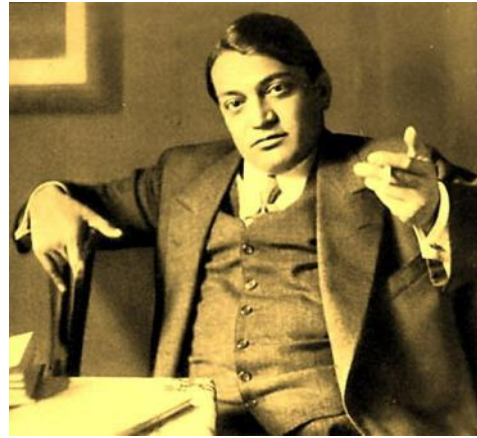


Neurocognitive mechanisms of creativity in health and disease

BME, 2015

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What do we mean by creativity?

- In a given social context, create a
- Novel, unusual

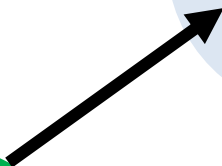
AND

- Useful product
- Interaction between aptitude, process, and context

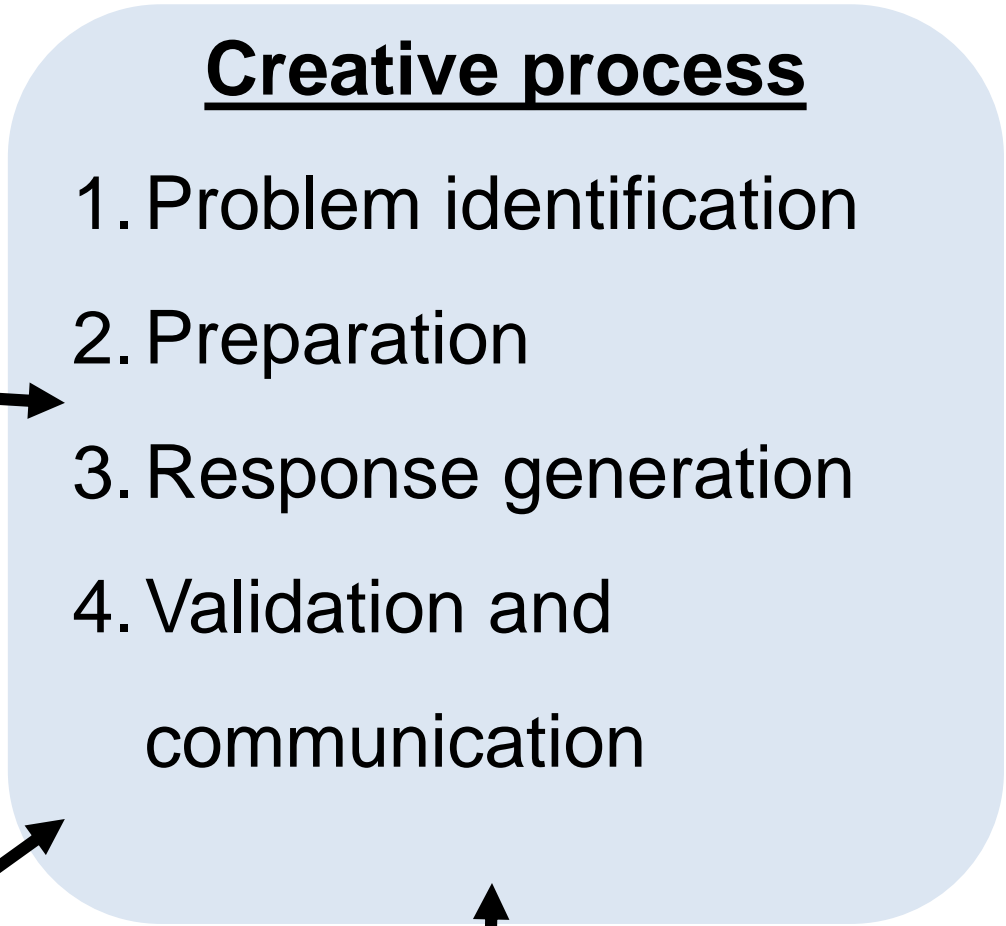
**Intrinsic
motivation**



Expertise



**Creative
thinking**



Creative process

1. Problem identification
2. Preparation
3. Response generation
4. Validation and communication

Creativity-relevant skills

Divergent thinking

eg list unusual uses of a brick



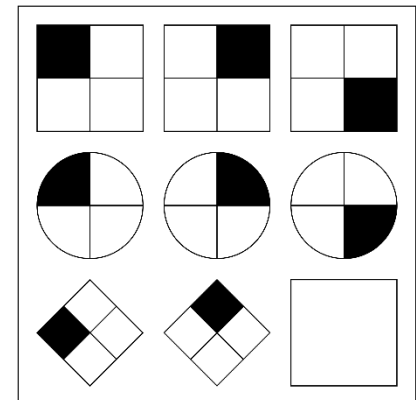
Insight problem solving

cottage – swiss – cake → cheese

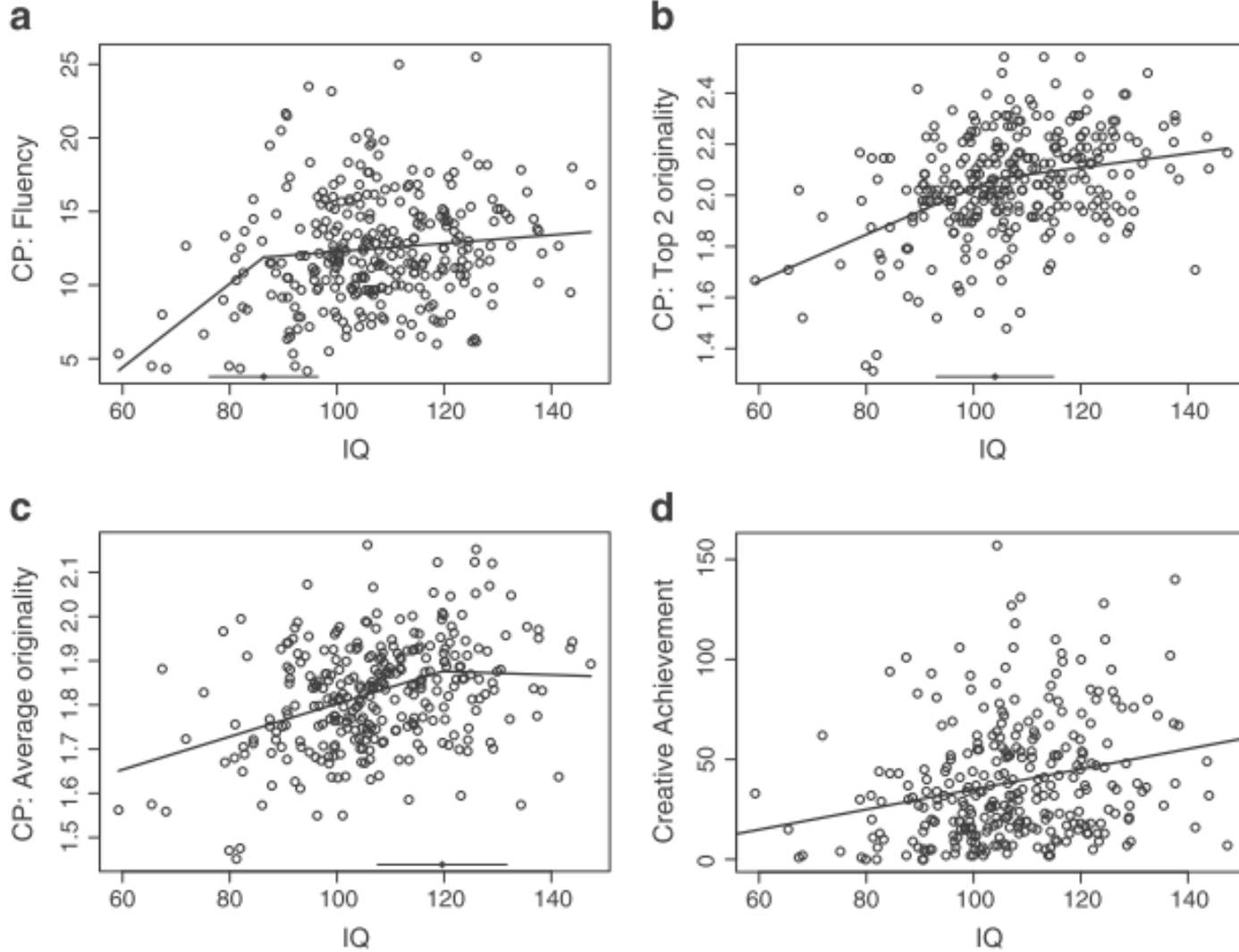
Convergent thinking

eg fluid intelligence (Raven)

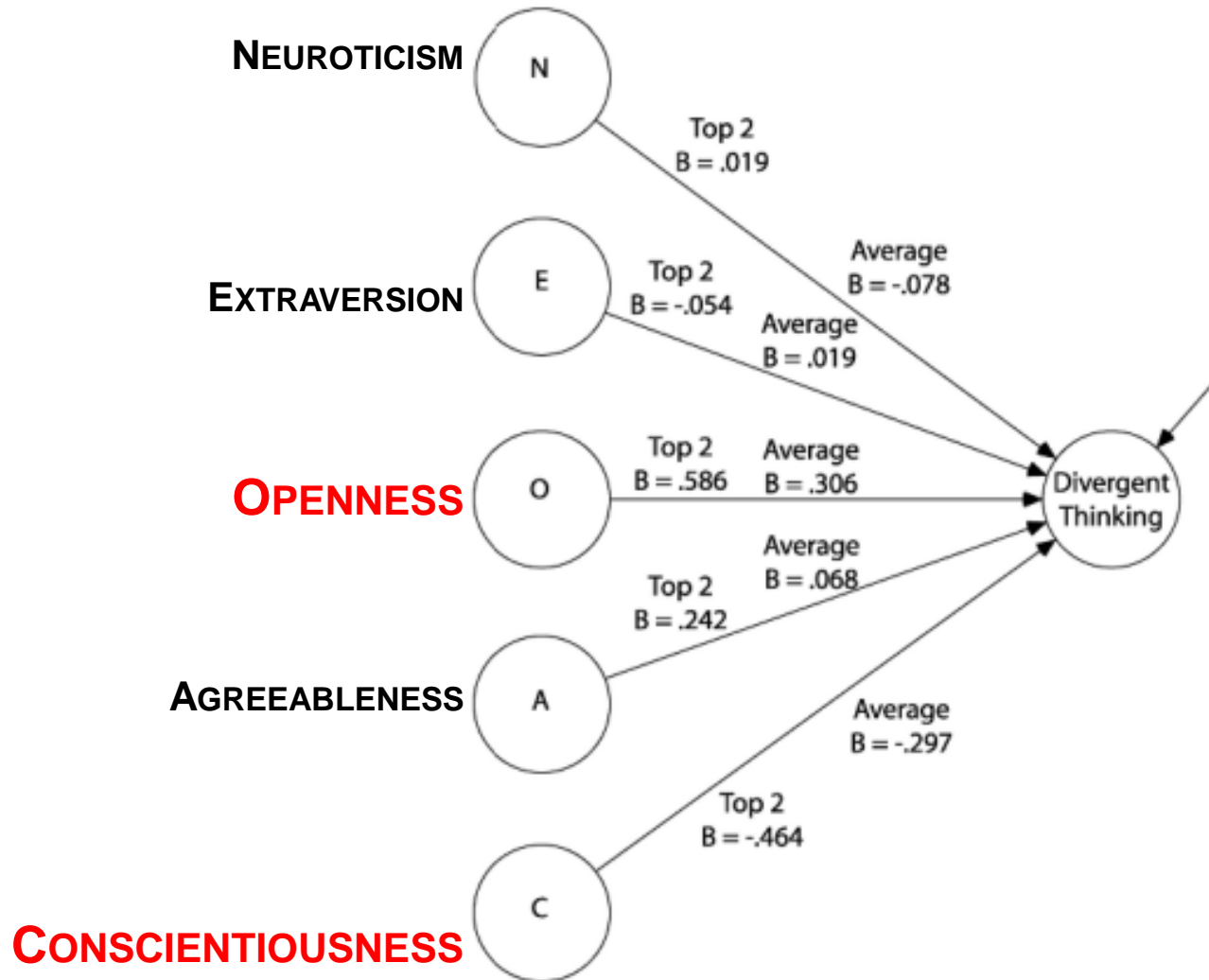
executive functions



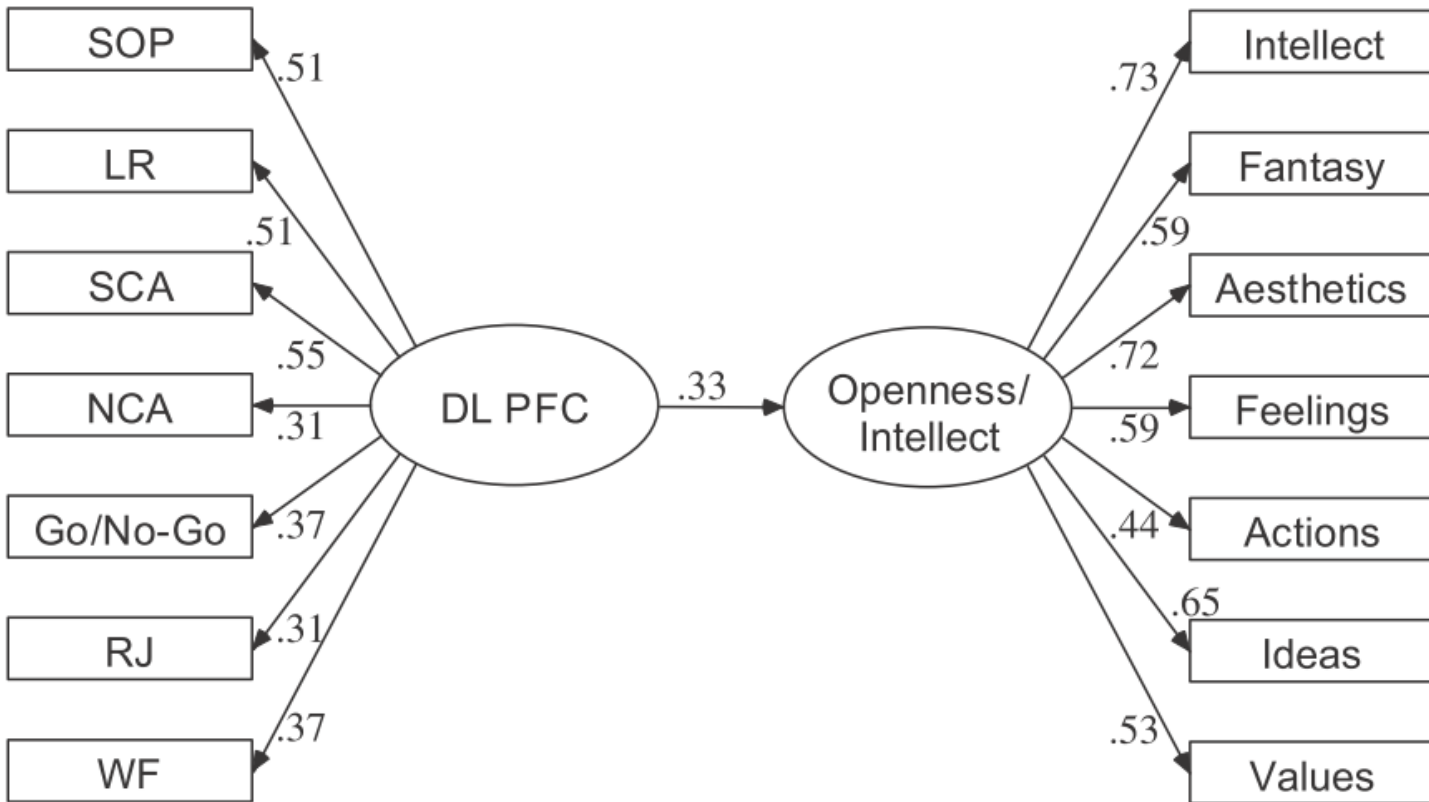
IQ, creativity and the threshold theory



More open and less conscientious people think more divergently



Openness is associated with cognitive control

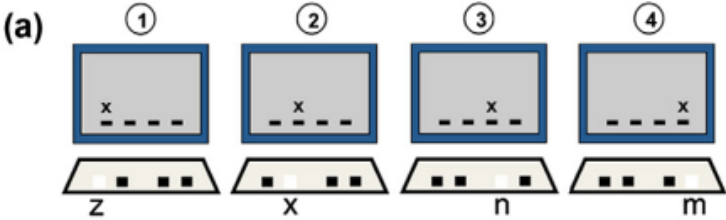


DL PFC: cognitive control latent variable;

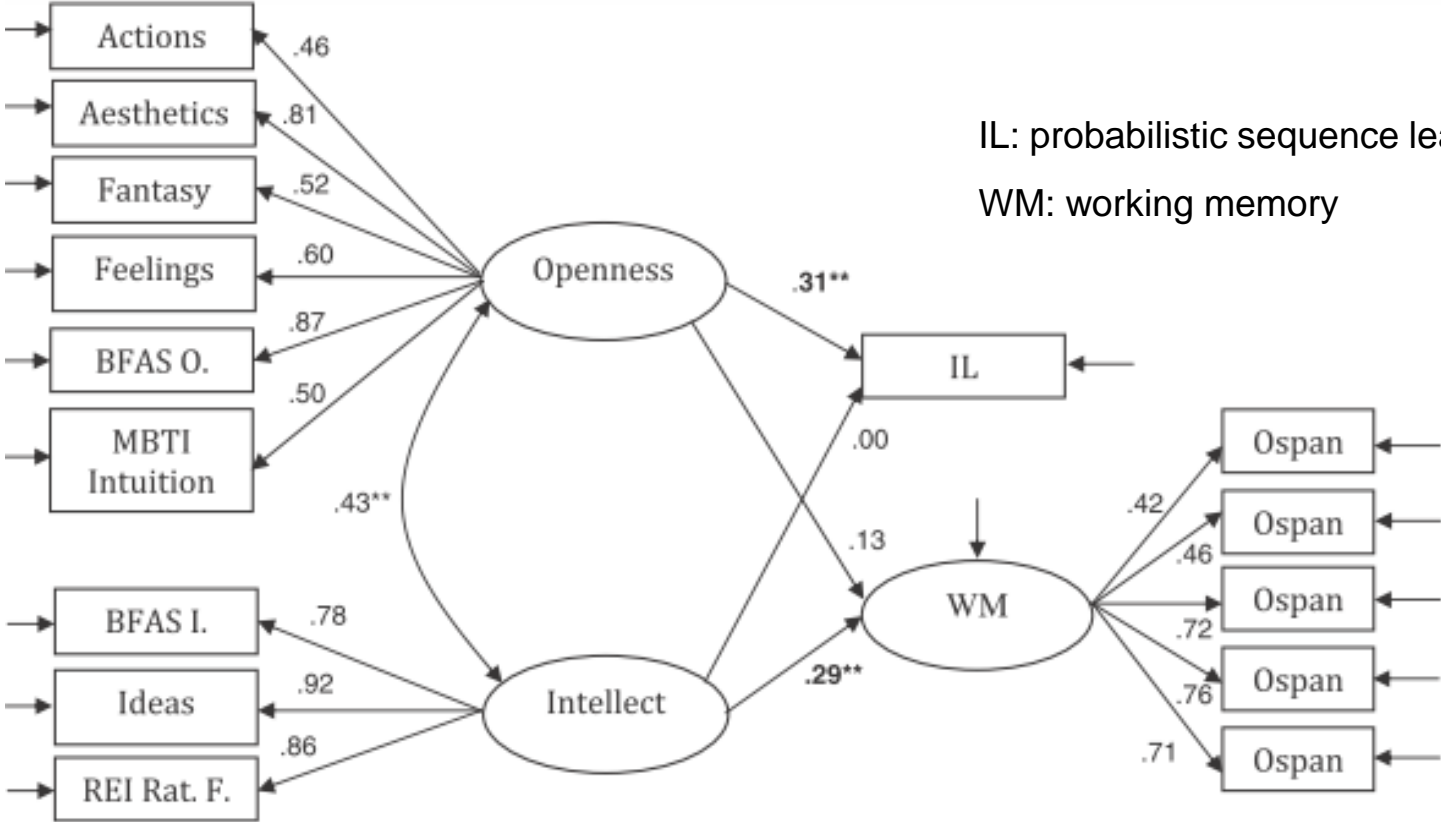
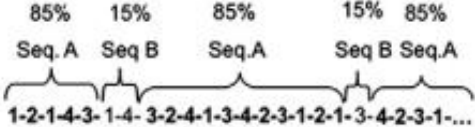
SOP, self-ordered pointing; LR, letter randomization; SCA, spatial conditional association;

NCA, nonspatial conditional association; RJ, recency judgment; WF, word fluency

Openness is associated with implicit learning



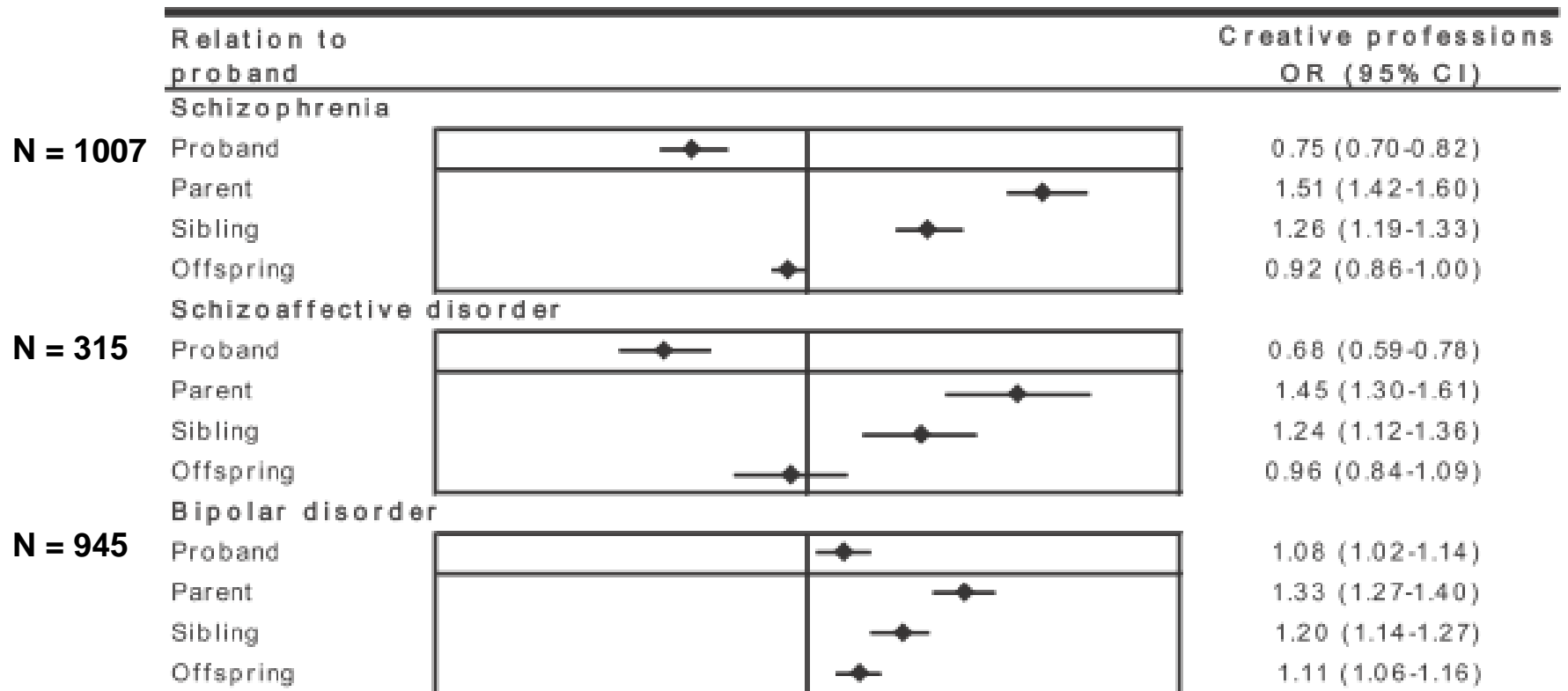
(c) Trial by trial substitution in a probabilistic sequence learning:



Section 1 - summary

- Creativity = novel & useful
- Creativity-relevant skills:
 - Divergent thinking,
 - Remote associations
 - Intelligence
- The role of Openness: cognitive control & implicit learning
- Creativity and mental disorders?

Familial association of psychotic disorders and creativity



The continuum between normality and psychotic disorders might be relevant

Schizotypal traits

- **Positive:** magical thinking, unusual perceptions
 - *„I have felt that I have special, almost magical powers”*
 - *„On occasions, have you seen a person’s face in front of you when no one was in fact there?”*
- **Negative:** social and physical anhedonia
 - *„Are people usually better off if they stay aloof from emotional involvements with people?”*
 - *„Do you enjoy many different kinds of play and recreation?”*
- **Disorganised:** social anxiety, odd speech, emotional sensitivity
 - *„I am easily distracted when I read or talk to someone”*
 - *„Are you sometimes so nervous that you are blocked?”*
- **Impulsive:** impulsive, asocial behaviour
 - *„Do you often feel the impulse to spend money which you know you can’t afford?”*
 - *„Do you at times have an urge to do something harmful or shocking?”*

Personality traits that resemble schizophrenia symptoms in the general population

Continuum at the level of neurocognition

Memory, attention and executive function

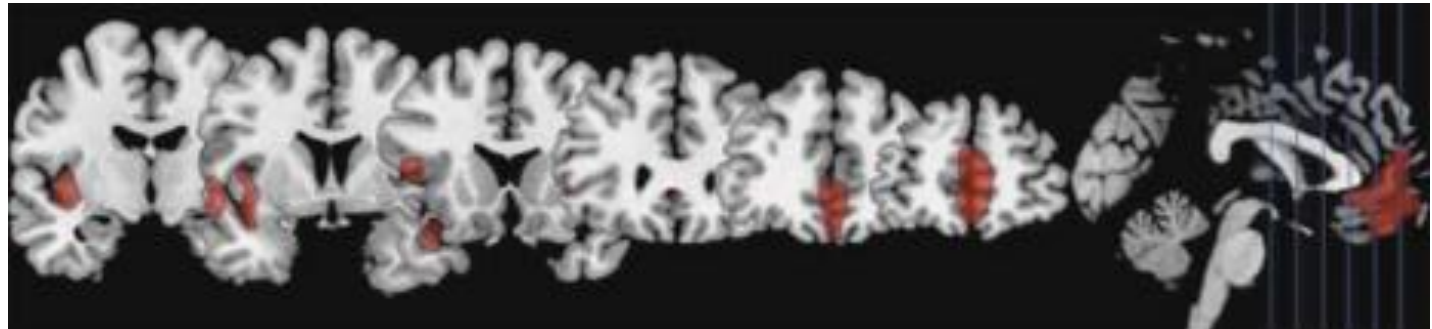
Slight, schizophrenia-like impairment, but not in all domains

Brain structure and function

Decreased and increased volume both have been reported

Brain activity somewhat similar to schizophrenia

Compensatory-protective mechanisms



Mild association between schizotypy and indicators of creativity

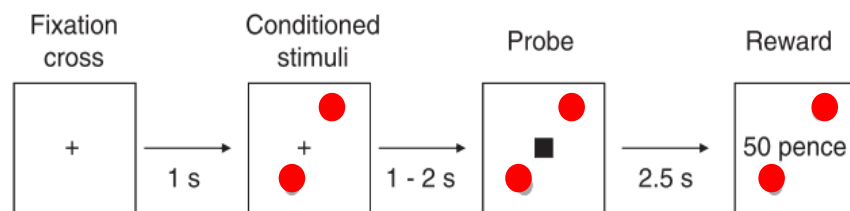
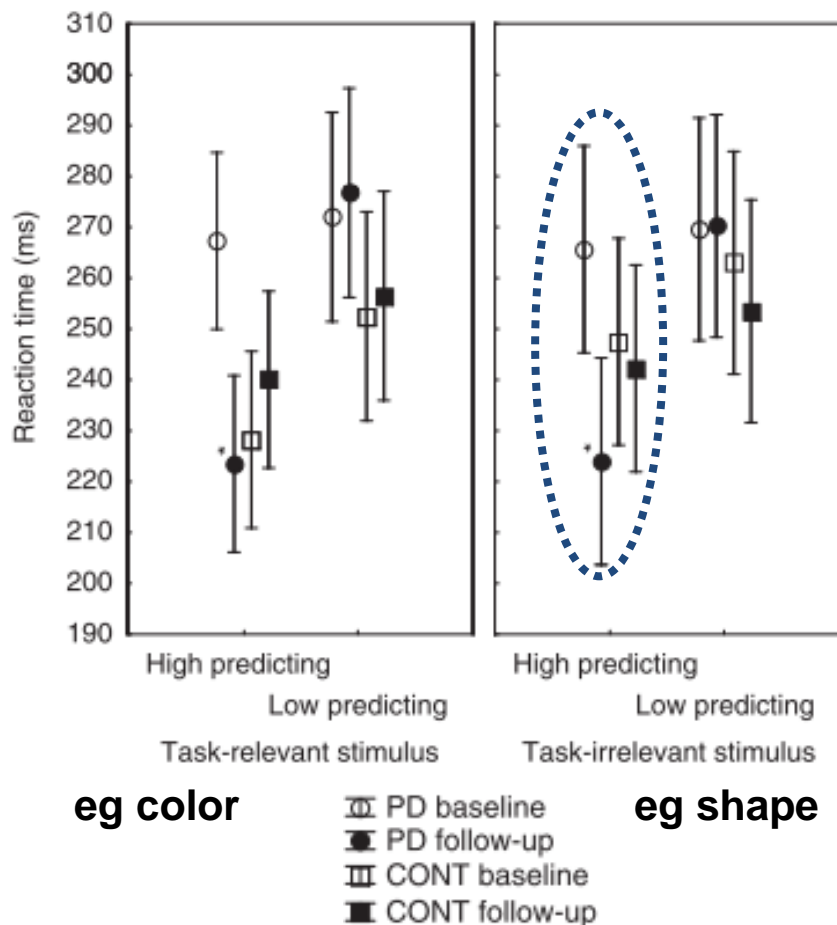
Meta-analysis of 45 studies

Positive & impulsive schizotypy: $r = 0.14$

Negative & disorganised schizotypy: $r = - 0.09$

Greater effects for artistic ($r = 0.21$) and eminent ($r = 0.20$) creativity, but more studies are needed

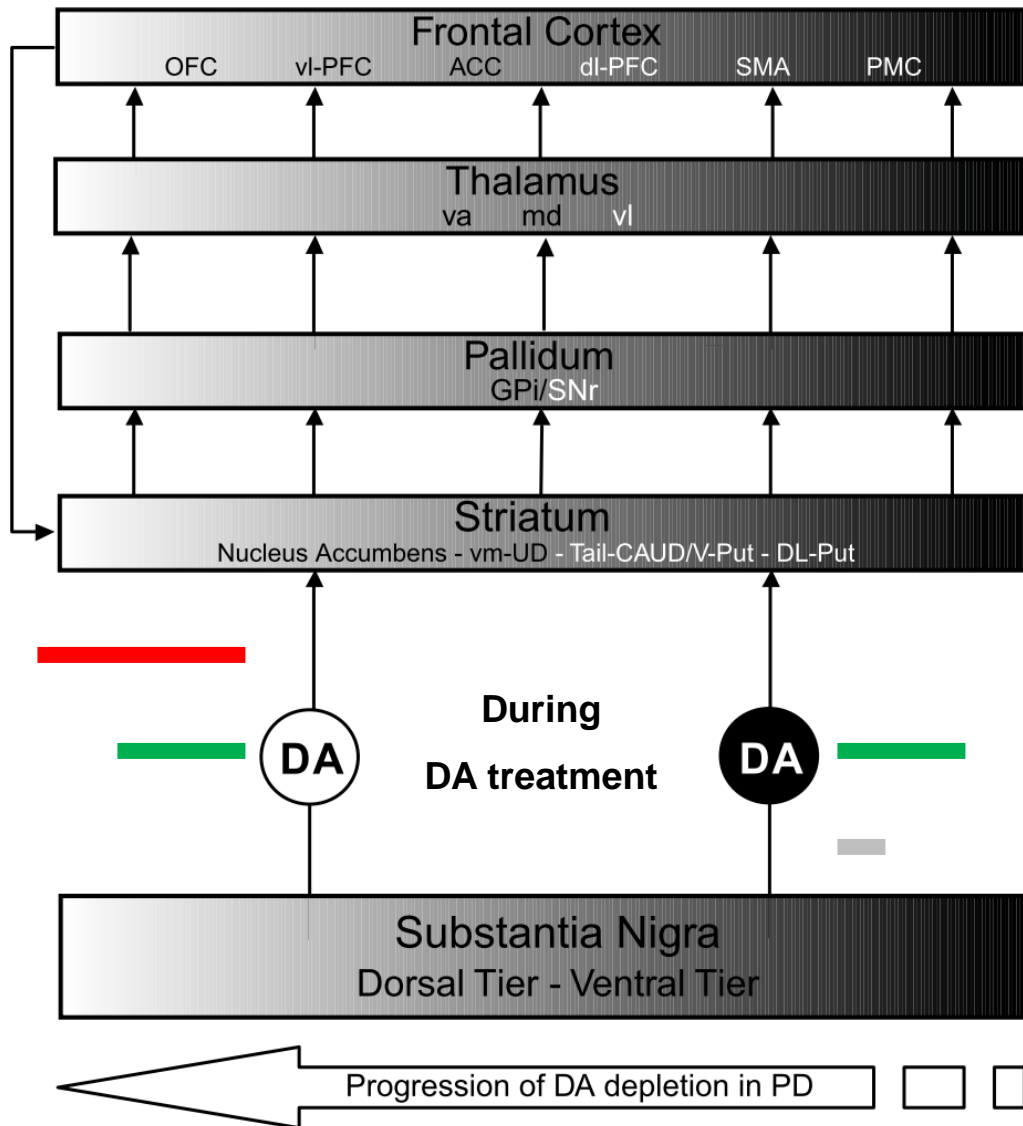
Aberrant salience and positive schizotypy in Parkinson's disease (PD)



Aberrant salience is related to positive schizotypy in medicated PD ($0,56 < |r| < 0,66$)

PD patients were tested before and after dopamine agonist treatment

Dopaminergic treatment and its side effects



Possible side-effects of DA treatment:

- Dopamine dysregulation syndrome
- Impulse control disorders

- Psychosis
- **CREATIVITY**

DA = dopamine

Creative drive, artistic style and dopamine agonists



Before PD: detailed, realistic style, one painting in months

PD onset: mild depression, apathetic towards painting

DA agonists: few paintings per week, impressionistic style

,need to express refreshed inner emotions'

Compulsive painting disrupts social life

Withdrawal of DA agonists →

Artistic drive reduced, apathy increased



47 y, amateur painter

Graphical art and visuomotor skills in Parkinson's

Obsessed by his art and also has a **strong urgency to produce:**

“The train has left the station and I have just been served a delicious dinner in the café car.

The train is picking up speed so I have to eat fast so I can finish my meal before we get to the last stop and I have to get off.”

Movement impairment is absent when drawing

Tookay is a sunny day.

mmmmmmmmmm

mmmmmmmmmm



68 y, graphic designer

Poetic Talent Unmasked by Treatment of Parkinson's Disease

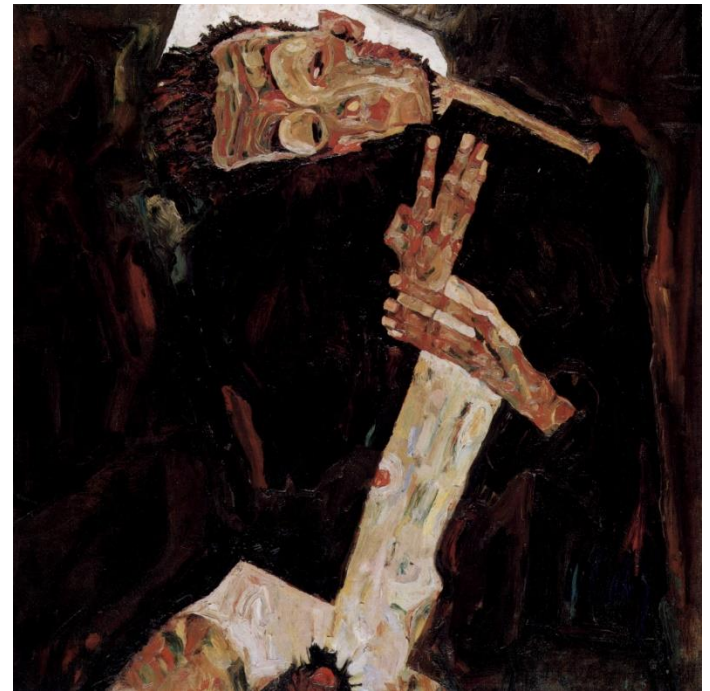
Anette Schrag, MD, PhD, and Michael Trimble, MD*

PD onset at 40

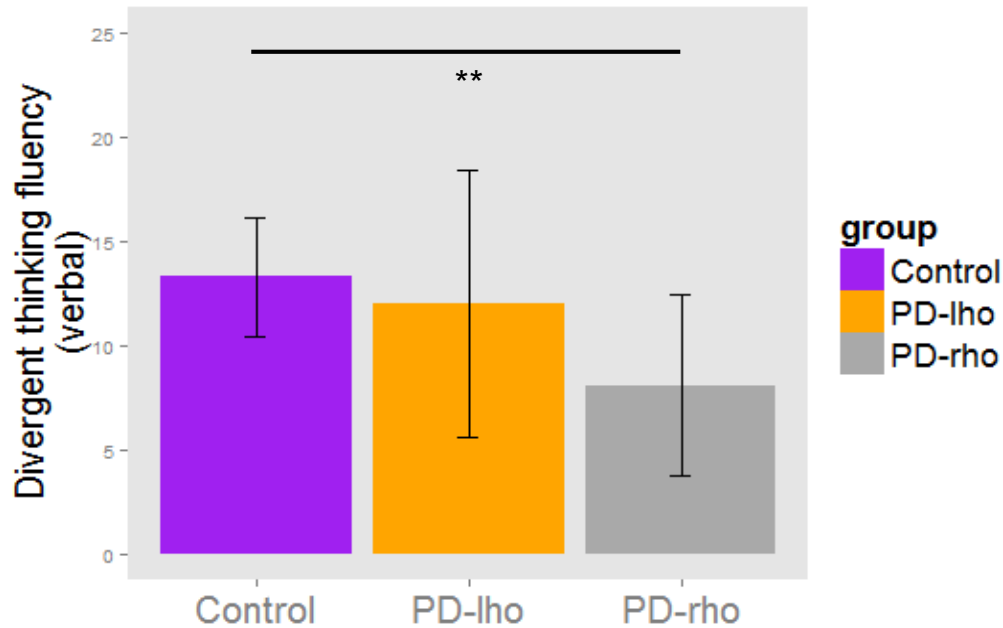
L-Dopa + DA agonist at 44, increase in libido, began writing poetry, won prizes

Paranoid and hypomanic symptoms, bizarre and extensive speech at 53

Preserved IQ, some executive impairment



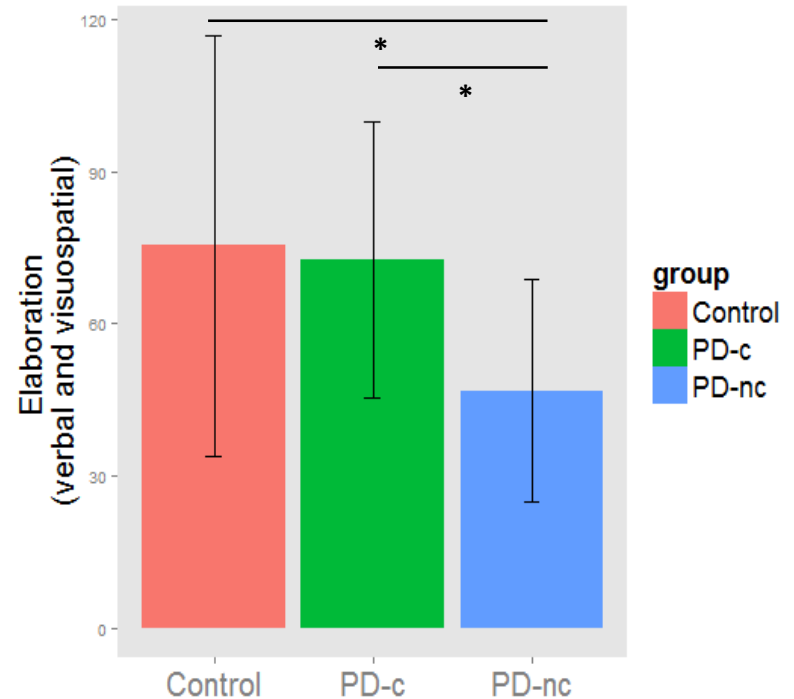
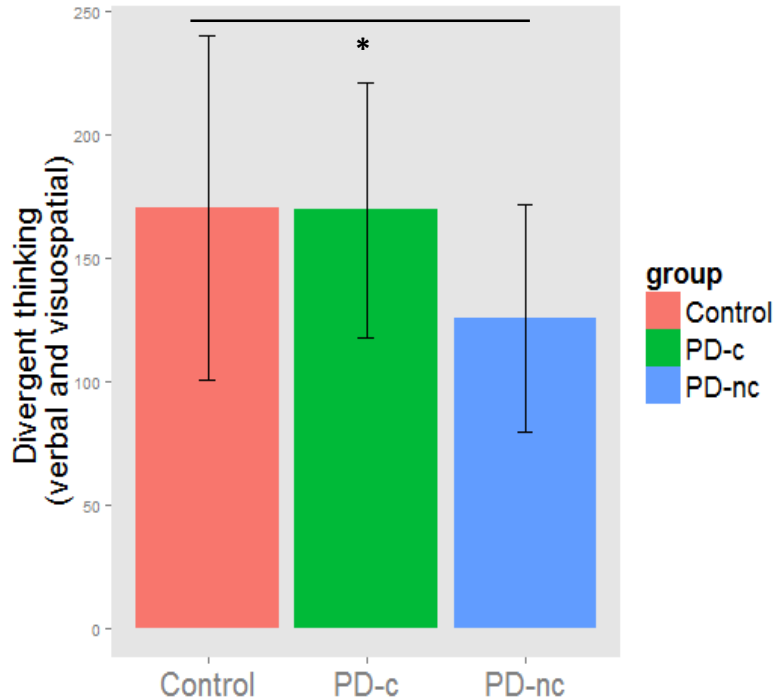
Divergent thinking and laterality of symptoms



Laterality had no effect on:

- divergent thinking originality and flexibility
- Visuo-spatial divergent thinking
- general verbal fluency

Divergent thinking and artistic creativity in PD



No professional artists, no artistic hobbies before the diagnosis of PD

PD-c: 2h+/day art (e.g., painting, writing, sculpturing) after dopaminergic treatment

No association of divergent thinking with impulsivity or impulse control disorders (ICDs)

What is the difference between creative and non-creative patients?

Study 1:

**Predicting the improvement
of divergent thinking in PD**

Study design and methods

Session 1: baseline

IQ (WAIS-R)

Lifetime creative achievement (CAQ)

Divergent thinking ('Just suppose')

Schizotypy (O-LIFE)

$N_{PD} = 18$

$N_{controls} = 19$

12 weeks



PD: dopamine receptor agonist
monotherapy

Session 2: follow-up

Divergent thinking ('Just suppose')

Schizotypy (O-LIFE)

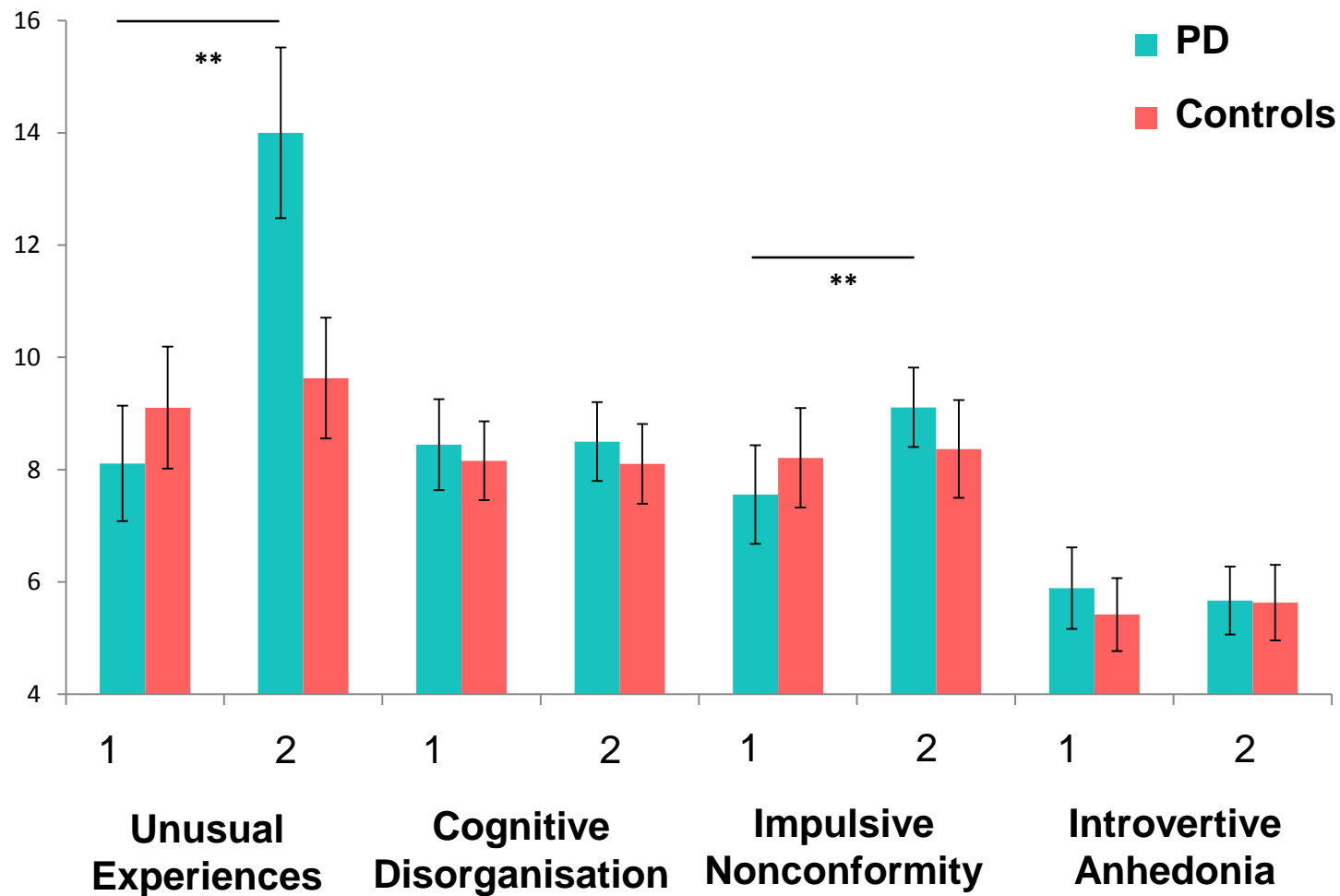
$N_{PD} = 18$

$N_{controls} = 19$

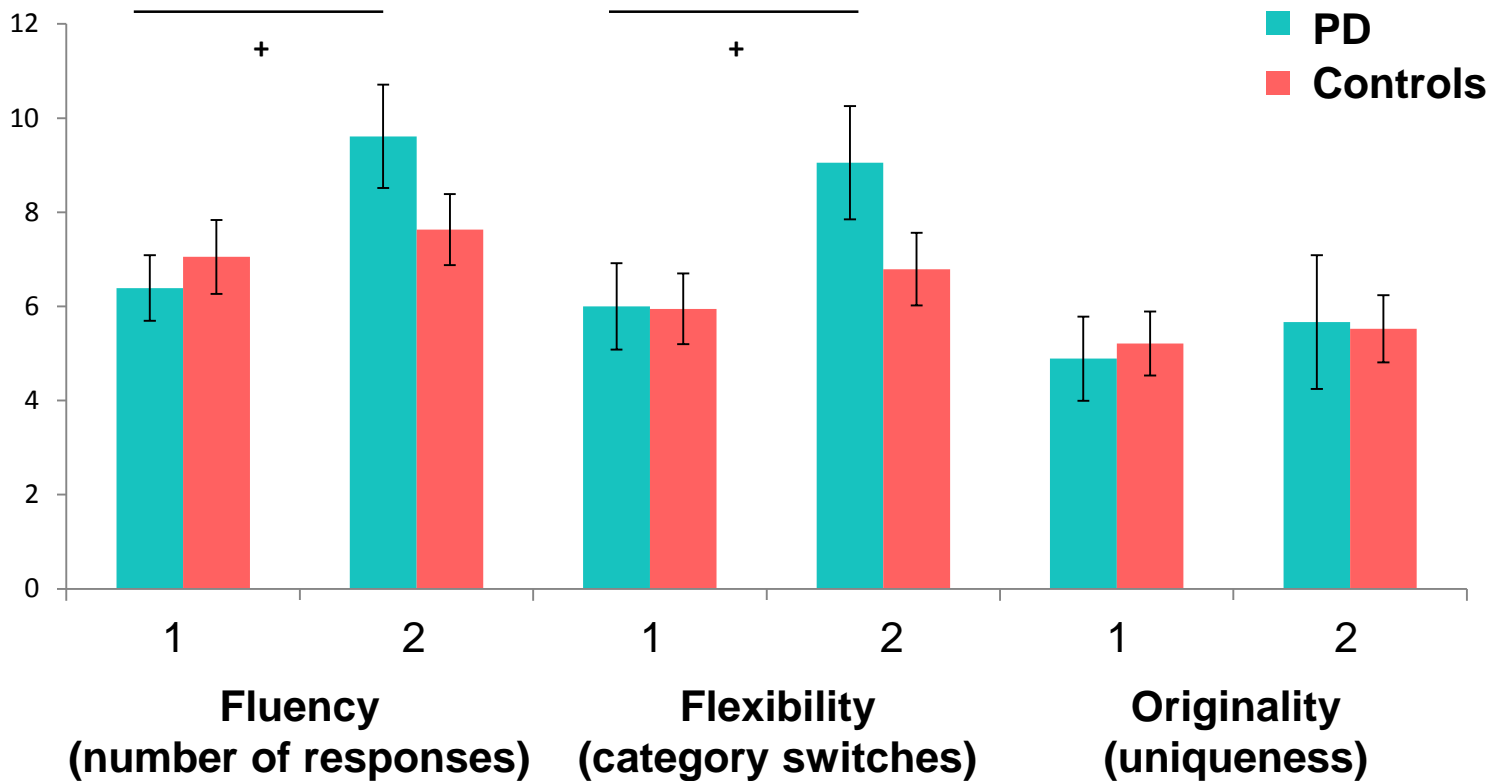
Results 1.:

PD vs. controls

Between-session changes in schizotypy



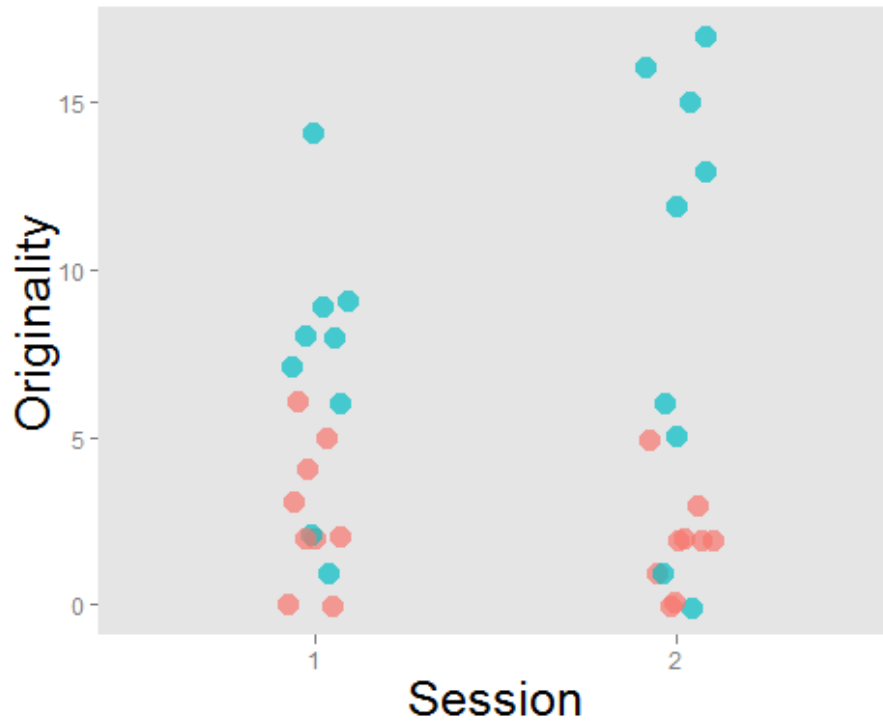
Between-session changes in divergent thinking



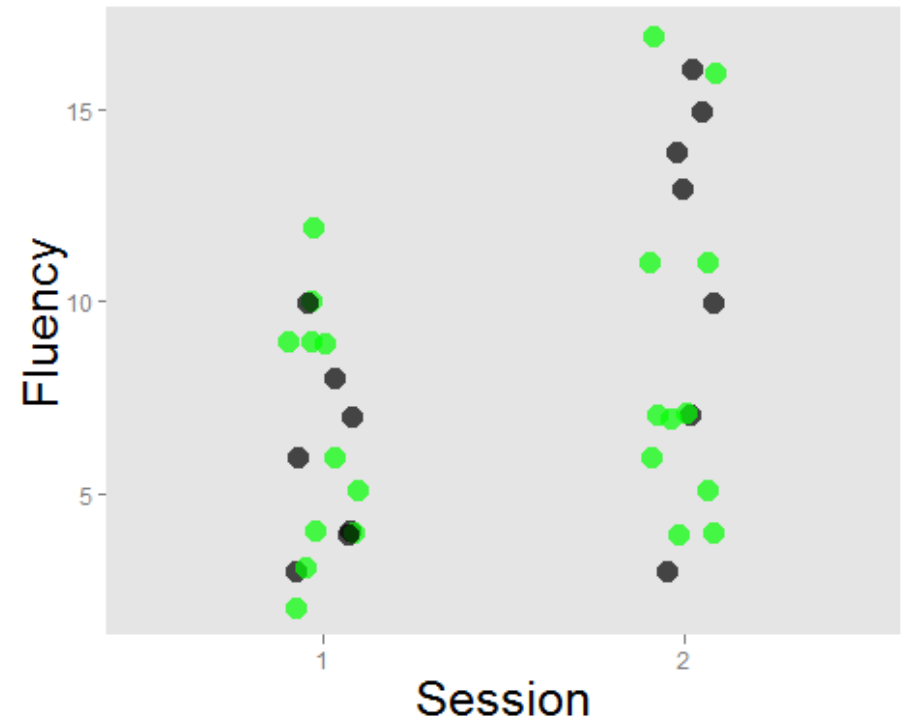
+ $p < 0.1$ * $p < 0.05$ ** $p < 0.01$

Results 2.: **differences in changes**

Predicting the improvement of originality and fluency



Unusual Experiences (baseline) ● Low ● High

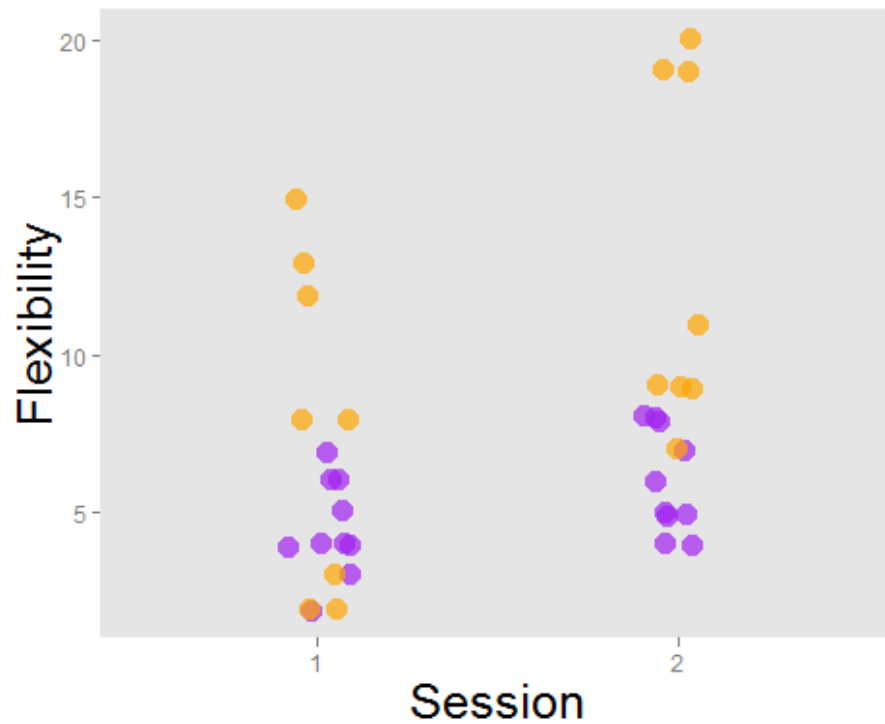


Intelligence (baseline) ● Low ● High

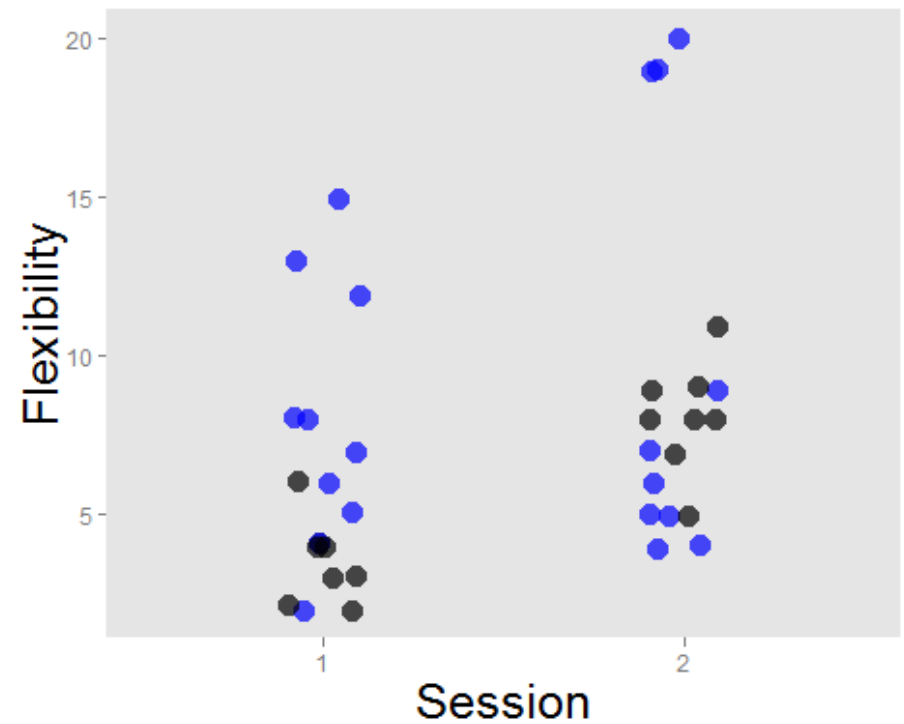
$\Delta R^2 = .05^*$	β	t	p
PD \times UnEx	0.53	2.37	.024

$\Delta R^2 = .05^+$	β	t	p
PD \times IQ	2.14	1.74	.091

Predicting the improvement of flexibility



Creative Achievements (baseline) ● Low ● High



Cognitive Disorganisation (baseline) ● Low ● High

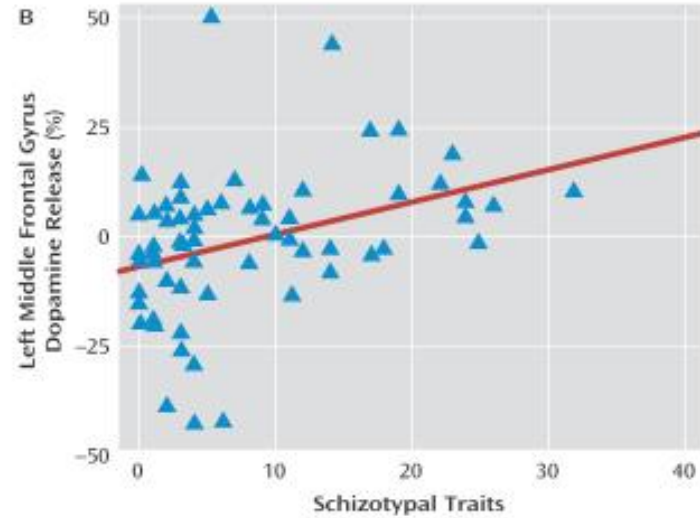
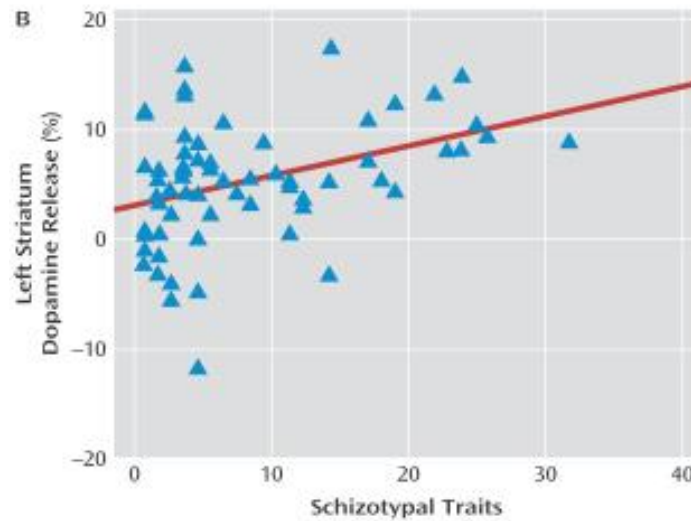
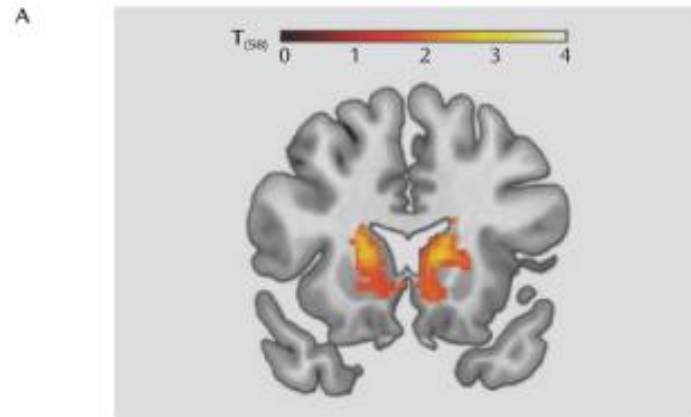
$\Delta R^2 = .10^*$	β	t	p
PD \times CAQ	0.63	2.60	.014

$\Delta R^2 = .08^*$	β	t	p
PD \times CogDis	0.85	2.24	.032

Summary of study 1

- Positive and impulsive schizotypy increased after dopaminergic therapy in PD
- Weak trend for elevated divergent thinking in PD
- Schizotypal traits, IQ(?), and lifetime creative achievement are potential predictors of the 'creativity side effect' in PD

Schizotypy and neural responsiveness to dopamine



Predictors of real life creative achievements

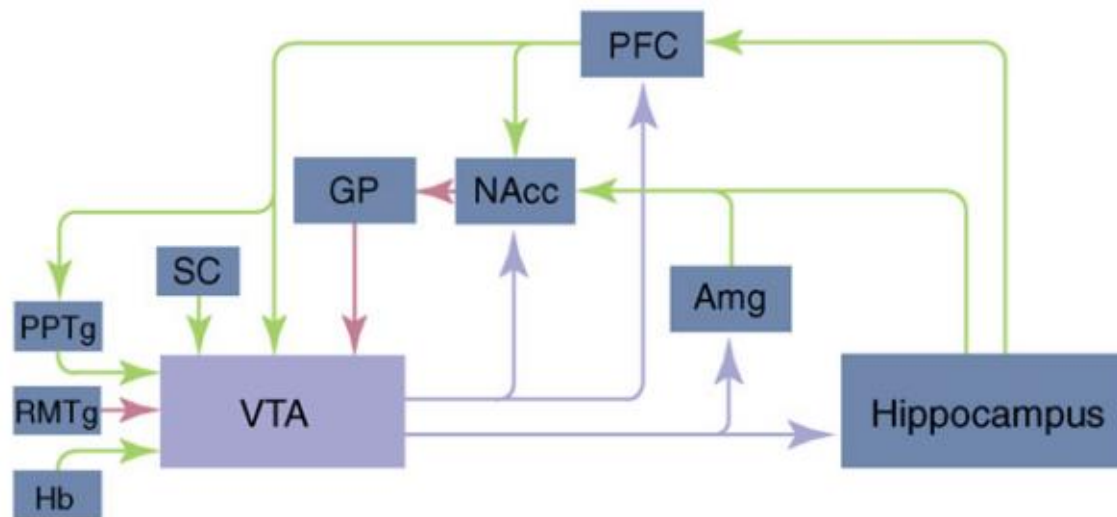
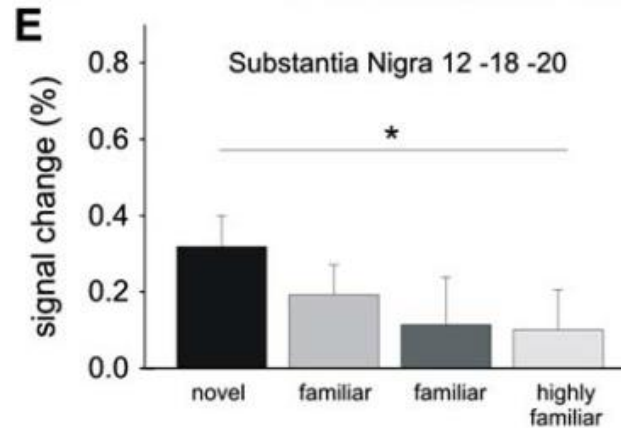
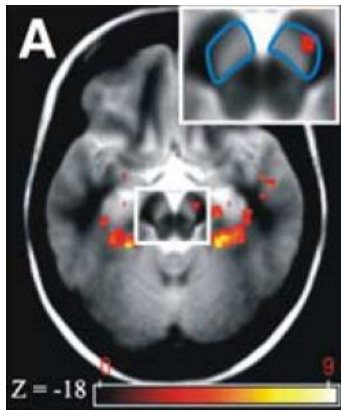
	β	Partial correlation	$t(102)$	p
Primary network	0.42	0.44	5.0	<0.0001
Latent inhibition	-0.28	-0.31	-3.24	0.002
IQ	0.28	0.32	3.45	0.0008
Broader network	-0.04	-0.05	-0.45	0.65
Unusual experience	0.07	0.08	0.81	0.42
Cognitive disorganization	0.05	0.06	0.60	0.56
Introvertive anhedonia	-0.03	-0.04	-0.39	0.70
Impulsive nonconformity	-0.0	-0.0	-0.02	0.98

Changes in latent inhibition in PD during dopaminergic therapy?

Study 2:

Lower-level mechanisms of creativity in PD

Dopaminergic systems in exploration



Exploration = actions and cognitions motivated by the incentive reward value of uncertainty (new interpretations, strategies, and patterns)

Explorative cognition and psychotic-like experiences

Latent inhibition: adapting to unexpected contingencies



Anomaly detection: processing and categorising an unlikely stimulus



Positive schizotypy: unusual, unlikely interpretations and pattern perception



Hypotheses of study 2

H1: covariation between latent inhibition, anomaly detection and positive schizotypy

H2: lower latent inhibition, improved anomaly detection and increased positive schizotypy in PD

H3: dose dependent effects of dopamine in PD

	<u>Controls</u>	<u>PD</u>	<u>PD-repl</u>
Male/female	15/9	16/10	18/7
Age	56.7 (2.5)	55.2 (1.7)	56.2 (1.7)
IQ (WAIS-R)	108.3 (2.2)	110.5 (2.4)	107.8 (2.1)
Education	12.2 (0.9)	12.3 (0.7)	12.7 (0.6)
LED	-	657.5 (78.9)	752.8 (98.6)
UPDRS*		35.5 (1.8)	44.1 (1.2)
Left/right ons		8/17	17/8
Disease dura		12 (7;48)	65 (20; 120)
Combined/L-		9/14	13/8

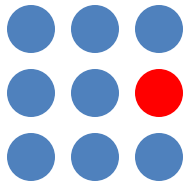
PD-repl:

- More severe symptoms
- Longer disease duration
- Different laterality and medication

* $p < 0.024$

Measurement of latent inhibition

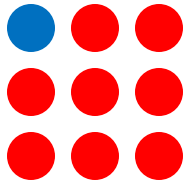
- Pre-exposition phase: search for the target among distractors!



- Test phase:

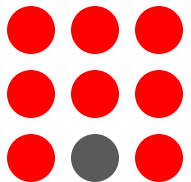
PRE-EXPOSITION (PE): Old distractor → target;

Old target → distractor



NO PRE-EXPOSITION (NPE): New target;

Old target → distractor



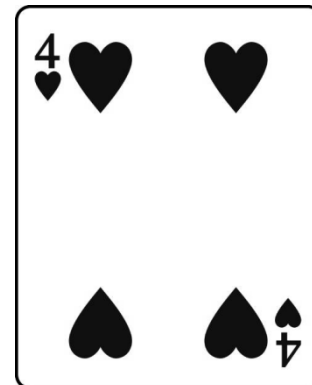
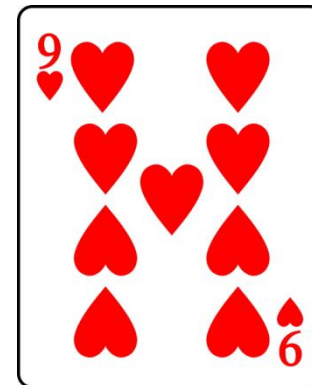
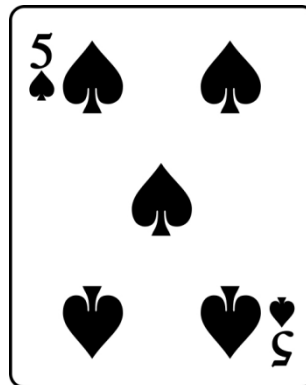
- Latent inhibition = **PE** - **NPE**

Measurement of anomaly detection

- What have you seen?
- 4 normal + 1 „trick” playing card
- Progressively increased presentation times:

15 ms → 7680 ms

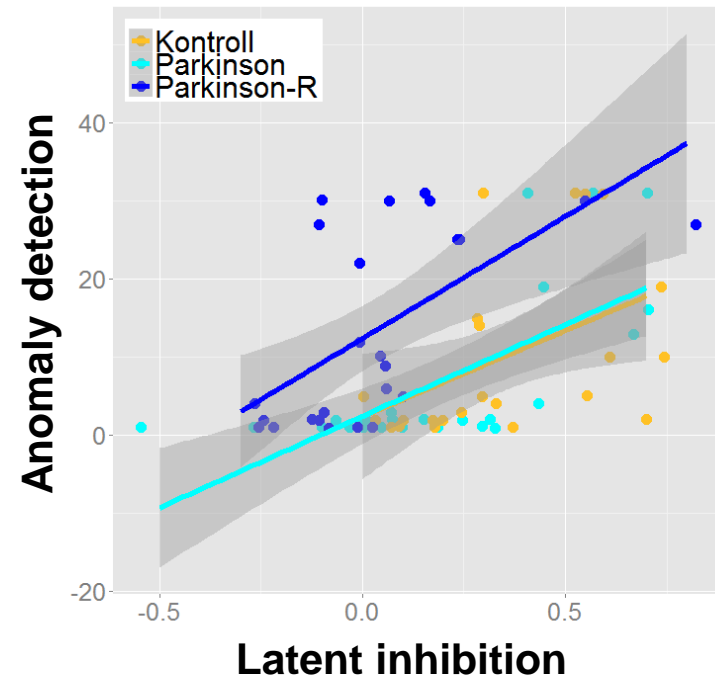
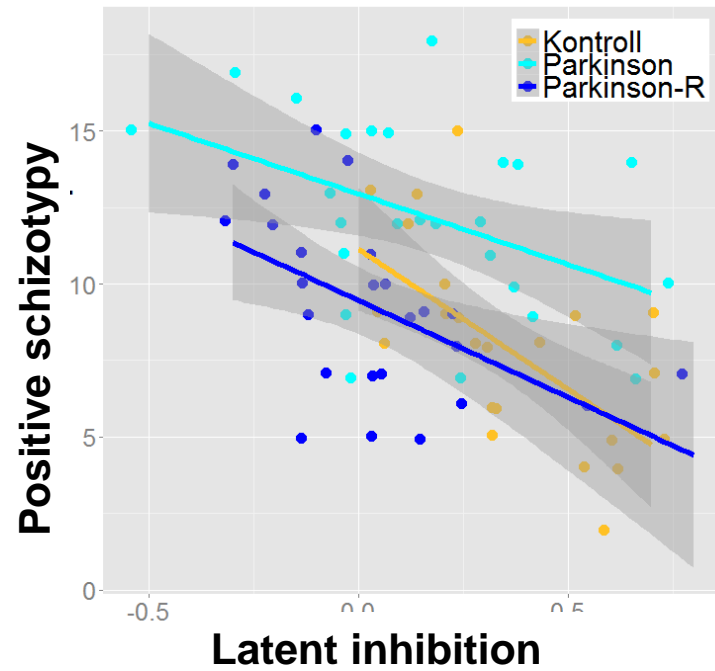
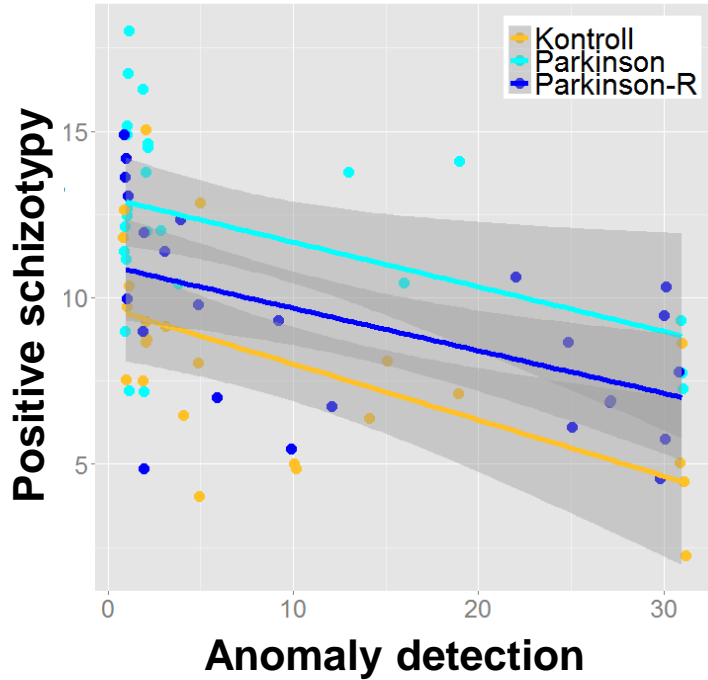
- Max. 30 presentations



Results 1.: **correlations**

- 0.68* / - 0.44* / - 0.56****

- 0.69* / - 0.31 / - 0.61****

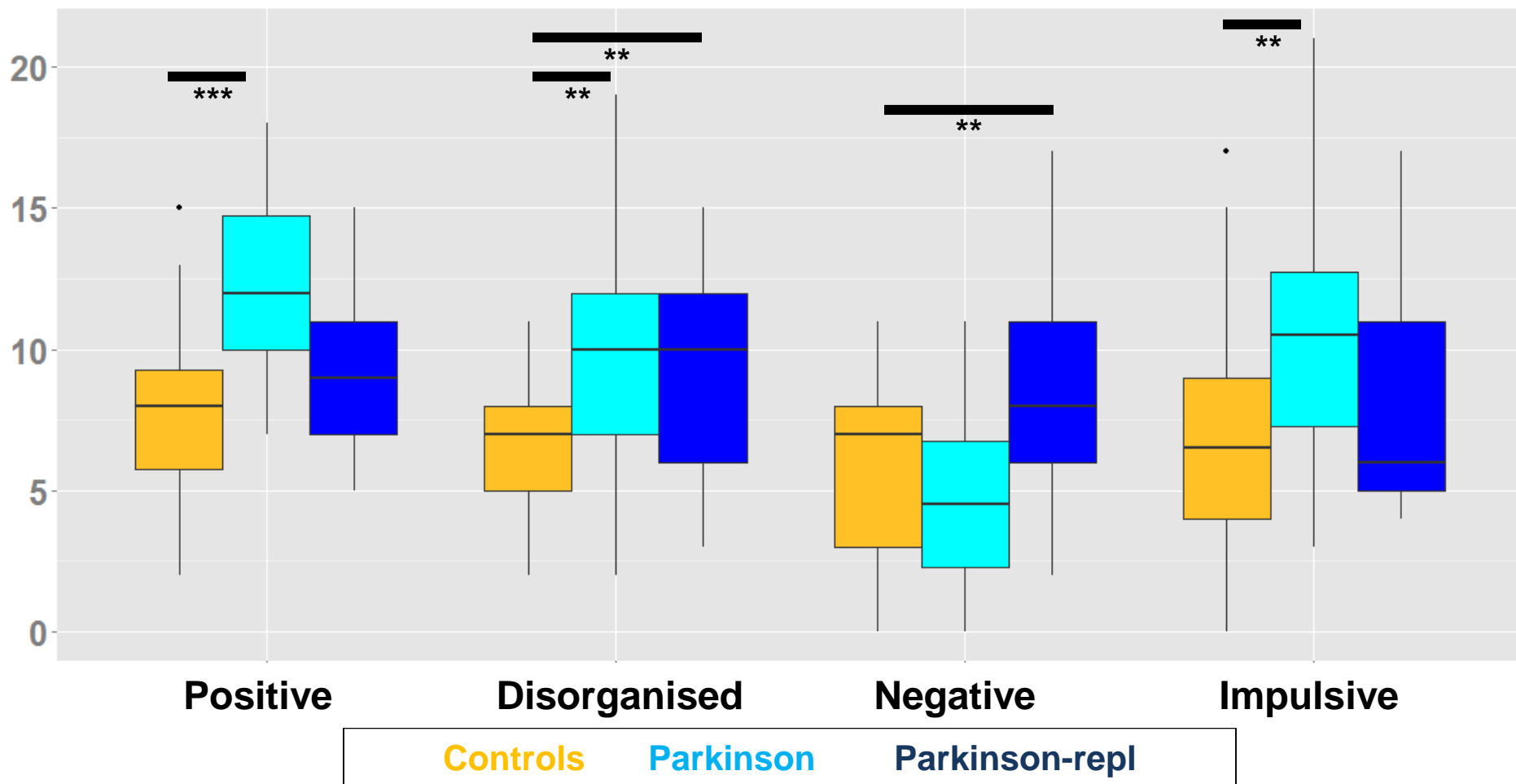


0.55 / 0.70*** / 0.65****

Spearman rho: + $p < 0.1$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

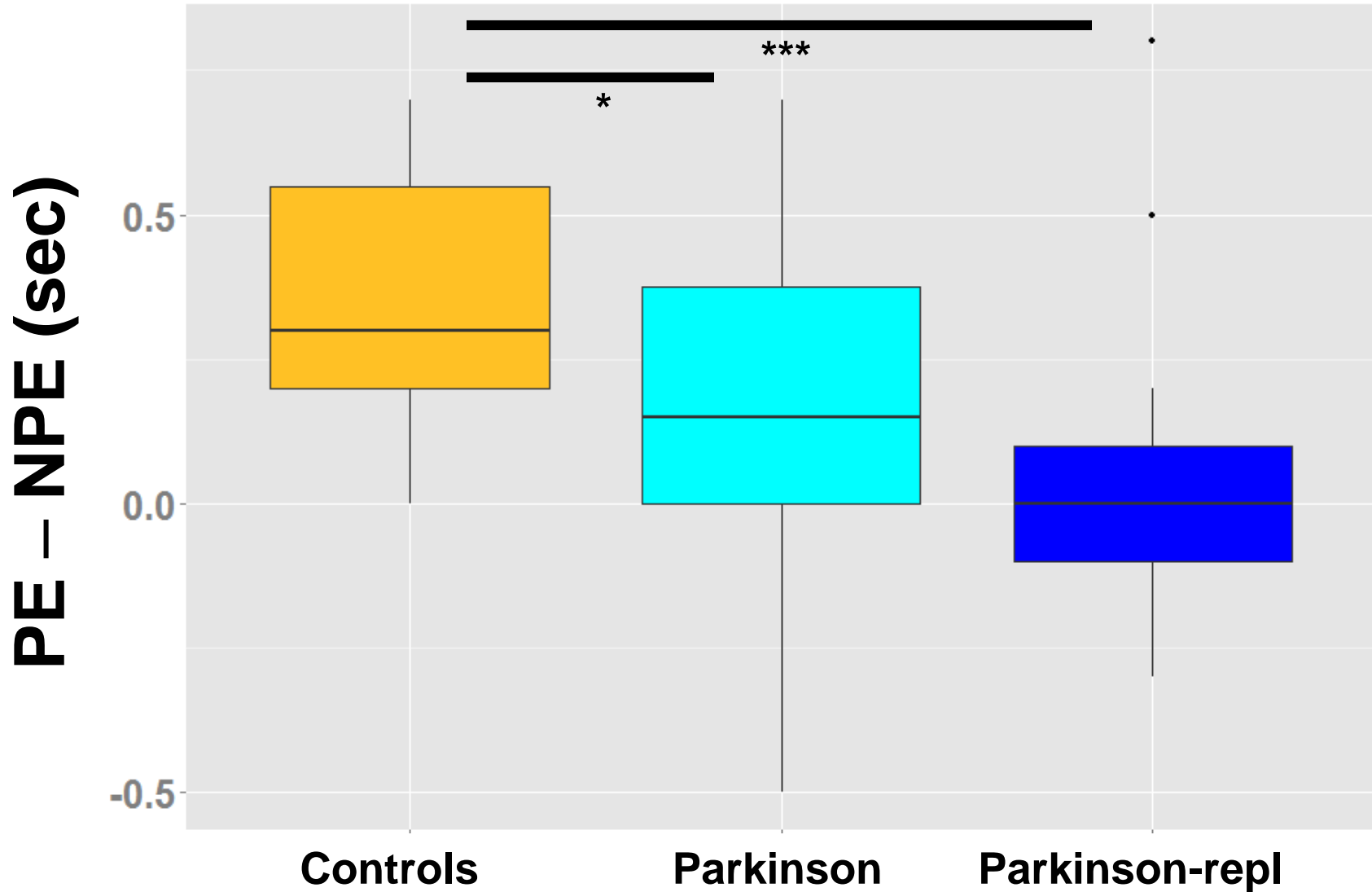
Results 2: PD vs. controls

Schizotypy dimensions



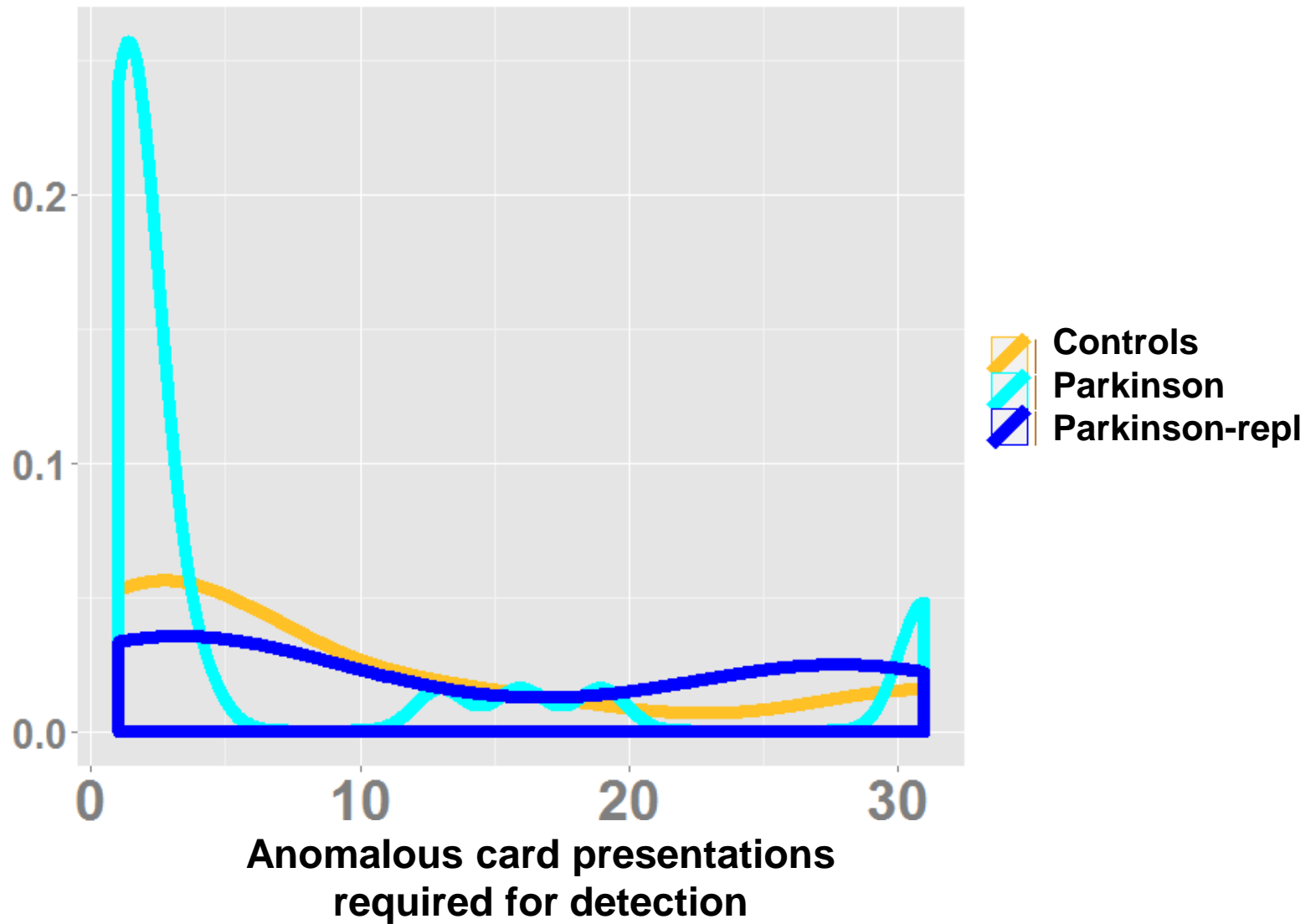
** $p < 0.01$ *** $p < 0.001$

Latent inhibition



* $p < 0.05$ *** $p < 0.001$

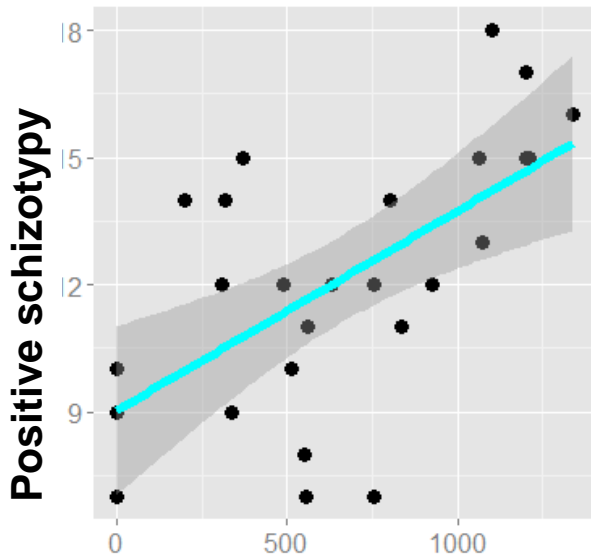
Anomaly detection



Controls vs. Parkinson $p = 0.078$

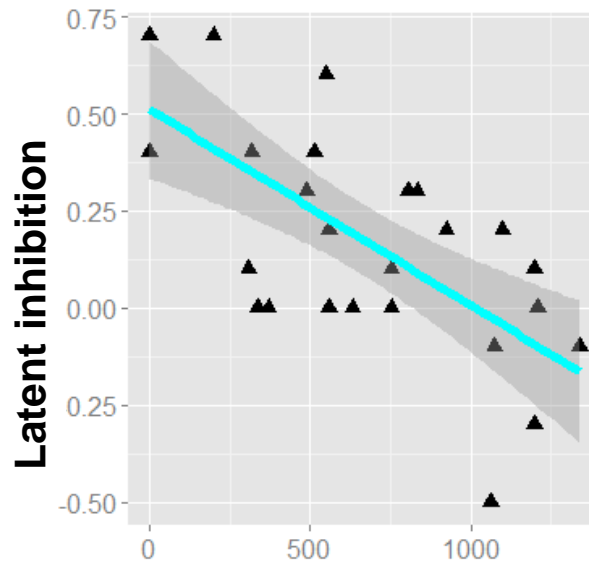
**Results 3:
dose dependent effects of DA**

Parkinson's disease, first sample



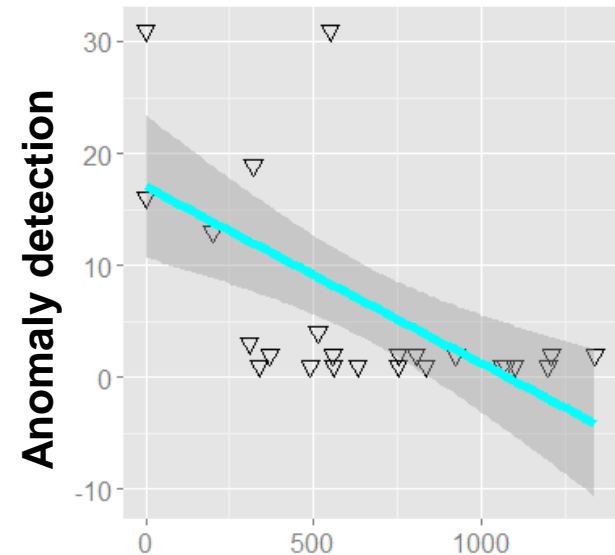
Levodopa equivalent dose

$$R^2_{adj} = 0.34$$
$$F(6,18) = 3.0^*$$



Levodopa equivalent dose

$$R^2_{adj} = 0.35$$
$$F(6,18) = 3.2^*$$



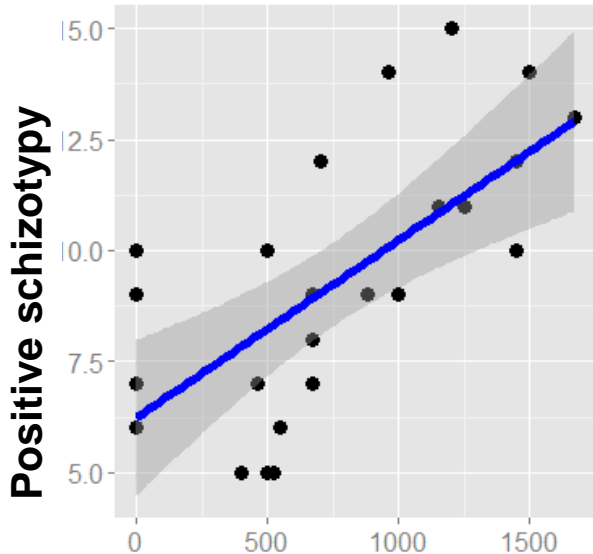
Levodopa equivalent dose

$$R^2_{adj} = 0.34$$
$$F(6,18) = 3.1^*$$

Controlling for age, gender, symptom severity, laterality of symptom onset, and duration of illness

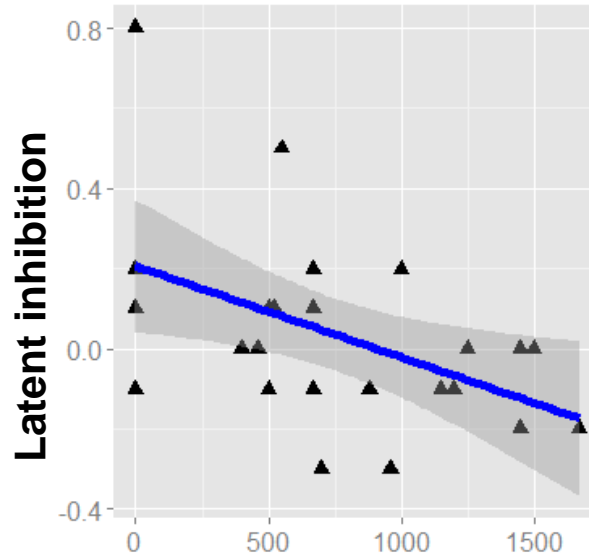
* $p < 0.05$

Parkinson's disease, replication



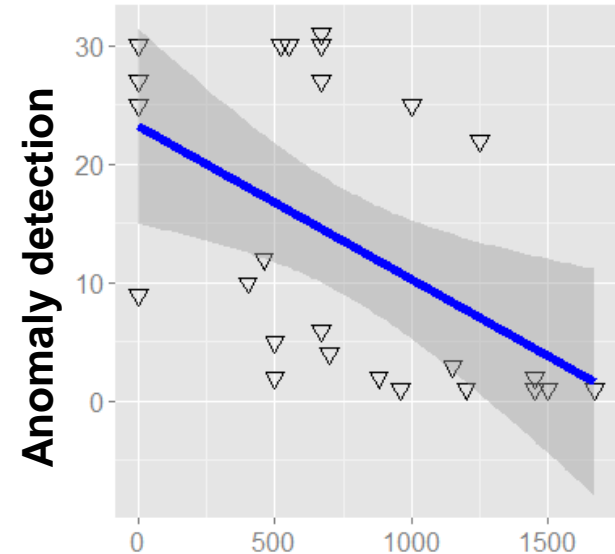
Levodopa equivalent dose

$$R^2_{adj} = 0.37$$
$$F(6,18) = 3.4^*$$



Levodopa equivalent dose

$$R^2_{adj} = 0.53$$
$$F(6,18) = 4.5^{**}$$



Levodopa equivalent dose

$$R^2_{adj} = 0.29$$
$$F(6,18) = 2.7^+$$

Controlling for age, gender, symptom severity, laterality of symptom onset, and duration of illness

Overview of the results

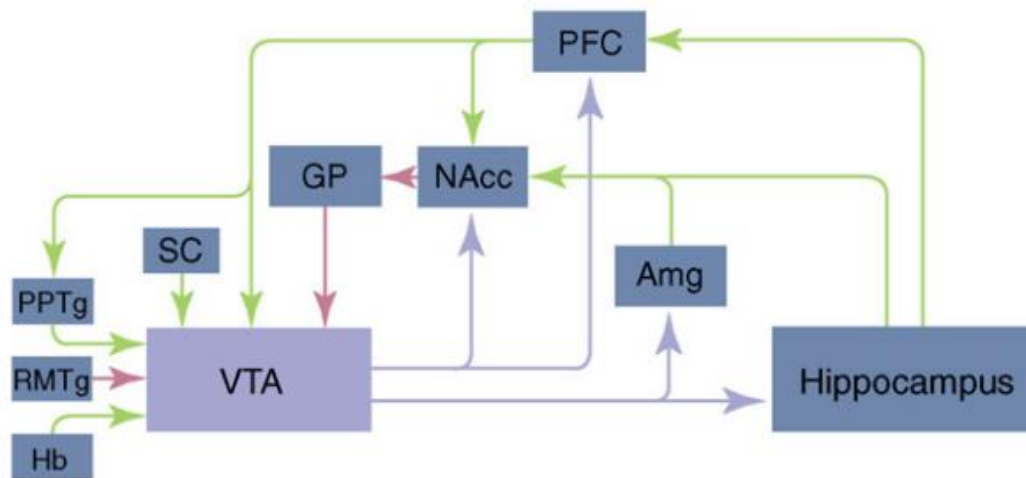
- **H1:** covariation between latent inhibition, anomaly detection, and positive schizotypy → exploration
- **H2:** in Parkinson's patients undergoing DA therapy:
 - Increased positive (?) and disorganised schizotypy
 - Reduced latent inhibition
 - Enhanced anomaly detection (?)
- **H3:** dose dependent effects of DA

Exploration and dopamine

Overactivation of the mesolimbic dopamine system in early PD undergoing DA treatment



Increased tendency to perceive new / unlikely patterns



Summary of the PD studies

Study 1

- DA agonists increase positive schizotypy, impulsivity
- Increase in divergent thinking is related to pre-treatment schizotypy and creative achievement

Study 2

- DA drugs decrease latent inhibition and increase disorganised schizotypy (positive?)
- DA drugs have dose dependent effects on positive schizotypy, latent inhibition, and anomaly detection
- Clinical factors (medication type, laterality, symptoms, ...) and age might modulate the effects

Neurocognitive aspects of creativity

- Creativity is associated with IQ and openness
- Schizotypy is weakly related to creativity
- Dopamine treatment in Parkinson's increases schizotypy and boosts creativity-related processes

Thank you for your attention!

Bertalan Polner

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