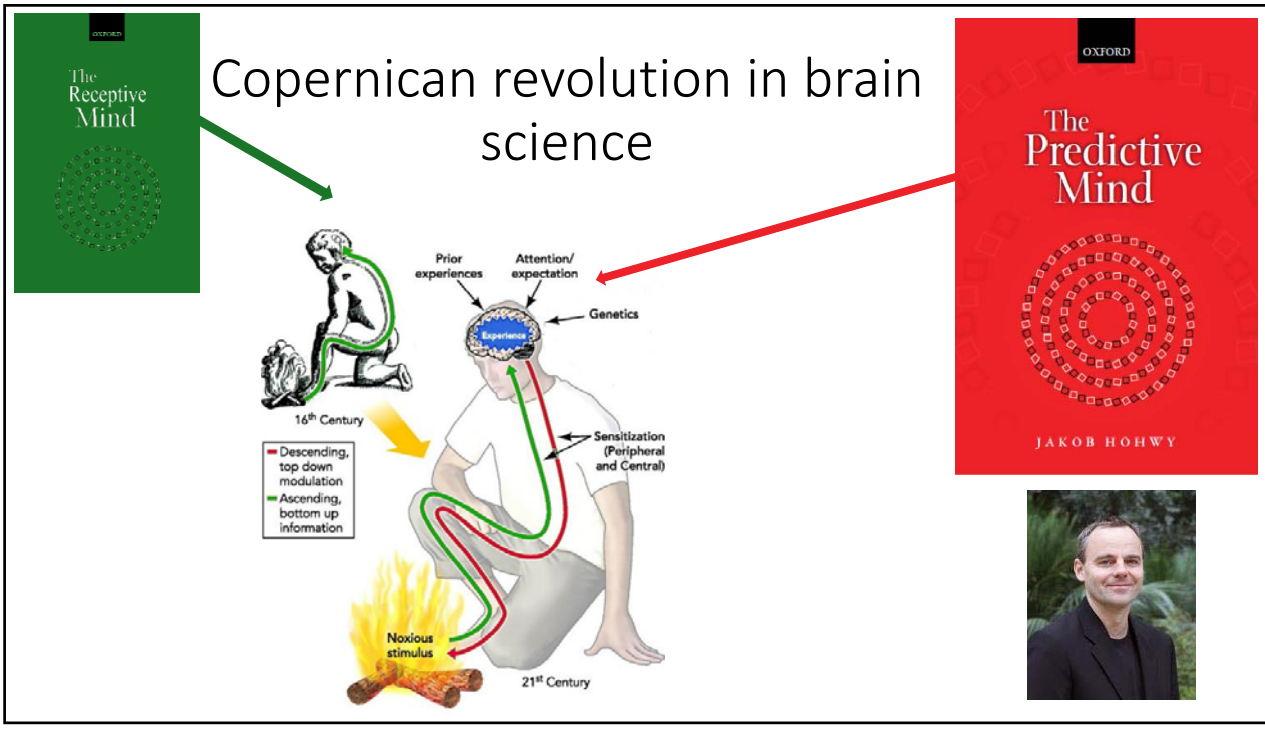
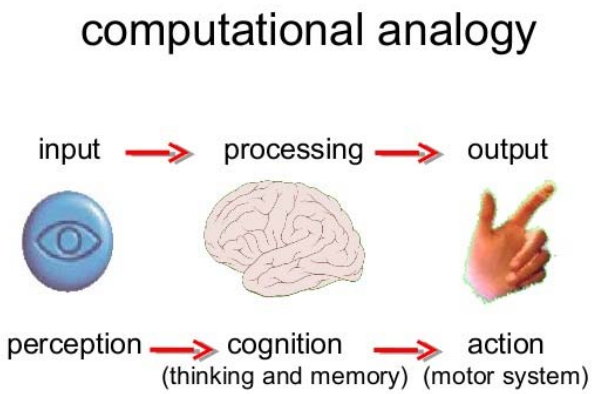
Autism and the predictive mind

PETER VERMEULEN, PhD

AUTISME CENTRAAL



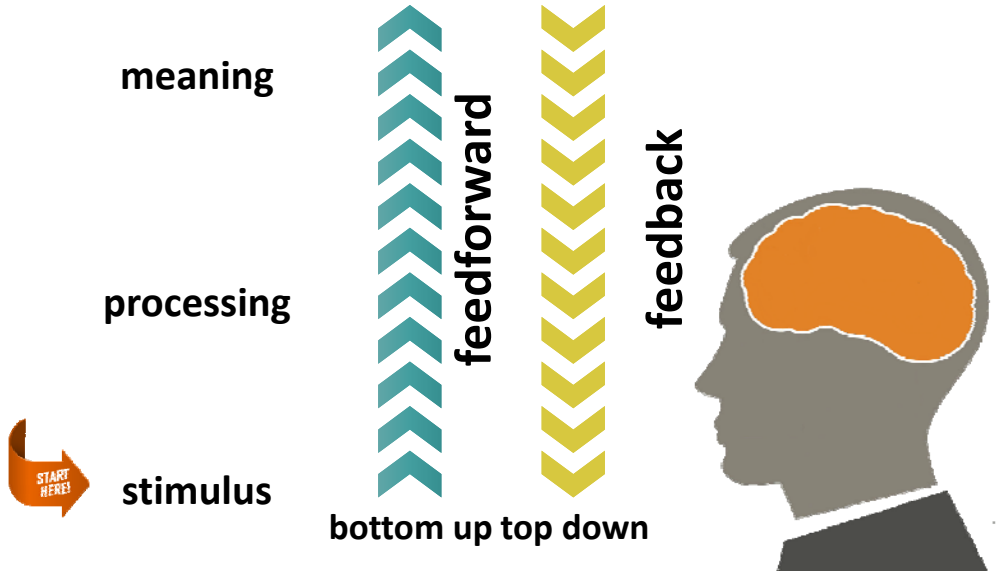
Default idea about the brain



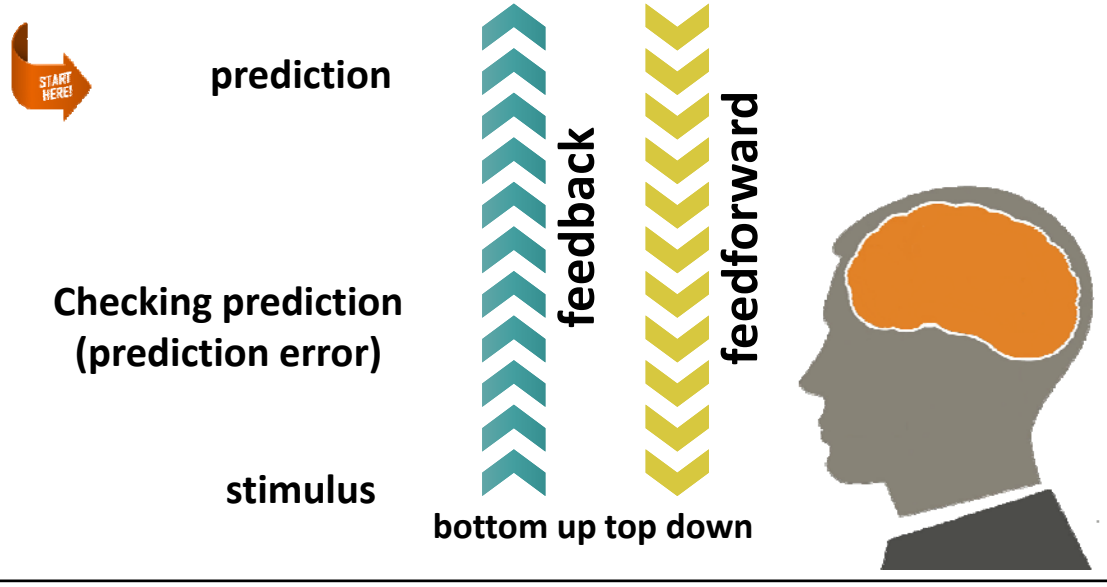
What's wrong with our current ideas about the brain?

- Information processing is not linear
- Sense making is not just integrating all the details of the sensory input
  - There isn't enough time to calculate and make that puzzle! (Daniel Kahneman)
  - Processing all the sensory input (computing) is not very helpful for survival! (Smilodon story)
- So, the brain does not compute, It guesses,
- And it can make smart guesses because it uses context,
- This is known as: **the predictive mind**

So, it does NOT work like this

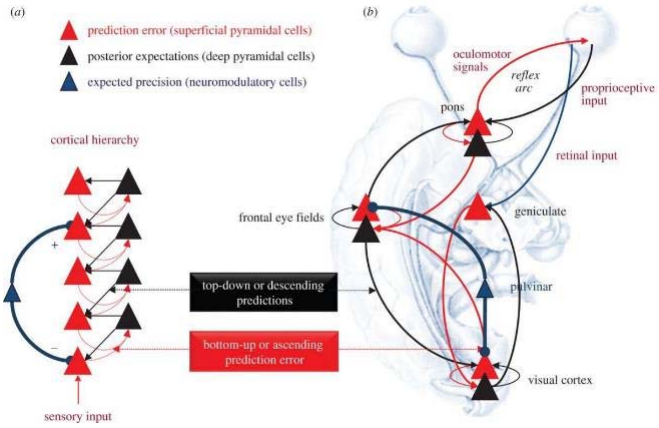


But it works like this



The brain does not process stimuli, only what is different from the stimuli it predicted…





From *The Lancet*

The brain likes it easy and efficient

The brain tries to minimize the prediction-error

Difference between predicted sensory input and actual sensory input

Big difference: surprise, stress

Small difference: relaxed and energy for more important things

We cannot avoid prediction errors

That's why the brain uses a **variable precision** of its own predictions

Sometimes, it must be precise
Sometimes, good enough is OK

Precision determines the filter in our brain

sensory input



prediction
(prior beliefs)



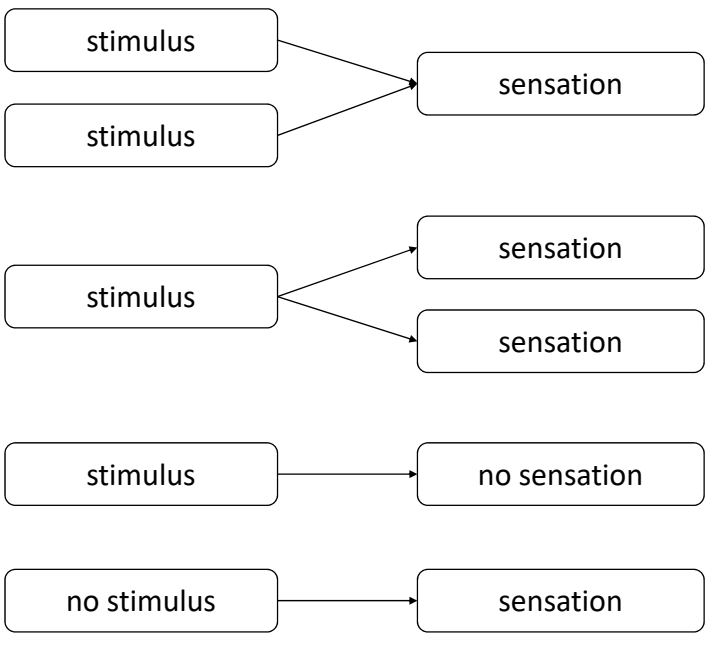
Why so complicated?

Bayesian brain:

Working with probabilities is appropriate in situations that are uncertain

The input coming from the senses is unreliable!





EXAMPLE:

Color is in your brain: Tomato is not always red, yet you 'see' red

Color is in your brain: you can see the same color as two different colors

The dancing gorilla you don't see

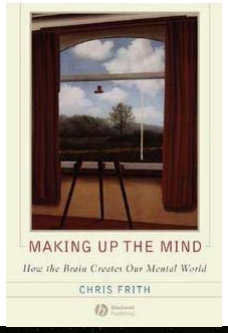
Hallucinations, phantom pain, illusions e.g.**Rubber Hand** illusion

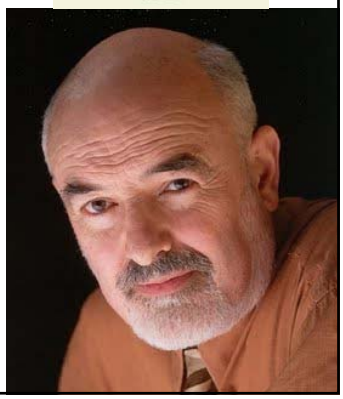
Perception is controlled hallucinating.

We don't see the world, but our model of the world.

Our perception of the world is an **illusion** that (in most cases, fortunately) coincides with reality.

Chris Frith





But how can we have a model without input?

- Obviously, experience is needed for more complicated things like your model of an airport or classroom
- But many basic models are built into the brain you were born with:
  - Light comes from above (domino illusion)
  - The world is 3D (hollow mask illusion, Shepard illusion)
  - Even blind people have a visual map of the world



Development of visual category selectivity in ventral visual cortex does not require visual experience

Job van den Hurk[a,b,1], Marc Van Baelen[a,c], and Hans P. Op de Beeck[a]

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The brain quickly and easily creates and adapts its model of the world

Anything you see after an experience will be a consequence of that experience.



Beau Lotto

Autism and the predictive mind: hypotheses

- Not enough, too broad predictions (hypo-priors) (Pellicano & Burr, 2012)
- Too specific predictions (Hohwy, 2015; Brock, 2012; Qian & Lipkin, 2011)
- HIPPEA: High, Inflexible Precision of Prediction Errors in Autism (Van de Cruys e.a., 2013, 2014)
- An imbalance of the precision ascribed to sensory evidence relative to prior beliefs. (Friston e.a., 2013; Lawson, Rees & Friston, 2014)

Autism and the predictive mind: context!

- In autism, there seems to be a problem with predictions, the precision of input and priors, and the handling of prediction errors.
- There's a deficit in the flexible adjustment of predictions and their precision in function of context

Hypothesis Palmer, Lawson, Hohwy (2017)

Psychological Bulletin

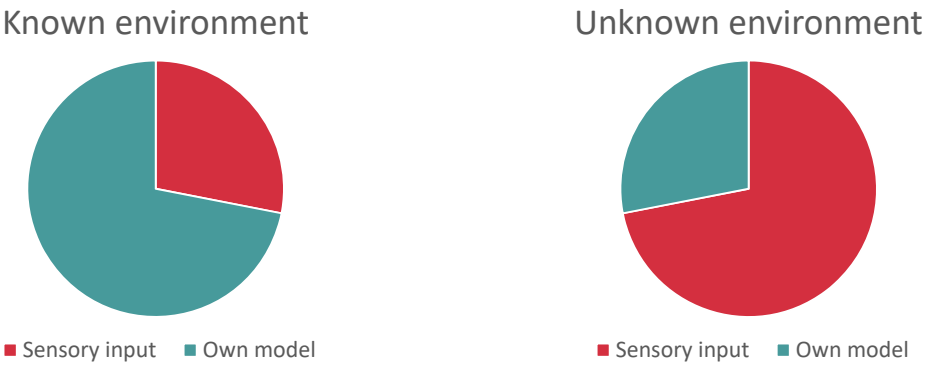
Bayesian Approaches to Autism: Towards Volatility, Action, and Behavior

Colin J. Palmer, Rebecca P. Lawson, and Jakob Hohwy

Online First Publication, March 23, 2017. http://dx.doi.org/10.1037/bul0000097

The autistic brain treats sensory input as more informative than its own model of the world (based on prior information)

The weight given to sensory input or own expectations depends on the context



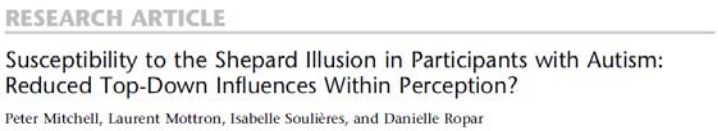
How much weight you give to a prediction error depends on how certain you are about your model of the world and the predictions based on that model (Lawson, Mathys & Rees, 2017)

Autism and the predictive mind: context!

- In ASD, the dysfunction of prediction based on context may impair the ability to adapt quickly to an ever changing socio-emotional world. (Gomot & Wicker, 2012, p. 245)
- In particular, we think autism is associated with an inability to flexibly adjust the degree of precision in a different context. (Van de Cruys e.a., 2013, p.97-98)
- Autism may be related to problems with making predictions sensitive to the wider context." (Palmer e.a., 2015)
- Comparably, reduced *global processing* in autism may reflect a reduced role for top-down predictions in *integrating* sensory features into a more broadly coherent or context-sensitive percept." (Palmer e.a., 2017)

Autism and the predictive mind: evidence

People with autism less susceptible for Shepard illusion (Mitchell e.a., 2010)

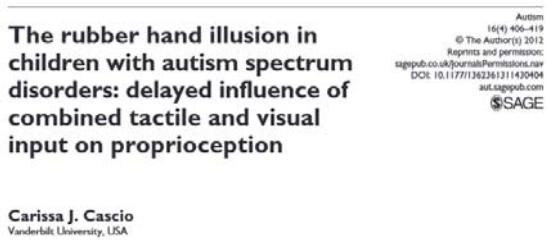


RESEARCH ARTICLE

Susceptibility to the Shepard Illusion in Participants with Autism: Reduced Top-Down Influences Within Perception?

Peter Mitchell, Laurent Mottron, Isabelle Soulières, and Danielle Ropar

People with autism less susceptible for Rubber Hand illusion (Cascio e.a., 2012; Palmer e.a., 2015)



The rubber hand illusion in children with autism spectrum disorders: delayed influence of combined tactile and visual input on proprioception

Autism
16(4) 406–419
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DOI: 10.1177/1362361311430404
aut.sagepub.com
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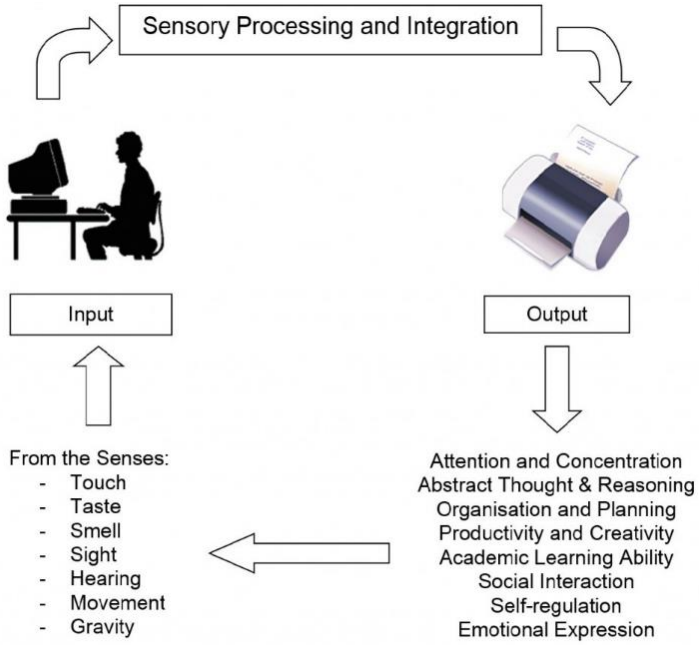
Carissa J. Cascio
Vanderbilt University, USA

Autism as a prediction disorder

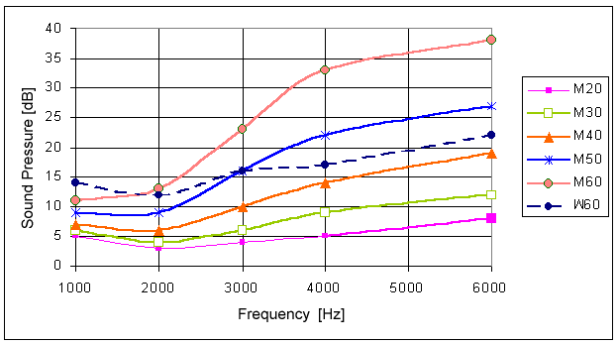
This new idea could change our ideas about many things in autism such as:

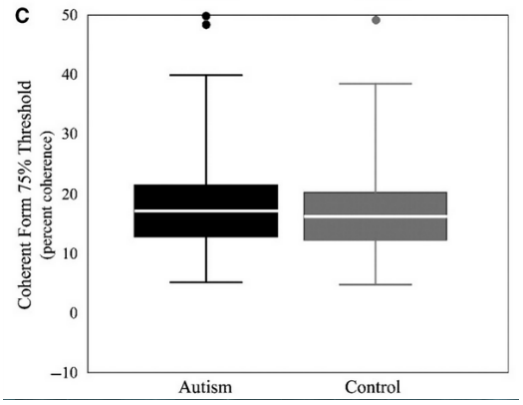
- Sensory issues and what to do about them
- Communication
- Emotion recognition and how to teach socio-emotional skills

Our ideas about sensory issues are based on the old computer metaphor



No unambiguous, clear indications for difference in sensory thresholds in autism





Hyperresponsivity:
reduced habituation in autism because of **reduced predictivity** (Turi et al., 2015)

Children with autism spectrum disorder show reduced adaptation to number

Marco Turi[a,b], David C. Burr[b,c], Roberta Igliozzi[d], David Aagten-Murphy[e], Filippo Muratori[d,f], and Elizabeth Pellicano[c,g,1]

"A key determinant of habituation is stimulus predictability.
… **a lack of predictability** would compromise habituation and lead to hypersensitivity."
(Sinha et al., 2014)

Autism as a disorder of prediction

Pawan Sinha[a,1], Margaret M. Kjelgaard[a,b], Tapan K. Gandhi[a,c], Kleovoulos Tsourides[a], Annie L. Cardinaux[a], Dimitrios Pantazis[a], Sidney P. Diamond[a], and Richard M. Held[a,1]

[a]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139; [b]Department of Communication Sciences and Disorders, Massachusetts General Hospital Institute of Health Professions, Boston, MA 02129; and [c]Department of Biomedical Engineering, Defense Institute of Physiology and Allied Sciences, New Delhi, India DL 110054

Again: **CONTEXT**

In other words, in autism there may be a failure to attenuate sensory precision and contextualize sensory information in an optimal fashion. (Lawson, Rees, Friston, 2014)

PNAS

LETTER

A more precise look at context in autism

In a recent paper, Rosenberg et al. (1) present a compelling explanation for the perceptual symptoms of autism in terms of a failure of divisive normalization. In divisive normalization the output of individual neurons is scaled (or divided) by the combined activity of the neural population in which they are embedded, and thus local visual context provides a means of gain control—a volume dial—for stimulus-evoked responses. However, to properly understand the wider mechanistic implications, beyond local inhibition or gain in the Rosenberg et al. (1). Furthermore, even precise (or disinhibited) visual responses within a single level of the cortical hierarchy may still be down-weighted if the precision of predictions at a higher level (e.g., NMDA-mediated synaptic gain) mandates this. Top-down attenuation of sensory precision accounts for psychophysical and physiological aspects of attention (4), providing a hierarchically and biologically plausible account of the "attentional field" modeled in Rosenberg et al. (1). Finally, beyond a single sensory event, adaptive perception and This role lies in the postsynaptic gain of superficial pyramidal cells encoding the prediction error within a cortical hierarchy and lies in the integrity of neuromodulatory function (2). Precision-weighting in autism could be aberrant in a number of ways, each resulting in context-insensitive perception and action (3); however, these are empirical questions that we look forward to seeing addressed with time.

Rebecca P. Lawson[a,b,1], Karl J. Friston[b], and Geraint Rees[a,b]

Sensory issues, predictability and context

The Research Autism Lorna Wing series of conferences & seminars presents:

Looking Forward Looking Back: The Janus View of Autism

RESEARCH AUTISM
IMPROVING THE QUALITY OF LIFE
IDENTIFICATION INTERVENTION INCLUSION

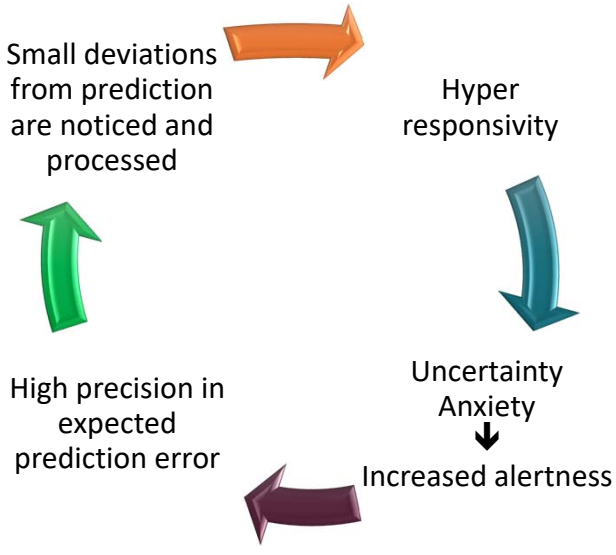


Wednesday 25th – Thursday 26th November 2015
9am – 5.15pm

Prince Philip House, London, SW1Y 5DG



Sensory or anxiety and uncertainty?



Uncertainty drives anxiety, sensory issues in autism

BY **ANN GRISWOLD** / 8 APRIL 2016



Sensory overload: Children with autism may perceive uncertainty as a threat.

©shutterstock.com/ Kuznetcov_Konstantin

J Autism Dev Disord (2016) 46:1962–1973
DOI 10.1007/s10803-016-2721-9

CrossMark

ORIGINAL PAPER

The Relationship Between Intolerance of Uncertainty, Sensory Sensitivities, and Anxiety in Autistic and Typically Developing Children

Louise Neil[1] · Nora Choque Olsson[2] · Elizabeth Pellicano[1,3]

No stronger sensory response, but stronger experience of stimuli

J Autism Dev Disord (2008) 38:127–137
DOI 10.1007/s10803-007-0370-8

RESEARCH ARTICLE

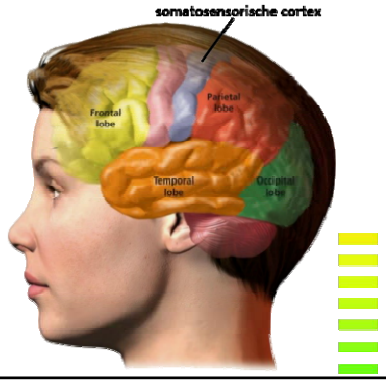
Perceptual and Neural Response to Affective Tactile Texture Stimulation in Adults with Autism Spectrum Disorders

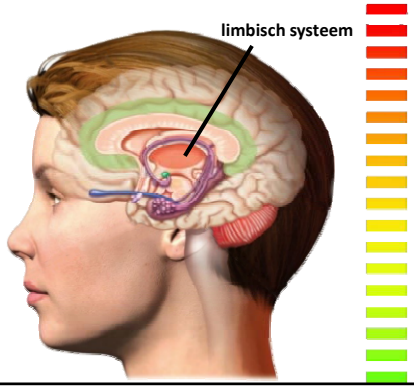
Carissa J. Cascio, Estephan J. Moana-Filho, Steve Guest, Mary Beth Nebel, Jonathan Weisner, Grace T. Baranek, and Gregory K. Essick

Tactile Perception in Adults with Autism: a Multidimensional Psychophysical Study

Carissa Cascio · Francis McGlone · Stephen Folger · Vinay Tannan · Grace Baranek · Kevin A. Pelphrey · Gregory Essick







Strategies for sensory issues: traditional way



But from **Hyperacusis – Tinnitus** we learned:

- Do not eliminate sounds, but make sounds predictable and controllable :
- Working on '**feedforward**' (*prediction*) instead of 'feedback' (*stimulus*)

Strategies for sensory issues?

Tackle the prediction errors!



- Predictability in (changes) in sensory environment
- Contextual clarifying of stimuli: **PUSH THE CONTEXT BUTTON**
- Changing the brains model of the world

PAIN

Pain 74 (1998) 327–331

The role of prior pain experience and expectancy in psychologically and physically induced pain

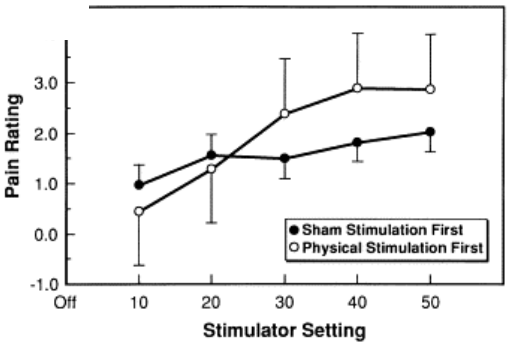
Timothy L. Bayer[b], John H. Coverdale[a,b,*], Elizabeth Chiang[b], Mark Bangs[b]

[a]Department of Psychiatry and Behavioural Science, School of Medicine, The University of Auckland, Private Bag 92109, Auckland, New Zealand
[b]Department of Psychiatry and Behavioral Science, Baylor College of Medicine, Houston, Texas, USA

Received 2 April 1997; received in revised form 27 October 1997; accepted 29 October 1997



If you can induce pain through information, you can also remove/reduce pain through information



Pain treatment 2.0 (Lorimer Moseley): placebo surgery and working on 'ideas'



The New England Journal of Medicine

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VOLUME 347 JULY 11, 2002 NUMBER 2

A CONTROLLED TRIAL OF ARTHROSCOPIC SURGERY FOR OSTEOARTHRITIS OF THE KNEE

J. Bruce Moseley, M.D., Kimberly O'Malley, Ph.D., Nancy J. Petersen, Ph.D., Terri J. Menke, Ph.D., Baruch A. Brody, Ph.D., David H. Kuykendall, Ph.D., John C. Hollingsworth, D.R.P.H., Carol M. Ashton, M.D., M.P.H., and Nelda P. Wray, M.D., M.P.H.

Correspondences

Visual distortion of a limb modulates the pain and swelling evoked by movement

G. Lorimer Moseley[1,2], Timothy J. Parsons[1] and Charles Spence[3]

The feeling that our body is ours, and is constantly there, is a fundamental aspect of self-awareness [1]. Although it is often taken for granted, our physical self-awareness, or body image, is disrupted in many clinical conditions [2] (see also [3] for a list of such conditions). One common



Strategies for sensory issues?

Tackle the prediction errors!

Changing prediction → Giving control → Changing stimulus → Stress coping

- Knowing how to 'control' the stimulus
- Generating a competitive stimulus (*again: predictability!*)

The importance of control



Perception, 2015, volume 44, pages 569–586

doi:10.1068/p7833

The sensory experiences of adults with autism spectrum disorder: A qualitative analysis

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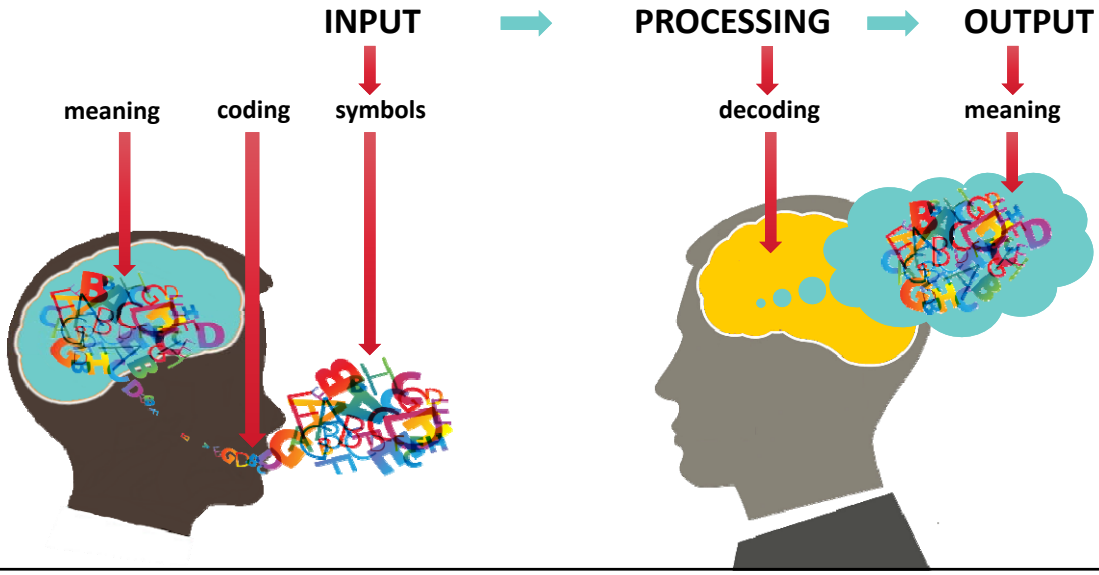
Received 6 August 2014, in revised form 2 April 2015

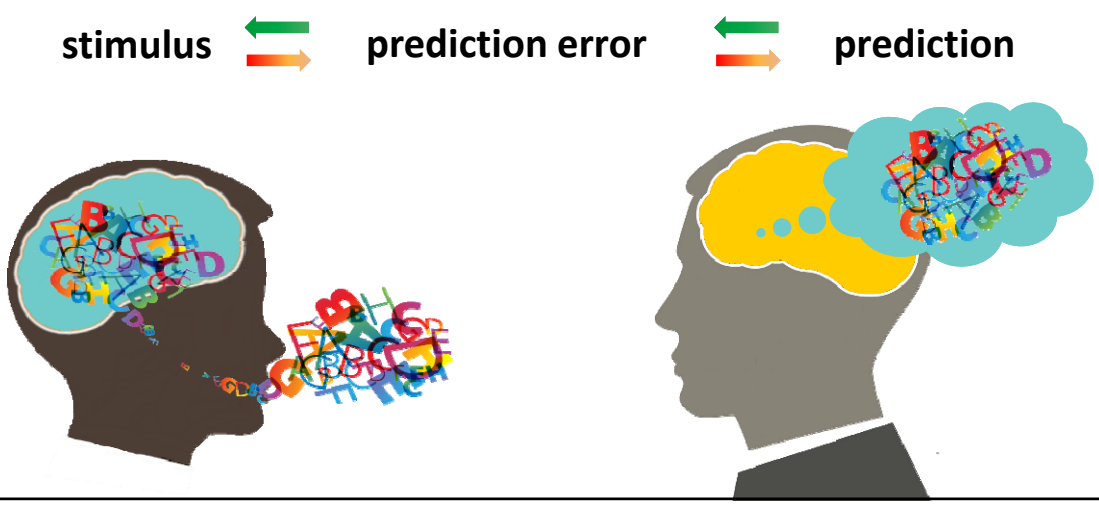
Abstract. It has been well established that individuals with autism spectrum disorder report unusual experiences with sensory stimuli compared with typically developing individuals. However, there is a paucity of research exploring the nature of such experiences. A focus group was conducted with six adults with a diagnosis of autism or Asperger syndrome. Data were coded and analysed using an inductive, qualitative thematic analysis. Four main themes encompassing both positive and negative sensory experiences emerged from these data: (a) the importance of particular aspects of stimuli in their perception, (b) the importance of having control over stimuli, (c) how emotions/mental states could impact/be impacted by sensory stimuli, and (d) physical responses to stimuli. These data are discussed alongside extant literature. Limitations, possible implications, and potential directions of future research are also discussed.

Keywords: autism spectrum disorders, sensory, qualitative, focus group

Understanding language and communication: old model



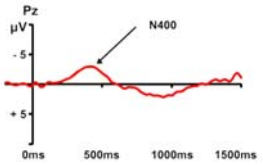
Understanding language and communication: new model



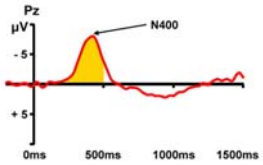
Context and predicting language and communication

The brain makes quick guesses about what someone is going to say or show, based on context

- N400
- **Lexical priming**

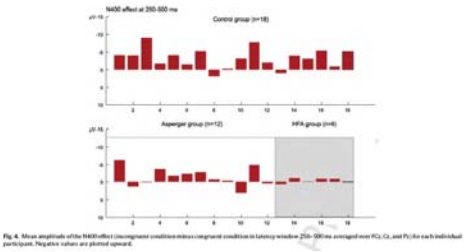


Jan eet friet met mayonaise



Jan eet friet met schoen.

- N400 lower in people with autism (Pijnacker e.a., 2010)



Special issue Cortex, July 2015



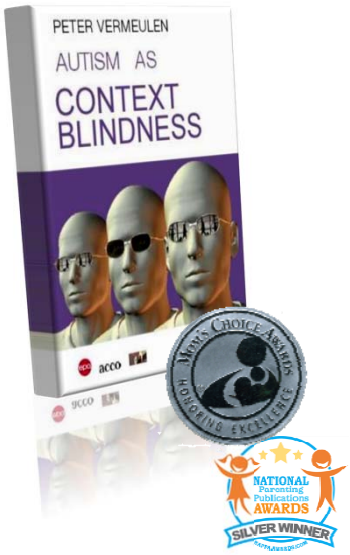
Special issue: Review

A predictive coding framework for rapid neural dynamics during sentence-level language comprehension

Ashley G. Lewis[a, b], Marcel Bastiaansen[a, c]

Understanding language = predicting language!

Context helps predicting communication



If your brain is *context blind*, it will have difficulties predicting (and hence understanding) communication

Context

- Does not only help us to predict and recognize communication
- It also helps us to avoid all the confusion of the ever changing meanings of what people say or show us

Context and communication

What is difficult for people with ASD, is to find out what something (a word, a sentence, a gesture, a picture etc.) means ***in this context***

Pushing the context button in communication

I will now ask you something about yesterday

And now something about the actors in the movie

OK, Let's now move on to question #2.

Facial expressions: inherently ambiguous!!

emotion review

Emotion Review
Vol. 5, No. 1 (January 2013) 60–65
© The Author(s) 2013
ISSN 1754-0739
DOI: 10.1177/1754073912451331
er.sagepub.com

Inherently Ambiguous: Facial Expressions of Emotions, in Context

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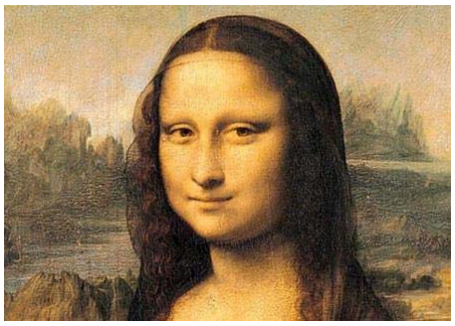
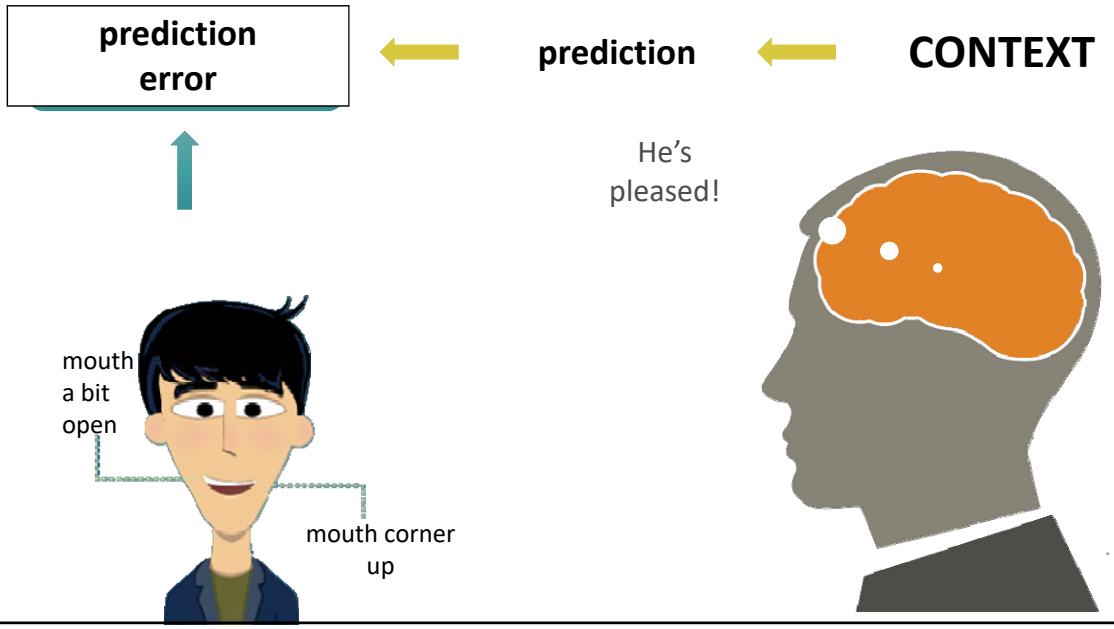


Recognizing emotions



Context more important than the face!

But people with autism rely on the face, not the context!

autism

Short Report

Emotion recognition from congruent and incongruent emotional expressions and situational cues in children with autism spectrum disorder

Dina Tell and Denise Davidson

Autism
1–5
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DOI: 10.1177/1362361314535676
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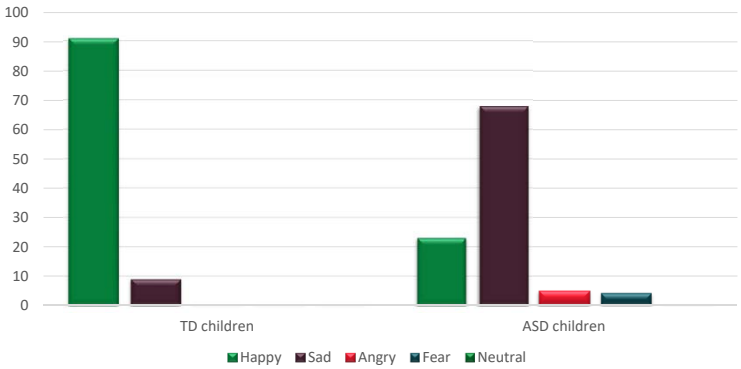
Context more important than the face!

But people with autism rely on the face, not the context!

Incongruent



Percentage of children's responses for the incongruent emotion condition



Tell & Davidson (2014)

Again: context…

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Current Directions in Psychological Science
20(5) 286–290
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DOI: 10.1177/0963721411422522
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Context in Emotion Perception

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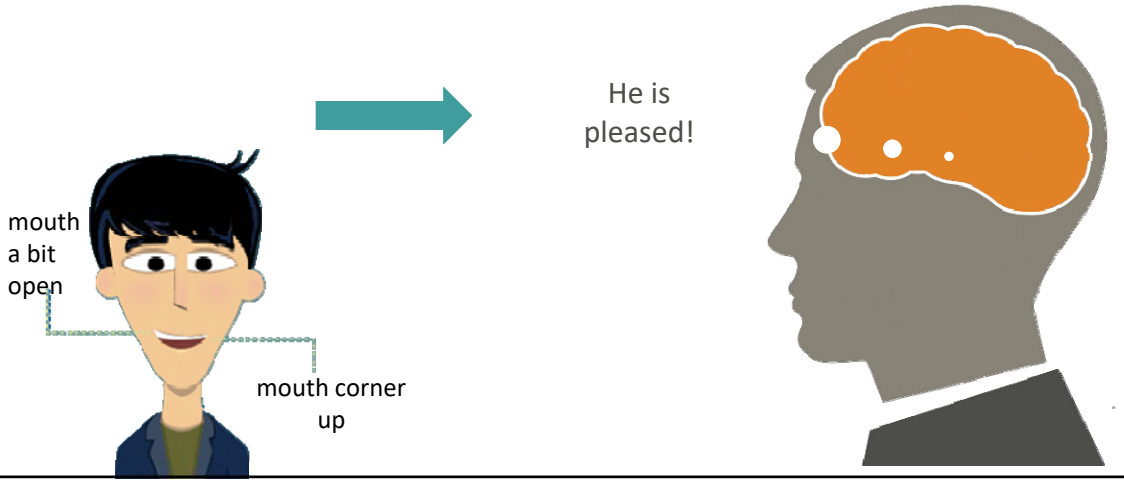
Abstract

We review recent work demonstrating consistent context effects during emotion perception. Visual scenes, voices, bodies, other faces, cultural orientation, and even words shape how emotion is perceived in a face, calling into question the still-common assumption that the emotional state of a person is written on and can be read from the face like words on a page. Incorporating context during emotion perception appears to be routine, efficient, and, to some degree, automatic. This evidence challenges the standard view of emotion perception represented in psychology texts, in the cognitive neuroscience literature, and in the popular media and points to a necessary change in the basic paradigm used in the scientific study of emotion perception.

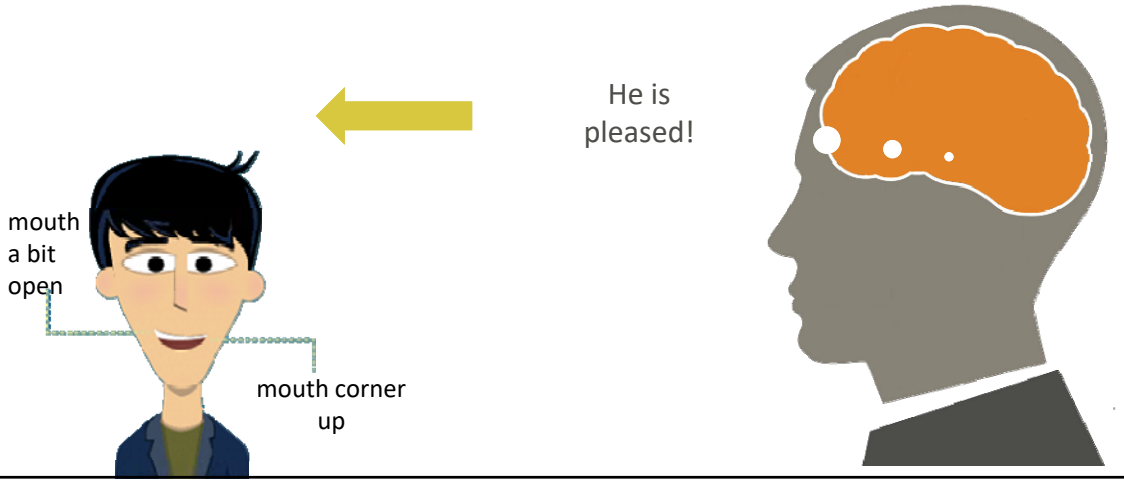
So, we thought emotion recognition went like this:

Reading emotions FROM faces



But it actually goes like this:

Reading emotions INTO faces



So we should teach people with autism to PREDICT emotions, using context, not faces



Link emotions to context









When we '***push the context button***', people with autism succeed better in recognizing emotions… (Balconi e.a., 2007; Wright e.a., 2008; Ramachadran e.a., 2011)



This is Andrew who went to bed with a sore throat and a bad cold.



This is Mathew who can afford to buy only from sales at charity shops.





sick

And it's not just about emotion recognition!

doi:10.1093/brain/aww287 BRAIN 2017: 140; 235–246 | 235

BRAIN
A JOURNAL OF NEUROLOGY

Disrupted prediction errors index social deficits in autism spectrum disorder

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Social deficits are a core symptom of autism spectrum disorder; however, the perturbed neural mechanisms underpinning these deficits remain unclear. It has been suggested that social prediction errors—coding discrepancies between the predicted and actual outcome of another's decisions—might play a crucial role in processing social information. While the gyral surface of the anterior cingulate cortex signalled social prediction errors in typically developing individuals, this crucial social signal was altered in individuals with autism spectrum disorder. Importantly, the degree to which social prediction error signalling was aberrant correlated with diagnostic measures of social deficits. Effective connectivity analyses further revealed that, in typically developing individuals but not in autism spectrum disorder, the magnitude of social prediction errors was driven by input from the ventromedial prefrontal cortex. These data provide a novel insight into the neural substrates underlying autism spectrum disorder social symptom severity, and further research into the gyral surface of the anterior cingulate cortex and ventromedial prefrontal cortex could provide more targeted therapies to help ameliorate social deficits in autism spectrum disorder.

Predictive coding explains social deficits in autism

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Research

Cite this article: von der Lühe T, Manera V, Barisic I, Becchio C, Vogeley K, Schilbach L. 2016 Interpersonal predictive coding, not action perception, is impaired in autism. *Phil. Trans. R. Soc. B* **371**: 20150373. http://dx.doi.org/10.1098/rstb.2015.0373

Interpersonal predictive coding, not action perception, is impaired in autism

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This study was conducted to examine interpersonal predictive coding in individuals with high-functioning autism (HFA). Healthy and HFA partici-

Context and social cognition

Social cognition in ASD only impaired when context is involved (Baez, Ibanez et al., 2012; 2014)

frontiers in NEUROSCIENCE

FOCUSED REVIEW
published: 03 September 2014
doi: 10.3389/fnins.2014.00270

The effects of context processing on social cognition impairments in adults with Asperger's syndrome



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Context and social cognition

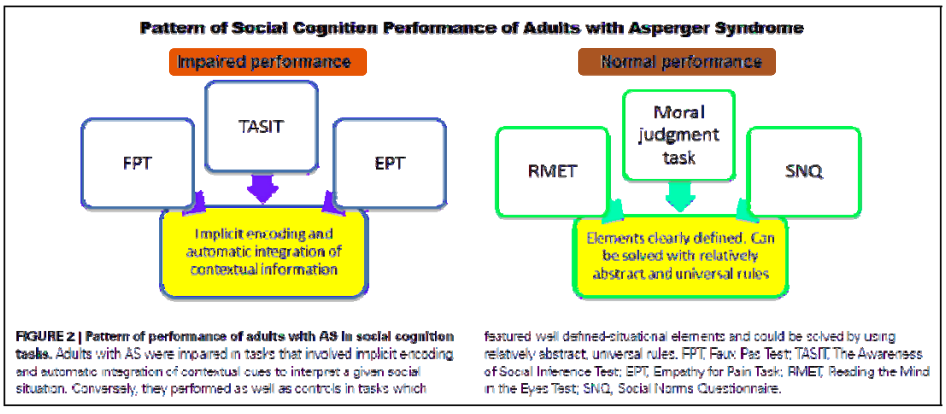


FIGURE 2 | Pattern of performance of adults with AS in social cognition tasks. Adults with AS were impaired in tasks that involved implicit encoding and automatic integration of contextual cues to interpret a given social situation. Conversely, they performed as well as controls in tasks which featured well defined-situational elements and could be solved by using relatively abstract, universal rules. FPT, Faux Pas Test; TASIT, The Awareness of Social Inference Test; EPT, Empathy for Pain Task; RMET, Reading the Mind in the Eyes Test; SNQ, Social Norms Questionnaire.

Source: Baez & Ibanez (2014)

Teaching: traditional approach: generic skills

Starting a conversation

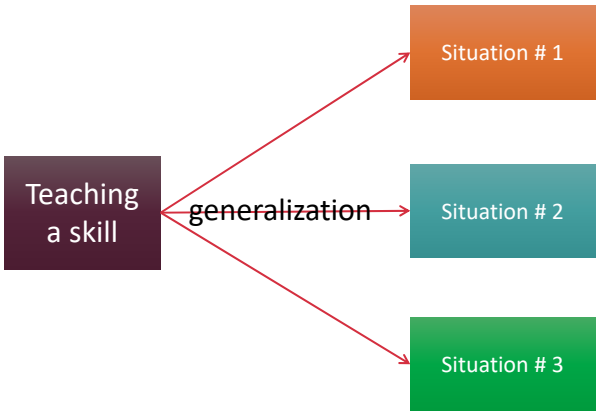


Step 1: Think of what you'd like to say

Step 2: Make sure you have the other person's attention. Look at the person.

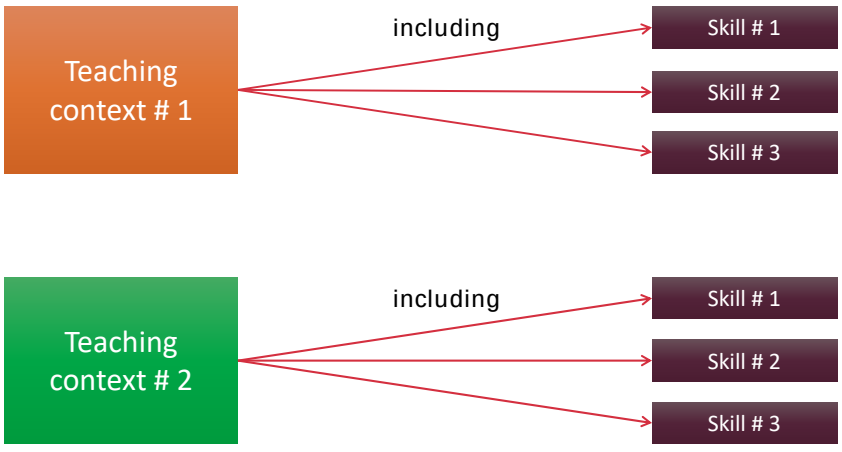
Step 3: Ask a question or make a comment.

Step 4: Listen carefully while the other person responds.



Contextualized teaching

Does not start from skills but from contexts



Contextualized teaching

- Do not use decontextualized materials
- Do not teach 'skills' but start from contexts
- Link behaviours always to contexts

Starting a conversation

Contextualized teaching

Teaching and clarifying context:

- ✓ What can happen in that context?
- ✓ What can you do in that context?
- ✓ What can you say in that context?


The Next Generation of Social Stories™:
• History & definition
• New Focus on Social Context
• Implications for Future Social Stories
Slide from Carol Gray's presentation


Pushing the context button helps to 'predict' an uncertain world with all its ever changing meanings
context