INVESTIGATING COGNITIVE MODELS BY THEIR PREDICTIVE POWER ON PERCEPTUAL PHENOMENA

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ABSTRACT

Bistable perception describes the phenomenon of perception alternating between stable states when a subject is presented two incompatible stimuli. Besides intensive research in the last century many open questions remain. As a phenomenon occurring across different perceptual domains such as olfaction [1], audition [2] and the tactile sense [3], understanding bistable perception can help to reveal properties of information processing in the human brain.

While computational models accurately predict the properties of bistable perception they often lack applicability to other perceptual processes [4].

We implemented a recurrent generative network based on hierarchical conceptors proposed by Jaeger [5] to investigate its behavior when fed an ambiguous signal as input. Conceptors in general have been proposed as a solution to the neuro-symbolic integration problem by implementing a filter mechanism on the hidden state dynamics of echo state networks [6]. They have also been successfully applied to other perceptual tasks, such as denoising.

The network consists of three layers. Each layers tries to produce a denoised version of its inputs, based on patterns it was previously trained on. The generation balances between observations from lower levels and predictions from higher levels. The model is similar to predictive error minimization [7], even though it passes denoised inputs to higher layers instead of prediction errors.

We used sine waves with different periods as ambiguous input patterns. After letting the network learn the clean prototypes for each pattern, we presented a noisy mixture of both patterns to the network. By introducing a feedback loop from the top to the lowest layer, we were able to push the network into an oscillating state, alternatingly predicting one or the other pattern.

Thus we can show that (1) it is possible to obtain precise predictions about the properties of bistable perception using a general model for perceptual inference, (2) hierarchical processes allow for reduction in prediction error, (3) random switches in the percept of the network are due to noise in the input and (4) dominance times exhibit a gamma distribution of stimulus dominance times compatible with experimental findings in psychophysics.

We believe that testing whether general cognitive models exhibit perceptual phenomena such as bistable perception, is a useful tool to verify whether they capture important aspects of human cognition.

Code for the experiments is available at `https://github.com/felixmzd/Conceptors`.

References

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