Early warning signals of critical transitions in mood

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What kinds of things are psychiatric disorders?

K. S. Kendler¹*, P. Zachar² and C. Craver³

- Essential characteristics of mental disorders?
  Psychological, neurological, genetic..
Medical disease

Alex

Problems:
• Headaches
• Forgetfulness
• Foggy eyesight

Brain scan

Diagnosis:
• Brain tumor

Treatment:
• Surgery
• Chemotherapy
Jenny

Problems:
- Problems sleeping
- Depressed mood
- Lack of interest

DSM symptom check

Diagnosis:
- Major depression

Treatment:
- Therapy
- Antidepressants

• MD is not an empirically identifiable entity which can be treated directly (e.g. like Down syndrome or cancer)
• No lab test for MD (e.g. 3rd chromosome, tumor)
Relation between Major Depression and its observable symptoms according to the medical disease model
Network approach

Network of Major Depression and General Anxiety Syndrome symptoms based on correlations in the National Comorbidity Survey Replication data

Symptoms could correlate because they are causally linked, instead of symptoms of a single disease
Individual differences

The network view allows us to define individual differences in terms of connection strengths (and thus individual paths to disorder):

Affected by e.g.:
- Genetic factors
- Hormones
- Life events
- Culture
- etc..
Kendler et al. essentially propose to view mental disorders as attractors in a large complex dynamical system.
Depression as a tipping point?

Slow driver (e.g. stress)

Small perturbation (e.g. upsetting phone call)

- Worrying
- Depressed mood
- Social isolation
Indications of positive feedbacks

Mood-related factors:

\[ R = \text{relaxed} \]
\[ C = \text{cheerful} \]
\[ E = \text{pleasant event} \]
\[ S = \text{sad} \]
\[ F = \text{fearful} \]
\[ W = \text{worry} \]
Early warning signals illustrated with a model describing mood dynamics

Critical slowing down as early warning for the onset and termination of depression

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Temporal data!! ESM: Experience Sampling Method

- 2 populations:
  - General (without diagnosis depression) (n=535)
  - Depressed (with diagnosis depression) (n=93)

- 6 consecutive days, 10 times a day (7:30 - 22:30)

- Monitoring of follow-up course depressive symptoms

<table>
<thead>
<tr>
<th>Emotion</th>
<th>Current state (1-7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content</td>
<td>...</td>
</tr>
<tr>
<td>Satisfied</td>
<td>...</td>
</tr>
<tr>
<td>Anxious</td>
<td>...</td>
</tr>
<tr>
<td>Sad</td>
<td>...</td>
</tr>
</tbody>
</table>
Results

- General population closer to depression:
  - Higher autocorrelation and variance of negative emotions

- Depressed population closer to recovery:
  - Higher autocorrelation and variance of positive emotions
Results

- General population closer to depression:
  - Higher autocorrelation and variance of negative emotions
  - Higher correlation between emotions

- Depressed population closer to recovery:
  - Higher autocorrelation and variance of positive emotions
  - Higher correlation between emotions
Emotional Inertia

Emotional inertia “refers to the degree to which a person’s current emotional state is predicted by their prior emotional state, reflecting how much it carries over from one moment to the next”

Increased emotional inertia predictive of onset of depressive disorder
Individual-level

Wichers et al. under review
Individual-level

Wichers et al. *under review*

**Phase 1 (before experiment)**

- PA
- SU
- MU
- WO
- NA

**Phase 2 (no anti-depr reduction)**

- PA
- SU
- MU
- WO
- NA

**Phase 3 (anti-depr reduction)**

- PA
- SU
- MU
- WO
- NA

**Phase 4 (before shift)**

- PA
- SU
- MU
- WO
- NA
Conclusions depression experiments

- Increased autocorrelation, variance, and correlation between emotions indicative for proximity ‘transition’ towards depression, and towards healthy state

- 1) Indication of positive feedbacks,  
  2) abrupt shifts, and  
  3) early warning signals  
  suggest that depression and healthy state are alternative stable states..

- .. and transitions between them are critical transitions/ tipping points

- Our results strengthen the network view of mental disorders

- Circumvent full understanding, but still improve ability to anticipate clinically relevant mood shifts
Future issues..

- What do the many roads to developing mental disorders look like?
- What sort of genetic/biological, psychological, and environmental factors govern individual differences in the strength of connections between symptoms?
- Replication of individual-level experiment (currently n=1)
- Causal links between symptoms? Convergent cross-mapping..
- How can the theory of early warning signals help in targeting and evaluating therapeutic interventions?
Mood tracking apps, rely on self-assessment
Tracking mood in social media updates

- Twitter: “I was diagnosed bipolar” or “I was diagnosed depression”
- Sentiment analysis from short texts
Social tipping points.. early warning signals

Small perturbation (e.g. local uproar)

- Peer-pressure
- # Active individuals
- Recognition
Thank you
Network approach

Network of Major Depression and General Anxiety Syndrome symptoms
based on putative causal relations between symptoms
The model

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

\[
C = \begin{pmatrix}
-0.2 & 0.04 & -0.2 & -0.2 \\
0.04 & -0.2 & -0.2 & -0.2 \\
-0.2 & -0.2 & -0.2 & 0.04 \\
-0.2 & -0.2 & 0.04 & -0.2
\end{pmatrix}
\]
The four emotions were a-priori chosen to represent each quadrant of the affective space:

- **Valence**
  - Negative: anxious
  - Positive: cheerful

- **Arousal**
  - Low: sad
  - High: content
Positive emotions in general population

Negative emotions in depressed patients

- autocorrelation (AR(1))
- variance (SD)

Tertiles of change in follow-up course of depression
- low
- medium
- high

Tertiles of change in follow-up course of recovery
- low
- medium
- high

- content
- cheerful
- sad
- anxious
The diagrams illustrate the variance, coefficient of variation, and mean for different emotional states across tertiles of change in the follow-up course of depression and recovery.

For the general population:
- **A**: Variance (SD) for different emotional states across tertiles.
- **B**: Coefficient of variation (CV) for different emotional states across tertiles.
- **C**: Mean for different emotional states across tertiles.

For depressed patients:
- **D**: Variance (SD) for different emotional states across tertiles.
- **E**: Coefficient of variation (CV) for different emotional states across tertiles.
- **F**: Mean for different emotional states across tertiles.

The emotional states are categorized as content, cheerful, sad, and anxious.