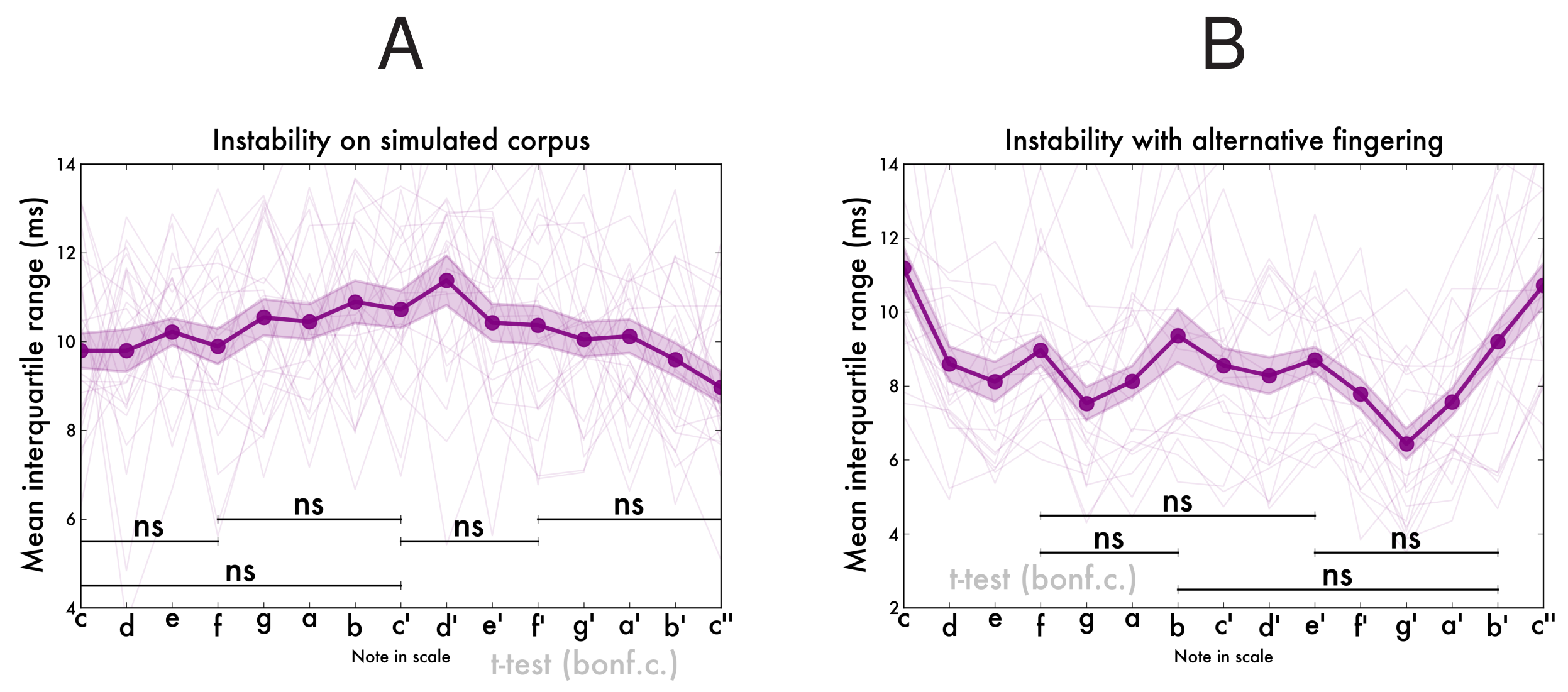
- Pianists were remarkably consistent in their deviations, but among pianists there were great differences.
  - Only final lengthening was consistent: last note 10.8ms later than previous note for upward scales (t-test $p \ll .001$) and 13.3ms later for downward scales ($p \ll .001$).
- Upward and downward scales show the same variability pattern ($r = 0.83$) and are therefore taken together in our analysis.
- **The spread of timing deviations was larger around octave boundaries.**



- This timing instability reveals that the motor program for two octaves is split into two "chunks" that are the two octaves.

Alternative hypotheses

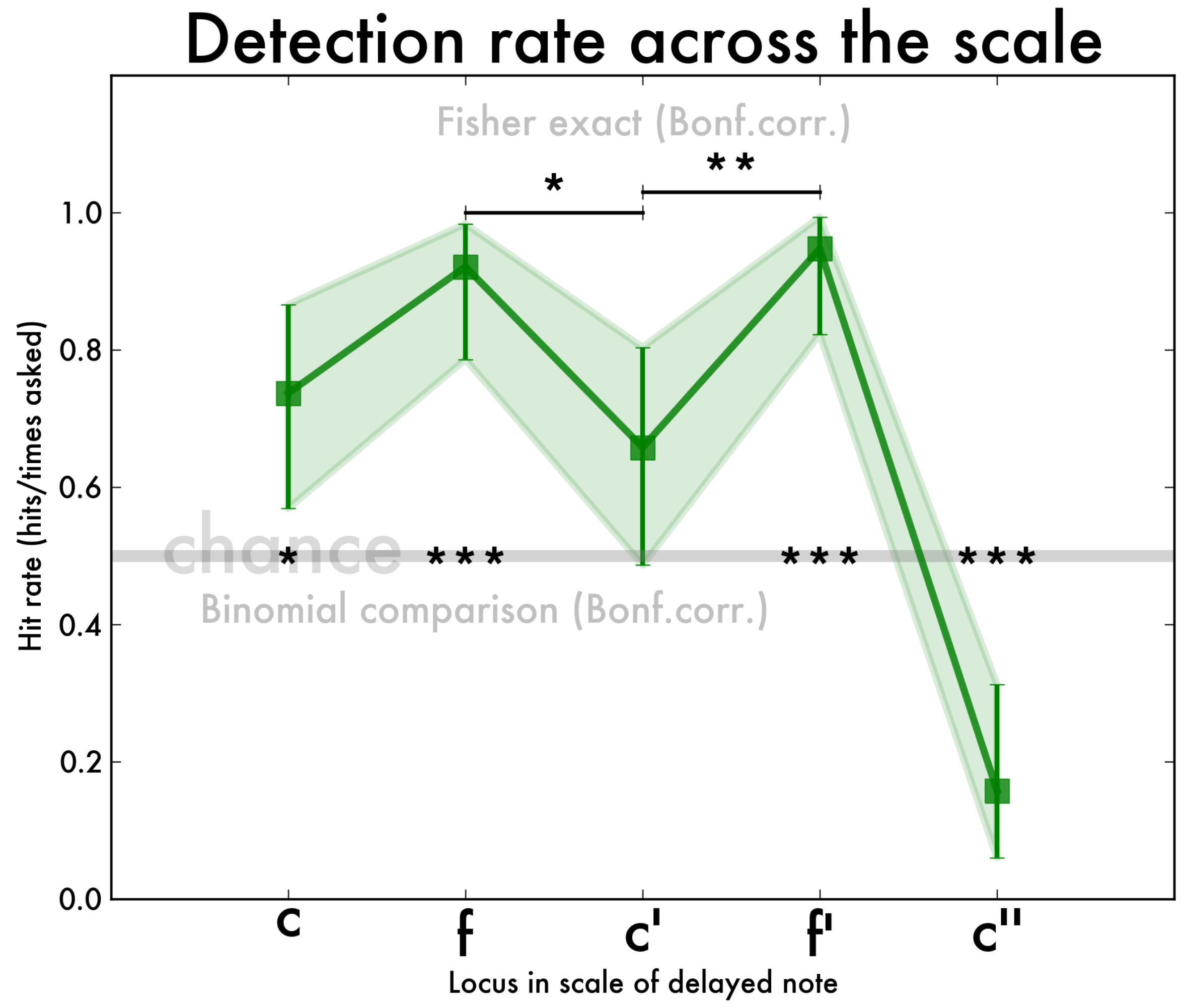
- This cannot be explained by synchronisation to metronome, because the metronome ticks fall on c,g,d',a'.
- This is not a low–level motoric constraint (thumb passage): there is another thumb passage in the middle of each octave. Also graph (B) below shows an alternative fingering. We compare the same fingering transitions and find no stability difference.
- This is not an artefact of our procedure: graph A shows the same analysis applied to 25 simulated pianists with normally distributed temporal jitter.
- This is not the octave as an abstract unit: graph B below shows the instability pattern for the same pianists with a new fingering scheme (234123123123412).



Perceptual precision is implicated

Are these timing deviations the result of decreased auditory resolution at these boundaries? (cf. *perceptual hypothesis*, Penel & Drake, 1998)

- N=19 music students participated in a timing deviation detection study
- Two-octave C major scales (8 notes/sec) were generated using MIDI and converted to wave files using Timidity. One note in the scale was delayed 40ms at one of five possible locations: c,f,c',f',c". Five scales with no deviation were included. Two randomized presentations totalling 20 stimuli.
- Participants responded whether they heard a deviation or not. Mean correctness ratio was 79% (SD=8.2%).



- **Crucially, we found that timing deviations at the octave boundary (c') was more difficult to detect than those in the middle of octaves (f or f').**
- There is a tendency for the detection profile to correlate inversely with the variability trace (Spearman $r = -.8$, $p = 0.1$).

Conclusion

- We analysed scale timing by **computing deviations from the closest regular scale**.
- Advanced pianists show a **boundary instability effect**.
- The boundary instability is also apparent in perception and, we speculate, reflects **statistical properties of the training material.**
- Further research: How does the playing depend on the musical content? Comparing C major scales with A minor scales will allow us to tease apart influences of musical content and low–level motor constraints on timing profiles.

Selected References

MacKenzie, C. L., & Van Eerd, D. L. (1990). Rhythmic precision in the performance of piano scales: Motor psychophysics and motor programming. *Attention and performance*, 13 (Hillsdale, NJ), 375–408.
Repp, B. H. (1994). Relational invariance of expressive microstructure across global tempo changes in music performance: an exploratory study. *Psychological Research*, 56(4), 269-284.
Sloboda, J. (2000). Individual differences in music performance. *Trends in Cognitive Sciences*, 4(10), 397-403.
Wagner, C. (1971). The influence of the tempo of playing on the rhythmic structure studied at pianist's playing scales. In Vredenbregt & J. Wartenweiler (Eds.), *Medicine and sport, Biomechanics II* (Vol. 6, p.129–132). Basel: Karger.

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