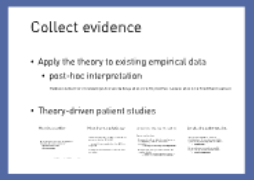
New theories ...

The Bayesian Brain

A computational framework of cognition

... to explain autism

Research to do



Computational Psychiatry

Past

Perception ⇄ Action

Weak central coherence (Happé & Frith 2006)

Reduced social motivation (Chevallier et al. 2012)

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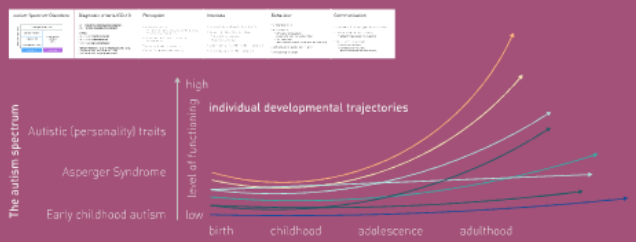

Current clinical problems

Future

Understanding and explaining

the huge variance, to affected, to relatives, to clinicians, ...

Diagnosing

quick, easy to apply, reliable tests

Treating

mechanistically informed psychotherapeutic and pharmacological concepts

Potential benefits

Reading

Translational Neuromodeling Unit

Autism

Current clinical problems
and how they can benefit from computational psychiatry

Computational Psychiatry Course
Zürich, 29. August 2016

Helene Haker (haker@biomed.ee.ethz.ch)
Translational Neuromodeling Unit, Zürich

Universität Zürich[UZH]

ETH
Eidgenössische Technische Hochschule Zürich
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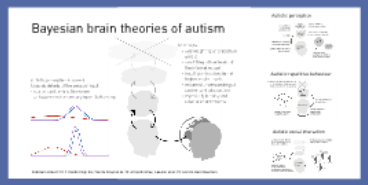

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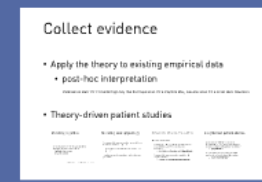

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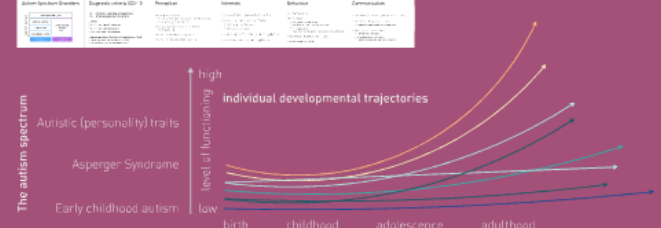

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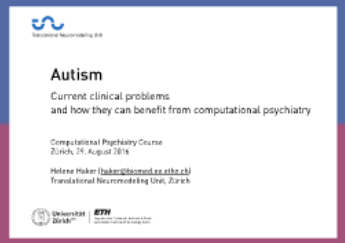

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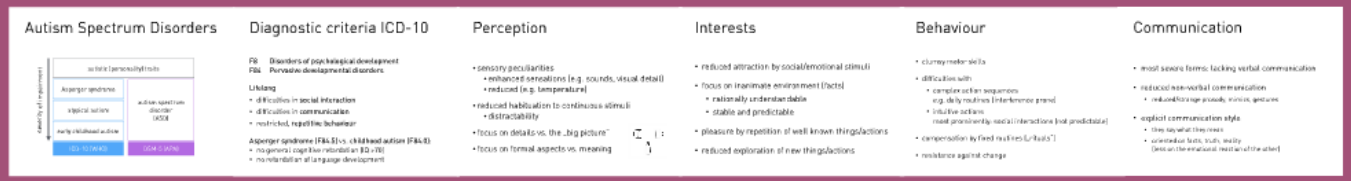

Autism Spectrum Disorders

Diagnostic criteria ICD-10

F8 Disorders of psychological development
F84 Pervasive developmental disorders

Lifelong
- difficulties in social interaction
- difficulties in communication
- restricted, repetitive behaviour

Asperger syndrome (F84.5) vs. childhood autism (F84.0)
- no general cognitive retardation (IQ >70)
- no retardation of language development

Perception

- sensory peculiarities
  - enhanced sensations (e.g. sounds, visual detail)
  - reduced (e.g. temperature)
- reduced habituation to continuous stimuli
  - distractability
- focus on details vs. the „big picture"
- focus on formal aspects vs. meaning

Interests

- reduced attraction by social/emotional stimuli
- focus on inanimate environment (facts)
  - rationally understandable
  - stable and predictable
- pleasure by repetition of well known things/actions
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Behaviour

- clumsy motor skills
- difficulties with
  - complex action sequences
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    need prominently social interactions (not predictable)
- compensation by fixed routines („rituals")
- resistance against change

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- most severe forms: lacking verbal communication
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  - they say what they mean
  - orientation facts, truth, reality
    (less on the emotional meta-aim of the utter)

spectrum

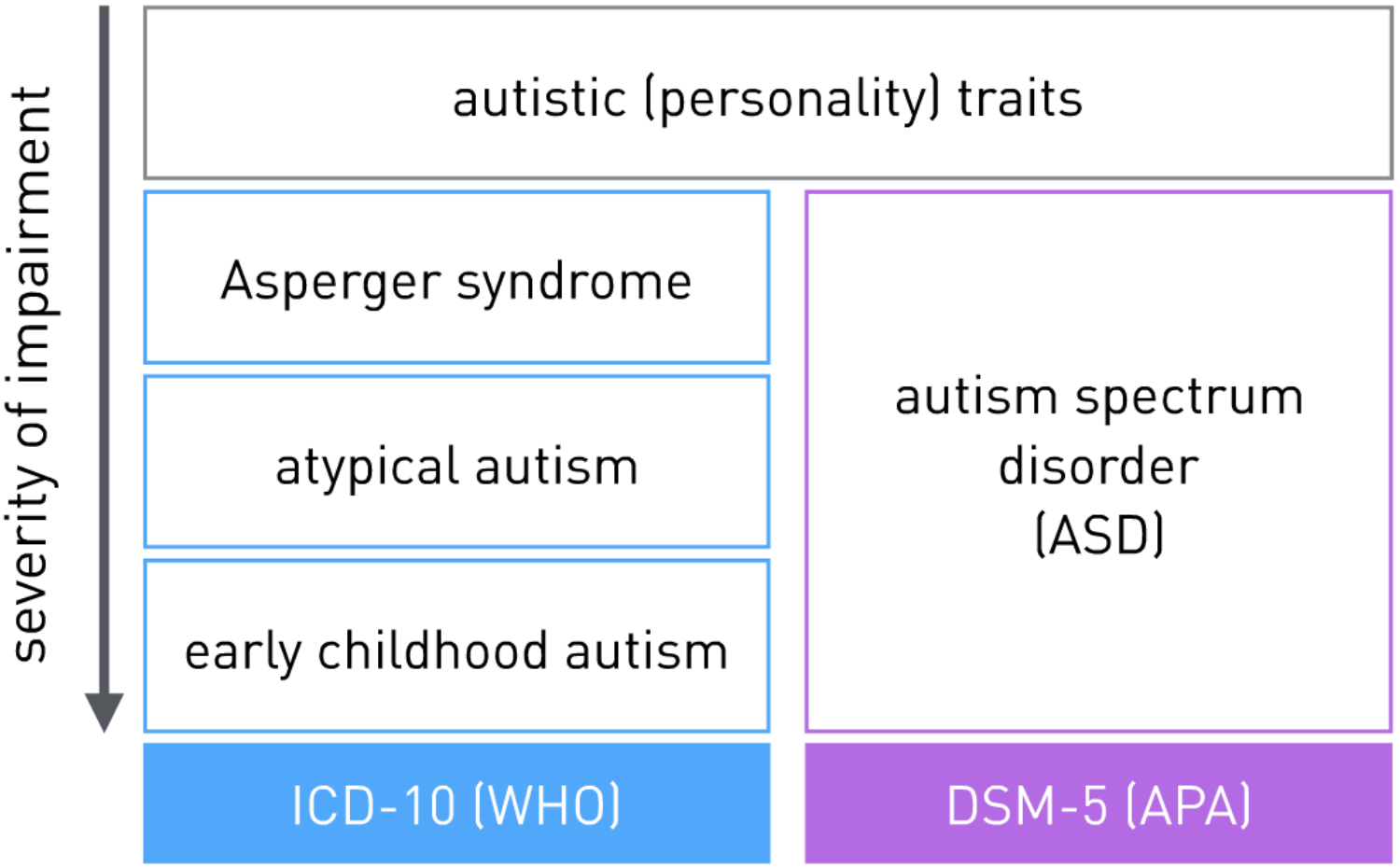
Autistic (personality) traits

high

functioning

individual developmental trajectories

Autism Spectrum Disorders



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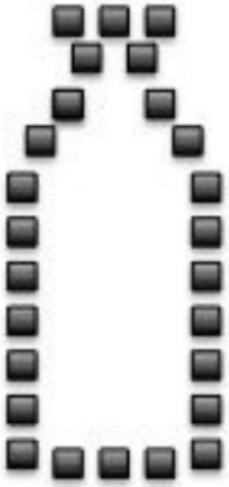

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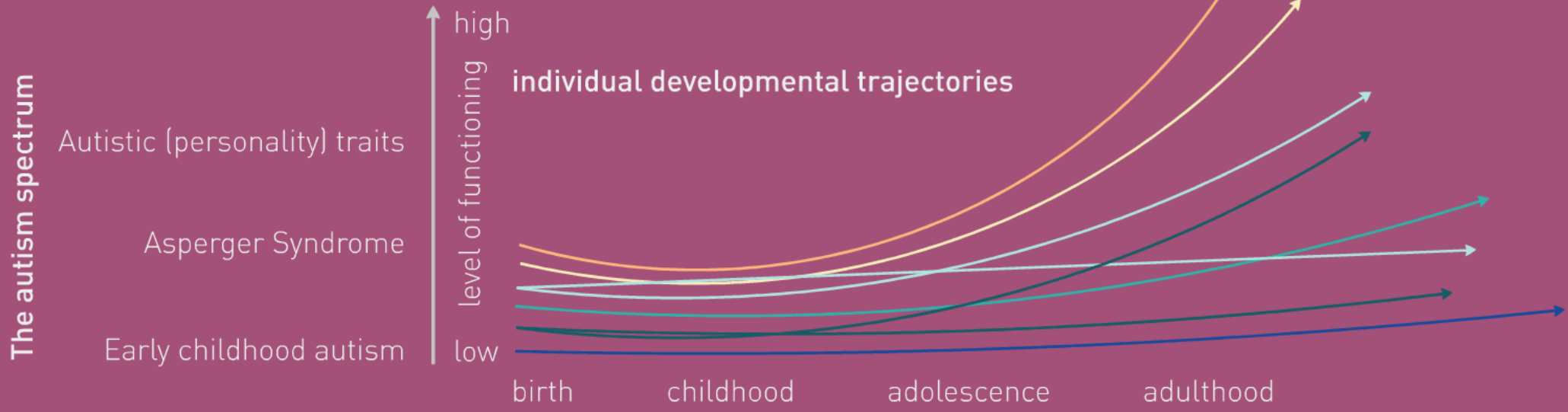


Current clinical problems

Diagnosis

- Gold-standard diagnostic procedures (ADOS/ADI-R)
  - are well validated **only for severely affected young children**
  - are time consuming and rely on specifically trained staff
- **No (validated) operationalized diagnostic procedure for less severely affected and older individuals**
  - careful clinical exploration by experienced clinicians
  - time consuming
  - experts are (still) rare

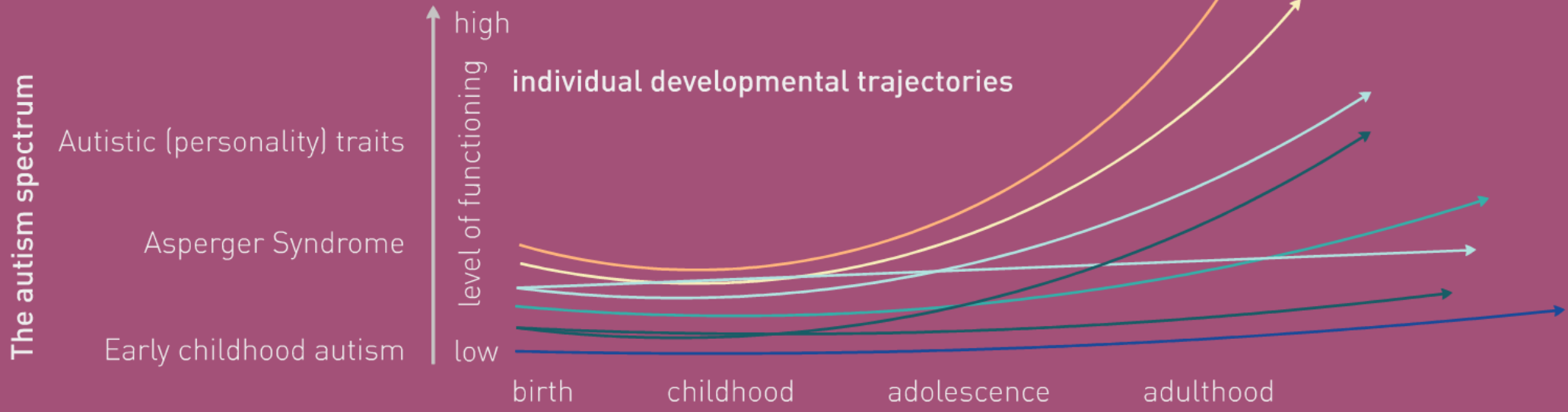
Behavioral-/Psychotherapy

- Well established treatment concepts exist
  - for severely affected young children (ABA)
  - for less severely affected teenagers (social training)
- but lack
  - for severely affected adults (without spoken language)
  - for hidden symptoms in less severeyl affected adults
  - for the autism-speficic treatment of comorbidities (depression, addiction, eating disorders, psychoses, ...)

Pharmacotherapy

- No pathomechanistically grounded pharmacotherapy
  - with studied effect of developmental trajectory
- No individual prediction of treatment response
  - for treatments of symptoms in adulthood
    (with stimulants, antidepressants, ...)

Autism



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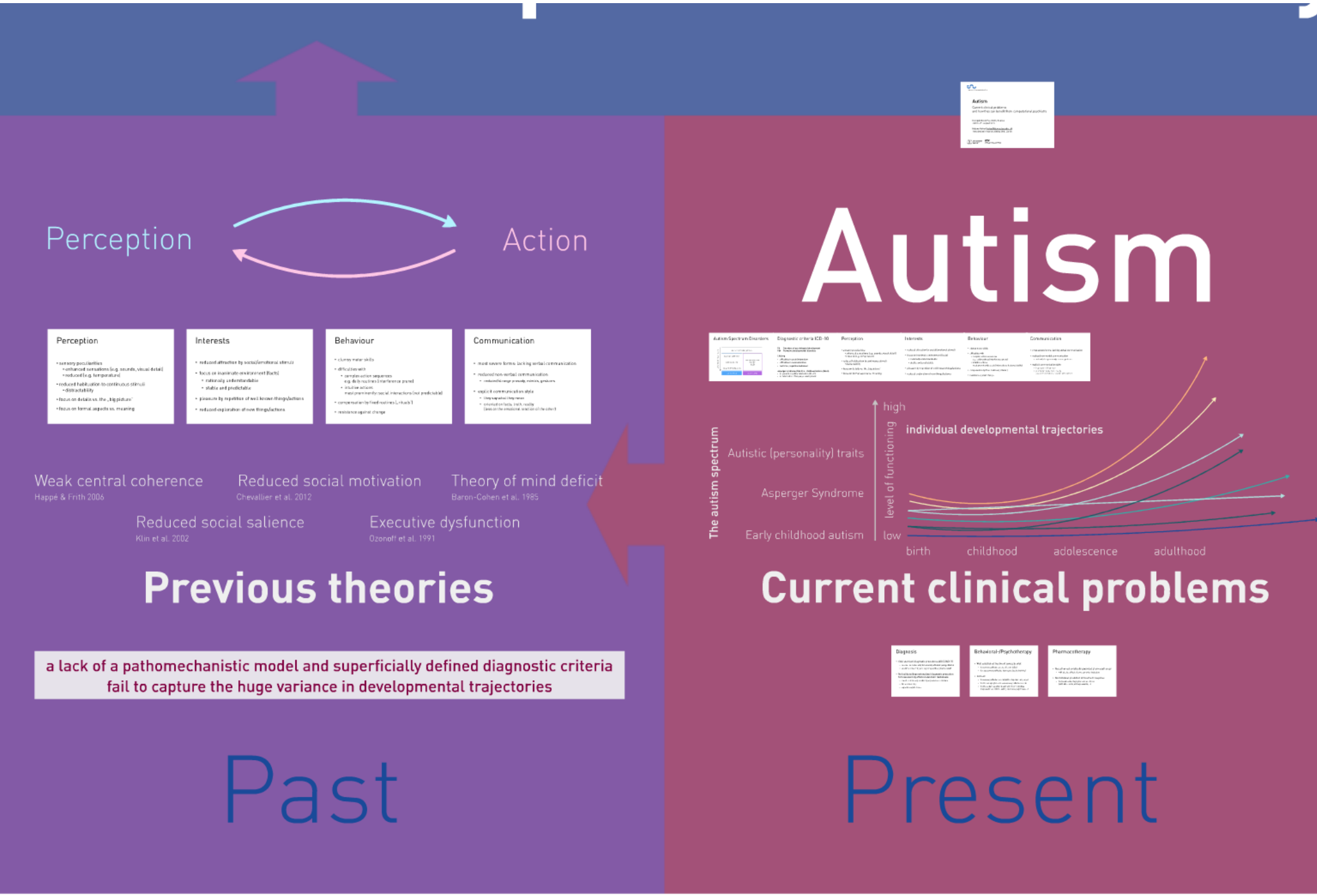
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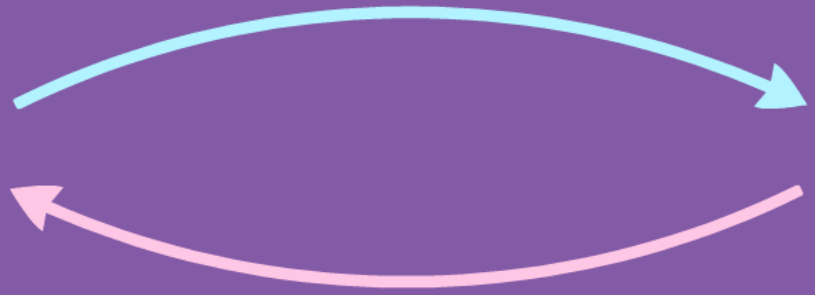

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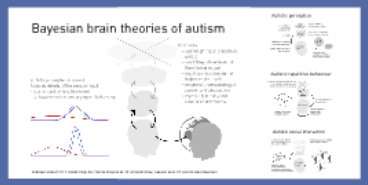

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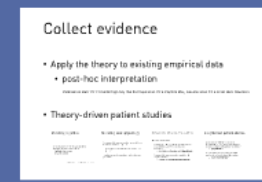

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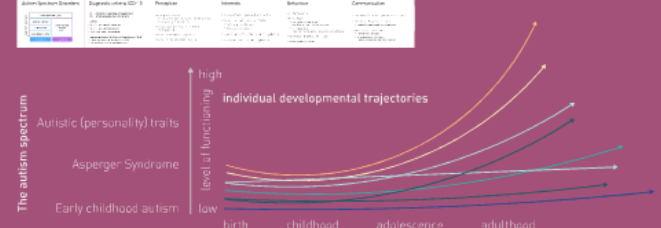

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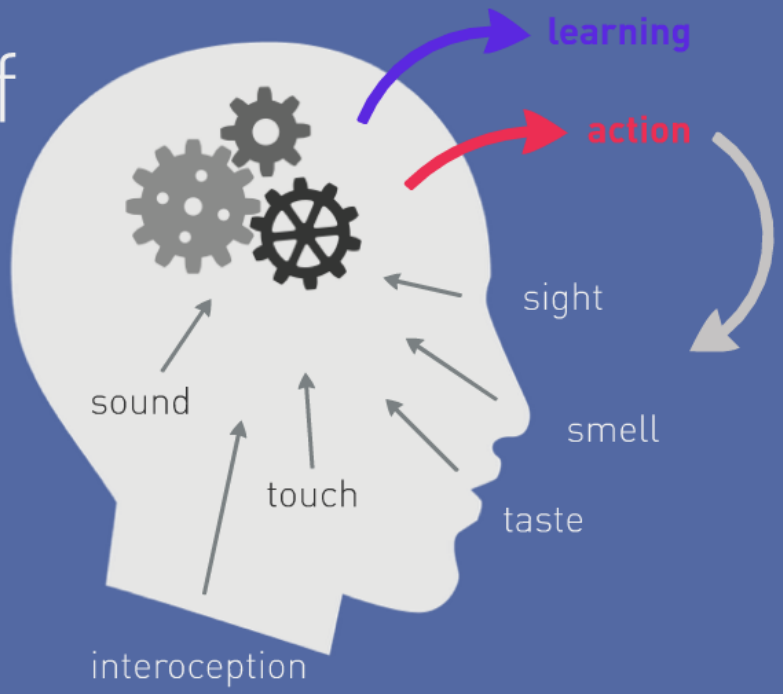
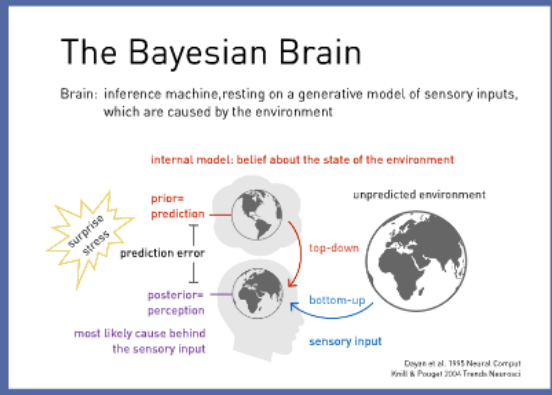
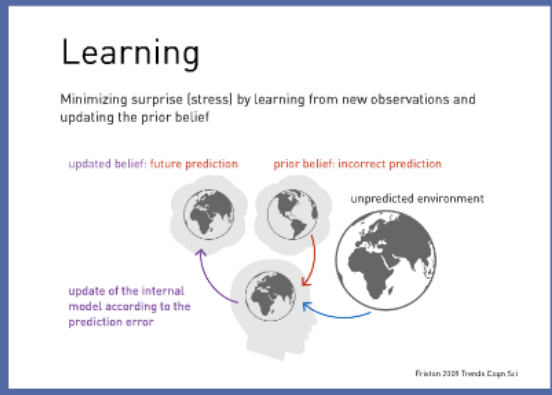
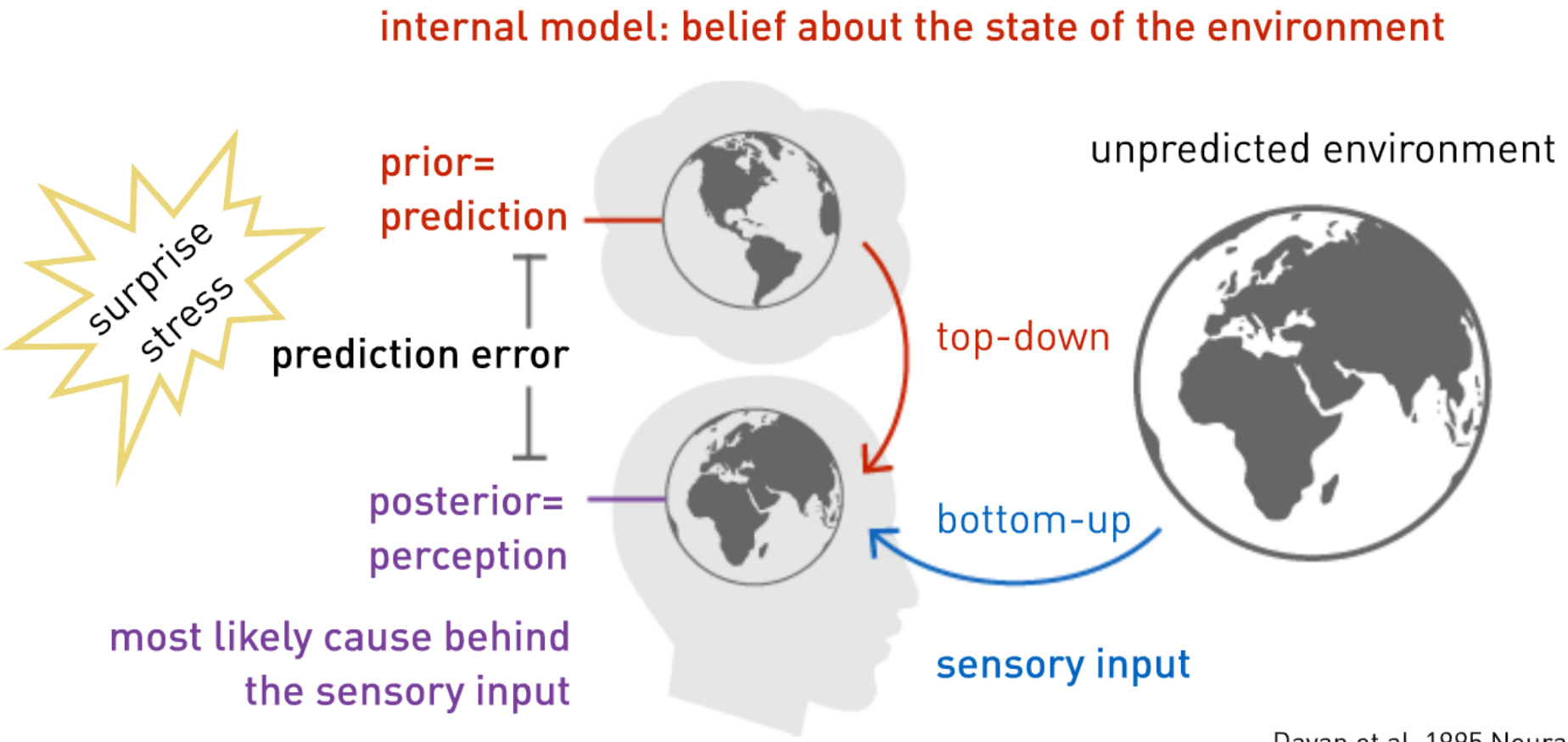






The Bayesian Brain

Brain: inference machine,resting on a generative model of sensory inputs, which are caused by the environment



Dayan et al. 1995 Neural Comput
Knill & Pouget 2004 Trends Neurosci

Beliefs as probability distributions

i.e. a probabilistic representation of a particular state of the world.

Bayes theorem describes how a prior belief is updated in light of newly observed data

posterior belief

updated belief, perception

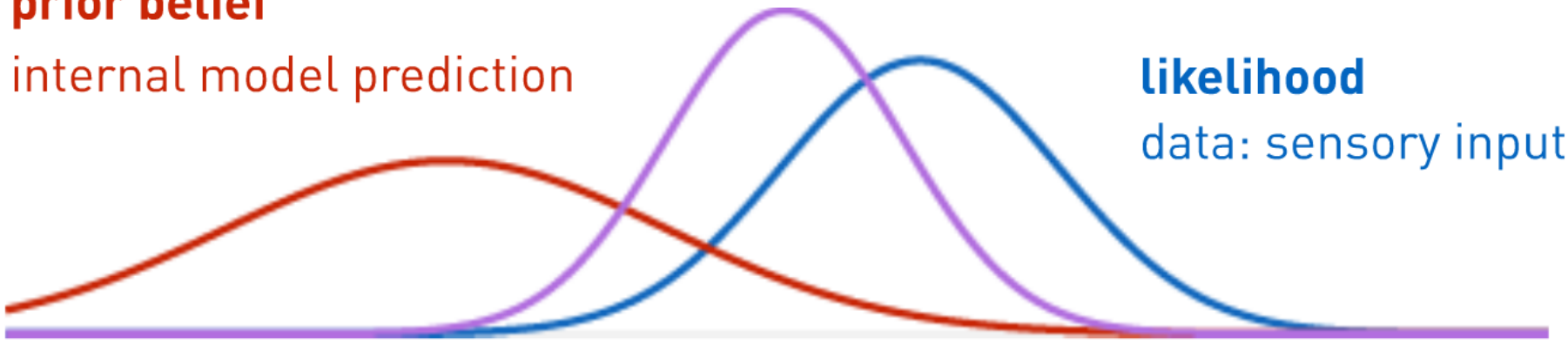
$$p(x \mid y) = \frac{p(y \mid x)\,p(x)}{p(y)}$$

prior belief

internal model prediction

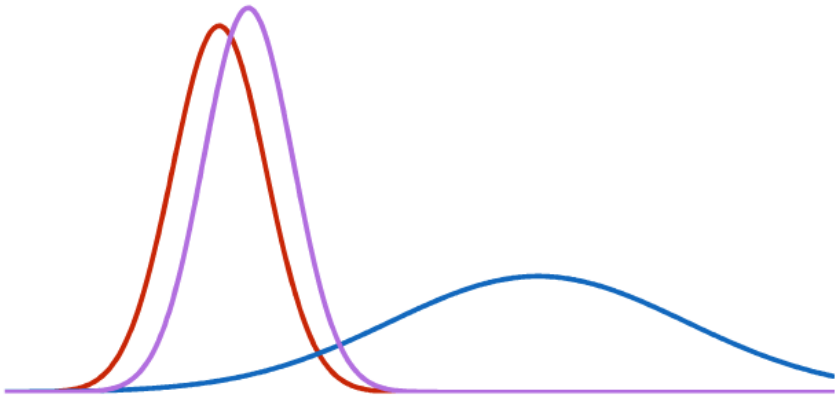
likelihood

data: sensory input



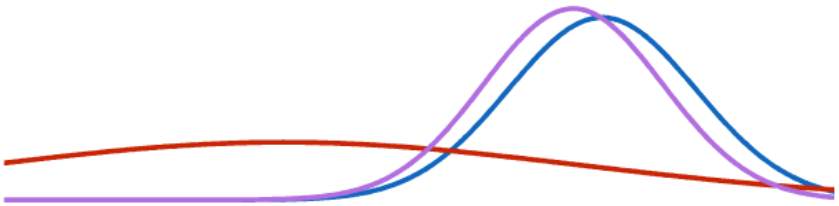
Bayes 1763 Phil Trans

The role of relative precision



The posterior belief is dominated by an overprecise prior belief and shows little influence of the actual observed sensory data

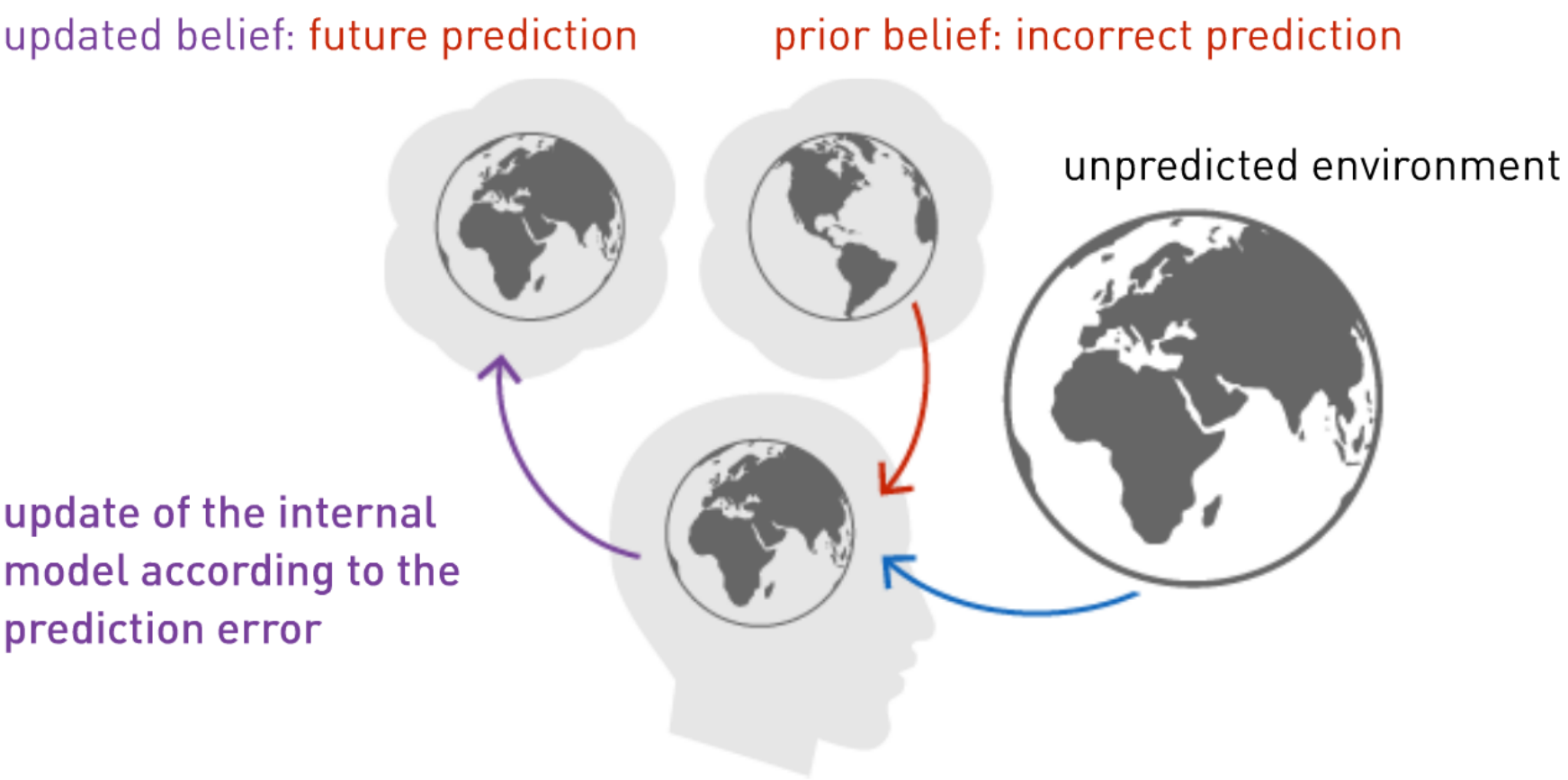
$$p(x \mid y) = \frac{p(y \mid x)p(x)}{p(y)}$$



Posterior belief is shifted away from a very unprecise prior belief towards the observed sensor data

Learning

Minimizing surprise (stress) by learning from new observations and updating the prior belief

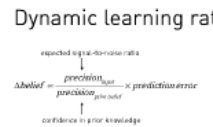


Friston 2009 Trends Cogn Sci

Uncertainty

weighting of the prediction errors depending on the precision of the prediction

higher levels of the internal model represent higher order regularities such as the precision of the prediction



internal model

prediction

ignoring

updating

unavoidable prediction errors

perception

environment
learnable regularities
+ stochasticity

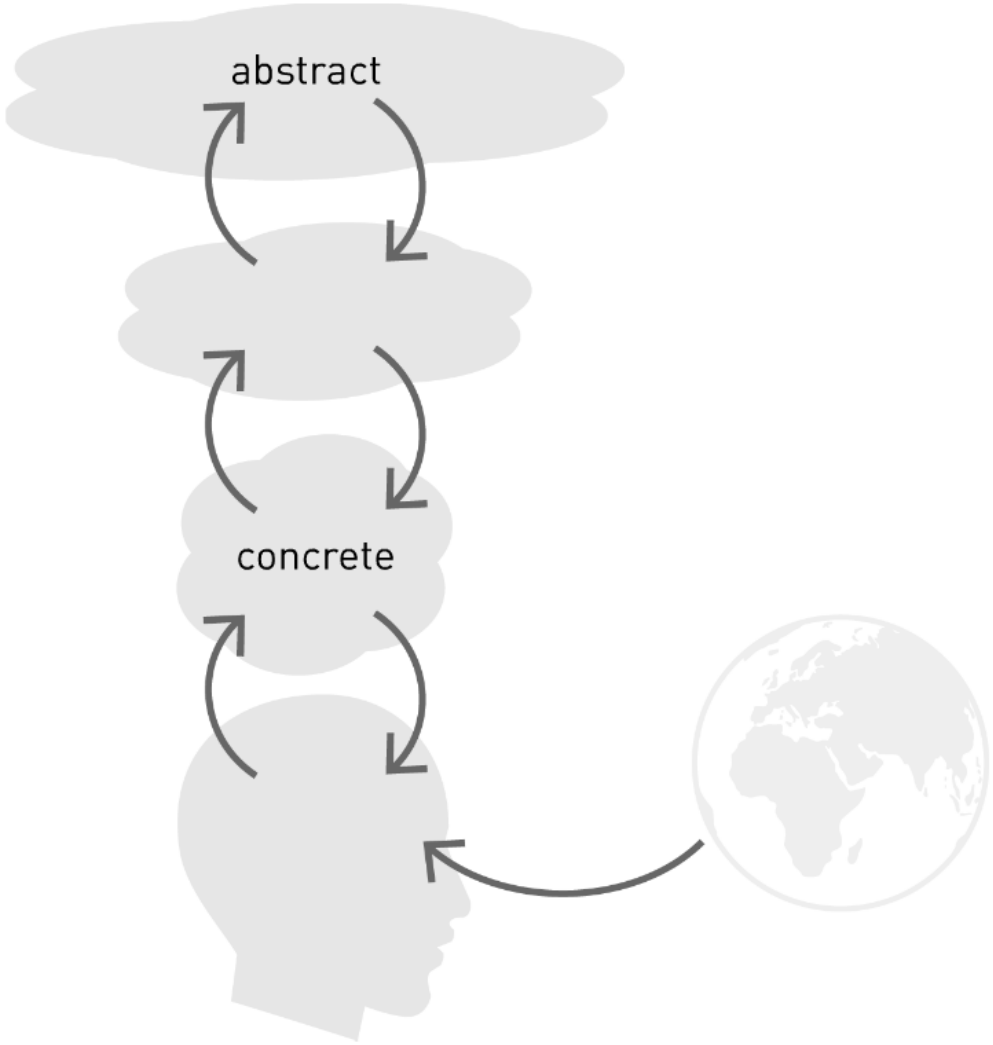
sensory input
+ noise

Mathys et al. 2011 Front Hum Neurosci

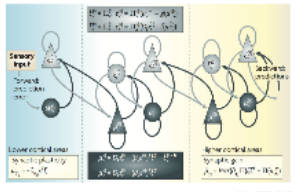
Hierarchy of inner representations

high levels

- represent very general, abstract features on a large temporal and spatial scale
- mature over time after more and more observations in different contexts



Biological implementation ...



Friston 2008 PLoS Comput Biol

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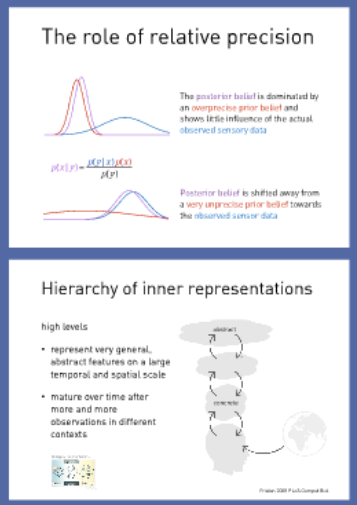
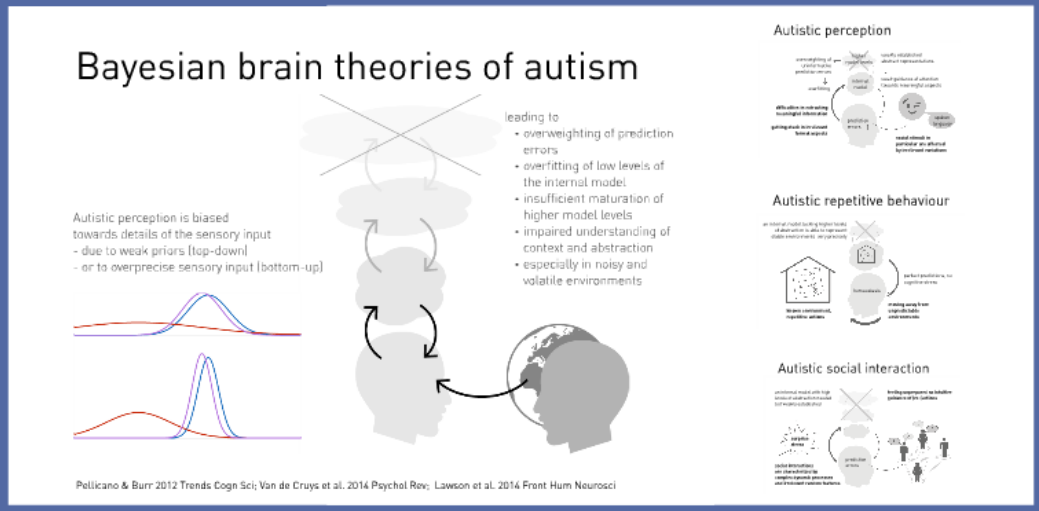
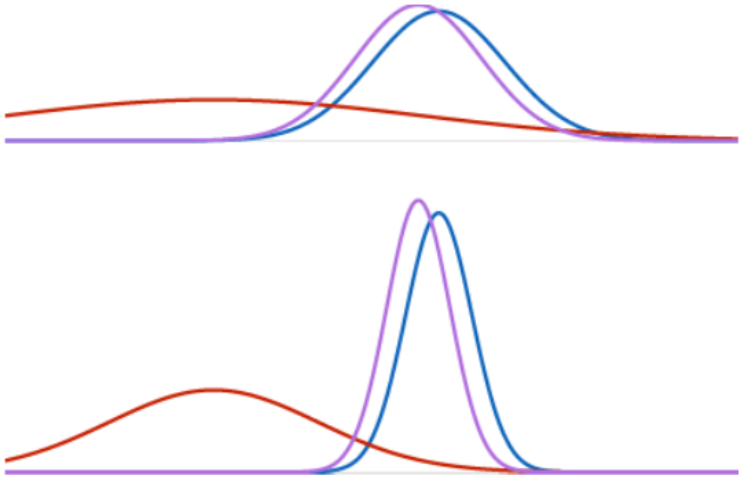


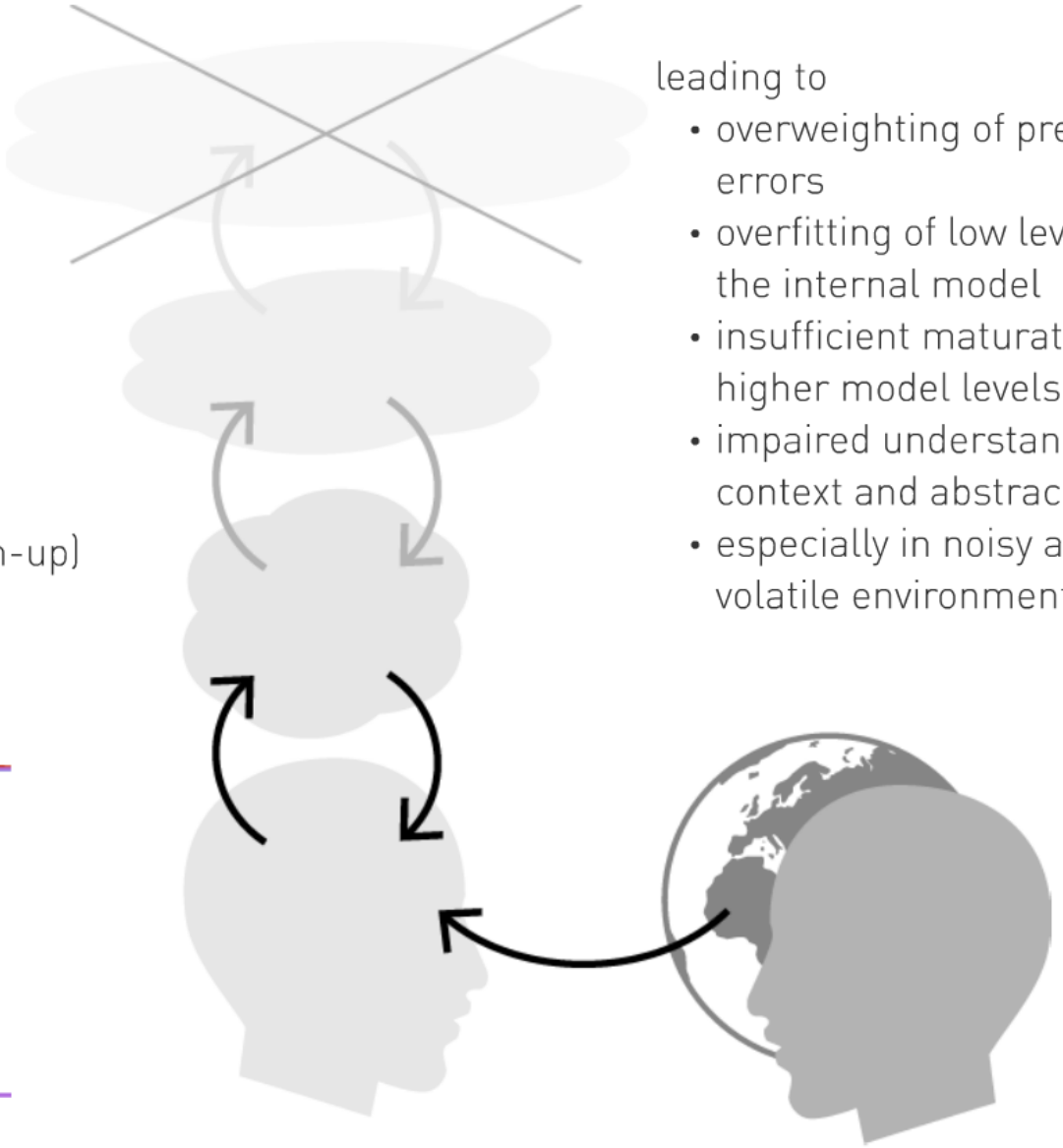


tational Psy

Bayesian brain theories of autism

Autistic perception is biased
towards details of the sensory input
- due to weak priors (top-down)
- or to overprecise sensory input (bottom-up)



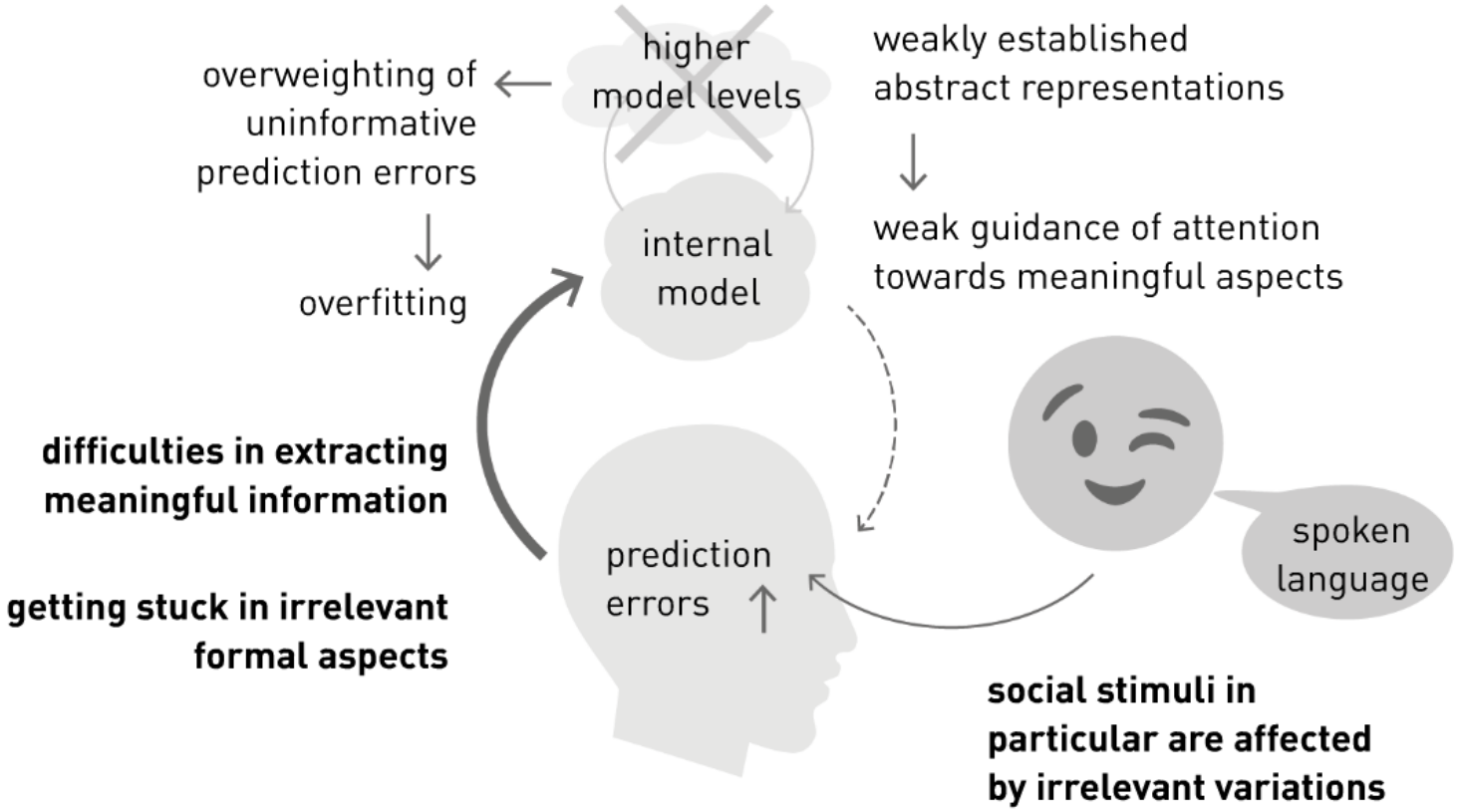


leading to

- overweighting of prediction errors
- overfitting of low levels of the internal model
- insufficient maturation of higher model levels
- impaired understanding of context and abstraction
- especially in noisy and volatile environments

Pellicano & Burr 2012 Trends Cogn Sci; Van de Cruys et al. 2014 Psychol Rev; Lawson et al. 2014 Front Hum Neurosci

Autistic perception



Autistic repetitive behaviour

an internal model lacking higher levels of abstraction is able to represent stable environments very precisely

known environment, repetitive actions

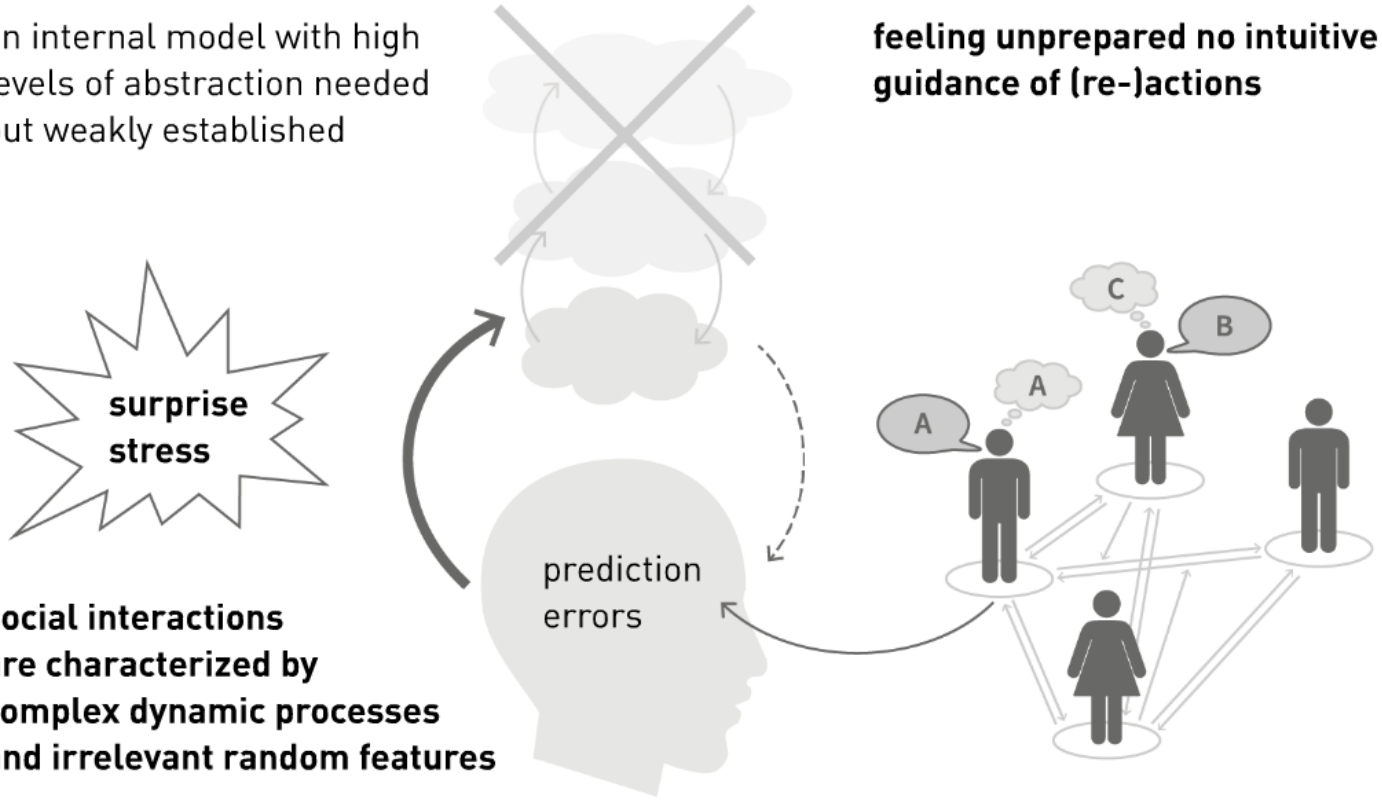
perfect predictions, no cognitive stress

moving away from unpredictable environments

Autistic social interaction

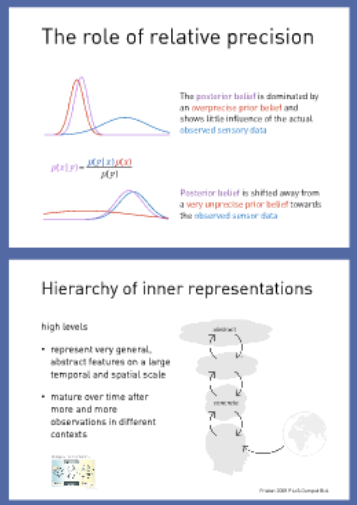
an internal model with high levels of abstraction needed but weakly established

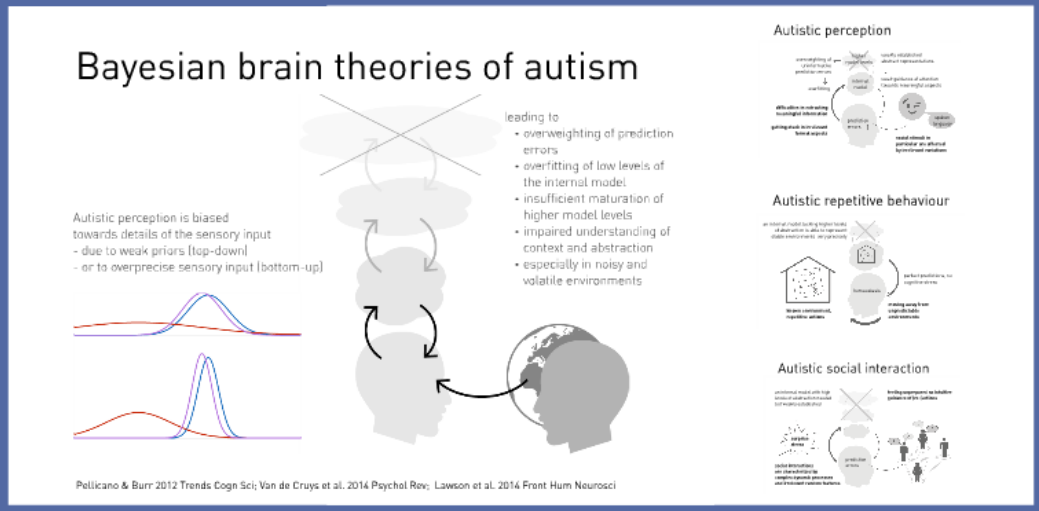
feeling unprepared no intuitive guidance of (re-)actions



social interactions are characterized by complex dynamic processes and irrelevant random features

… to explain autism





tational Psy

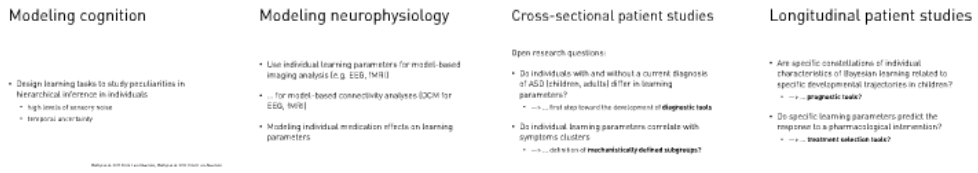
Research to do

Collect evidence

- Apply the theory to existing empirical data
  - post-hoc interpretation

    Pellicano & Burr 2012 Trends Cogn Sci; Van de Cruys et al. 2014 Psychol Rev; Lawson et al. 2014 Front Hum Neurosci

- Theory-driven patient studies



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Modeling cognition

- Design learning tasks to study peculiarities in hierarchical inference in individuals
  - high levels of sensory noise
  - temporal uncertainty

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Modeling neurophysiology

- Use individual learning parameters for model-based imaging analysis (e.g. EEG, fMRI)
- ... for model-based connectivity analyses (DCM for EEG, fMRI)
- Modeling individual medication effects on learning parameters

Cross-sectional patient studies

Open research questions:

- Do individuals with and without a current diagnosis of ASD (children, adults) differ in learning parameters?
  - —> ... first step toward the development of **diagnostic tools**
- Do individual learning parameters correlate with symptoms clusters
  - —> ... definition of **mechanistically defined subgroups?**

Longitudinal patient studies

- Are specific constellations of individual characteristics of Bayesian learning related to specific developmental trajectories in children?
  - —> ... **prognostic tools?**
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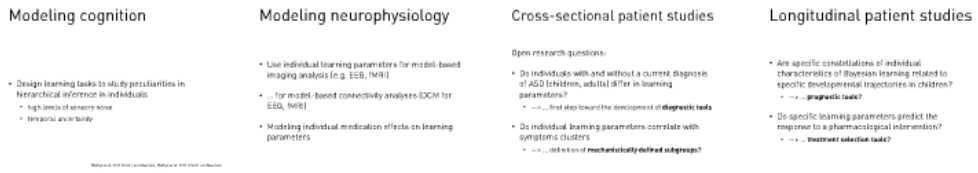


Understanding and explaining

the huge variance, to affected, to relatives, to clinicians, ...

Diagnosing

quick, easy to apply, reliable tests

Treating

mechanistically informed psychotherapeutic
and pharmacological concepts

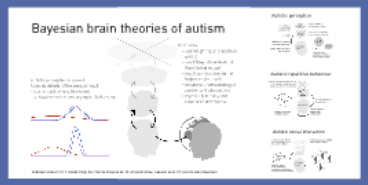
Potential benefits

New theories ...

The Bayesian Brain

A computational framework of cognition

... to explain autism



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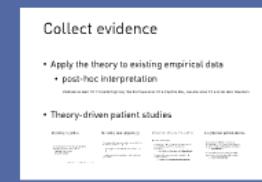


Computational Psychiatry

Perception ⇄ Action

Weak central coherence
Happé & Frith 2006

Reduced social motivation
Chevallier et al. 2012

Theory of mind deficit
Baron-Cohen et al. 1985

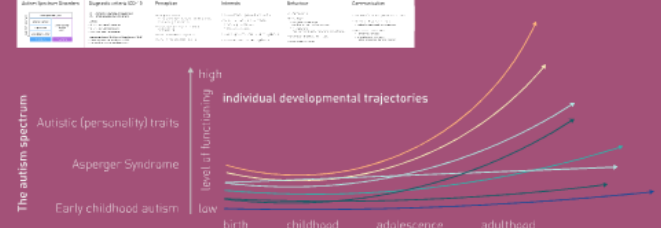
Reduced social salience
Klin et al. 2002

Executive dysfunction
Ozonoff et al. 1991

Previous theories

a lack of a pathomechanistic model and superficially defined diagnostic criteria fail to capture the huge variance in developmental trajectories

Autism



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Past

Present

Future

Reading