Safe or susceptible? Assessing the risk for the development of critical transitions in psychopathology

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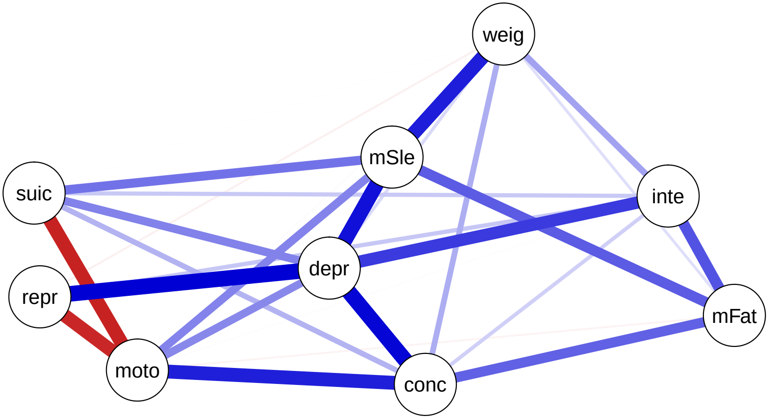
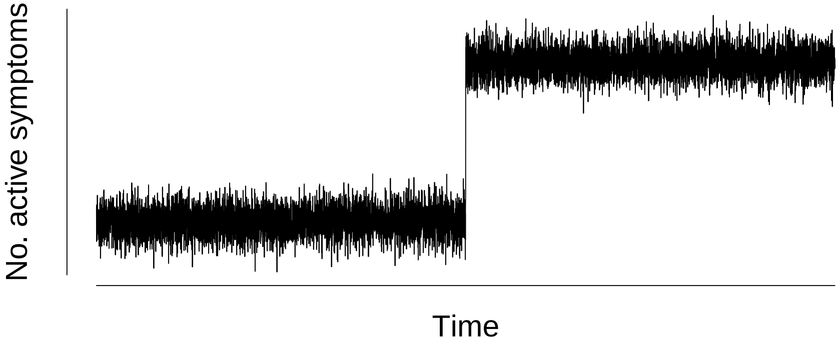
Symptom interactions are key to any psychological disorder



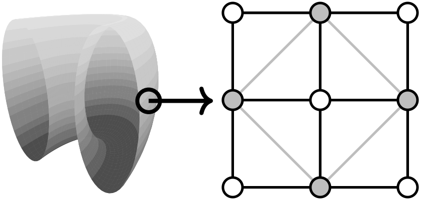
Introduction

- Networks of psychological disorders may change over time
- Networks like these may ‘suddenly’ move from a healthy stage to a depressed stage



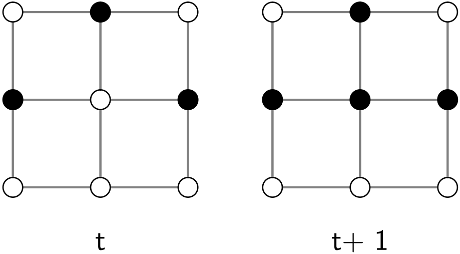
Cellular Automata

- Dynamic networks can be seen as *cellular automata* with deterministic, local rules to move across time.
- Each node in a finite grid (torus) can be either ‘active’ (1) or ‘inactive’ (0).



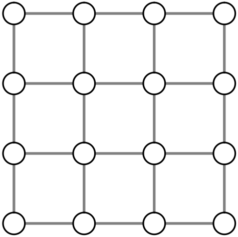
Probabilistic Cellular Automata

A local, probabilistic update rule p_Φ determines whether or not a node becomes active at time point $t+1$, and depends on the behaviour of the majority of a node's neighbours (Γ).

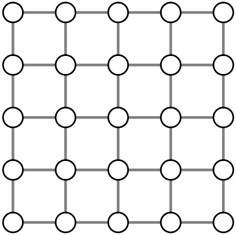


$$p = \begin{cases} p & r \leq |\Gamma|/2 \\ 1-p & r > |\Gamma|/2 \end{cases}$$

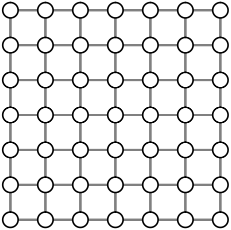
Probabilistic Cellular Automata



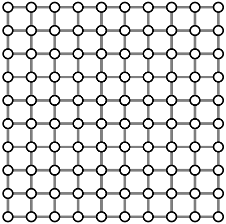
$n = 16$



$n = 25$

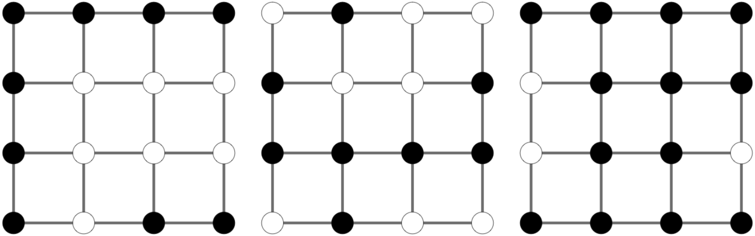


$n = 49$



$n = 100$

Evolution of probability p



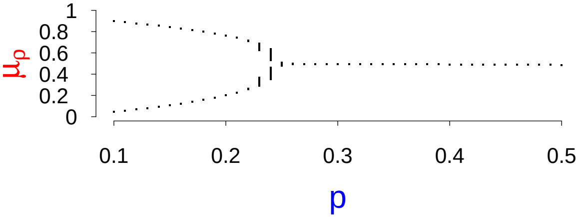
$p = 0.1$ $\qquad$ $p = 0.5$ $\qquad$ $p = 0.9$

We assume that nodes behave in a similar manner. Therefore, we only need to know the proportion of active neighbours each node has.

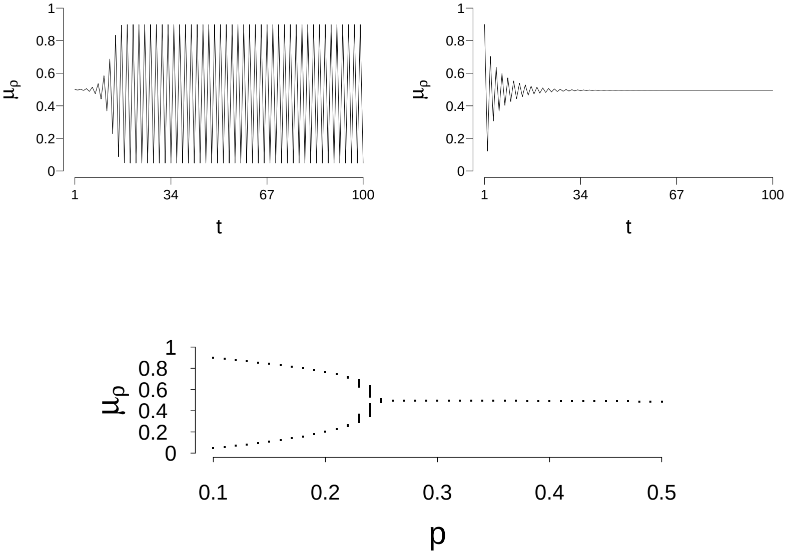
Mean Field Approximation

When we combine a binomial distribution with the majority rule, we get

$$\mu_p = p\sum_{r=0}^{|\Gamma|/2} \binom{\Gamma}{r} \rho_t^r (1-\rho_t)^{|\Gamma|-r} + (1-p)\left(1 - \sum_{r=0}^{|\Gamma|/2} \binom{\Gamma}{r} \rho_t^r (1-\rho_t)^{|\Gamma|-r}\right)$$

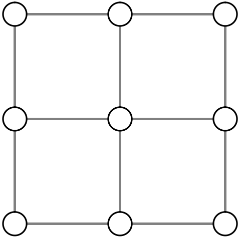


Mean Field Approximation

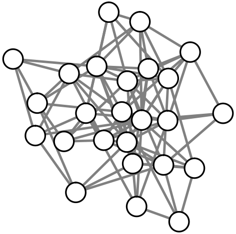


Mean Field Approximation

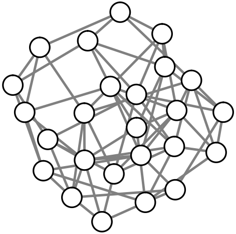
Network structures



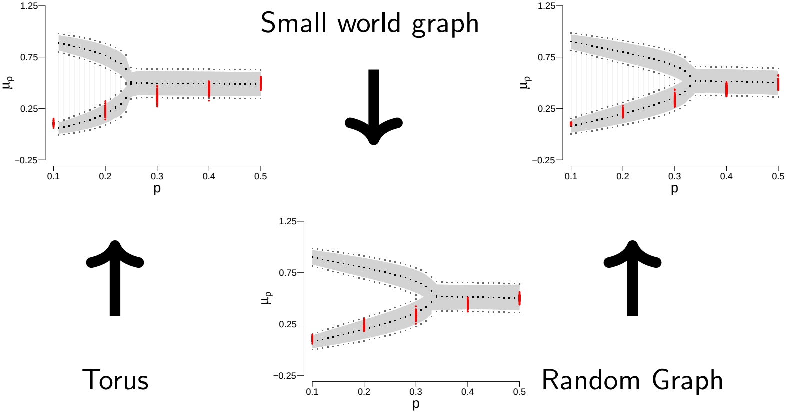
Torus



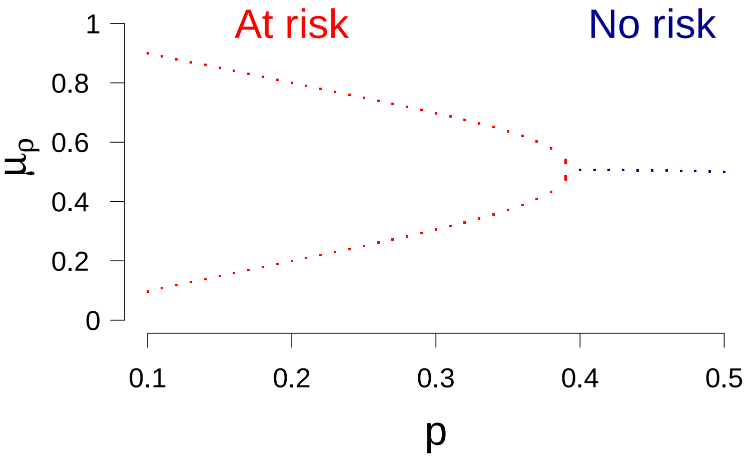
Random Graph



Small World Graph



Small world graph
Torus
Random Graph
1.25
0.75
0.25
−0.25
0.1
0.2
0.3
0.4
0.5
p
μ_p



At risk
No risk
1
0.8
0.6
0.4
0.2
0
μ_p
0.1
0.2
0.3
0.4
0.5
p

Fitting the Mean Field Approach to Empirical Data

Empirical Data

- Participant: 57- year old male with a history of Major Depressive Disorder.
- Participant's daily life experiences were monitored for 239 days using the *Experience Sampling Method* (ESM).
  - During this period, the participant gradually reduced his anti-depressant medication in a double-blind fashion.
- Participant experienced a phase transition around day 127, making this data ideal for validation.
- Data was selected up until the anti-depressant medication was reduced to 0 mg

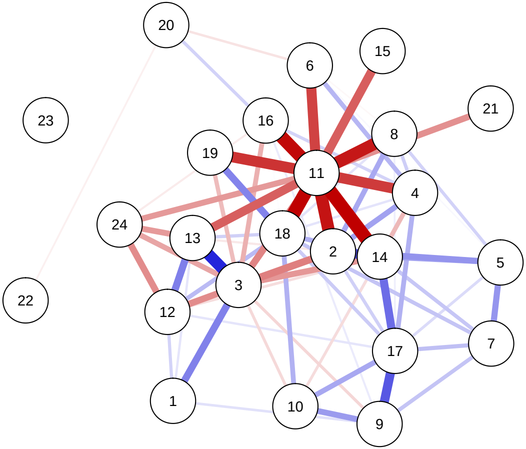
Fitting the Mean Field Approach to Empirical Data

Procedure

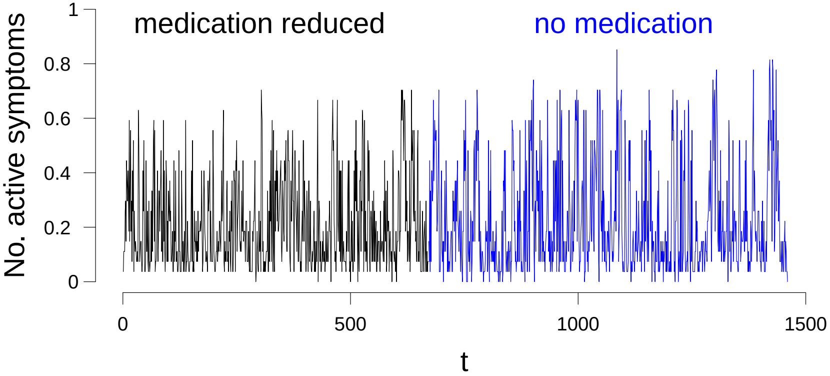
- 28 affect items were measured on 671 occasions
- Positive items ($n = 7$) were recoded; high scores indicate a more negative affect
- Missing measurements were replaced by the previous measurement
- All items were dichotomised using a median split
- 4 items were removed due to observing one of two response categories less than four times.
- A network was constructed using `IsingFit()`

Fitting the Mean Field Approach to Empirical Data

Results

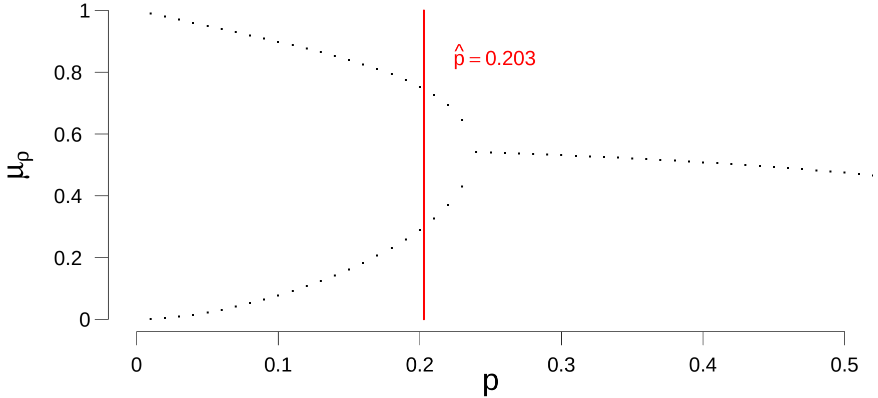


1: I feel relaxed
2: I feel down
3: I feel irritated
4: I feel satisfied
5: I feel lonely
6: I feel enthusiastic
7: I feel suspicious
8: I feel cheerful
9: I feel guilty
10: I feel indecisive
11: I feel strong
12: I feel restless
13: I feel agitated
14: I worry
15: I can concentrate well
16: I like myself
17: I am ashamed of myself
18: I doubt myself
19: I can handle anything
20: I am hungry
21: I am tired
22: I am in pain
23: I have a headache
24: I am sleepy



medication reduced
no medication
No. active symptoms
1
0.8
0.6
0.4
0.2
0
0
500
1000
1500
t

Fitting the Mean Field Approach to Empirical Data
Results



Conclusion

- We can use a mean field approximation to estimate the proportion of active nodes in networks
- In an empirical example, we showed the potential of the mean field approximation, by demonstrating that a participant who experienced a phase transition, had an increased risk for experiencing a phase transition before the transition itself.

Collaborators

Lourens Waldorp

Marijke Gordijn

Harriette Riese

Marieke Wichers

References

Lourens J Waldorp and Jolanda J Kossakowski.
Mean field dynamics of graphs: Evolution of probabilistic cellular automata on different types of graphs.
submitted for publication.

Jolanda J Kossakowski, Marijke C M Gordijn, Harriette Riese, and Lourens J Waldorp.
Assessing the risk for the development of phase transitions applied to clinical data: Mean field dynamics of graphs.
submitted for publication.

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