Computational modelling of the dopamine system and investigation of Internet addiction phenomena

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What is addiction?

- Addiction is a complex phenomenon influenced by environmental, social and biological factors.

Environmental factors:

- Education and family background
- Availability
- Economic Resources

Social factors:

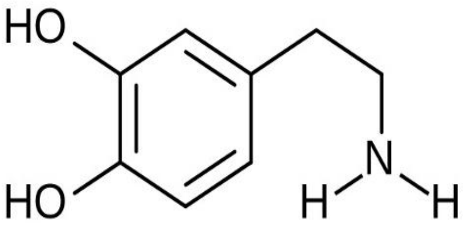
- Consensus
- Imitation
- Social acceptance

Biological factors:

- Dopamine system
- Stress
- Chemical substances

The Dopamine System

- Dopamine is a neurotransmitter involved in many cognitive processes
  - In particular, in the reward system (satisfaction)



Dopamine

- The reward systems is the main cognitive system involved in the development of addiction

Gutkin’s model

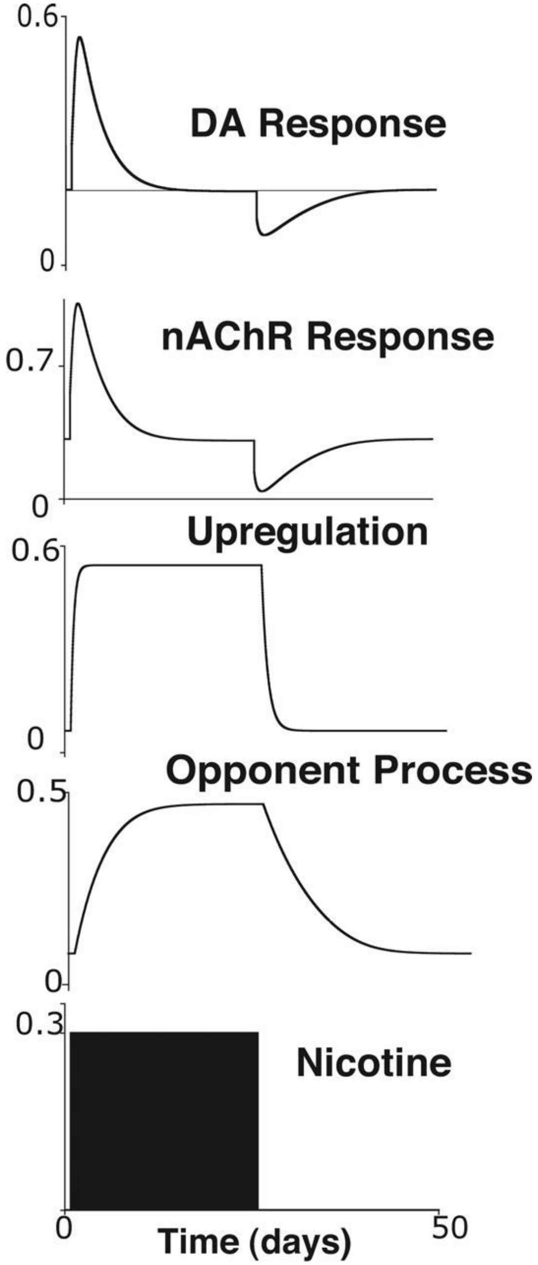
Gutkin’s model(1) specifically analyses nicotine addiction. It shows how a constant stimulus causes a consequent decrease in neuronal activity.

$$\frac{dU_{DA}}{dt} = -U_{DA} + S_{DA}\left\{\sum_i r_i; N(t)\right\}$$

$$S_{DA} = \frac{1}{2}\left(1 + \tanh\left(N(t)\sum_i r_i(t) - \theta_{DA}\right)\right).$$

$$\tau_A \frac{dU_1^A}{dx} = -U_1^A + S_A\{w^e_{11}U_1^A - w^i_{12}U_2^A - \theta_A\} + \sigma\xi \text{ and}$$

$$\tau_A \frac{dU_2^A}{dx} = -U_2^A + S_A\{w^e_{22}U_2^A - w^i_{21}U_1^A - \theta_A\} + \sigma\xi.$$



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(1) Boris S Gutkin, Stanislas Dehaene, and Jean-Pierre Changeux. A neurocomputational hypothesis for nicotine addiction. Proceedings of the National Academy of Sciences of the United States of America, 103(4):1106{1111, 2006.

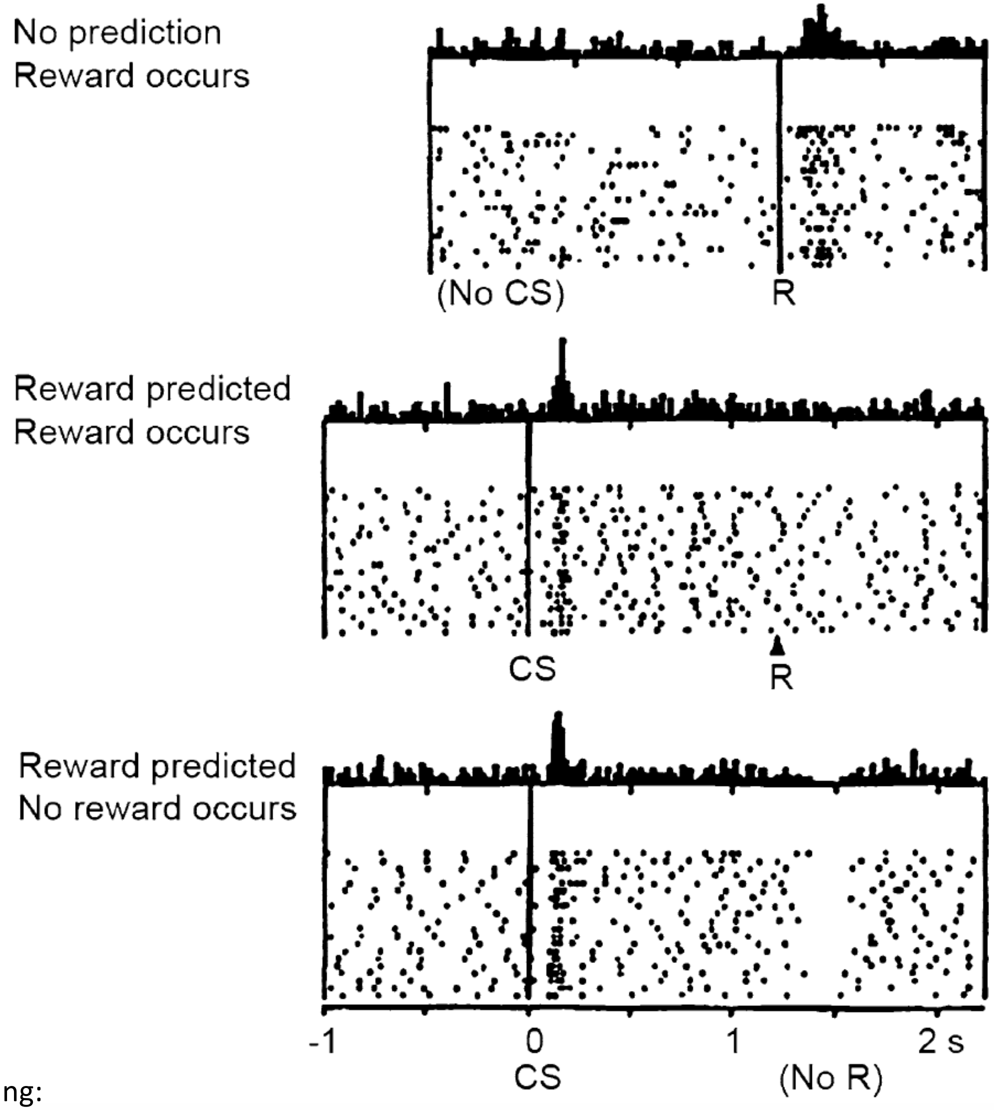
Samson’s model

Samson’s model(2) focuses on the role of dopamine as a reward system.

- Neurons are activated in two cases:

➤ in case of a reward

➤ when a reward is predicted



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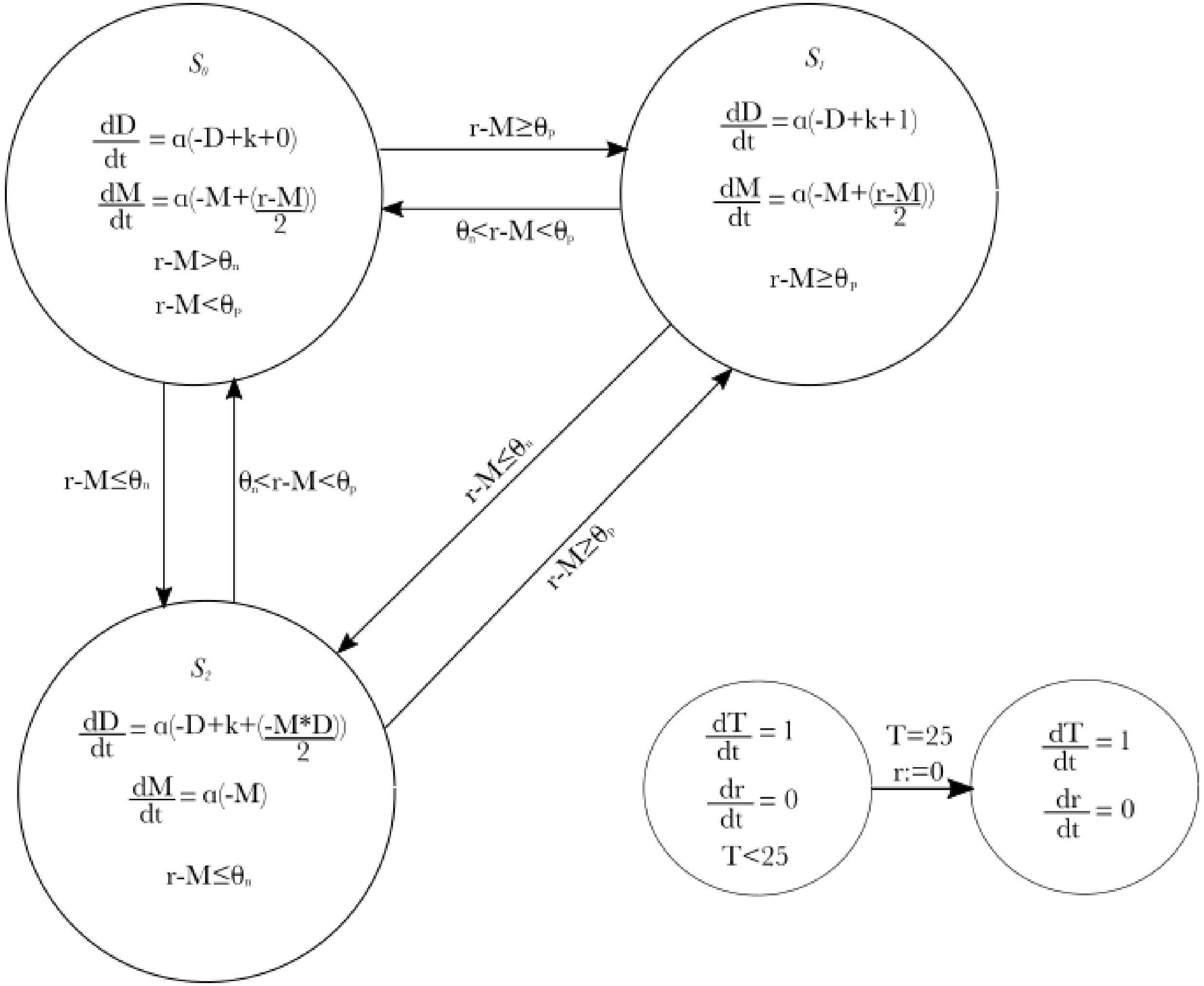
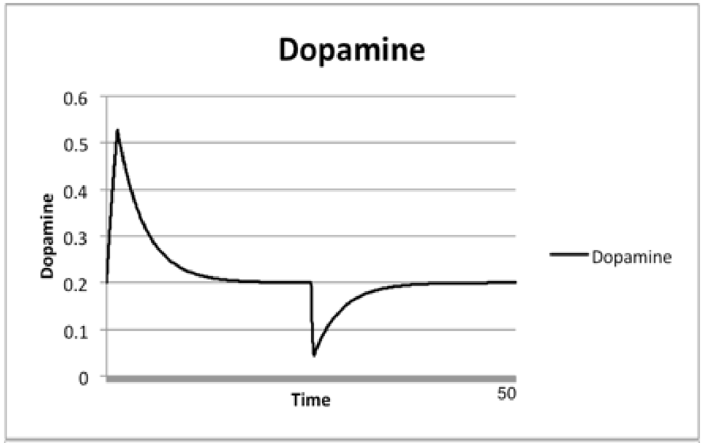
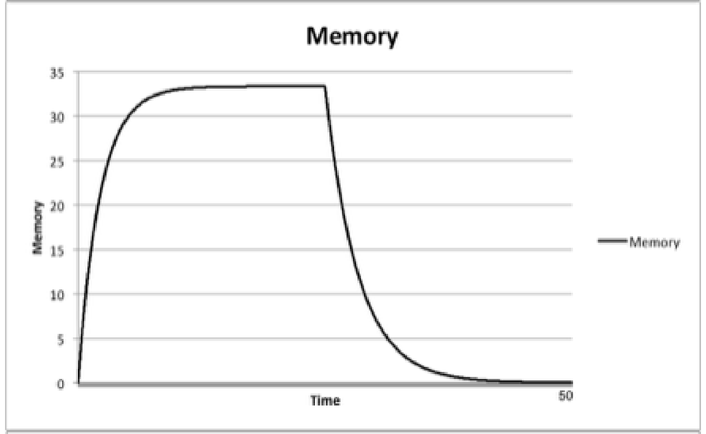
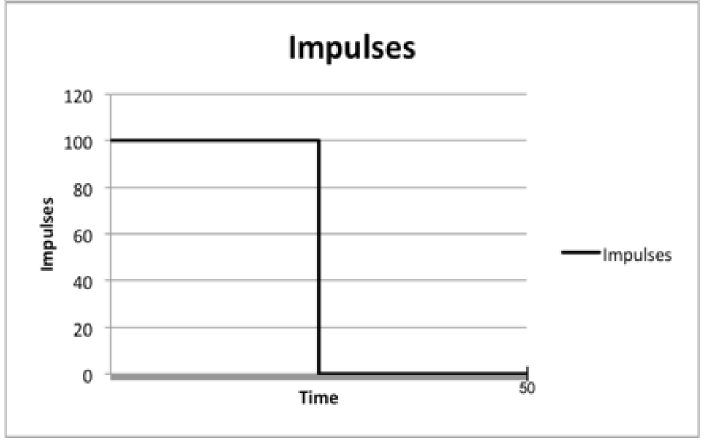
(2)RD Samson, MJ Frank, and Jean-Marc Fellous. Computational models of reinforcement learning: the role of dopamine as a reward signal. Cognitive neurodynamics, 4(2):91{105, 2010.

Hybrid Automata model



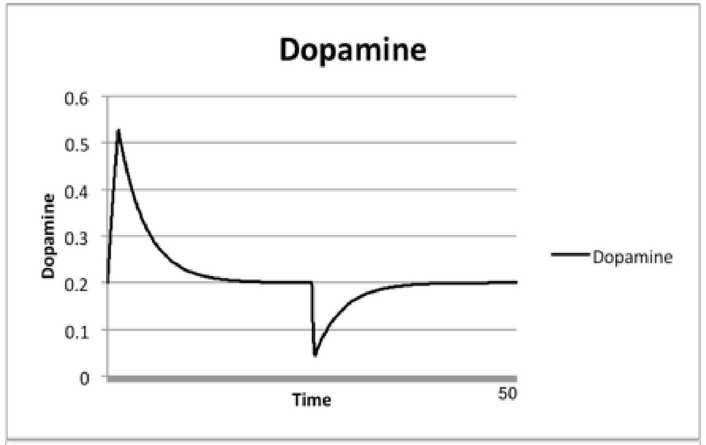


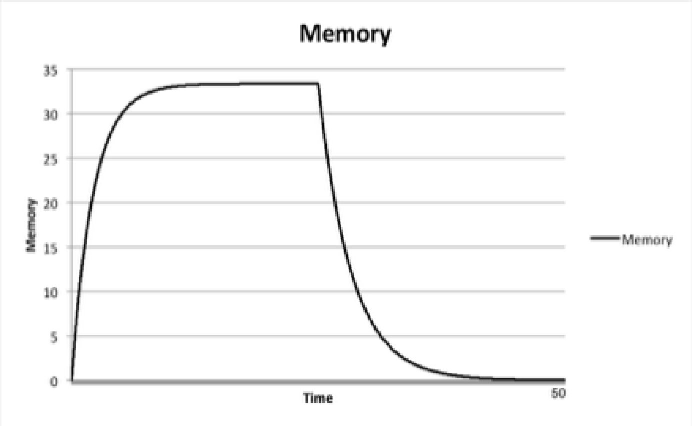


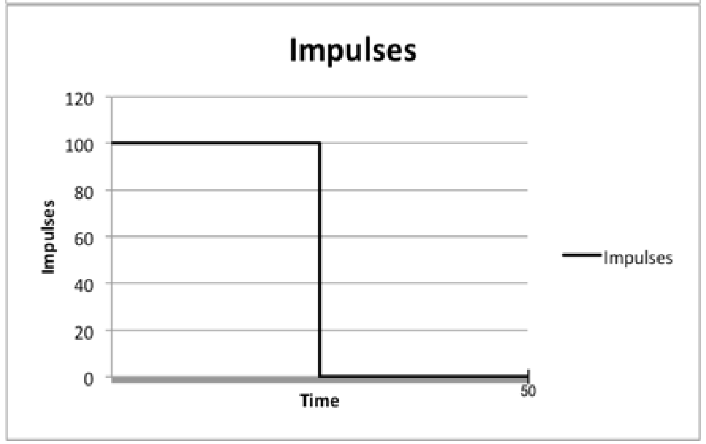


Some considerations

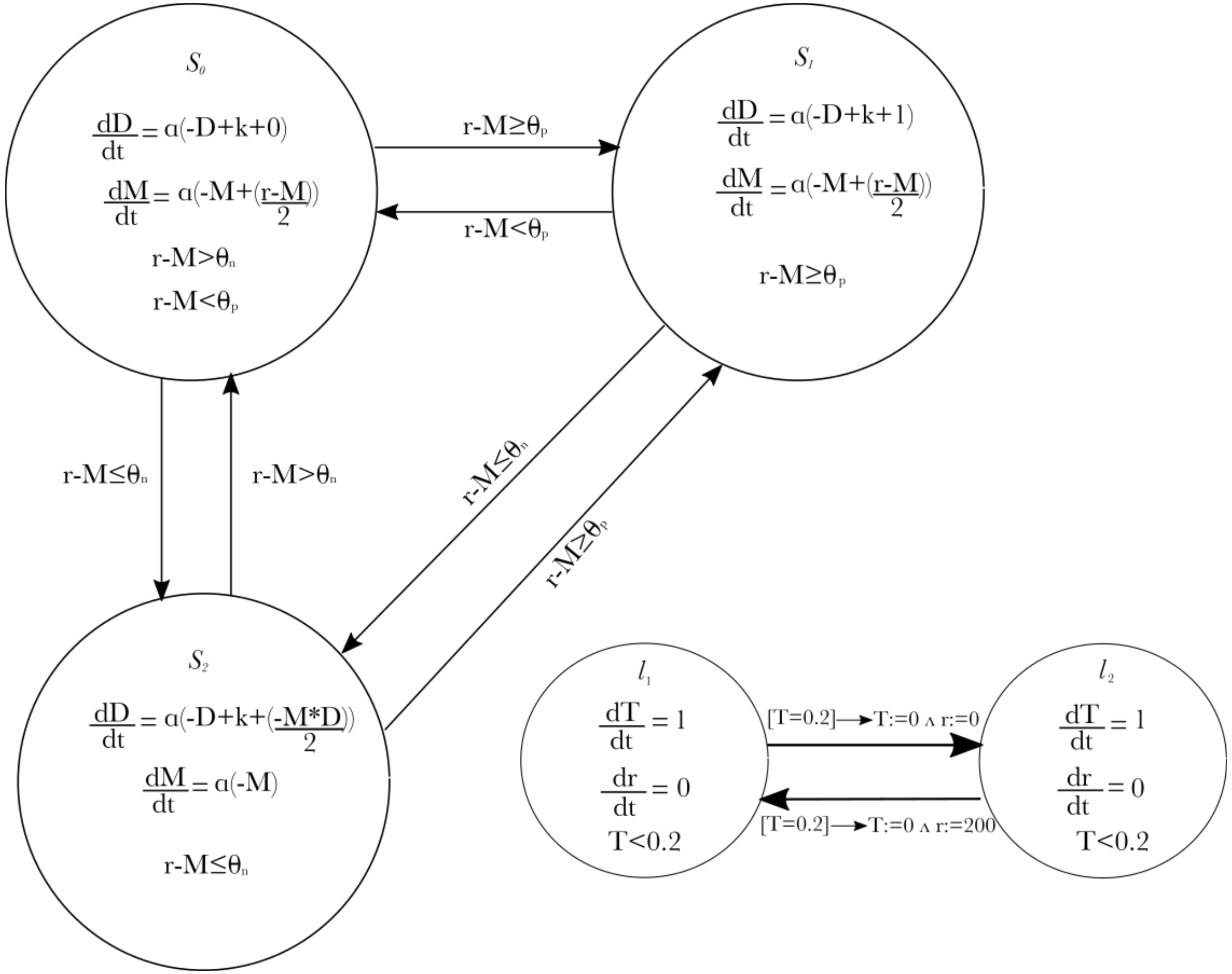
- The trend of dopamine is similar to the one obtained by Gutkin.
- The memory is an abstract description of the opponent process
- We use the memory threshold M>=15 to represent addiction

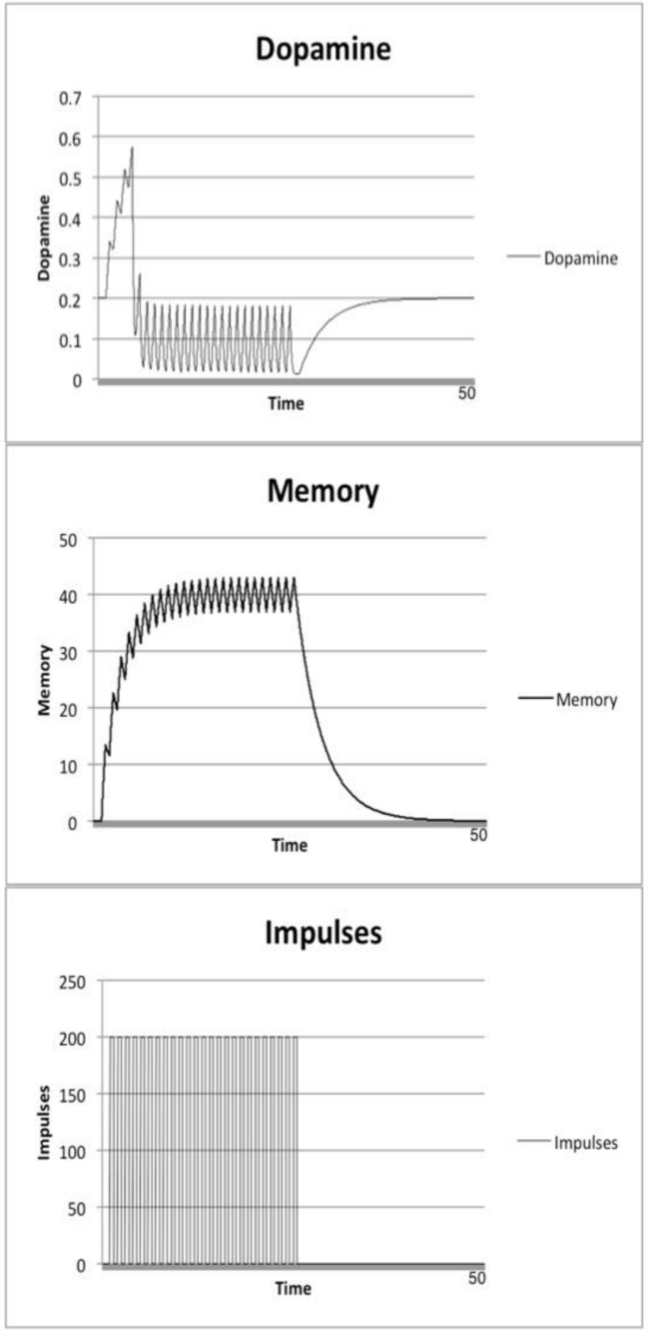




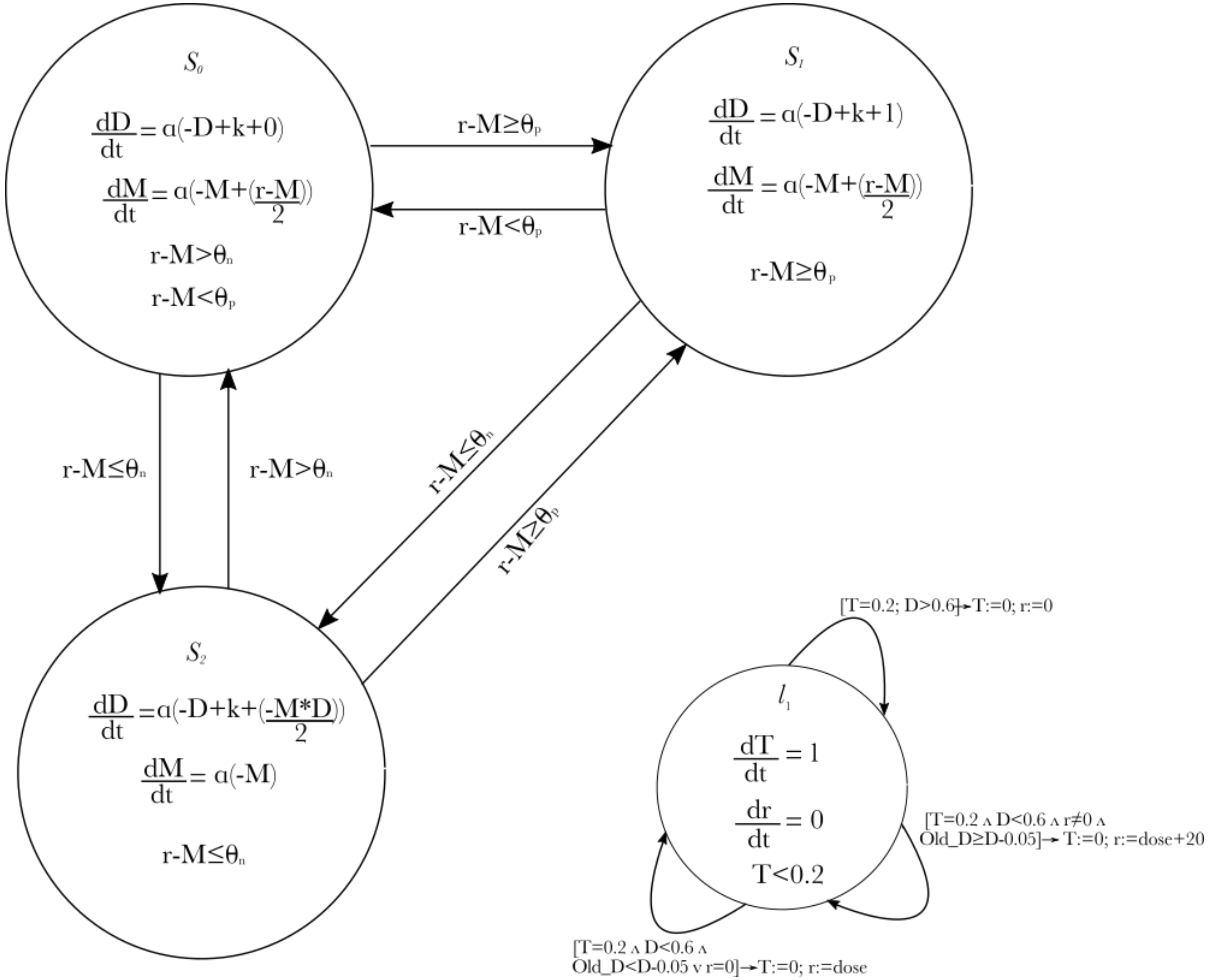


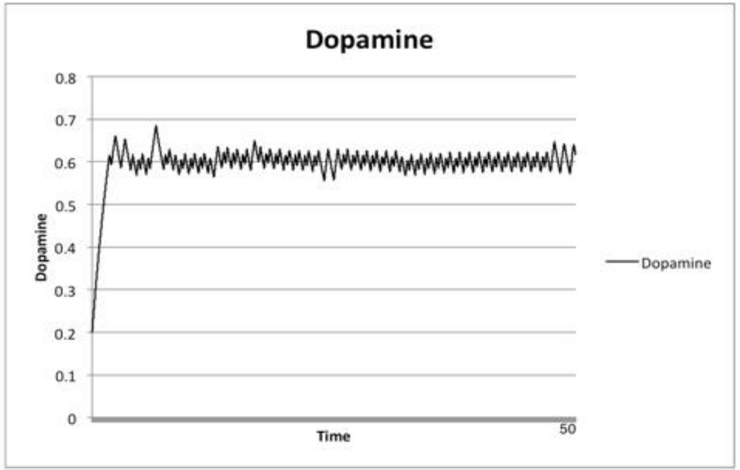
Varying the stimulus (1)

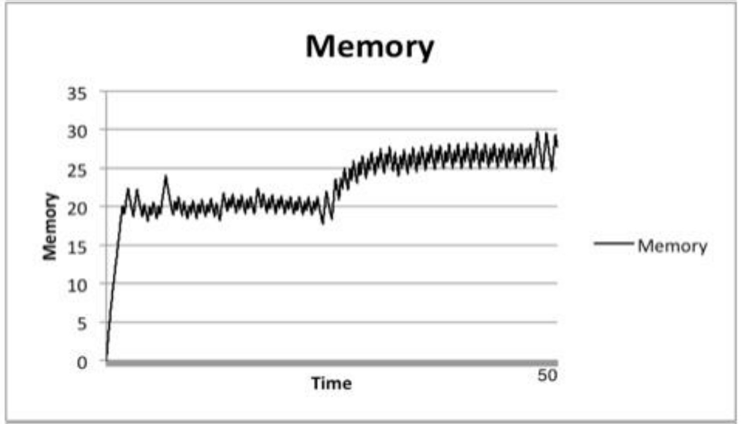


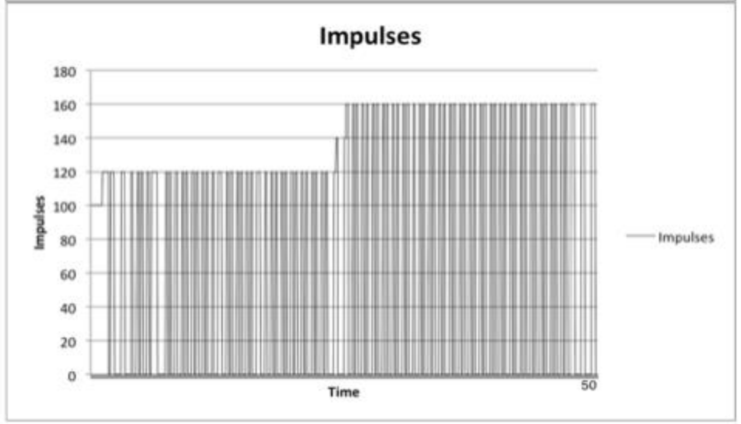


Varying the stimulus (2)









Internet addiction

- Excessive use of Internet as a mechanism to escape from the daily dissatisfaction.

Main expressions:

➤ Gaming

➤ Social network

➤ Surfing

We represent the social network as a graph:

➤ Each node of graph is a user

➤ Each user has a dopamine system and a propensity factor

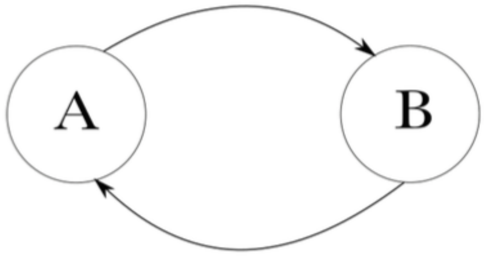
Model assumptions

- The propensity factor (real value in [0,1]) summarizes user's predisposition to communicate (probability of sending messages)
- Each user sends 0 or 1 original messages and 0 or 1 replies per day
  - Abstract way of representing the user involvement

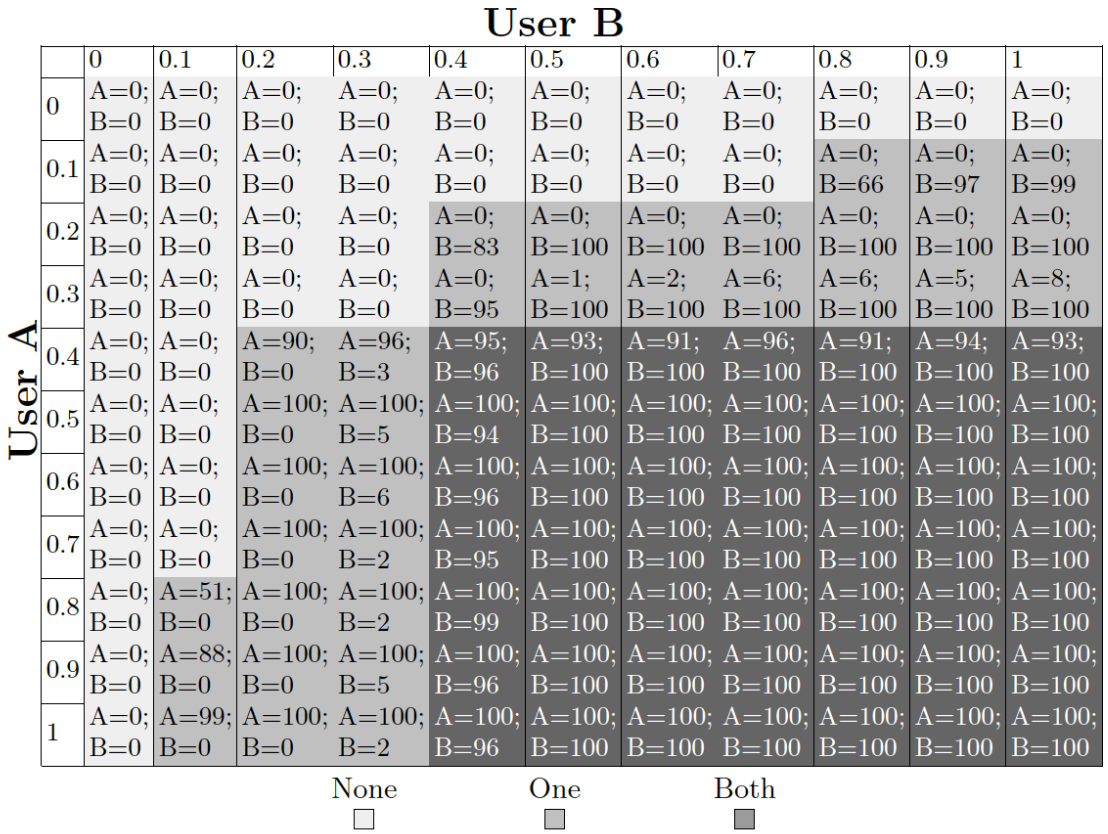
Dopamine stimuli:

- When a user receives a message (reward)
- When and addicted user sends a message (reward prediction)

Two-nodes graph



Used to examine the role of the propensity factor. All possible combinations of users have been tested to count how many times each of the two becomes addicted



User B

User A

	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0
0.1	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=66	A=0; B=97	A=0; B=99
0.2	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=83	A=0; B=100	A=0; B=100	A=0; B=100	A=0; B=100	A=0; B=100	A=0; B=100
0.3	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=0	A=0; B=95	A=1; B=100	A=2; B=100	A=6; B=100	A=6; B=100	A=5; B=100	A=8; B=100
0.4	A=0; B=0	A=0; B=0	A=90; B=0	A=96; B=3	A=95; B=96	A=93; B=100	A=91; B=100	A=96; B=100	A=91; B=100	A=94; B=100	A=93; B=100
0.5	A=0; B=0	A=0; B=0	A=100; B=0	A=100; B=5	A=100; B=94	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100
0.6	A=0; B=0	A=0; B=0	A=100; B=0	A=100; B=6	A=100; B=96	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100
0.7	A=0; B=0	A=0; B=0	A=100; B=0	A=100; B=2	A=100; B=95	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100
0.8	A=0; B=0	A=51; B=0	A=100; B=0	A=100; B=2	A=100; B=99	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100
0.9	A=0; B=0	A=88; B=0	A=100; B=0	A=100; B=5	A=100; B=96	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100
1	A=0; B=0	A=99; B=0	A=100; B=0	A=100; B=2	A=100; B=96	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100	A=100; B=100

None ☐ One ▨ Both ▨

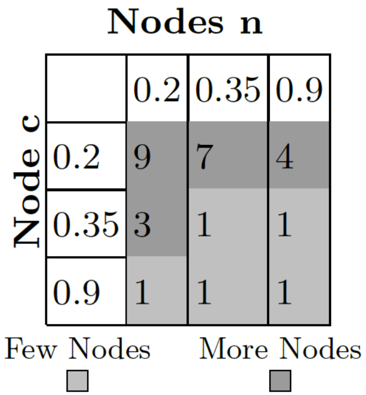
We find three values:

- low propensity: 0.2
- medium propensity: 0.35
- high propensity: 0.9

Star graph

Used to study propagation of addiction.

- How many nodes n are necessary in order for c to become addicted ?



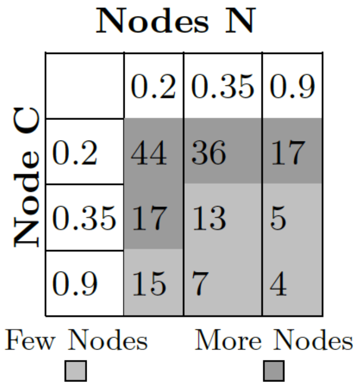
Nodes n

Node c

	0.2	0.35	0.9
0.2	9	7	4
0.35	3	1	1
0.9	1	1	1

Few Nodes ░ More Nodes ▓

- How many for x ?

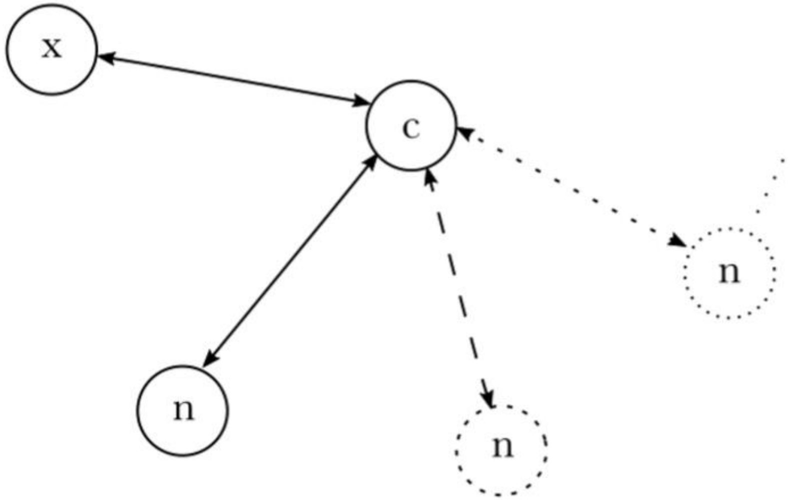


Nodes N

Node C

	0.2	0.35	0.9
0.2	44	36	17
0.35	17	13	5
0.9	15	7	4

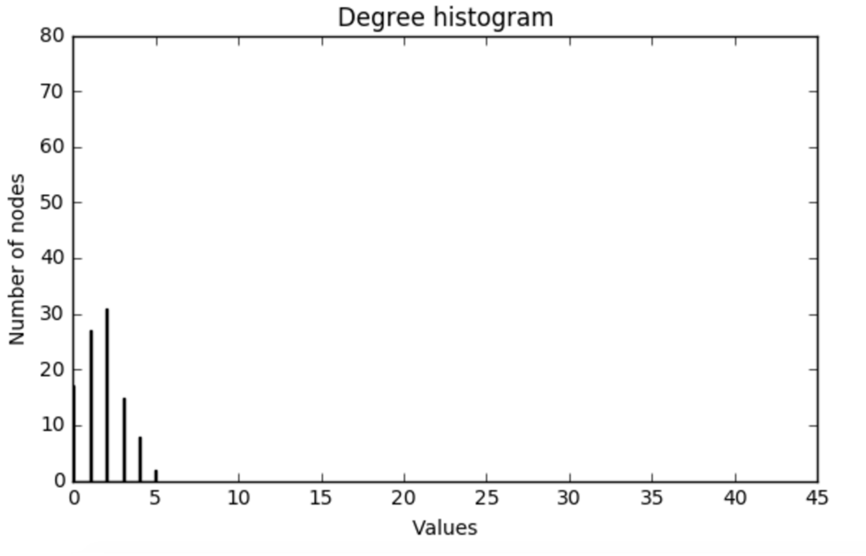
Few Nodes ░ More Nodes ▓

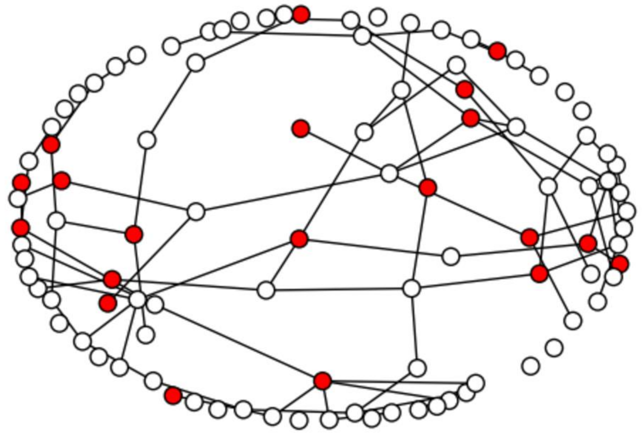


Whole networks (1)

Used to study the role of the (scale-free) network topology.

- Random graph -- Erdős-Rényi method (ER)



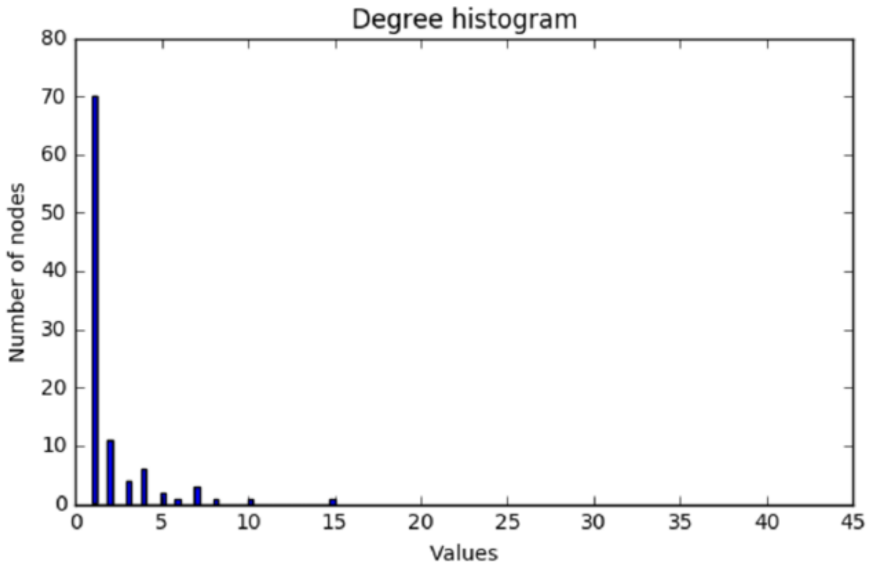


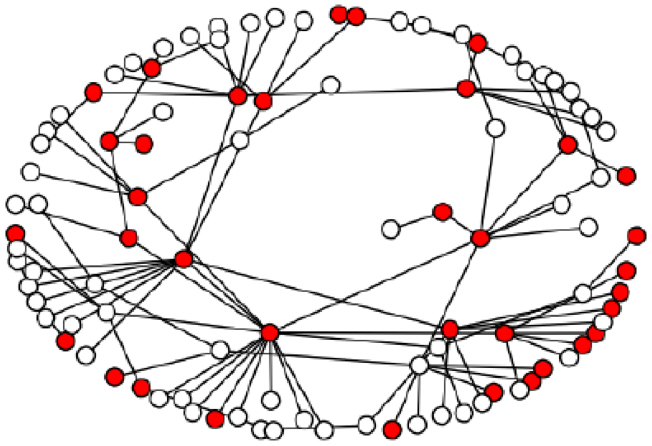
20 addicted users

Whole networks (2)

Used to study the role of the (scale-free) network topology.

- Scale-free graph -- Barabási-Albert method (BA)



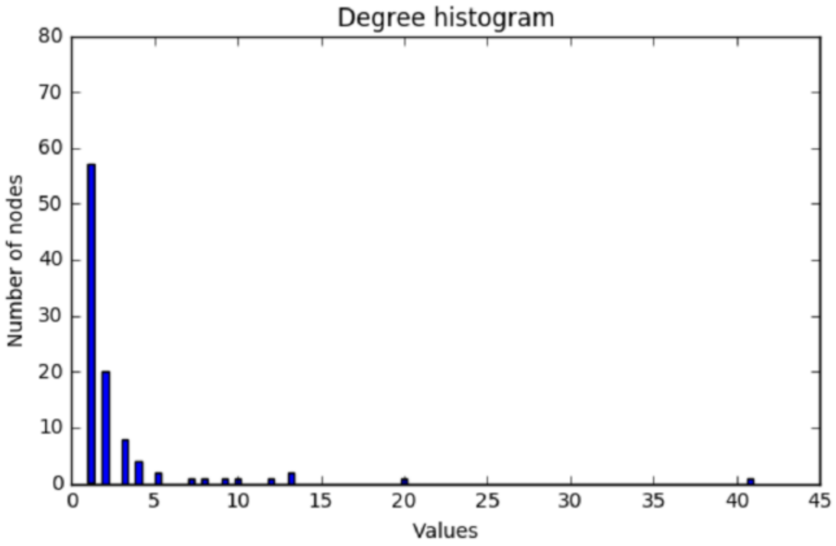


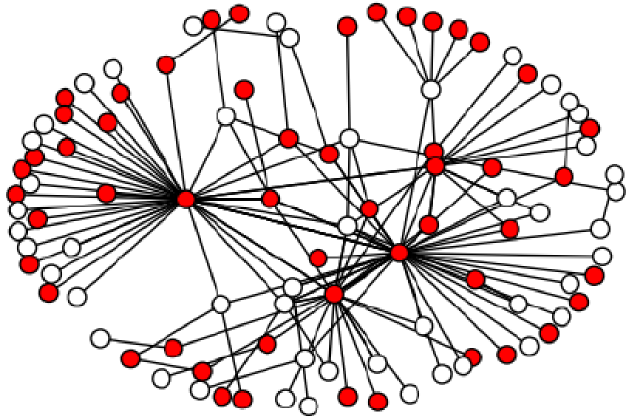
35 addicted users

Whole networks (3)

Used to study the role of the (scale-free) network topology.

- Scale-free graph -- Bollobás-Riordan method (BR)





52 addicted users

Summary of the results

- Under our assumptions on the dopamine stimuli created by social network interactions, we have shown that:
    1. Addiction can be caused by the interaction on social networks
    2. Addiction can be «transmitted» through social networks
    3. The topology of social networks (scale free) favours the spread of addiction