Predictive Coding Models in Human Cognition

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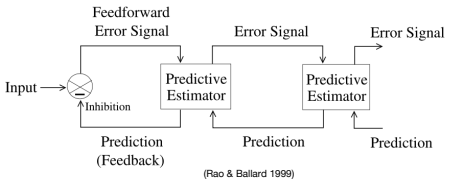
Background

Predictive coding (PC): A popular information-theoretic paradigm used to describe human neocortical perceptual phenomena, including *spoken word recognition (SWR)* (Blank & Davis 2016), and *vision* (Rao & Ballard 1999).
PC hallmarks: "Top-down information influences lower-level estimates [of an input signal], and bottom-up information influences higher-level estimates" (Rao & Ballard 1999). "Only *residual error* between the top-down prediction and the bottom-up input [signal] is [*fed forward*] … along the processing pathway" (Spratling 2008).



(Rao & Ballard 1999)

Our goal: Gather evidence for or against the operation of PC in human cognition by (i) creating PC (and competitor theory)-based computational models of perceptual systems and associated phenomena, (ii) simulating behavioral tasks with those models, and (iii) comparing simulation outcomes to known human behavior.
Research stream 1 (vision): Our implementation of Rao & Ballard's flagship, formal PC vision model can (a) classify natural images, (b) learn large (10000+) natural image sets (MNIST), and (c) shows human-like behavior when presented with foreign images that is consistent with the PC theory. *Next steps: classify MNIST, extend to 6 layers.*
Research stream 2 (SWR): Stream 1 model modified to learn over-time, speech-like input; it (a) classifies speech-like input, and (b) exhibits cohort and rhyme competition, key human behaviors. *Next steps: larger lexicon, priming experiments, real audio.*
Research stream 3 (SWR): When we rectify simplified PC and competitor models (Blank & Davis 2016), a previously reported signature of PC-based brain activity is shown to be flawed. *Next steps: formal models for competitor (1,2) and signature (3) investigation.*
Future: The primary difficulty in testing for PC in humans is detecting its hypothesized error signals in the brain, directly or indirectly, using common, gross measures of brain activity (e.g. hemodynamics in fMRI, neural current in MEG), which are not meant to differentiate signal type. Thoughtful collaboration between cognitive and computational scientists is thus needed to devise experiments where (i) prediction error is likely to generate a detectable neural and behavioral outcome, and where (ii) reasonably-analogous simulations of (i) are feasible using PC and competitor computational architectures.

Overview

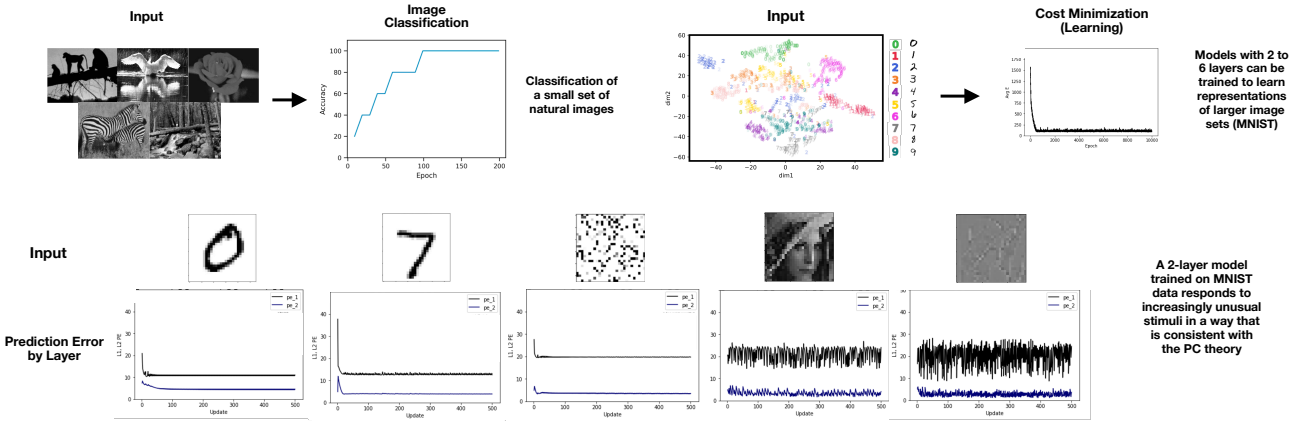
1 Key features of human *visual perception* exhibited by our formal PC model.

2 Model (1) modified to learn over-time, speech-like input. Key features of human *spoken word recognition* exhibited.

3 Purported PC signature from the literature is shown to be flawed, revealing the precision needed to test for PC, and quantitative theories of cognition in general.

Findings

1



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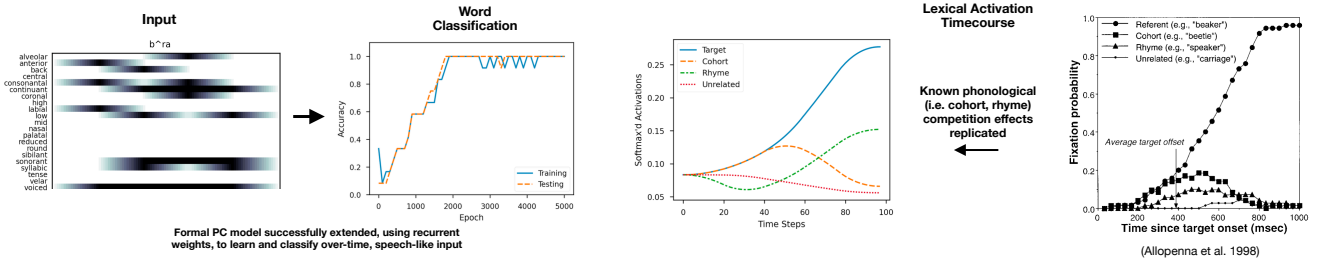

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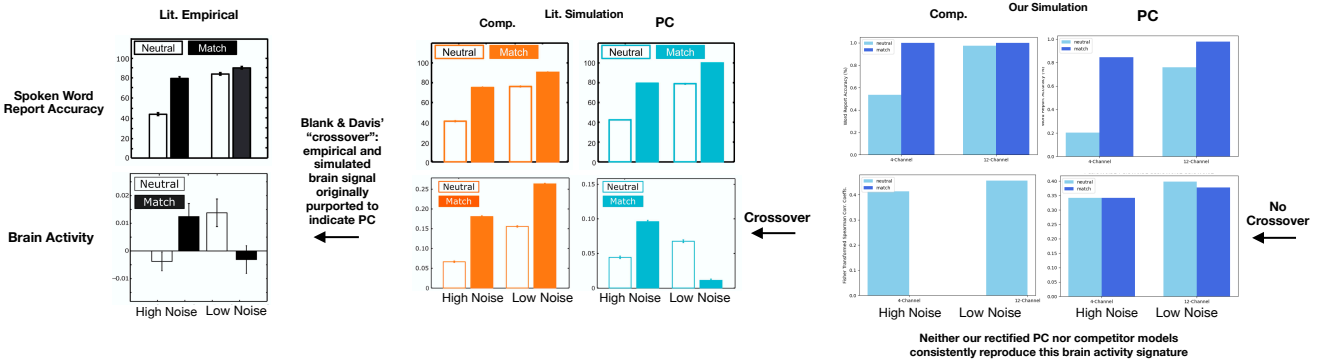

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