A graph-theoretic approach to neuroimaging experimental design

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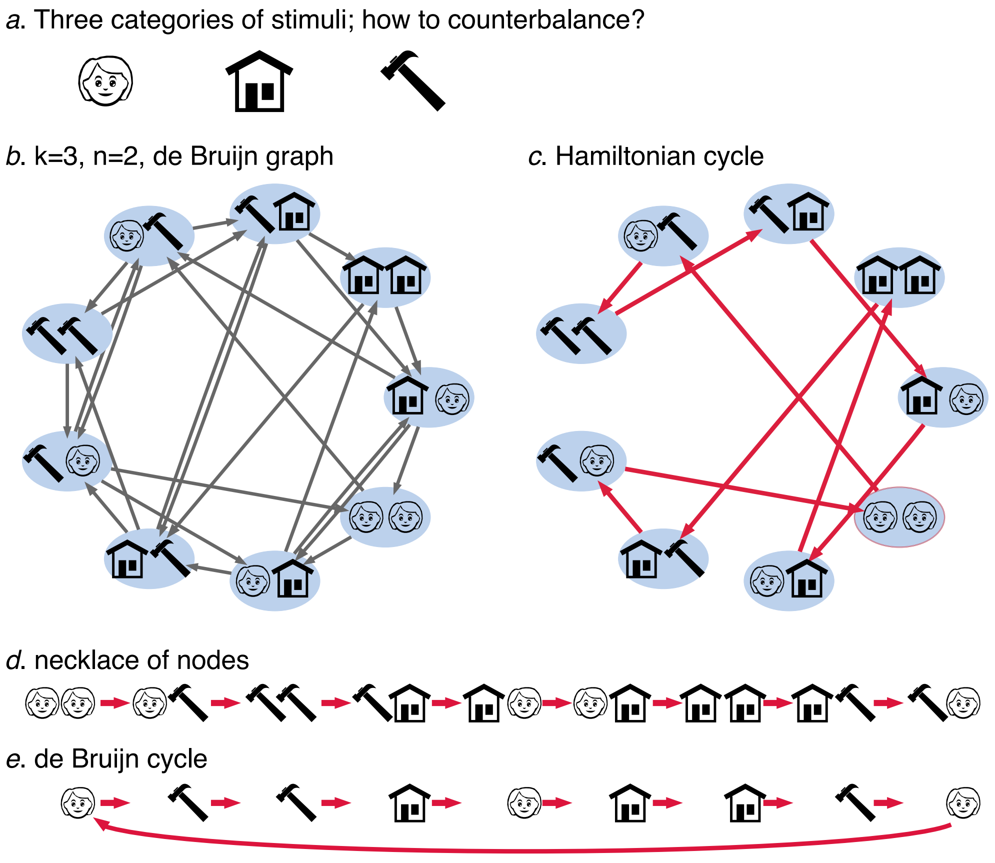
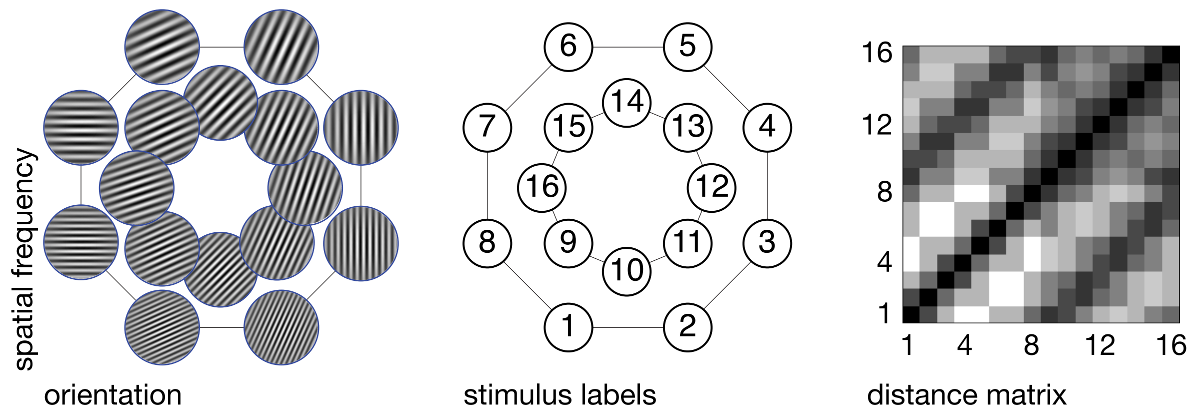
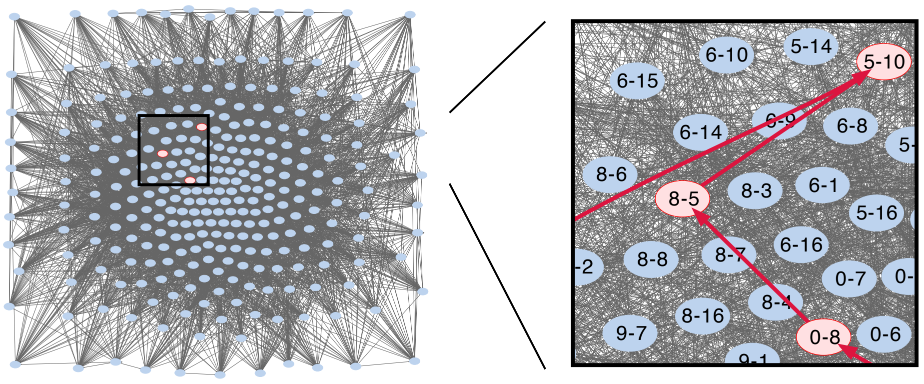
- Stimulus counterbalance is critical for experimental design
- A graph-theoretic approach considers stimuli (or the transitions between them) as nodes within a graph
- The Hamiltonian cycle yields a counter-balanced sequence (de Bruijn cycle)
- Mathematical optimization methods (e.g., simulated annealing) may be used to select paths that have desirable properties, for example:
  - low discrepancy (high uniformity)
  - modulation at frequencies detectable by BOLD fMRI

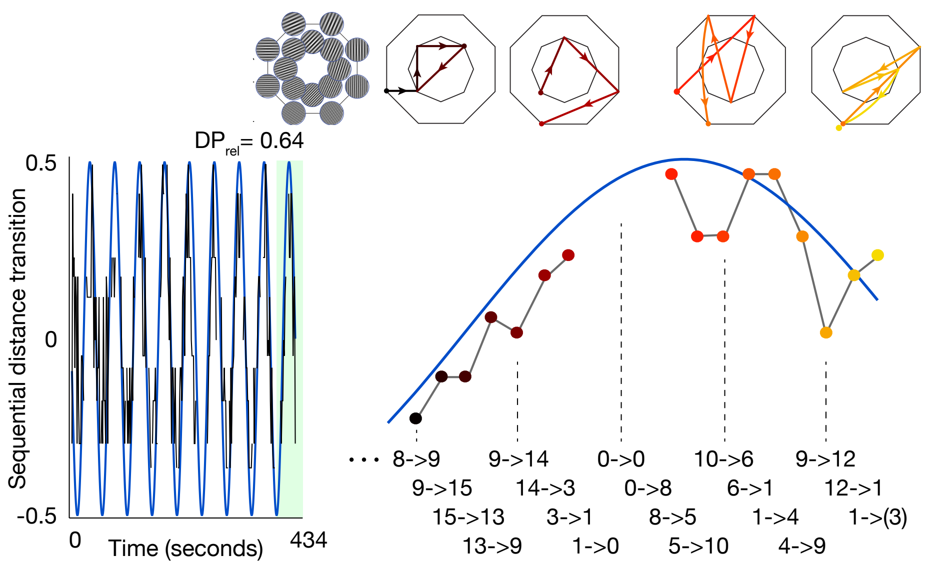




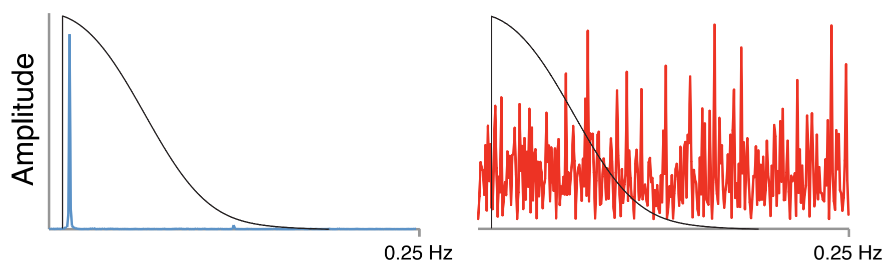
Temporal positioning of neural modulation

1st order counterbalancing (n=2)





2nd order counterbalancing (n=3)



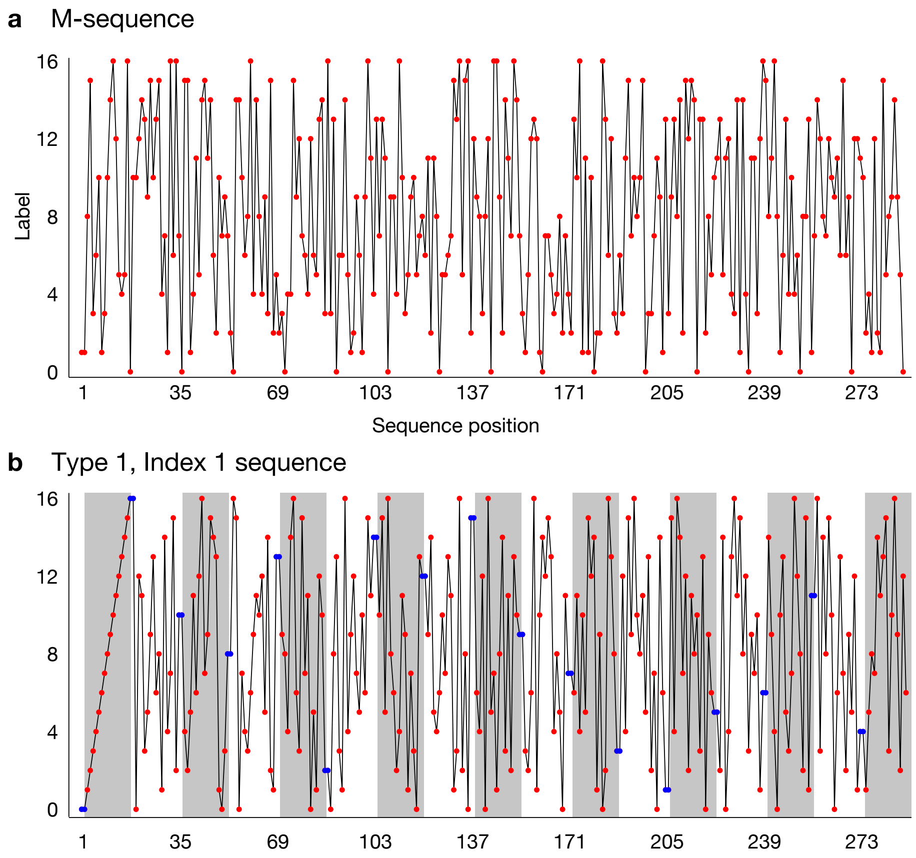
	Sequence	Detection Power
n=2	M-sequence	0.32
	Random de Bruijn	0.29
	Optimized de Bruijn	0.75
n=3	M-sequence	0.05
	Optimized de Bruijn	0.32

Minimizing discrepancy for MVPA studies

- Design goals:
  - maximize responses vs. null condition
  - uniform (minimal discrepancy) distribution of events to optimize prediction
  - 1st order counterbalance to minimize / remove carry-over effects

T1I1 sequences minimize discrepancy

a de Bruijn cycle prohibited from returning to a label node prior to exhausting labels



	Sequence	DP-main	Balance
n=2	Random de Bruijn	0.34	1309
	M-sequence	0.32	1135
	T1I1	0.34	293

Balance is a measure of the even distribution of labels across the sequence; small numbers indicate more balance (Y Hsieh et al. 2004. Ars Combinatoria, 72, 277–286)

Download software from:
http://cfn.upenn.edu/aguirre

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GK Aguirre, MG Mattar, L Magis-Weinberg. (2011) de Bruijn cycles for neural decoding. *NeuroImage* 56: 1293-1300

GK Aguirre (2007) Continuous carry-over designs for fMRI. *Neuroimage*, 35, 1480-1494