Towards Understanding and Utilizing Simultaneous Pattern Processing

Tsvi Achler, S. Barr, M. Ham, C. Rinaudo, S. Brumby, J. S. George, G. Kenyon, L. M. Bettencourt

T-5, Applied Mathematics and Computational Neuroscience Sub-Group

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Goals:

1) Better understand how human recognition mechanisms address simultaneous patterns
2) Improve AI algorithm performance given simultaneous patterns

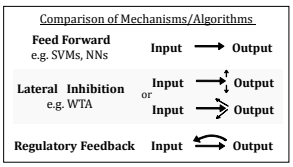
Background:

To survive animals must interpret simultaneous patterns (scenes) quickly, e.g.: find the best escape path from an encircling predator pack; identify food in a cluttered forest. Simultaneous patterns are also found in AI scenarios such as scene understanding, satellite image interpretation, multiple voice recognition "the cocktail party problem", and robot disambiguation of sensory information. While natural for humans and animals, such processing is often insurmountable with computer algorithms.

Sensory processing regions of the brain (e.g. thalamus, olfactory bulb, sensory cortex) have a massive amount of output-to-input "top-down" re-entrant feedback pathways which regulate input processing. Such large-scale amounts of feedback are difficult to incorporate into models and algorithms, because the mathematics become highly nonlinear, chaotic, and much care is required to ensure stability.

We have found a formulation of feedback we call regulatory feedback that monitors and parcels inputs in a way that can be proven mathematically to maintain stability. Several inherent properties of simultaneous pattern processing emerge: a) processing similar patterns simultaneously is harder and b) pattern combinations that are easier to process will become harder if the combinations are reversed. Such phenomena have been previously described in the human cognitive literature that focuses on searching as: phenomena of similarity and asymmetry.

We show that this phenomena occurs more prominently than previously believed (in human tasks such as masking) suggesting: the brain performs simultaneous processing ubiquitously and through regulatory feedback. To reinforce the importance of such processing we show how regulatory feedback is beneficial simultaneous processing scenarios where conventional algorithms falter.

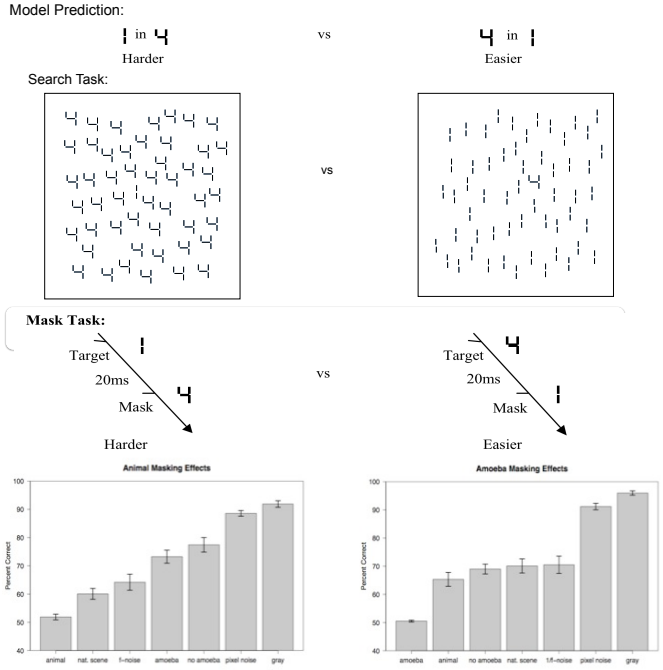


Comparison of hypothesized mechanisms utilized during recognition. Feedforward connections: neural networks and support vector machines. Lateral inhibition: winner-take-all. Feedback regulation: top-down self-inhibition, negative feedback.

1) Evaluating Simultaneous Pattern Processing in Humans

Mechanisms of simultaneous pattern processing are much more ubiquitous than previously considered.

Tasks commonly assumed to embody single pattern processing (**Mask Task**) show robust pattern interactions consistent with simultaneous processing. Pattern interactions are identical to tasks known to involve simultaneous pattern processing: (**Search Task**).



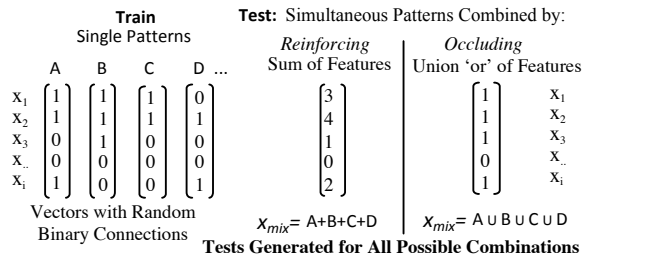
Future Experiments: Evaluate performance on a battery of combinations predicted and ranked for their degree of asymmetry by the regulatory feedback model. Example:

Pattern Combination:	**Q and O**	**K and R**
Model Prediction:	**More Asymmetry**	**Less Asymmetry**
Mask Task Prediction:		
Easier (less errors)	O is Mask and Q is target	Similar if K or R
Harder (more errors)	Q is Mask and O is target	are target or mask
Search Task Prediction:		
Easier (faster)	O is Distractor and Q is target	Similar if K or R
Harder (slower)	Q is Distractor and O is target	are target or Distractor

2) Algorithm Performance Improvement

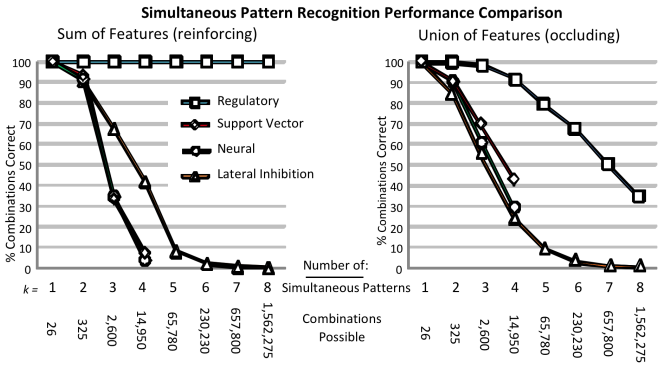
We utilize regulatory feedback to perform simultaneous pattern recognition on random patterns, and compare performance with standard algorithms.

Algorithm Comparison Setup



Tests Generated for All Possible Combinations

Training with 26 single, randomly generated patterns and testing with simultaneous patterns. Test patterns are combinations of the trained patterns (either addition or union). Only 5 features are shown.



Simultaneous Pattern Demonstration Whether simultaneous patterns are combined via addition or union, regulatory feedback is able to better recognize simultaneous pattern combinations without training. Single learned patterns (*k=1) and pattern mixes of up to 8 simultaneously (k=2 .. 8) are presented to the networks that were trained on single patterns. Left: simultaneous patterns are composed by adding overlapping features. Only feedback regulation can inherently recognize all simultaneous patterns. Right: simultaneous patterns are composed by a union of overlapping features. Even though information can be lost in the union, regulatory feedback still outperforms other methods. SVM and NN performance is unavailable for k>4 because WEKA does not support such large numbers of test sets.*

Implications:

1) Regulatory feedback performs simultaneous pattern processing and inherently generates properties of difficulty with similarity and asymmetry.
2) The brain displays simultaneous processing phenomena of similarity & asymmetry more ubiquitously than previously thought.
3) Simultaneous processing via regulatory feedback is a significant step forward in understanding brain processing and improving algorithm performance.