Emotion Dynamics incorporating External Stress Function

Liam Kischuck

BP8117 Final project presentation

The study of emotions

- Helps us understand mental illnesses and disorders
- Traditionally, symptoms of mental illnesses were thought to stem from some single cause.
- Recently, a dynamical view that sees different emotions as forming a network of interactions has gained much interest.

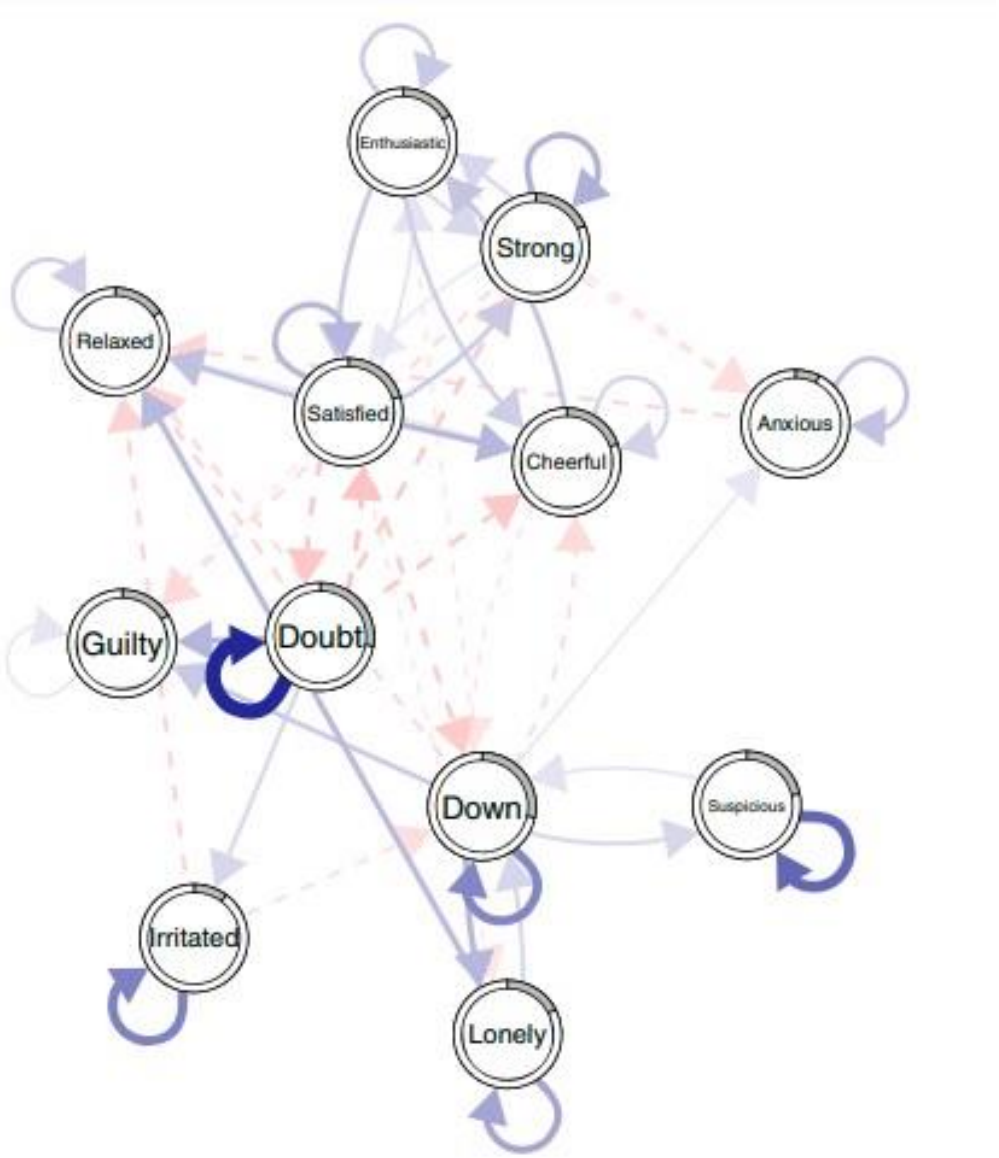
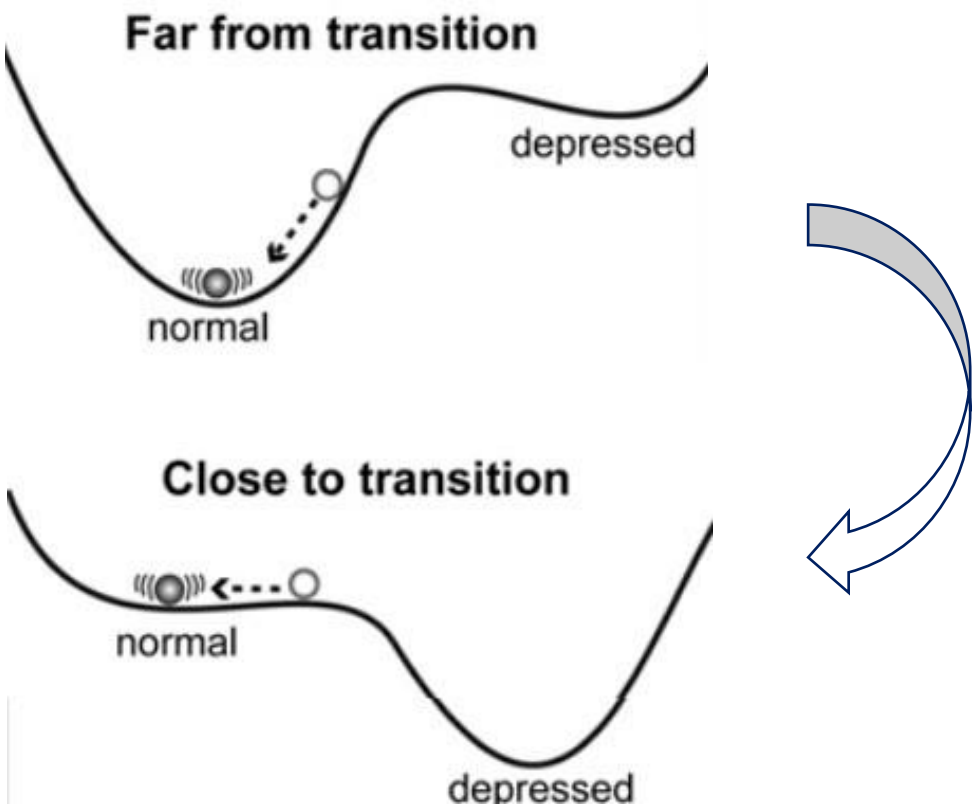


Image reference: Haslbeck, Jonas MB, Laura F. Bringmann, and Lourens J. Waldorp. "A tutorial on estimating time-varying vector autoregressive models." *Multivariate behavioral research* 56.1 (2021): 120-149.

Emotions as a dynamical system



$$\frac{dx_i}{dt} = (r_i + \epsilon_r)x_i + \sum_j^4 C_{i,j}x_j x_i + \mu,$$

Critical slowing down: process whereby the system becomes increasingly slower in its ability to recover

→ Can be used as an early indication for the onset of mental illnesses

Reference: van de Leemput, Ingrid A., et al. "Critical slowing down as early warning for the onset and termination of depression." (2014).

How do we measure Emotional change?

- Experience Sampling Method (ESM) is a widely used technique
- Only requires mobile device
- Participants are asked to record their emotions on 10~90 minute intervals.

Typically, Vector Autoregressive (VAR) model is used to make a simple network representing the interactions → each variable is predicted by a linear function of all variables at previous time points

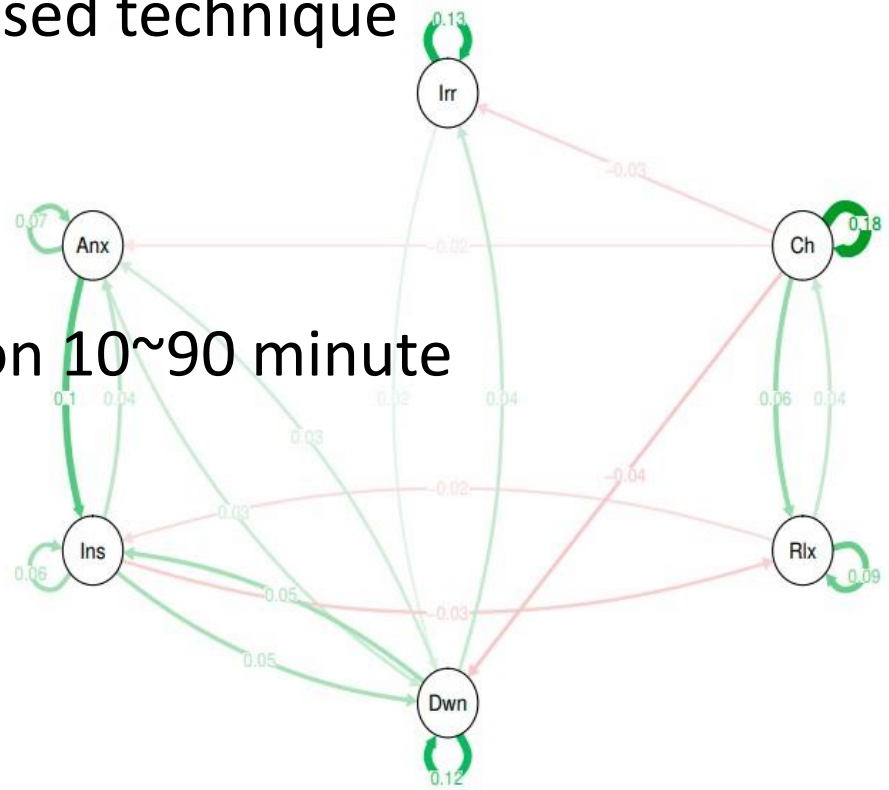
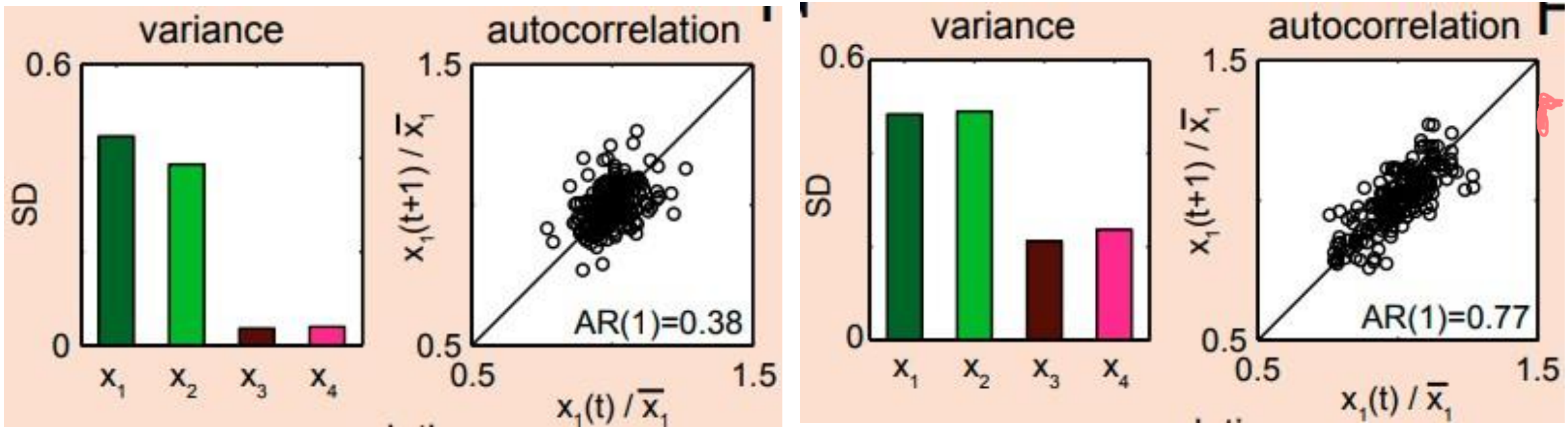


Image reference: Hasmi, Laila, et al. "Network approach to understanding emotion dynamics in relation to childhood trauma and genetic liability to psychopathology: replication of a prospective experience sampling analysis." *Frontiers in Psychology* 8 (2017): 1908.

Near transition the variance increases, greater correlation



Graph reference: van de Leemput, Ingrid A., et al. "Critical slowing down as early warning for the onset and termination of depression." (2014).

They experimentally tested this prediction.

→ Correlation between emotions of the same category increases near transition

Emotions can depend strongly on environment

- Events that occur periodically in our life can be a cause of stress, or the lack of stress.
- Examples of periodic events: events at work, certain chores, certain busy seasons like Christmas, holiday season, weekends etc.
- Depending on the strength of the stress or the lack of it, these events can affect our emotional state
- Not many studies include time-varying external stress levels

How to incorporate external periodic stress

- Express the periodic stress function as a sine function.

- $\dot{x}_i = r_i x_i + \sum_j C_{ij} x_j x_i + \mu$ $i = 1,2$ (positive emotions)

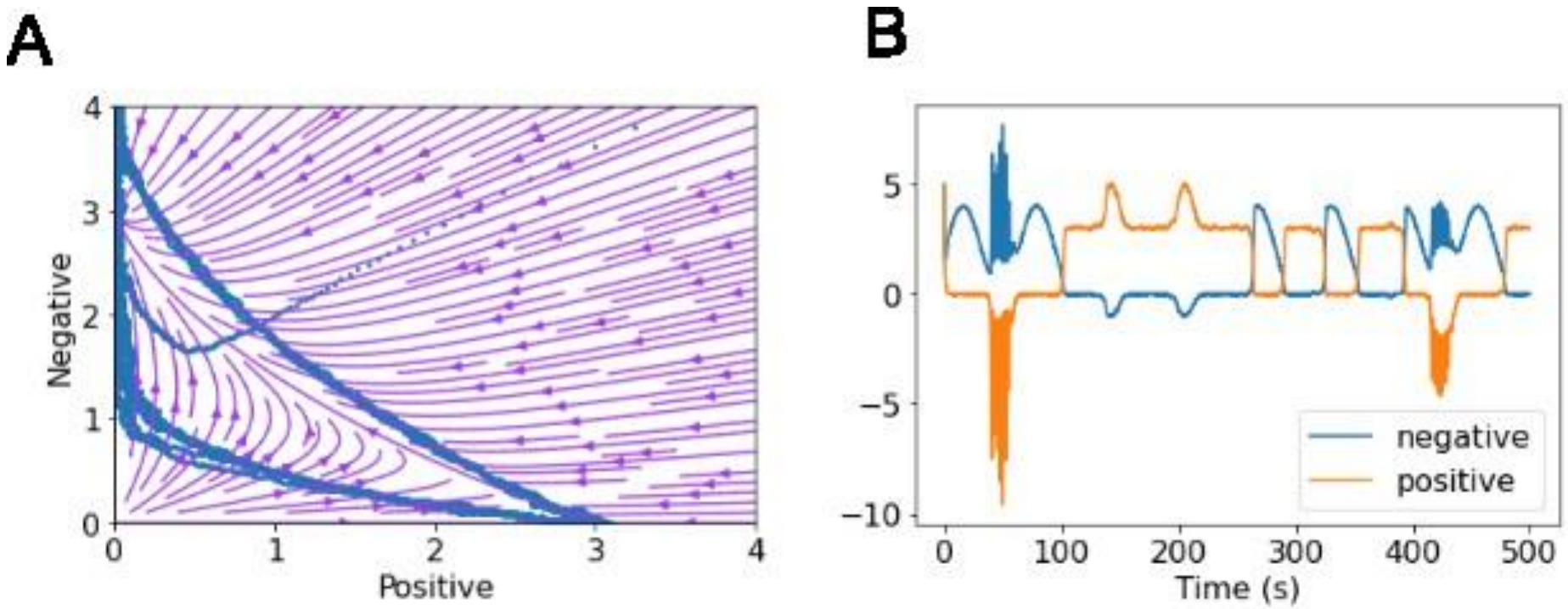
- $\dot{x}_i = (r_i + M \sin(2\pi t/T))x_i + \sum_j C_{ij} x_j x_i + \mu$ $i = 3,4$ (negative emotions)
- $\dot{t} = \frac{\omega}{2\pi}$ (additional equation for the second scenario)

- Euler's method was used to simulate the trajectories.

Preliminary test of our periodic forcing

$$\dot{x} = 3x - x^2 - 2xy$$
$$\dot{y} = (2 + \sin\left(\frac{t}{10}\right))y - y^2 - xy$$

Lotka-Volterra system introduced in class
→ The sine function leads to transition between states



4d with no external forcing

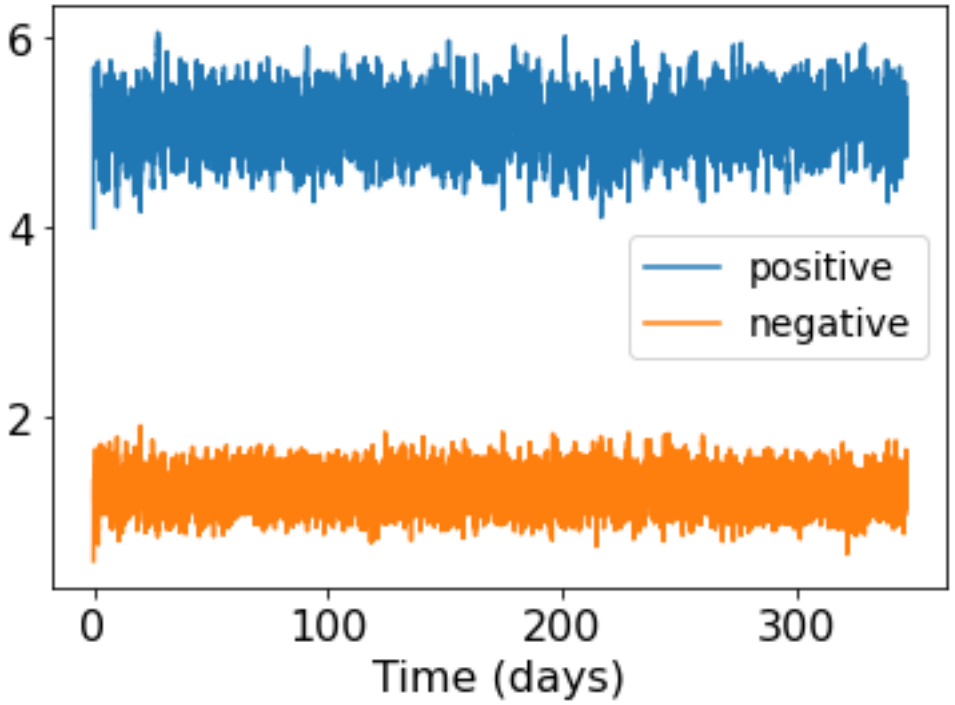
Wiener Process

M: environmental stress level

$$\dot{x}_i = (r_i + M)x_i + \sum_j C_{ij}x_j x_i + \sigma dM_t$$

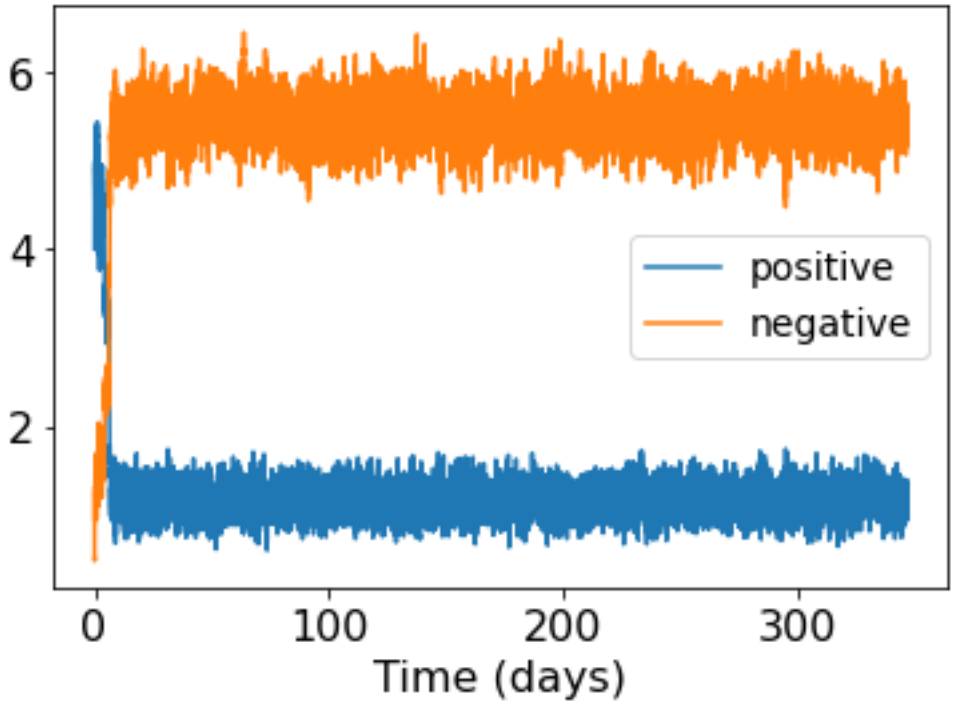
M = -0.05

Positive wins

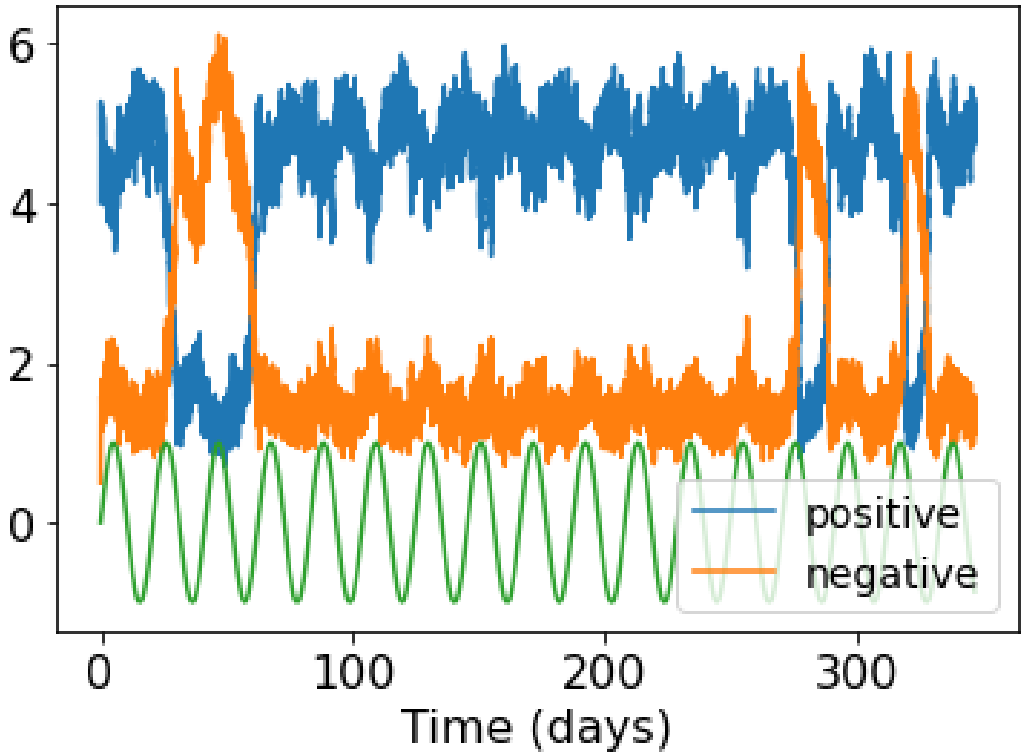


M = 0.05

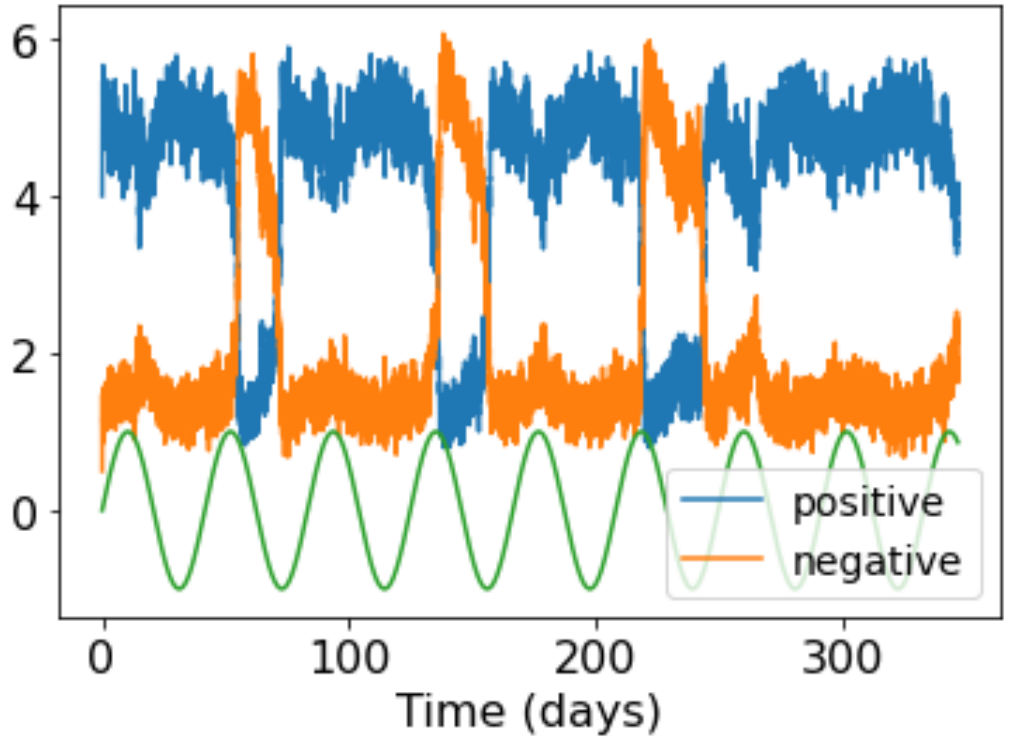
Negative wins



Simulations with external forcing



Period = 47 days



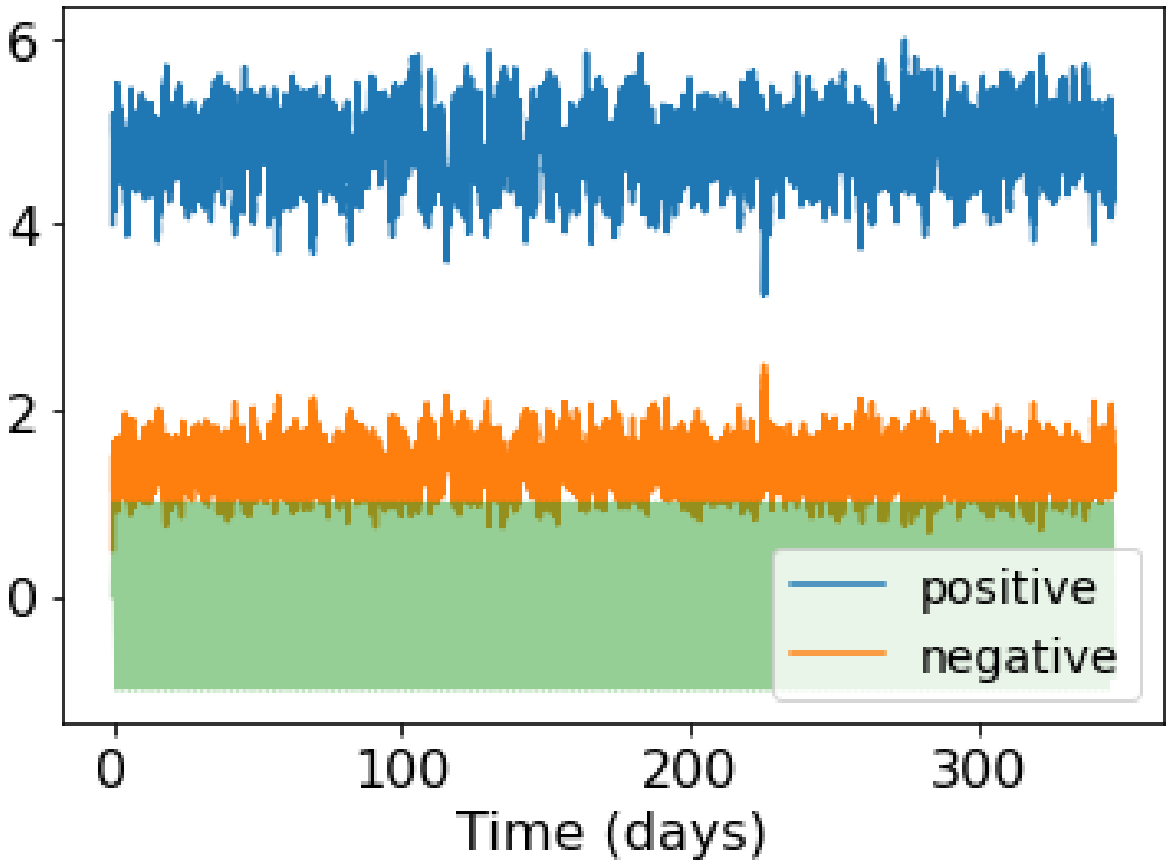
Period = 95 days

For M = 0.05, the periodic stress function does not deterministically lead to transitions→ transitions a still occur stochastically

No transitions at low frequency

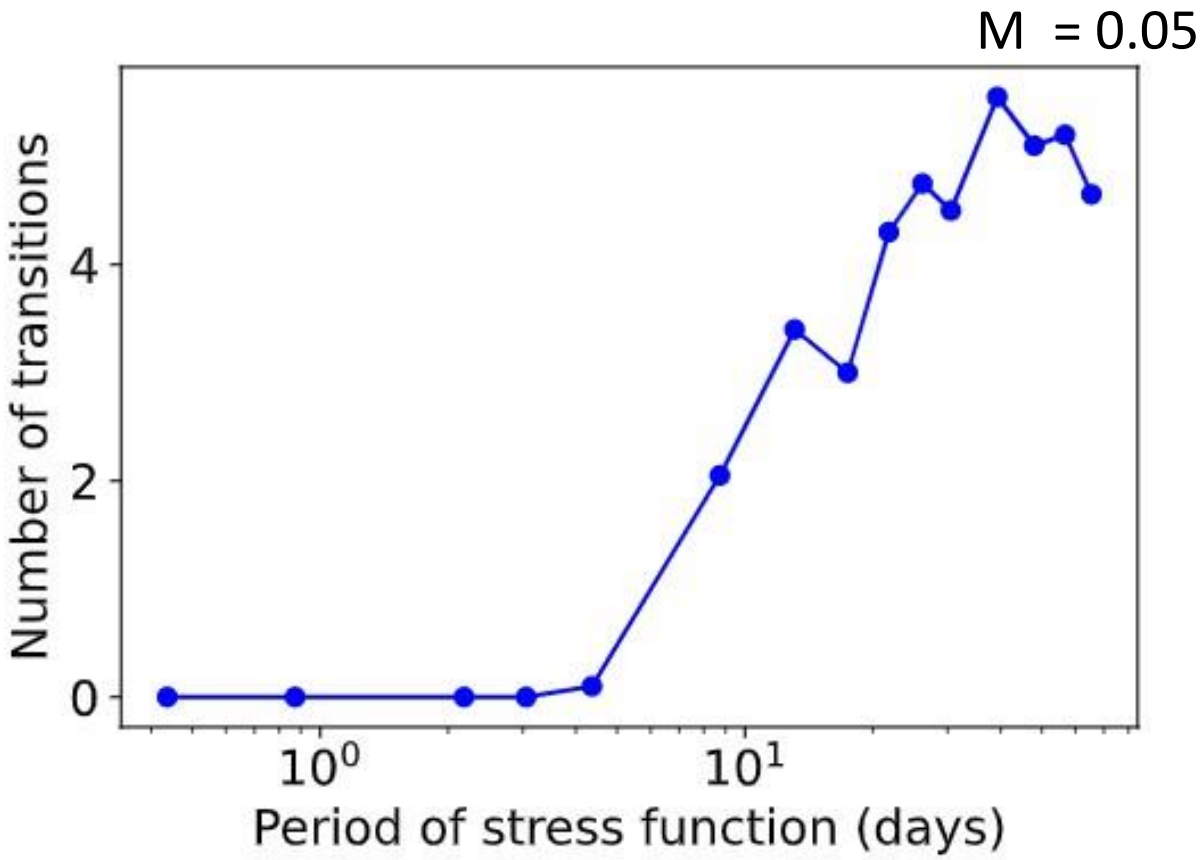
- Even at the same stress amplitude M = 0.05, a frequency corresponding to 4.3 days leads to no transitions!

- Question: How does the system behave depending on the period of the stress forcing?



The system does not respond to high frequency stress

- At high frequency (small period) there are no transitions between the states (up to ~5days)
- The system is resilient to fast and frequent stress intervals, but transitions upon infrequent and longer stress intervals



Suggests that the length of the stress stimuli is more significant than the frequency even if the stimuli are of equal magnitude

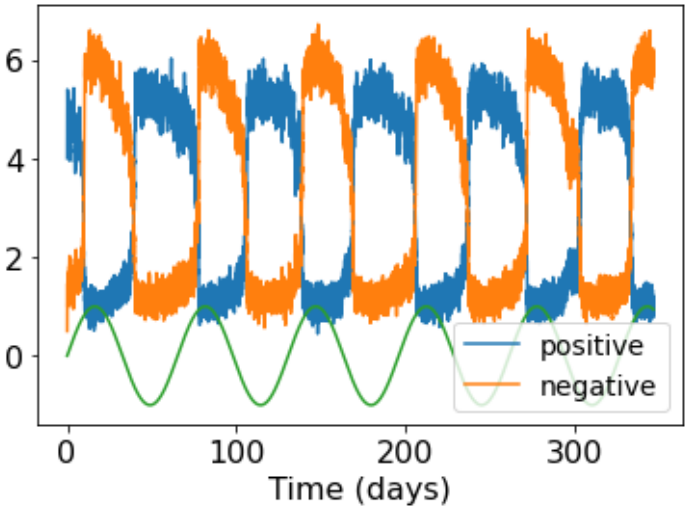
Varied the period T

Stress function = $M \sin\left(\frac{2\pi t}{T}\right)$

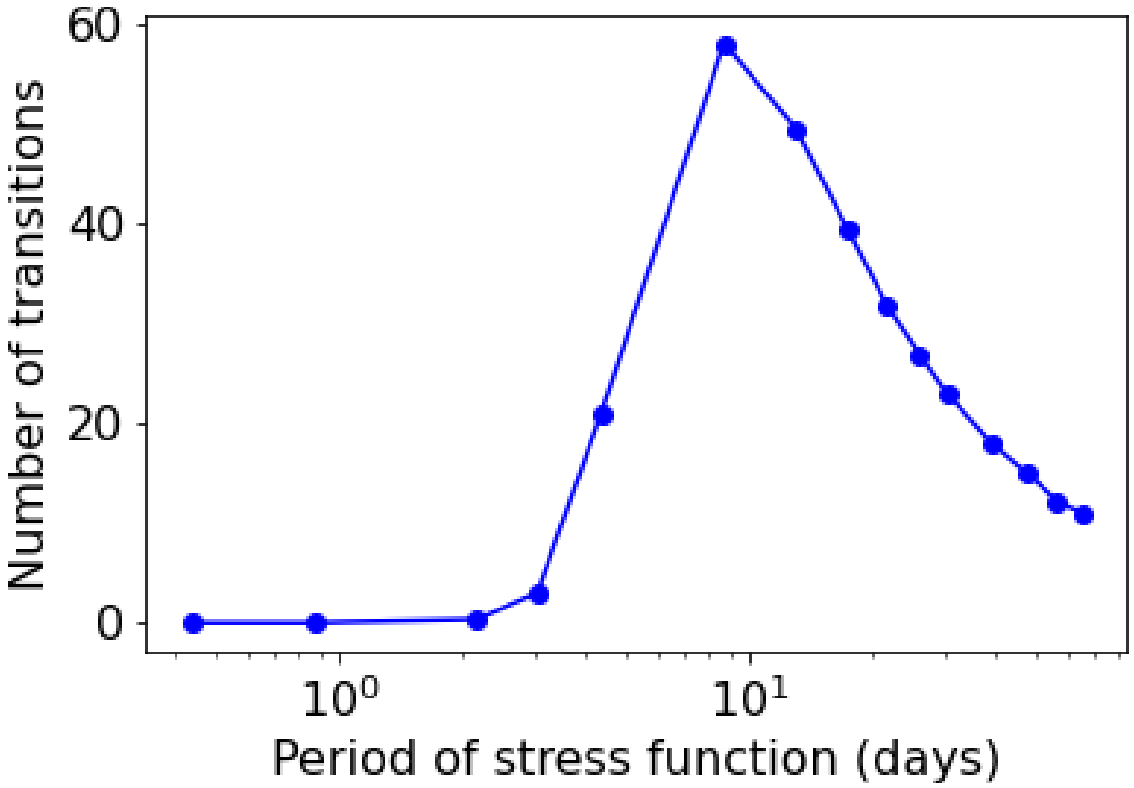
Magnitude of stress increases maximum number of transitions

- The maximum number of transitions increase 10 times
- Transitions start to occur at earlier values for the period (~3days)
- Longer stress periods leads to a deterministic dependence of the system on the stress function
- Decay in # of transition is just due to the time window of (347 days). Longer periods meaning fewer opportunities for transitions.

65 day period cycle



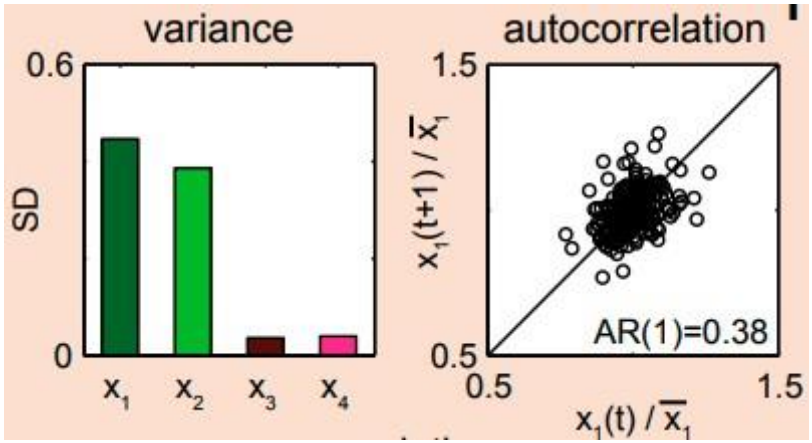
M = 0.1

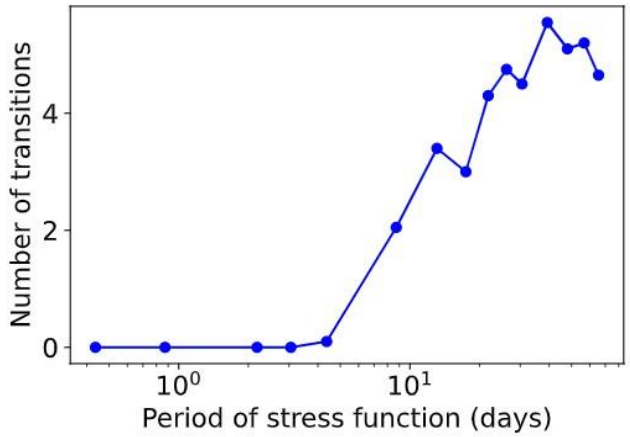


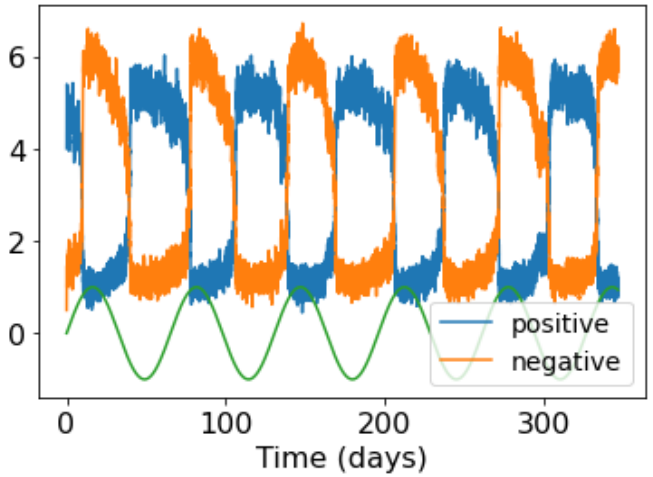
Summary

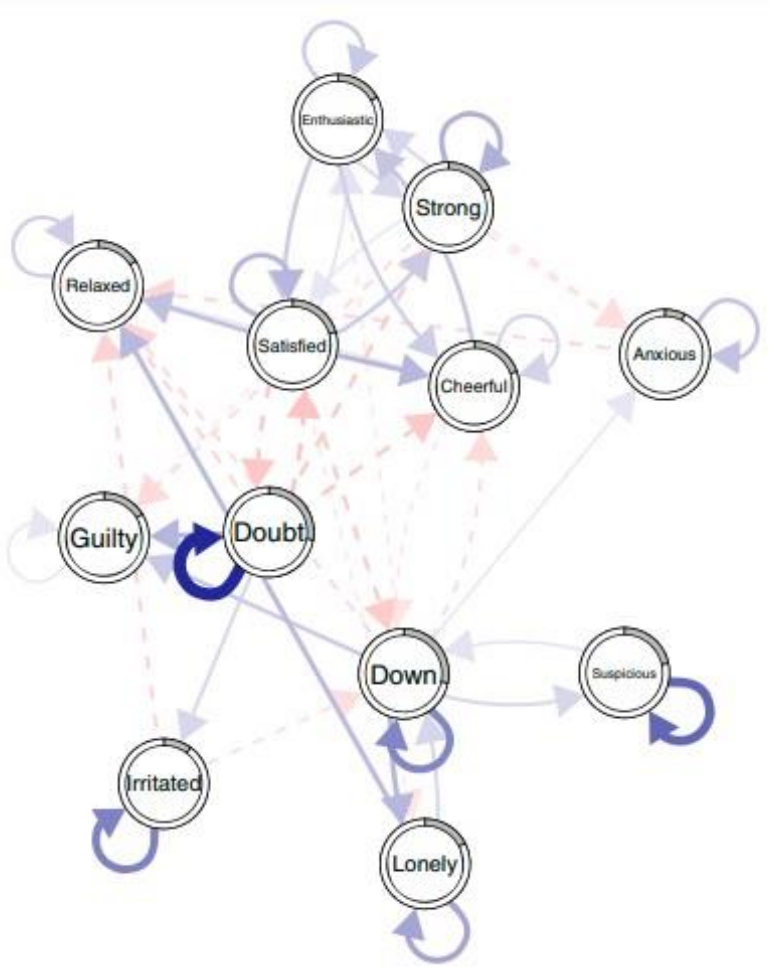
- Emotion dynamics is used to study problems in psychology (early warning sign, quantitative description of illnesses)
- Periodic stress function leads to transitions between states
- The length of the stress stimuli has a more dominating effect on the systems behavior than the frequency of the stimuli.

Thank You!.


variance
autocorrelation
0.6
SD
0
x_1 x_2 x_3 x_4
1.5
$x_1(t+1) / \overline{x_1}$
0.5
AR(1)=0.38
0.5
1.5
$x_1(t) / \overline{x_1}$


Number of transitions
4
2
0
10^0
10^1
Period of stress function (days)


6
4
2
0
positive
negative
0
100
200
300
Time (days)


Enthusiastic
Strong
Relaxed
Satisfied
Cheerful
Anxious
Guilty
Doubt
Down
Suspicious
Irritated
Lonely