Can we use ACT-R to move towards precision medicine? The case of depression

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Depression

• Disorder characterized by persistent feeling of sadness and loss of interest, difficulty doing normal day-to-day activities
• Associated with tremendous cost to society (Kessler et al., 2015)
• Considerable heterogeneity makes finding treatment challenging (Marquand et al., 2016)
Variety in proposed depression mechanisms

• Ruminative thinking
• Deficiencies in reward learning
• Attentional bias towards negative information
• Overly general autobiographical memory
An ACT-R model of depression

- Formalizes ruminative thinking: competition between on-task and mind-wandering
- Difference between healthy and depressed:
  - Memory structure: more negative memories, tightly bound together for depressed
  - Makes returning to task challenging
An ACT-R model of depression

- Memory structures based on experience sampling data

experience sampling model

van Vugt & van der Velde (2018)
Model predicted impairment in attention performance

van Vugt & van der Velde (2018)

data: Besten et al (in prep)
Similar model attempted to predict working memory performance

For successful prediction, attentional bias to negative information was needed as well!

van der Velde & van Vugt (2018)
Possible explanation: individual differences

- Some individuals may be more impaired in attentional bias, others in reward learning, others in ruminative thinking

Data from Bachelor project of Boris Winter

Can we find the dominant mechanism for an individual?

- Inspiration: drift diffusion models (Ratcliff, 1978) can distinguish between individuals’ quality of attention, speed-accuracy trade-off
- Requires detailed statistics on response time distribution
- Can this be applied to ACT-R depression models?
Step 1: make ACT-R models of different depression mechanisms

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Possible ACT-R implementation</th>
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<tbody>
<tr>
<td>Rumination</td>
<td>Add mind-wandering process that gets stuck in negative recalls</td>
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<tr>
<td>Reward learning impairment</td>
<td>Reduce reward learning parameter</td>
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<tr>
<td>Negative attentional bias</td>
<td>Make chunks with a negative valence slot more active</td>
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<tr>
<td>Overgeneral autobiographical memory</td>
<td>??? Inability to make subgoals on self-related tasks</td>
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Step 2: Connecting individuals to mechanisms

- Collect detailed behavioural data across a range of tasks
  - Sustained attention to response task
  - Reward learning
  - Attention task with emotional stimuli
  - Autobiographical memory (maybe)
- Compare an individual’s performance to a bank of simulated **detailed** performance patterns turning mechanisms on or off (adjusting strength if possible)
  - Find best fit
Person 1

Rum RL bias self

Person 2

Rum RL bias self

Person 3

Rum RL bias self
Summary

• Depression is a heterogeneous disorder
• Current ACT-R model centered around a single mechanism
• Modeling individual differences in common in simple models such as the diffusion model
• Can we create families of models to simulate patterns of task performance across individuals?
• Can we use these simulated cognitive profiles to predict effects of interventions? (e.g., mindfulness, van Vugt & Moye, 2019)