Perceptual Learning On Musical Chord Inversions

Jacob Bernstein & Dr. Nestor Matthews, Department of Psychology

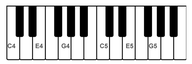
Poster

Preregistration on OSF

Introduction

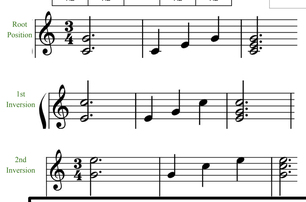
Why are chord inversions difficult to classify? Most music is based on chords. Chords contain three notes played simultaneously. By contrast, arpeggios contain three separate notes played successively, and dyads contain two notes played simultaneously. The notes in a chord, arpeggio, or dyad can be arranged into different positions called "inversions." Prior research on the perception of chord inversions has suggested that people can *hear the differences* among various chord inversions[1]. In principle, listeners could hear differences while lacking the ability to *classify the differences* into specific categories. Here, we sought to expand on the prior research[1,2] to better understand *how listeners best learn to classify chord inversions*.

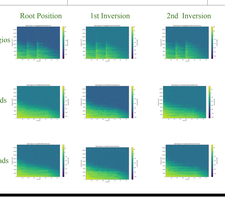
Chord Inversions

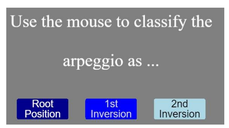


C4	E4	G4	C5	E5
261.63 Hz	329.63 Hz	392 Hz	523.25 Hz	659.25 Hz

Root Position	First Inversion	Second Inversion
Note, Note +4, Note +7	Note, Note +3, Note+8	Note, Note +5, Note+9
Midi Notes 60, 64, 67	Midi Notes 64, 67, 72	Midi Notes 67, 72, 76







Method

Ethics: The Denison University IRB approved this study.

Participants: The *Prolific* online crowdsourcing service recruited 51 adults. All 51 participants completed the experiment online after adjusting their computer audio level before the experiment.

Stimuli & Task: Stimuli were chords, arpeggios, and dyads, each played for 1 second. The task required each participant to classify the musical stimulus on each trial as either root position, 1st inversion, or 2nd inversion; a 3-alternative forced-choice (3-AFC) task.

Procedure: In Phase 1, participants either classified ninety ascending major arpeggios or ninety major dyads as either root position, 1st inversion, or 2nd inversion. In Phase 2, participants classified ninety major chords. After each response, participants received feedback indicating both the accuracy of their response and the correct response.

Measures: Our dependent variable was the speed and accuracy of the responses. The independent variables were musical chord inversions (root position, 1st inversion, 2nd inversion; within-subjects), training group assignment (arpeggios versus dyads; between subjects), and experimental phase (practice phase and test phase; within subjects).

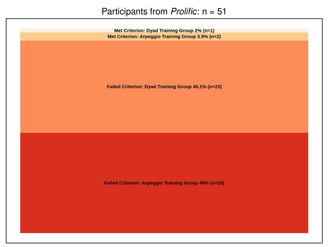
Design: The study had a 3x2x2 mixed experimental research design.

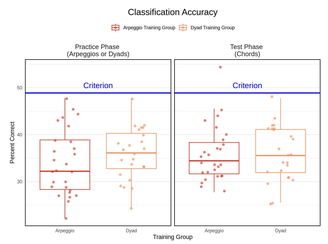
Hypotheses

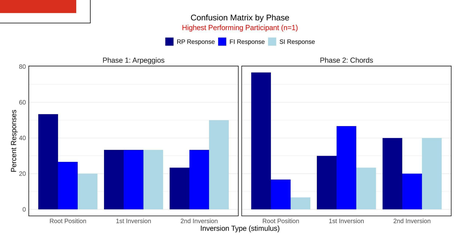
The **arpeggio hypothesis** predicts that people best learn to classify musical chord inversions by first learning to classify a chord's three notes heard separately. By contrast, the **dyad hypothesis** predicts that people best learn to classify musical chord inversions by first learning to classify a chord's "critical dyad." We operationally define a critical dyad as a chord's lowest and the highest notes heard together. Stated differently, arpeggios and critical dyads are each "embedded" in a three-note chord.

Results

- 51 participants from Prolific completed our study.
  - 27 participants completed our arpeggio training.
  - 24 participants completed our dyad training.
- Inclusion Criterion: To be included in our *pre-registered* data analyses, a participant had to exceed chance-level accuracy (binomial $p < 0.001$).
- We observed a salient floor effect. The task was very difficult, as demonstrated by the fact that only three (5.9%) of 51 participants met our inclusion criterion.
  - 2 of the 27 arpeggio training group participants met criterion.
  - 1 of the 24 dyad training group participants met criterion. (See stacked bar chart below.)
- Further evidence of the floor effect can be seen below in the box plots. Importantly, the median of each box plot lands near chance-level accuracy (33.33% correct on our 3 alternative forced choice task).
- Because only 3 of 51 participants met inclusion criteria, we were not able to conduct our *pre-registered* inferential statistics. Here is a link to our *pre-registered* hypotheses and statistical plans on the Open Science Framework: https://osf.io/mhb2g.
- Regarding descriptive statistics, the confusion matrix below offers a close inspection of our highest performing participant. The participant demonstrated precision in classifying root position chords, but performed only at chance when classifying 1st inversion arpeggios.







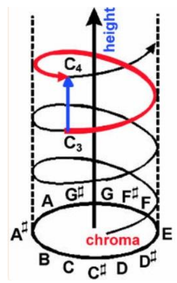
Discussion

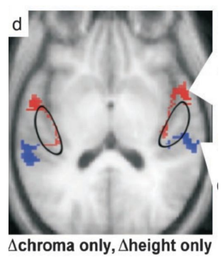
Summary & Implications

- Among music educators, it is known that classifying chord inversions is a difficult perceptual task.
- Motivated by this task's challenge, we attempted to scaffold the chord classification task using a perceptual learning paradigm.
- The perceptual learning paradigm had participants practice either arpeggios or dyads.
- Surprisingly, even these scaffolded steps generated floor effects (see the box plots on arpeggio accuracy and dyad accuracy).
- Our finding that the scaffolded steps generated floor effects suggests that the various chord inversions generate highly similar neural responses.
  - When the neural responses overlap, the behavioral response is not distinct.
- As the pitch helix demonstrates, the notes, or chroma (angular differences in the pitch helix) in any given chord inversion are identical, regardless of pitch height[3].
- fMRI experiments show that the anterior auditory cortex registers changes in chroma, while the posterior auditory cortex registers changes in pitch height[3].
- Our floor effects suggest that participants were relatively insensitive to pitch height manipulations, which would register in the posterior auditory cortex[3].

Future Research

- Although our scaffolded steps were not sufficiently accessible to our participants, future research might more precisely scaffold the components of chord inversions.
- Future research might also harness the power of mnemonics on musical memory.





Red corresponds to a pitch chroma change in the stimulus, generating anterior activity[3].

Blue corresponds to a pitch height change in the stimulus, generating posterior activity[3].

Selected References & Acknowledgments

1. Hubbard, T. L. (1998). Listeners can discriminate among major chord positions. *Perceptual and motor skills, 87*(3), 891-897.
2. Hubbard, T. L,. & Datteri, D. L. (2001). Recognizing the component tones of a major chord. *The American Journal of Psychology, 114*(4), 569-589.
3. Warren J.D., Uppenkamp S., Patterson R.D., & Griffiths, T.D. Separating pitch chroma and pitch height in the human brain. Proc Natl Acad Sci U S A. 2003 Aug 19;100(17):10038-42. doi: 10.1073/pnas.1730682100. Epub 2003 Aug 8. PMID: 12909719; PMCID: PMC187755.

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