Supplemental Information 5

In the present work, the ABBM is compared to two null models with randomized connectivity, and we show that the ABBM out-performs these null models. Here we perform density classification using a third null model, a lattice network.

The density-classification problem was originally used (Mitchell, Crutchfield, & Das, 1997) to demonstrate that genetic algorithms can be combined with elementary cellular automata (CA) in order to solve computational tasks. Their elementary CA consisted of 149 nodes with each node receiving information from its nearest 6 neighbors. This CA can be equated to a 149-node binary undirected ring lattice where each node has a degree of 6. The purpose of this section is to explore the performance of a null model that is based on the lattice-like structure of an elementary CA, but having the same average degree (20.8) and connection weight distribution as the original network. The connections are arranged such that each node is connected to its immediate 20 or 21 neighbors, and therefore the degree distribution is not preserved in this null model. Each value in the set of connection weights in the original network is randomly assigned to a connection in the lattice network. Thus, the connection weight distribution in the lattice network is identical to the original network.

A genetic algorithm was used to find a rule and thresholds τ_p and τ_n using the same procedure as described in the text. The GA population included 100 individuals, and the top 20 individuals were selected for crossover with an additional 10 randomly selected from the bottom 80 individuals. Crossover was performed at a single point per variable, and offspring were mutated at 3 locations (bits) by default. If the hamming distance of the population was below 0.25 and the fitness was less than 0.9, the mutation rate was randomly increased to 4 – 22 bits. The GA was run for 100 generations.

The results of the density-classification task using the lattice null model are shown in Figure S5.1. At the completion of the GA, the latticized null model achieved fitness values of approximately 90%, exceeding the accuracy of the original thresholded weighted brain network. For a comparison to the original brain network, refer to Figure 14, center row, of the main text.

The highly clustered structure improves the sharing of local information in the lattice network. The latticized structure appears to be better suited to this task than the brain network of this size. However, in a larger network such as the voxelwise networks that have become more common, local connections may not convey sufficient information about the state of the entire system. In fact, the previous work using the density-classification problem (Mitchell, et al., 1997) notes that as the CA size increases, the neighborhood size (i.e. the number of connections to each node) must increase as well. Alternatively to increasing the number of connections to each node, a small world connectivity pattern would enable a combination of both locally and globally shared information. At large network sizes, the small-world architecture intrinsic to brain networks would allow for local clustering with long range “short-cut” connections to promote global sharing of information.

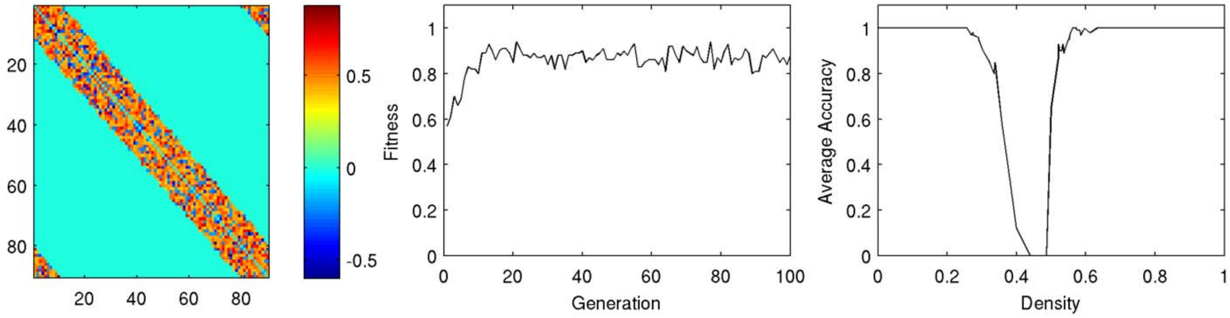

Figure S5.1. Density classification results using a latticized null model. Pictured are the latticized null model (left), the fitness of the best chromosome in the current population over the 100 generations of the GA (middle), and the average accuracy of the final chromosome on varying density levels (right).

References

Mitchell, M., Crutchfield, J. P., & Das, R. (1997). Computer Science Application: Evolving Cellular Automata. In T. Back, D. Fogel & Z. Michalewicz (Eds.), *Handbook of Evolutionary Computation*. Oxford: Oxford University Press.