Aging Deficits as a Side-Effect of Optimization

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Aging Effects in Selective Attention

Behavioral Experiments

Theoretical Psychology

ERP Analysis

Computational Modeling

EEG Recordings

Advanced Averaging

Single Trial ERPs

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See Poster #12 by Jörg Behrendt

See Poster #52 by Matthias Ihrke

ERP analysis

ERP

Biology of Aging

Psychology

Theoretical Behavior

Experiments

Real-Time EEG Recordings
Cognitive Aging

Manifestations/Causes of Cognitive Aging

- slower speed (Salthouse (1996))
- fewer resources (Craik and Byrd (1982))
- less inhibition (Zacks and Hasher (1997))
- explicit memory decline (Park and Shaw (1992))
- impaired memory recall (Craik and Byrd (1982))

Recent Theories

- common cause theory (Baltes and Lindenberger (1997))
- motivational change (Baltes 1997)
Probing Fluid Intelligence

Raven’s Progressive Matrices
- measure for fluid intelligence
- insertion of the correct piece
- increasing complexity
- error classification

Performance of Older Subjects
- number of errors is age dependent
- type of error depends on ability
- but ability confounds with age

(Babcock (2002))
Fundamentals for Modeling of Aging

Ways to incorporate aging into neurocomputational models

- reduction of the number of neurons (Shefer 1973)
- reduction of white matter volume $\rightarrow$ number of synapses (Horn et al. (1993))
- suboptimal neuromodulation (dopamine) (Braver and Barch (2002))
- less cognitive control (Brown (2007), Cohen (2001))
- noise increase (Li et al. 2006)
- longer learning history (Nadel and Moscovich (2002), Schrobsdorff et al. in preparation)
Learning impairs Flexibility

main idea

A decline in fluid intelligence may be caused by adaptation of the brain towards every day stimuli.

fluid intelligence

- intellectual flexibility
- complex associations
- optimal search strategies

in network models

- optimal computation
- high connection degree
- self-organized criticality
Self-Organized Criticality

Neural Model
- Hopfield network
- dynamical synapses
- homogeneous connectivity
- fixed connectivity

Properties
- parameter independent
- stable critical state
- scale-free exploration

(Levina, Herrmann, Geisel (2007))
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Avalanches in a Hebbian Hopfield-Network

Model Structure
- integrate and fire neurons
- all to all coupled
- dynamical synapses
- Hebbian learning rule

Simulation
- exposed to input patterns
- tested for avalanche size distribution during development
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Loss of Criticality

Results

- formation of highly connected clusters
- attractors for the avalanche dynamics
- global criticality vanishes
- avalanches within clusters
- intercluster avalanches
- no global flexible associations
Solving Raven Matrices

Layers
1. retinotopic map
2. feature units
3. mappings
4. rules
5. rule management
6. process control

Basics
- input via feature→location
- hierarchy of rules
- receptive fields for rules

Meta-Model for Easy Examples
- rules are activated by the figure for the different receptive fields
- propagate into the void place if they converge for both directions to the same response, done
- if not, search for more rules
Solving Raven Matrices

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**Full Implementation**
- feature units
- mapping of features between positions
- rule units, row-wise, column-wise
- rule input: features or mappings
- search in rule space (see Fig.)
- meta-rules (how to apply rules)

**Rules**
- geometrical relations
- algebraic relations
- different for different features
- identify irrelevant features
Conclusion

Take Home Message
- Aging impairments can be accessed in various ways.
- There is a tradeoff between adaptation to input and flexibility.
- Our model can deal with Raven matrices.

Outlook
- Consider different learning rules.
- Statistical comparison with convergence of the connectivity.
- Implement the Raven solving model in detail.
Thanks ...

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Solving Raven Matrices
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... and to You!