# Learning to improvise figured bass – a case for deep learning?

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## **Figured Bass**

Exercise 6

• In the Baroque period, chord accompaniment was notated as a combination of a bass part and figures.

Cognitive Modeling Approach: ACT-R

- ACT-R: Adaptive Control of Thought Rational (Anderson, 2007)
- A cognitive architecture that includes a psychological theory of memory, perceptualmotor processing, and learning
- Players of chord instruments (e.g. cembalo) improvised the accompaniment.
- There are numerous rules that govern the realization of the chords.
- Nonetheless there is freedom to shape the accompaniment in a great variety.
- The improvisational moment is an important ingredient of the charm of baroque music.



## **Rules for Realization**

Rules can be classified according to their scope:

- Rules for single chords:
  - with and w/o figures, accidentals ...
- Rules for voice leading (connection of consecutive chords): no parallel fifths, octaves, ...
- Rules for sequences:
  - scales, descending fifths, fauxbourdon, ...

- Allows to write models that mirror characteristics and limitations of human information processing and behavior
- Artificial intelligence in a broader sense. Focus is not on maximizing performance, but on psychologically plausible or valid models.



# • Rules for cadences:

|-|V-V-|,...

# **Empirical Approach**

- Expert Interviews: qualitative and semi-quantitative analyses
- Standardized exercises: Analyses of harmonic realization, timing and errors
- Recording and analysing progress of students



#### Times (s) for chords in Exercise 6 - six participants



#### Central structure: Chord schemas

(cs-four isa chordschema fig f-four c1 fourth c2 fifth c3 prime



### Differences between model and human players

Model	Human
Selects strategies probabilistically	Have a feeling of knowing
Takes ~ 2s for constructing a chord	Play most chords in ~ 1s
Makes few errors	Make errors (speed-accuracy tradeoff)
Has no problems with accidentals	Often play wrong accidentals
Relies almost exclusively on	Use external memories (vision,

- Results of a 2-level mixed linear model
- Dependent variable: Times for chords (Ex. 6)
- Individual differences explain 51% Variance (random intercepts, p<.001).
- Chords before figured notes are played 0.22 s longer than chord before unfigured notes (fixed effect, p<.05).

Times (s) for chords in Exercise 6 - model



working memory

audition, proprioception)

## Lessons learned

- Learning to improvise figured bass is mainly a rule based process
- Humans do not need to play thousands of different examples to learn it
- Humans utilize their keyboard playing skills in that process
- A symbol processing cognitive model can accomplish the task with relatively compact knowledge
- The model makes the required knowledge explicit
- The model proposes strategies that could be applied in teaching the skill