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.

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<th>Environmental factors:</th>
<th>Social factors:</th>
<th>Biological factors:</th>
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<td>➤ Availability</td>
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The Dopamine System

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

• 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.

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

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

\[
\tau_A \frac{dU_1^A}{dx} = -U_1^A + S_A\left\{ w_{11} U_1^A - w_{12} U_2^A - \theta_A \right\} + \sigma \xi \quad \text{and}
\]

\[
\tau_A \frac{dU_2^A}{dx} = -U_2^A + S_A\left\{ w_{22} U_2^A - w_{21} U_1^A - \theta_A \right\} + \sigma \xi.
\]

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

Hybrid Automata model

\[ S_0 \]
\[ \frac{dD}{dt} = \alpha(-D+k+0) \]
\[ \frac{dM}{dt} = \alpha(-M-(r-M)/2) \]
- \( r-M \geq \theta_2 \)
- \( r-M < \theta_2 \)
- \( \theta_2 < r-M < \theta_3 \)
- \( r-M \leq \theta_3 \)

\[ S_1 \]
\[ \frac{dD}{dt} = \alpha(-D+k+(-M*D)) \]
\[ \frac{dM}{dt} = \alpha(-M) \]
- \( r-M \leq \theta_1 \)

\[ S_2 \]
\[ \frac{dD}{dt} = \alpha(-D+k+(-M*D)) \]
\[ \frac{dM}{dt} = \alpha(-M) \]
- \( T < 25 \)
- \( T = 25 \)
- \( r = 0 \)

Graphs:
- Dopamine
- Memory
- Impulses
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 $M \geq 15$ to represent addiction.
Varying the stimulus (1)
Varying the stimulus (2)

\[
\begin{align*}
\frac{dD}{dt} &= \alpha(D+k+0) \\
\frac{dM}{dt} &= \alpha(M+M/2)
\end{align*}
\]

- \( r-M > \theta \)
- \( r-M \leq \theta \)

\[
\begin{align*}
\frac{dD}{dt} &= \alpha(D+k+1) \\
\frac{dM}{dt} &= \alpha(M+M/2)
\end{align*}
\]

- \( r-M \geq \theta \)
- \( r-M < \theta \)

\[
\begin{align*}
\frac{dD}{dt} &= \alpha(D+k+M+D) \\
\frac{dM}{dt} &= \alpha(M)
\end{align*}
\]

- \( r-M \leq \theta \)
- \( r-M > \theta \)

\[
\frac{dT}{dt} = 1 \\
\frac{dr}{dt} = 0 \\
T < 0.2
\]

- \( T = 0.2; D = 0.6; r = 0 \)
- \( T > 0; r = \text{dose} + 20 \)

- \( T = 0.2; D = 0.6 \) and \( r = 0 \)
- \( T = 0; r = \text{dose} \)
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.

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?

• How many for $x$?
Whole networks (1)

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

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

![Degree histogram](image1)

20 addicted users
Whole networks (2)

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

- Scale-free graph -- Barabási-Albert method (BA)
Whole networks (3)

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

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

![Degree histogram](image)

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