TOWARDS A NEW MEASURE OF AUDITORY STREAM SEGREGATION BASED ON MOLECULAR PSYCHOPHYSICS

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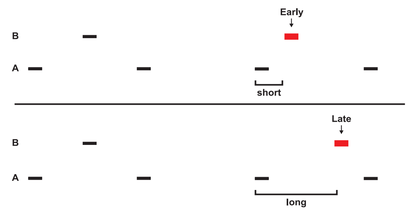
INTRODUCTION

Sensitivity-based measures of auditory stream segregation

Performance-based measures of stream segregation find increasing use as a complement or alternative to subjective ratings of the perceived organization of a sequence. For example, listeners are asked to detect a temporal displacement of a target B-tone in an ABA rhythm (e.g., Neff *et al.*, 1982). It is assumed that it is difficult to use between-streams information when the sequence is perceived as segregated, for instance when judging the inter-onset interval (IOI) between the target B-tone and its preceding A-tone. Because gap duration difference limens (GDDLs) increase with the interval duration, the task should be easier when the sequence is perceived as integrated and thus the relatively short between-streams IOIs A-B and B-A can be used for inferring the temporal position of the target.



Limitations:

- ABA sequence with fixed Δ*f* between A- and B-tones: **slow** tempo ⟶ integrated, **fast** tempo ⟶ segregated
  - At the fast tempo, GDDLs should be *increased* due to streaming, but *decreased* because the IOI durations are shorter ⟶ not possible to infer the perceived organization from accuracy in the temporal shift discrimination task.
- Increase of the GDDL with the frequency separation between the two markers may confound effects of streaming

What may be learnt from "molecular" measures?

The present study combines measurements of a) **sensitivity** ("molar" psychophysics), b) **decision weights** assigned to the different IOIs ("molecular" psychophysics), and c) **subjective ratings** of streaming. The importance of within-stream and between-streams IOIs for the decision in a temporal shift discrimination task (i.e., decision weights) was estimated via perceptual weight analysis (cf. Berg, 1989). The decision weights were compared between sequences perceived as integrated and segregated. According to the concept underlying sensitivity-based measures of streaming, listeners should make stronger use of between-streams intervals in integrated than in segregated sequences. The weights were also compared to optimum decision weights in the absence of stream segregation, which were determined on the basis of individual GDDLs measured in the experiment. Finally, the molar and molecular estimates and the GDDLs were combined into efficiency measures (Berg, 1990) quantifying effects of stream segregation on two different factors limiting sensitivity in the temporal shift discrimination task.

Hypotheses:

- Lower weights are assigned on between-streams intervals when the sequence is perceived as segregated rather than integrated.
- For a fast sequence compared to a long sequence with the same Δ*f* between A- and B-tones we expected no difference in sensitivity, but a difference in the decision weights.
- Stream segregation causes an increase in internal noise rather than in weighting efficiency (cf. Swets *et al.*, 1959).

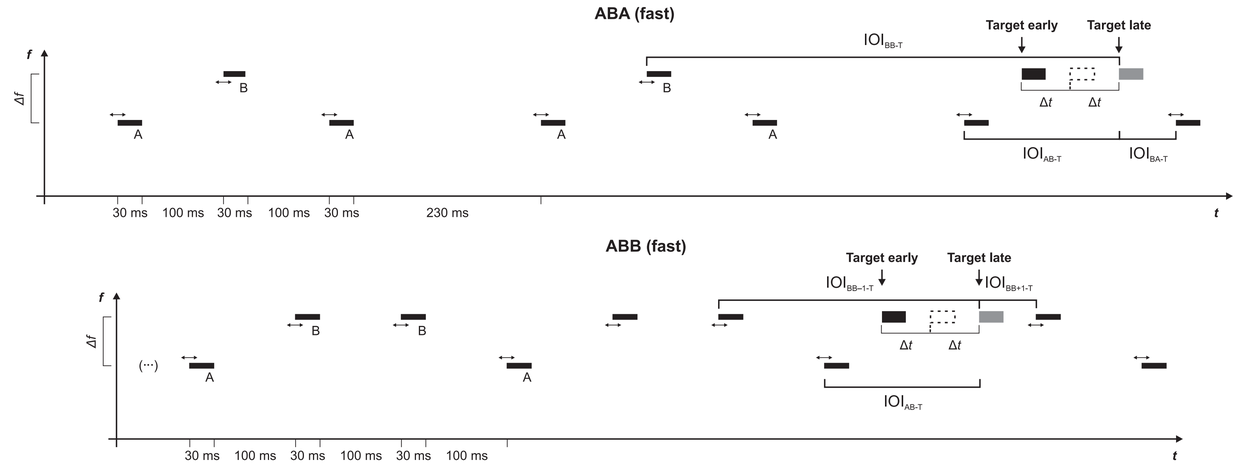
METHOD

Stimuli

- ABA and ABB sequence. 30-ms pure tones. f_B = 800 Hz. Δ*f* = 9 semitones. 60 dB SPL. Presented diotically via HDA 200 headphones.
- Varied: **tempo** (fast / slow = IOIs doubled) and **sequence duration** (3 triplets versus ≥ 7 triplets corresponding to ≈ 8 s)

Task and procedure

- **Task**: decide whether the target tone was presented **early** or **late** (backward/forward shift by Δ*t* = 26 ms, selected via pre-test)
- For estimation of decision weights: **random perturbations** of the tone onsets. *N*(0, 20 ms) for fast and *N*(0, 40 ms) for slow sequences (selected via pre-test)
- 500 trials per sequence (rhythm × tempo × duration), no trial-by-trial feedback
- **Subjective rating** ("*One stream*" or "*Two streams*") collected on each trial
- Individual measurement of **GDDLs** for all IOIs presented in the experiment (IOI duration × frequency separation), 1I task
- 8 NH listeners (7 female, 1 male; 20-29 years)



Data analysis

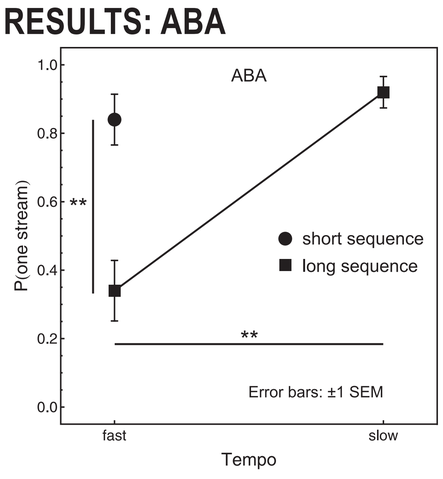
- **Sensitivity**: ROC-fitting ⟶ AUC ⟶ ***d´***
- **Decision weights**: multiple logistic regression (e.g., Oberfeld & Plank, 2011)
  - *Predictors*: three IOIs containing the target. *Criterion*: response.
  - Regression coefficients = weight estimates. *Normalization*: sum of the absolute values of the three decision weights = 1.0

Efficiency measures

The performance is limited by **external noise** (timing perturbations), **internal noise** (imprecise information about IOI duration available at the decision stage), and **suboptimal integration of information** (non-optimal decision weights)

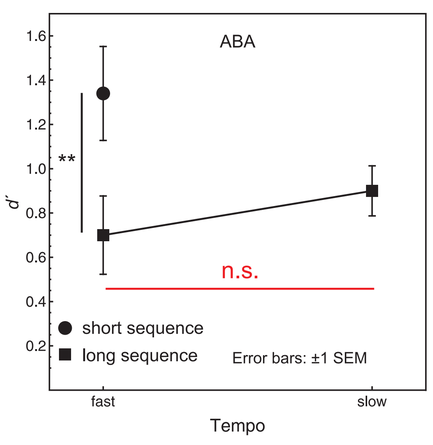
- d'_{ideal}: IOI representation as precise as for the isolated temporal intervals, and the *optimal* decision weights are applied (estimated from the individual GDDLs & ideal weights)
- d'_{wgt}: IOI representation as precise as for the isolated temporal intervals, but *observed* rather than optimal decision weights applied
- Weighting efficiency $\eta_{wgt} = (d'_{wgt}/d'_{ideal})^2$: loss in efficiency due to **suboptimal weights** (Berg, 1990)
- $\eta_{noise} = (d'_{obs}/d'_{wgt})^2$: additional loss in efficiency due to **increased internal noise**
- Overall efficiency: $\eta = (d'_{obs}/d'_{ideal})^2$

RESULTS: ABA



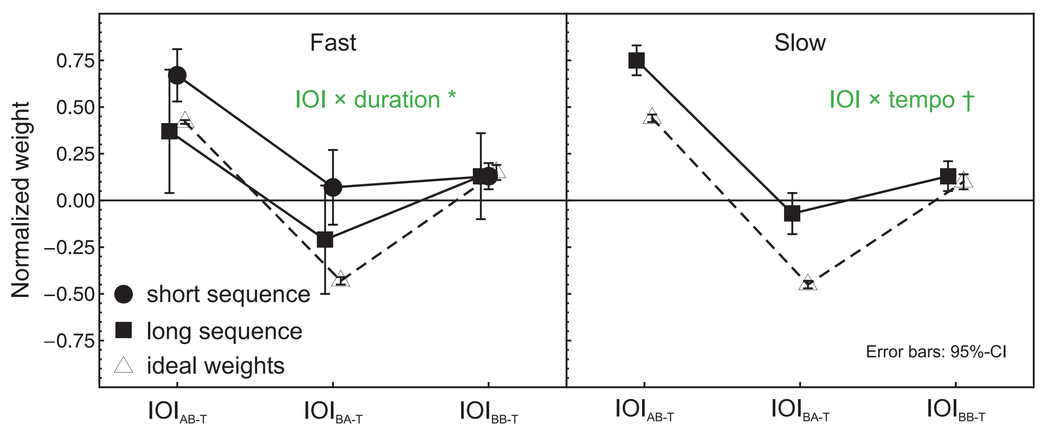
Subjective ratings

- Significantly lower proportion of fusion for fast long sequences (as expected)



Sensitivity

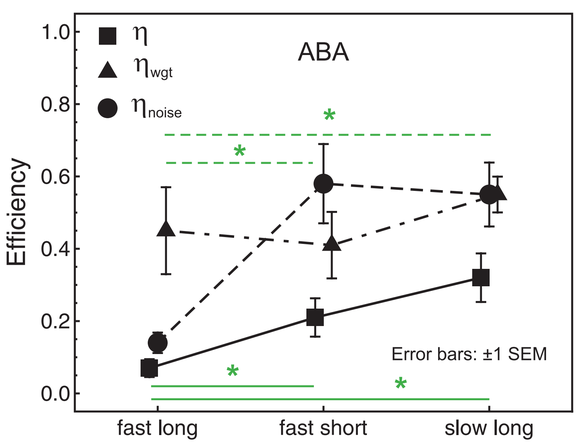
- The difference in perceived organization between long & short fast sequences is reflected by *d´*
- **No** significant difference in sensitivity between the fast and the slow long sequence (as expected)!



Decision weights

- Open triangles: **optimal weights** in the absence of streaming (determined from individual GDDLs)
- **Fast short** (integrated)**:**
  - High weight on IOI_{AB-T} (between-streams), but not on the equally informative IOI_{BA-T}, significant weight on IOI_{BB-T} (within-streams)
- **Fast long** (segregrated)**:**
  - Smaller but still significant weight on IOI_{AB-T} (between-streams), weight on IOI_{BA-T} even stronger than for fast short, non-significant weight on IOI_{BB-T} (within-streams)
- **Slow long** (integrated)**:** Similar pattern as for fast short sequence

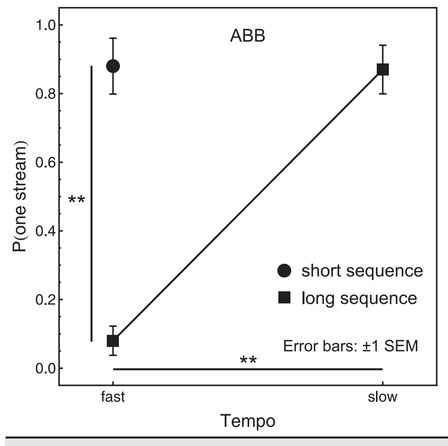
ANOVAs: pattern of weights differs between short and long fast sequence (p = .028), and between slow and fast long sequence (p = .075)

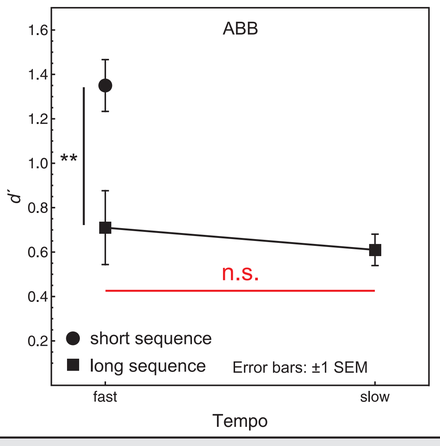


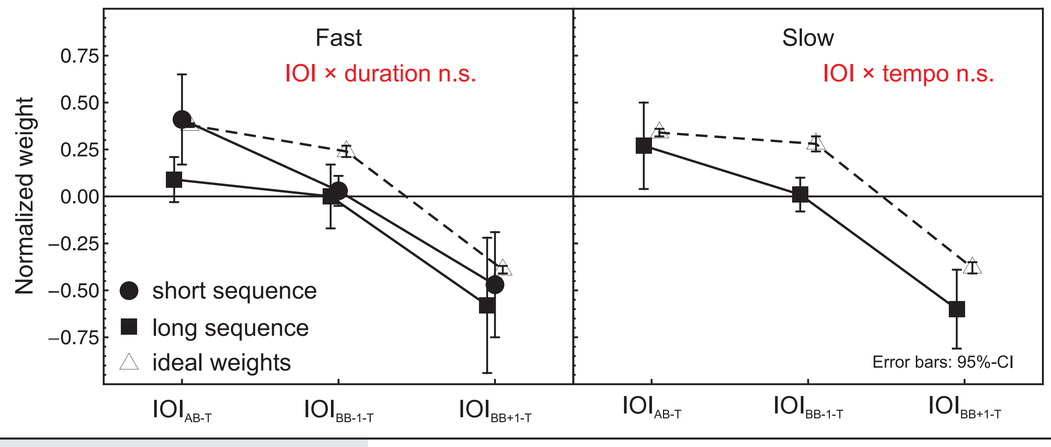
Efficiency

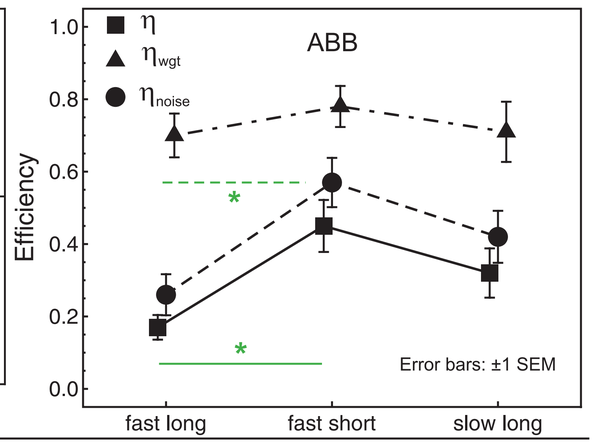
- Weighting efficiency η_{wgt}: **no** significant effect of sequence type
  - Reduced sensitivity for segregated sequences is not caused by an inferior weighting strategy
- Stream segregation resulted in significantly lower η_{noise} (i.e., caused an increase in internal noise)
  - **η_{noise} reflects the differences in perceived organization!**
- Significant effect of sequence type on overall efficiency η

RESULTS: ABB









SUMMARY

- The experiment demonstrated a **limitation of sensitivity-based measures of streaming** (perceived difference between slow and fast sequence is not reflected by *d´*)
- Decision weights are influenced by the perceived organization (see also Richards, Carreira, & Shen, 2012), but the weighting patterns **deviate** from the assumptions underlying sensitivity-based measures of streaming (also large inter-individual differences)
- **Efficiency measures (especially η_{noise}) in most cases reflected the differences in perceived organization** ⟶ appear useful as "objective" measures of auditory stream segregation

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