Curriculum learning for human categorisation of naturalistic stimuli

Dekker, R., Balaguer, J., Flesch, T., Holton, E. Luyckx, F., Saxe, A., Summerfield, S.
University of oxford

Experimental Psychology
UNIVERSITY OF OXFORD

contact: ron.dekker@psy.ox.ac.uk

Theoretical motivation

In novel environments, humans are often faced with the problem of learning to categorize high-dimensional stimuli with minimal prior knowledge of the relevant decision criteria. Here, we asked humans to categorize naturalistic stimuli (trees) according to one of two uninstructed criteria, that depended on their "leafiness" and "branchiness" (see figures below). Our research questions concerned (1) the nature of the training regime that promotes learning about naturalistic stimuli, and (2) the neural mechanisms that underlie differences between effective and ineffective learning curricula.

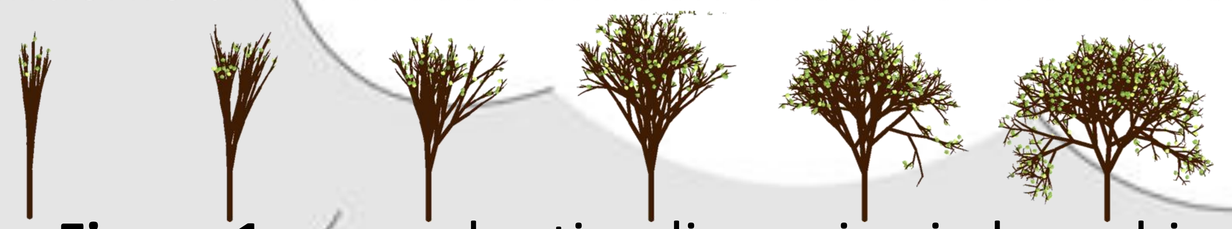
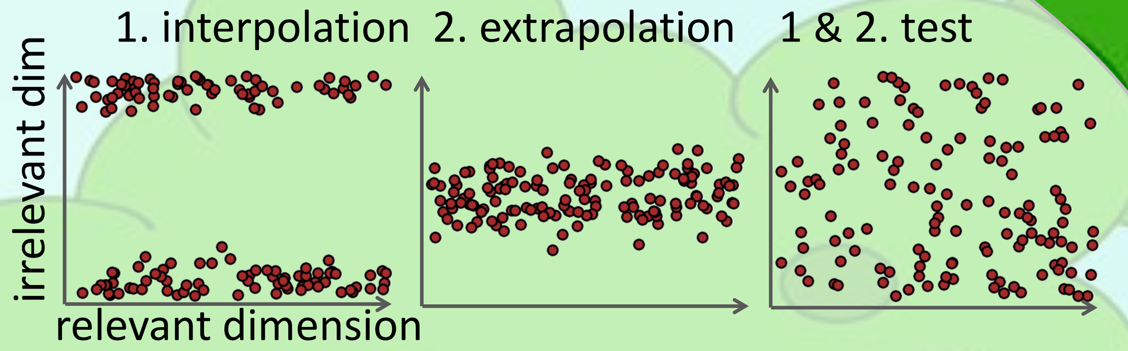


Figure 1: example stimuli, varying in branchiness

Figure 2: example stimuli, varying in leafiness

Design



- 200 online participants for behavior, 48 for EEG
- Interleaved training and test trials. Test trials were uniform and without feedback.
- 2 conditions (between-subjects, see figure above):
  - **Interpolation**: train only on easy
  - **Extrapolation**: train only on hard

Behavior

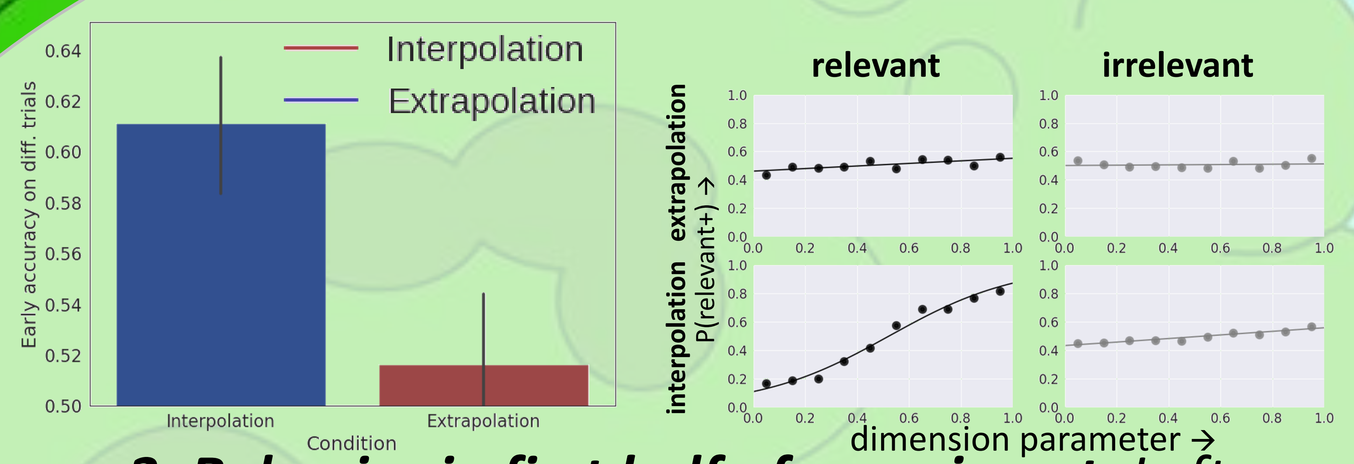


***Figure 3**: **Behavior in first half of experiment.** Left: accuracy (y) by condition (x) for hardest 33% of trials. Right: psychometric curves.*

Looking only at difficult test trials, accuracy was highest in the interpolation group (75 ± 1.0%), and lowest in the extrapolation group (51 ± 1.1%). The psychometrics are well-behaved

Neural results

CPP thought to reflect accumulated evidence or decision certainty (Twomey et al., 2015). Novel contributions are to relate CPP to:
(1) the time course of learning
(2) the curriculum
(3) an irrelevant dimension

Hypotheses:

- CPP increases with distance to bound
- tuning to relevant dimension increases with time
- tuning to relevant dimension greater in interpolation
- tuning to irrelevant dimension greater in extrapolation

***Figure 5:** CPP waveform and topography*

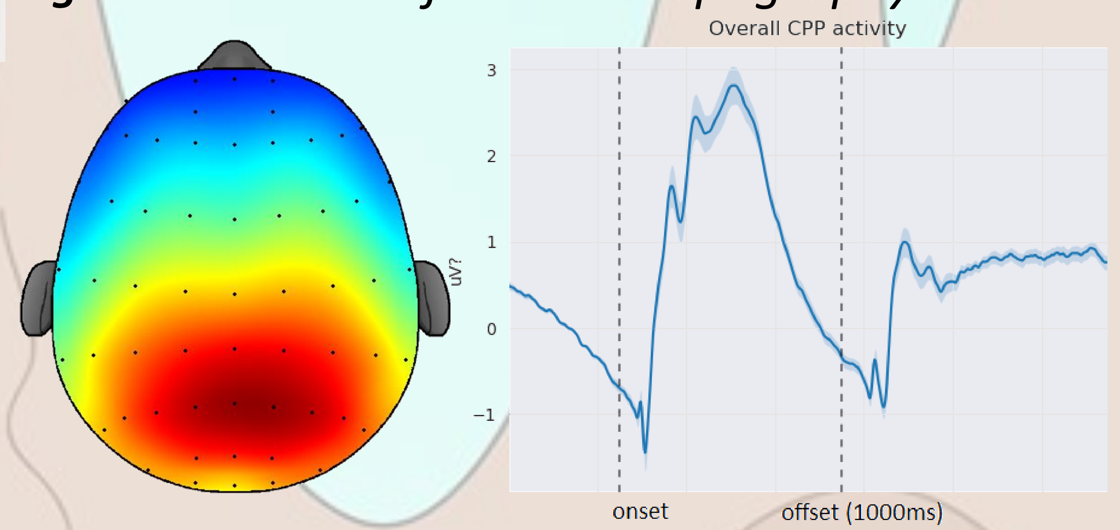
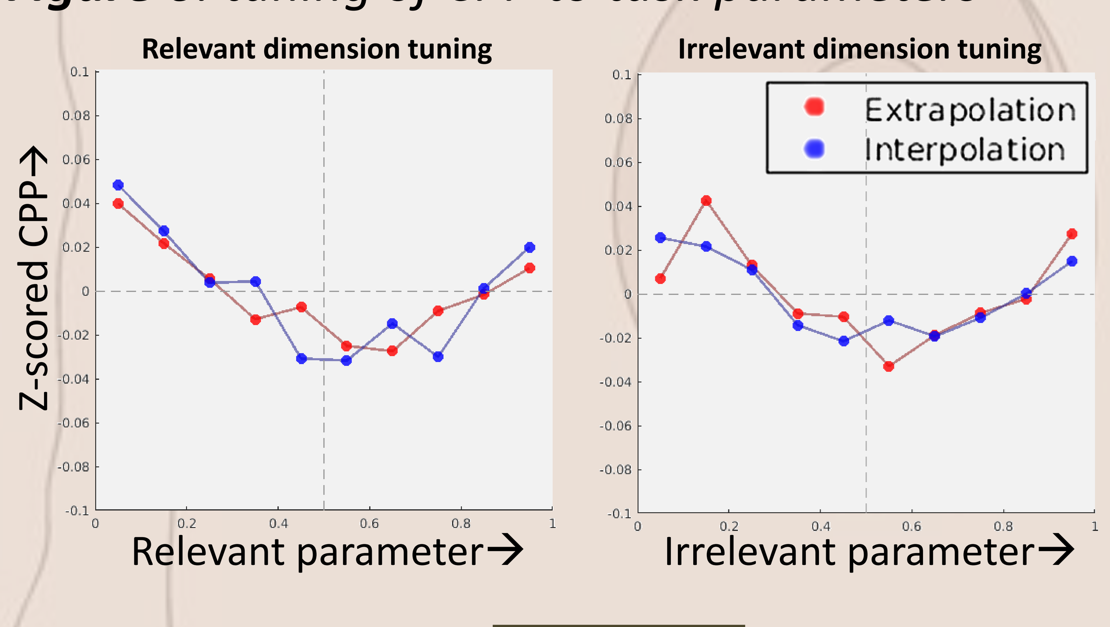


***Figure 6**: tuning of CPP to task parameters*



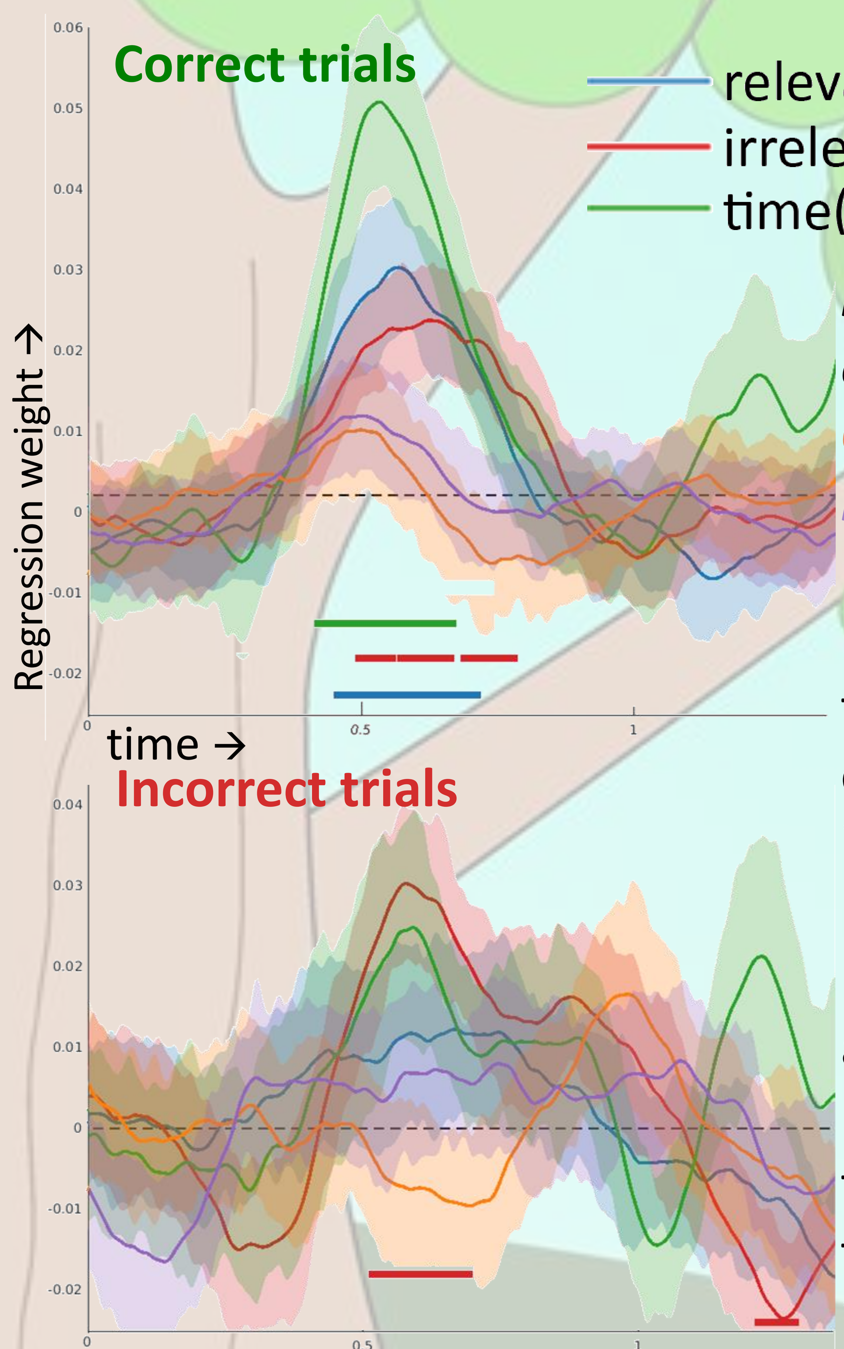


***Figure 7**: MLR of CPP amplitude.*
*Orange = time*rel*
*Purple = time*irr*

For correct trials, we find significant tuning of time, relevant and irrelevant dimension, but no interactions between dimensions and time.
For incorrect trials, we find only significant tuning of the irrelevant dimension.

Conclusions

Clear behavioral result - interpolation learners perform better on the most difficult trials, despite never encountering them during training. Neural results: distance to the category boundary predicts CPP amplitudes, *but* tuning is similar between relevant and irrelevant dimensions, and does not in/decrease with learning. We do find a different correspondence between learning and CPP, as CPP amplitudes increase over time, for correct trials only.

We conclude with a summary of observed discrepancies between the CPP and psychometrics, which challenge its interpretation as a measure of accumulated evidence :

- psychometrics are steepest at the boundary, while CPP tuning is steepest at the extremes.
- psychometrics are much steeper for the relevant than for the irrelevant dimension, but their contribution to CPP is similar.
- psychometrics get steeper over time, while CPP tuning remains constant.