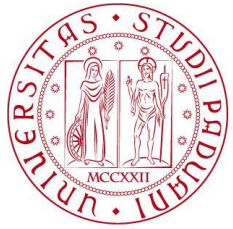


UNIVERSITÀ DEGLI STUDI DI PADOVA

>

DIPARTIMENTO DI PSICOLOGIA GENERALE

>

MEMORY AND LEARNING LAB

Learning Disorders: A Categorical or a Dimensional Approach?

Enrico Toffalini – enrico.toffalini@unipd.it

University of Padua, Italy

Friday, 02 September 2022

Structure of the talk

0. Foreword on intelligence
1. What is the dimensional framework
2. How it can be implemented (and tested) in studies on learning disorders
3. Pros and cons of it

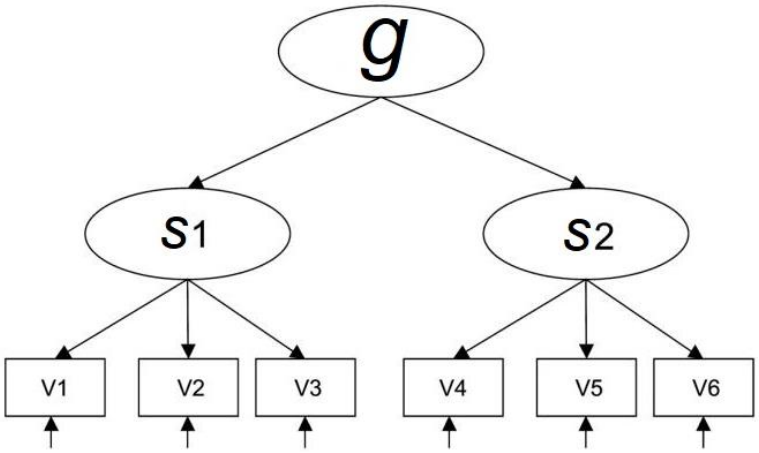
0. Foreword on intelligence

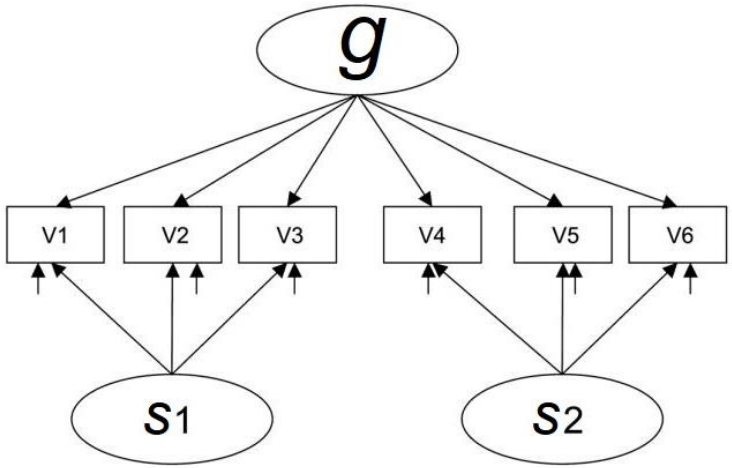
- Intelligence is involved in any *task* that requires cognitive abilities (include reading, writing, maths: see "Grw" and "Gq" in the CHC model)

- Intellectual abilities are treated as *continua*

- Strong consensus on the preeminence of the general "g" factor (Spearman, 1904) has re-emerged in the last few decades (e.g., Warne, 2020). E.g., >70% of non-error variance of different tasks like Vocabulary, Digit span, Matrix reasoning, is attributed to the "g factor", while only a minority is explained by more specific factors (e.g., verbal comprehension, working memory, fluid intelligence) (Watkins, 2006). Also, g has the strongest impact in real life (Warne, 2020).

> Many scholars in intelligence tend to focus mostly/only on “g” and dismiss the relevance of specific factors… yet the latter are still included in models





When we study *specific* learning disorders, we choose to be explicitly concerned with more *specific* factors…

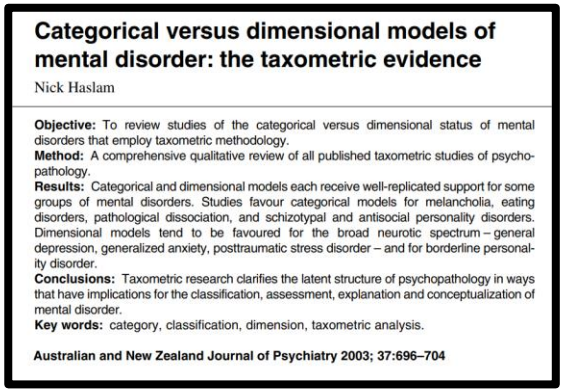
In a sense, that’s all folks! ☺

1. What is the dimensional framework and what it implies

A dimensional framework is potentially applicable to many psychopathological (and even medical) conditions

anxiety, depression, sleep disorders, addictions, compulsive behavior…

do we all have them to some degree? is normality quantitatively or qualitatively different from disorder? do they range continuously from totally "ok" to severe conditions?



Categorical versus dimensional models of mental disorder: the taxometric evidence

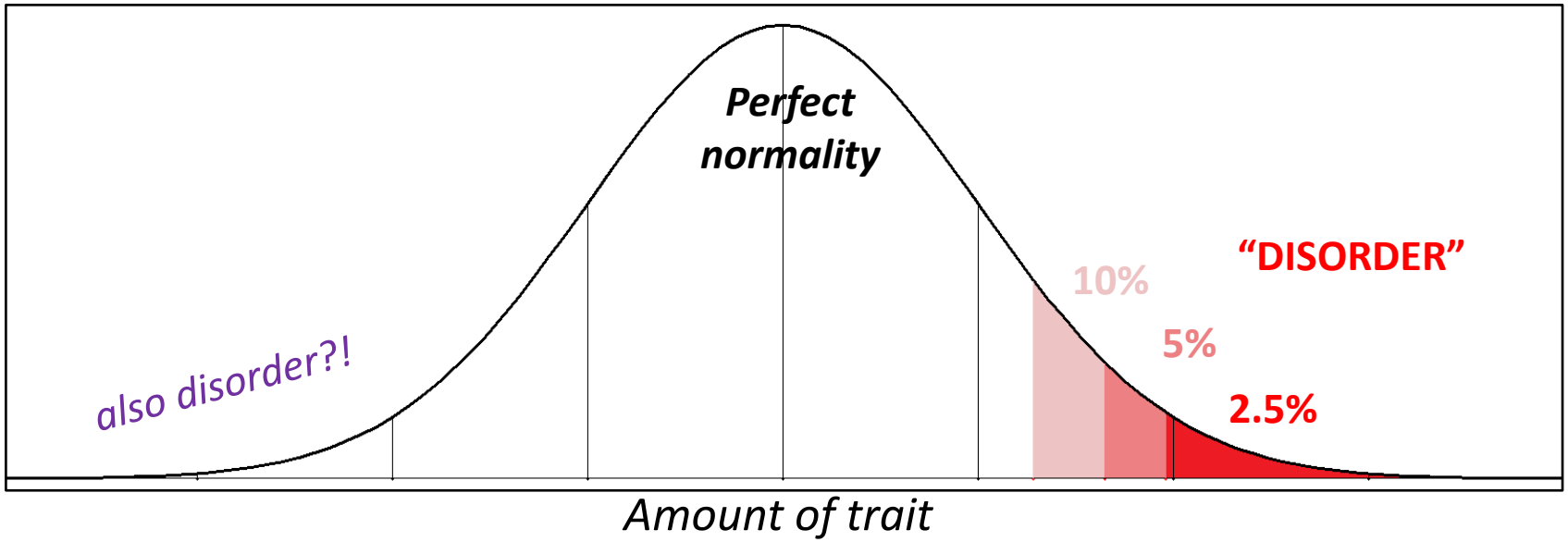
Nick Haslam

Objective: To review studies of the categorical versus dimensional status of mental disorders that employ taxometric methodology.
Method: A comprehensive qualitative review of all published taxometric studies of psychopathology.
Results: Categorical and dimensional models each receive well-replicated support for some groups of mental disorders. Studies favour categorical models for melancholia, eating disorders, pathological dissociation, and schizotypal and antisocial personality disorders. Dimensional models tend to be favoured for the broad neurotic spectrum – general depression, generalized anxiety, posttraumatic stress disorder – and for borderline personality disorder.
Conclusions: Taxometric research clarifies the latent structure of psychopathology in ways that have implications for the classification, assessment, explanation and conceptualization of mental disorder.
Key words: category, classification, dimension, taxometric analysis.

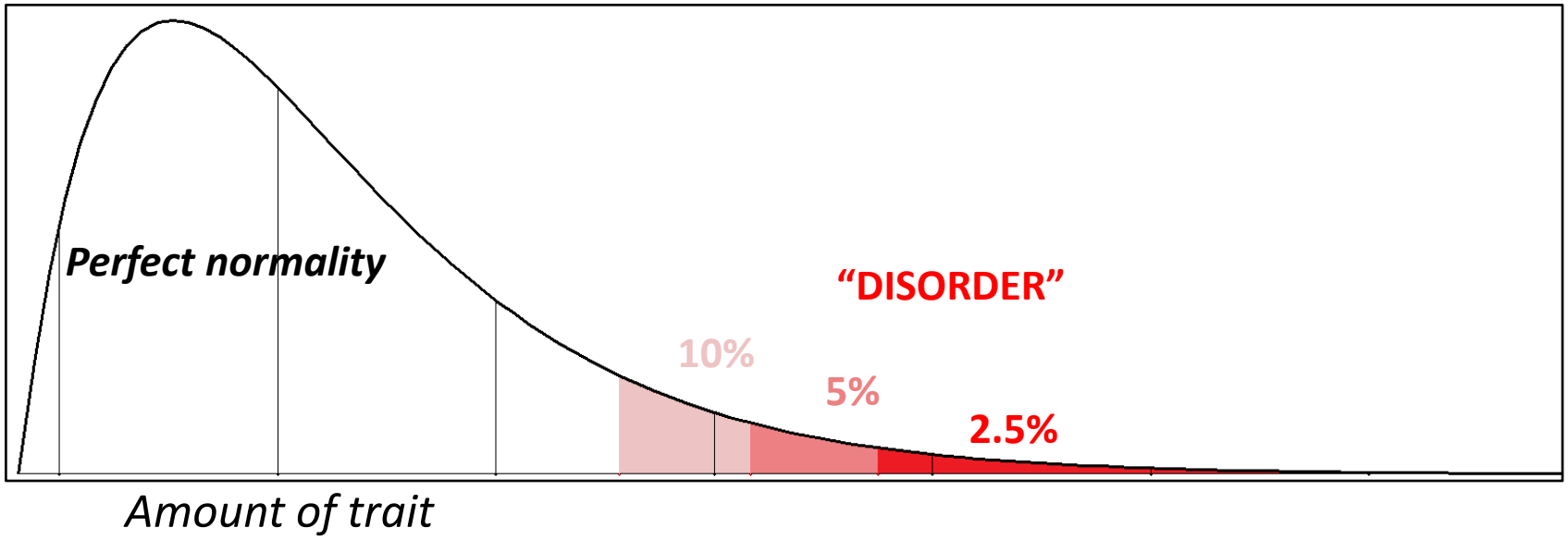
Australian and New Zealand Journal of Psychiatry 2003; 37:696–704

Are disorders discrete, internally homogenous "clusters" or the extreme ends of continuous "traits"?

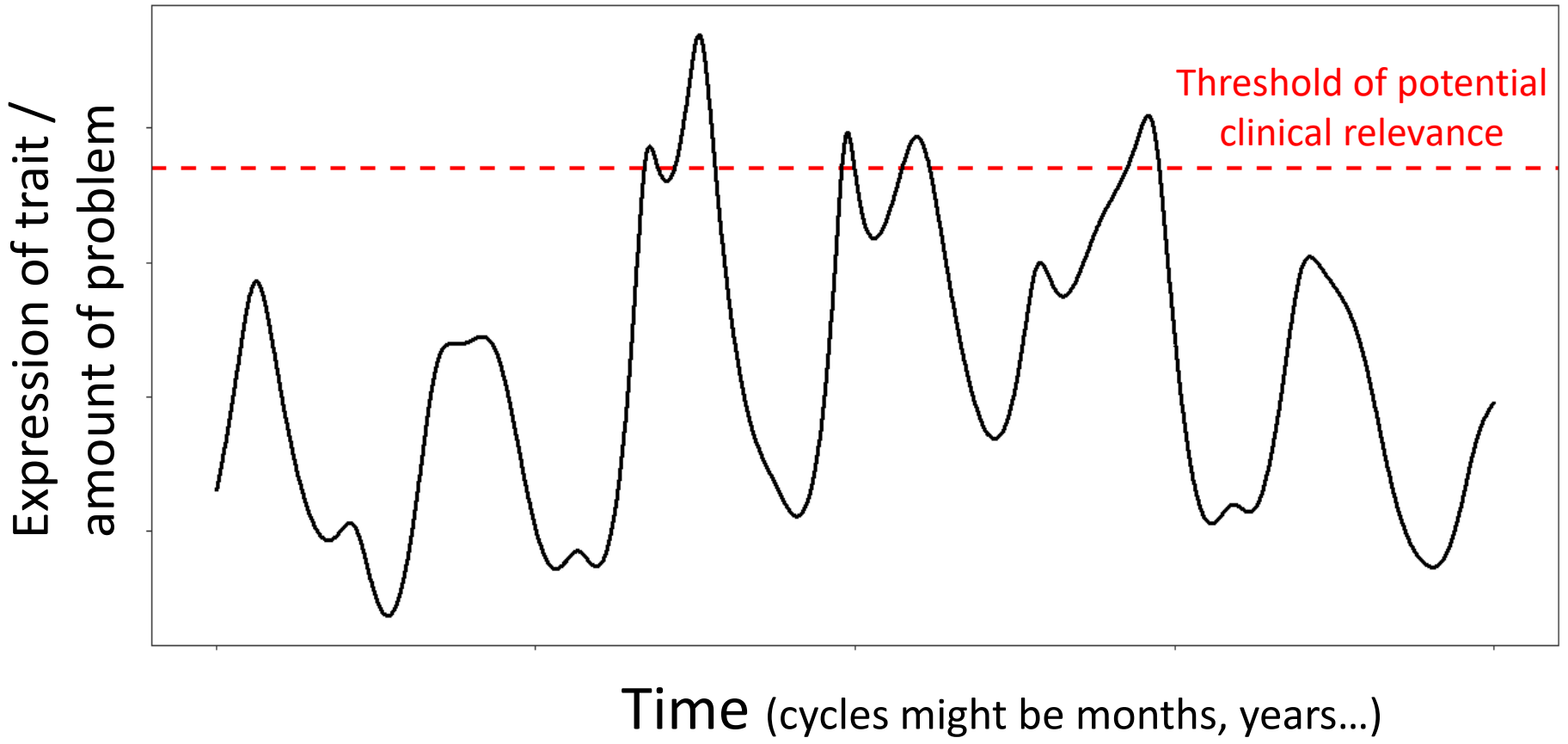
Quantitative traits might be normally distributed, with two tails



or they might be not (but they might still be traits)



The expression of a trait might be unstable over time within the same person, and perhaps follow cycles



Now I will focus on neurodevelopmental disorders,

and in particular on **specific learning disorders**

They are:

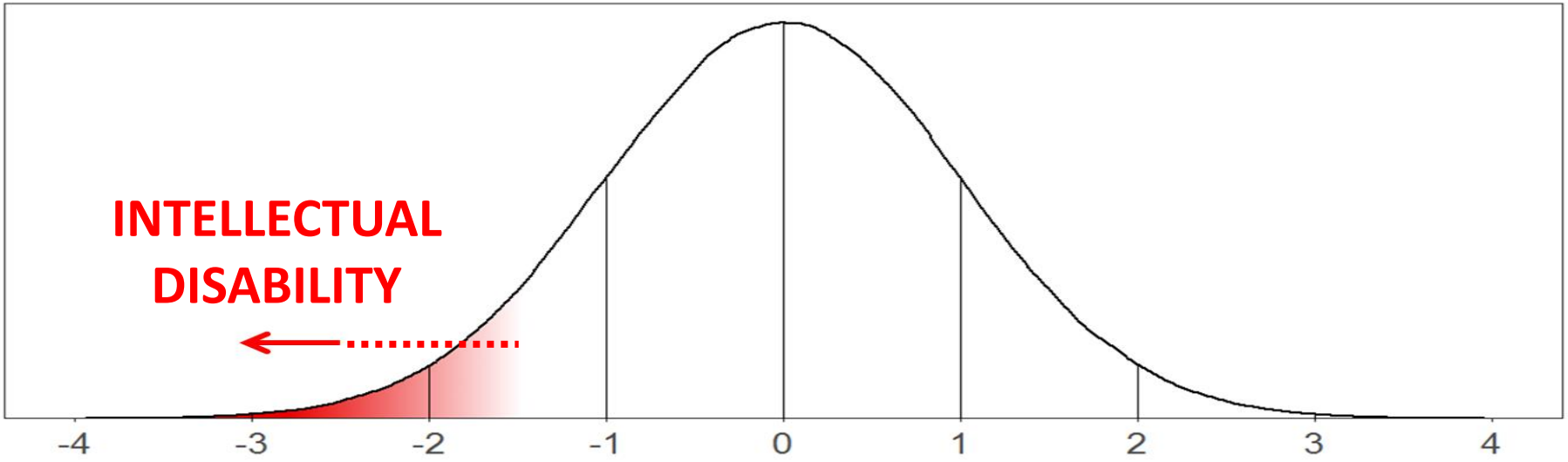
- *Very much **stable** over time* (a diagnostic criterion!);
- *Largely **heritable** conditions;*
- *Emerging from the **development** of the brain* (in interaction with the environment), *not due to trauma, sensory deficit, lack of schooling, motivational issues, etc.*

(Non-syndromic) Intellectual disability

Most agree that it represents a «dimensional» condition.

As the amount of *g* factor (IQ as proxy) decreases: ***Normal range > Borderline intellectual functioning > Intellectual disability*** (the cut-offs are always arbitrary) *[You also have **Giftedness** on the upper tail!]*

General population (without syndromic disability)

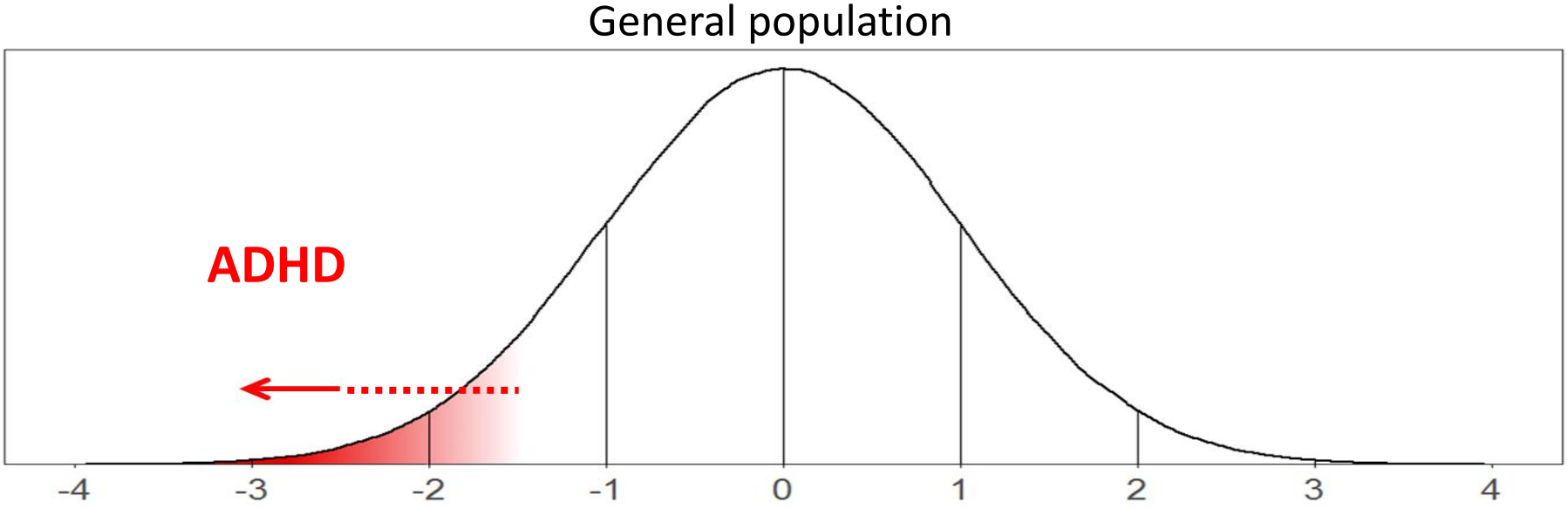


IQ score (and/or adaptive abilities)

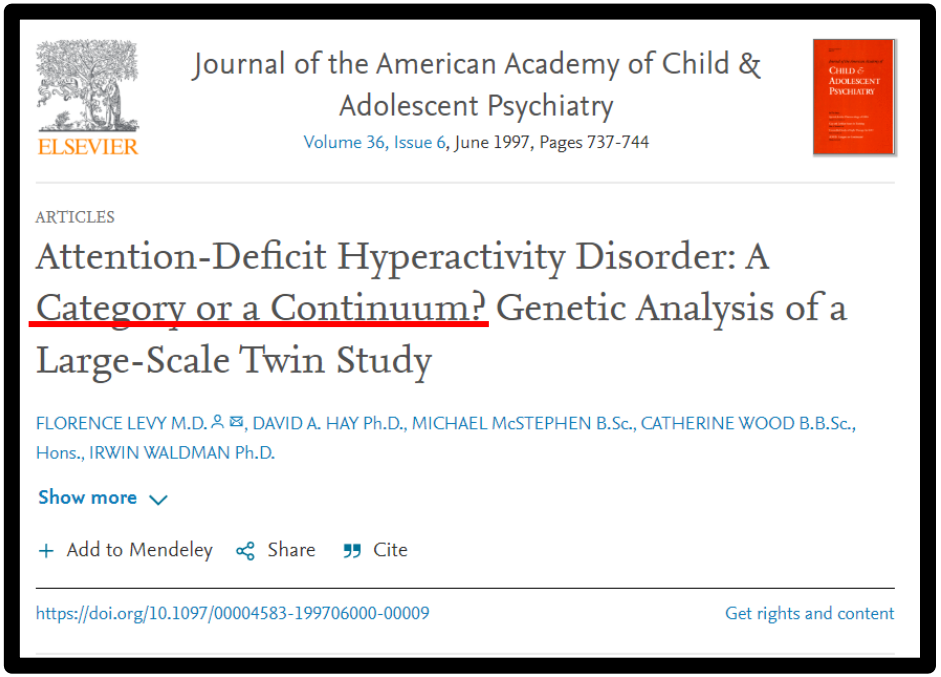
ADHD?

The dimensional framework is easily scalable to neurodevelopmental disorders primarily diagnosed via psychometric criteria

ADHD might well represent another case



Early pieces of evidence on **ADHD** have already addressed the issue and suggest that it is better conceptualized as a **CONTINUUM** – both ***genetically*** (many genes contributing independently and additively to the trait) and ***behaviorally*** (no latent category underlying ADHD indicators)



ELSEVIER

Journal of the American Academy of Child & Adolescent Psychiatry

Volume 36, Issue 6, June 1997, Pages 737-744

ARTICLES

Attention-Deficit Hyperactivity Disorder: A Category or a Continuum? Genetic Analysis of a Large-Scale Twin Study

FLORENCE LEVY M.D., DAVID A. HAY Ph.D., MICHAEL McSTEPHEN B.Sc., CATHERINE WOOD B.B.Sc., Hons., IRWIN WALDMAN Ph.D.

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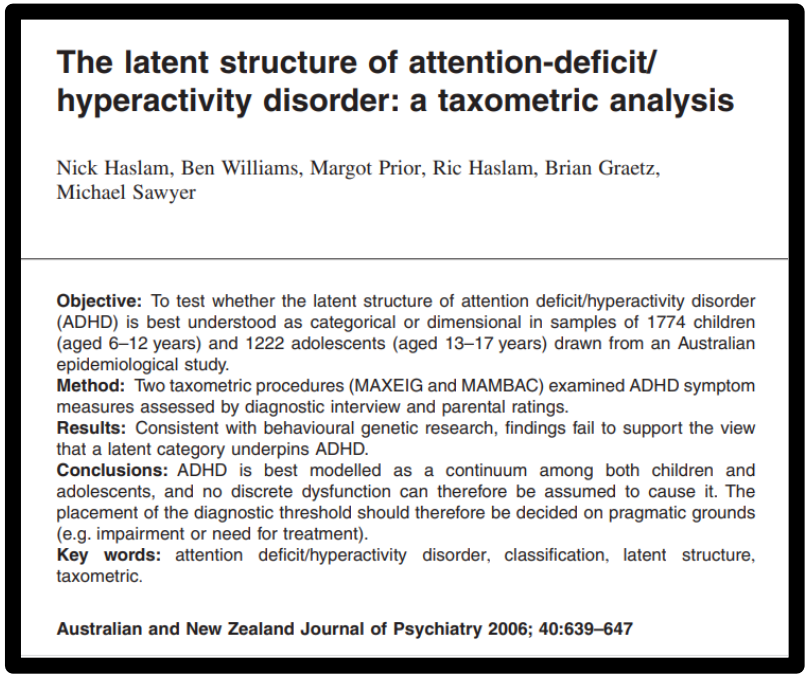
"(…) ADHD is best viewed as the extreme of a behavior that varies genetically throughout the entire population rather than as a disorder with discrete determinants"



The latent structure of attention-deficit/ hyperactivity disorder: a taxometric analysis

Nick Haslam, Ben Williams, Margot Prior, Ric Haslam, Brian Graetz, Michael Sawyer

Objective: To test whether the latent structure of attention deficit/hyperactivity disorder (ADHD) is best understood as categorical or dimensional in samples of 1774 children (aged 6–12 years) and 1222 adolescents (aged 13–17 years) drawn from an Australian epidemiological study.
Method: Two taxometric procedures (MAXEIG and MAMBAC) examined ADHD symptom measures assessed by diagnostic interview and parental ratings.
Results: Consistent with behavioural genetic research, findings fail to support the view that a latent category underpins ADHD.
Conclusions: ADHD is best modelled as a continuum among both children and adolescents, and no discrete dysfunction can therefore be assumed to cause it. The placement of the diagnostic threshold should therefore be decided on pragmatic grounds (e.g. impairment or need for treatment).
Key words: attention deficit/hyperactivity disorder, classification, latent structure, taxometric.

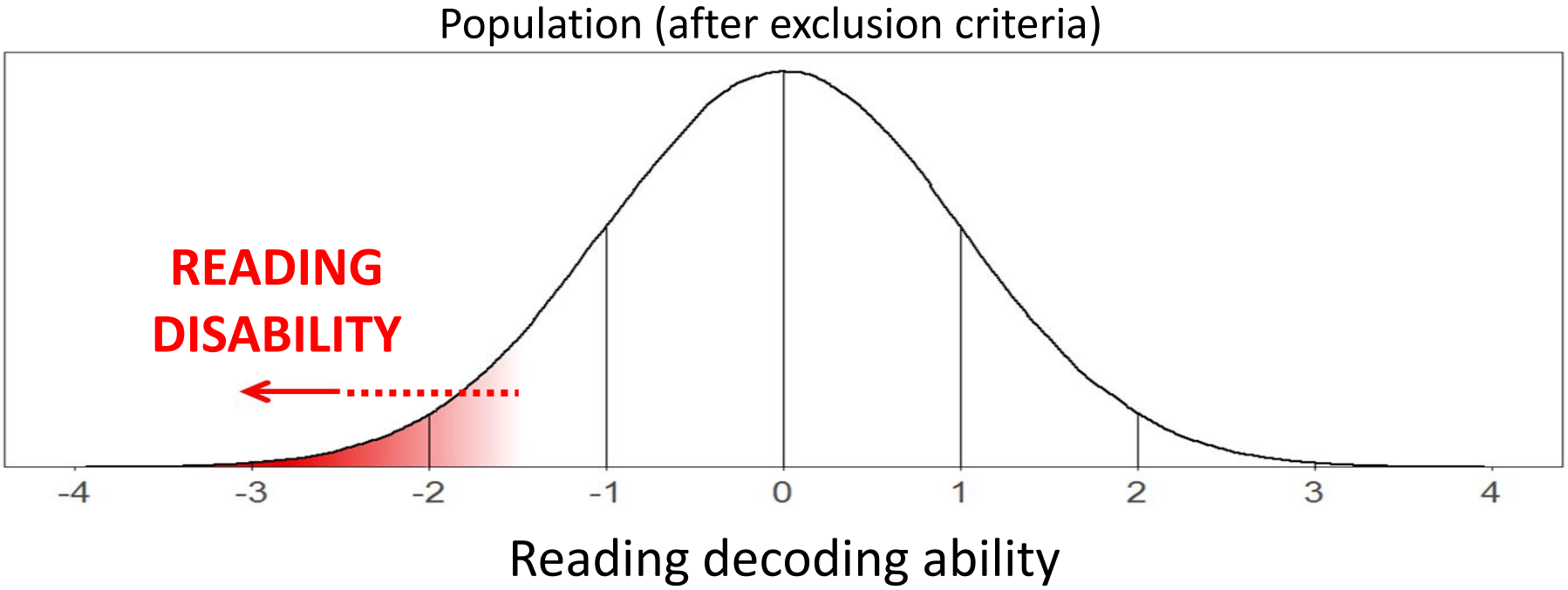
Australian and New Zealand Journal of Psychiatry 2006; 40:639–647

"ADHD is best modelled as a continuum among both children and adolescents, and no discrete dysfunction can therefore be assumed to cause it. The placement of the diagnostic threshold should therefore be decided on pragmatic grounds (e.g., impairment or need for treatment)"

- Some children can maintain excellent levels of attention all the time → good!
- Some children have normal levels of attention most of the time → good!
- Some children sometime show trouble keeping sustained attention → bad…
- Some children never can focus for more than 5 minutes. *Auch!!!* → "ADHD"!

Dyslexia (as reading disability)

Dyslexia might be identified as the lower tail of the distribution of reading *decoding ability*, after ascertaining its persistency and applying exclusion criteria (Catts & Petscher, 2022; Elliott, 2020). The continuum ranges from ***Excellent reader > Normality > Dyslexia*** (with the cut-offs being somehow arbitrary)

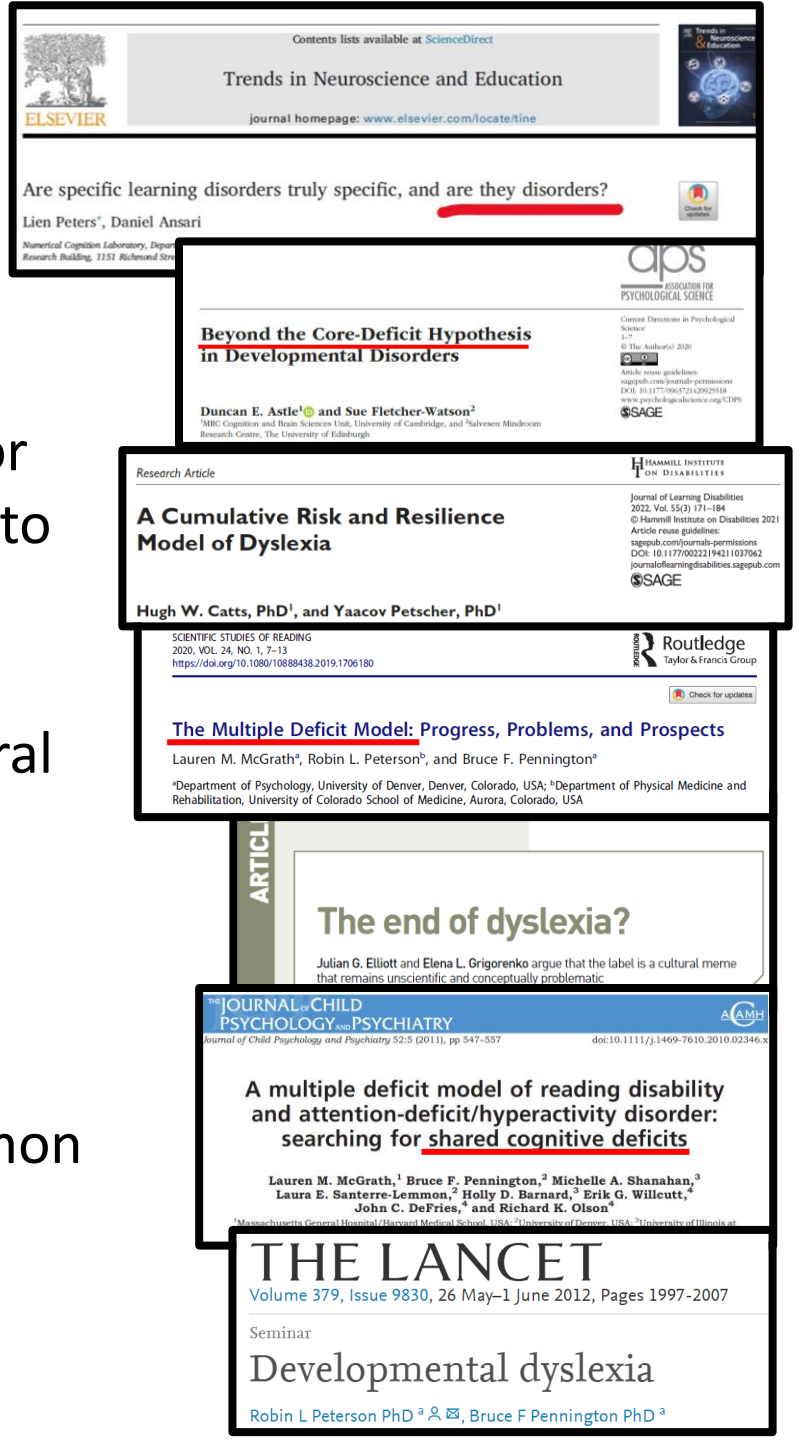


A trend towards a dimensional approach for learning disorders has emerged in the last decade

→ No single specific cognitive, sensory, or genetic feature is sufficient or necessary to explain a disorder *("no core deficit")*

→ Increasing emphasis on domain-general abilities (e.g., WM)

→ High comorbidity, and → Similar cognitive impairments (e.g., dyslexia, dyscalculia, ADHD) further suggest common underlying mechanisms



→ high levels of comorbidity and → similar cognitive impairments

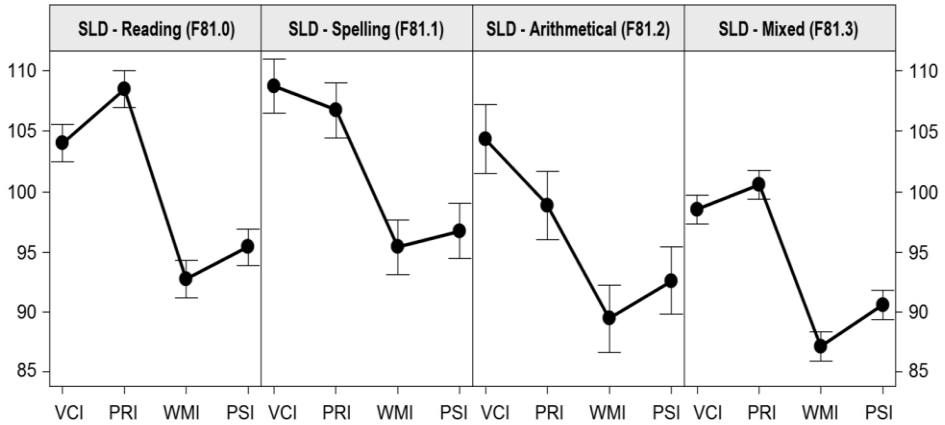
Even “pure” conditions in LD and ADHD present quantitatively similar mean deficits (in domain-general abilities such as phonological working memory, visual speed of processing)

Clinical Psychological Science aps Association for Psychological Science

Strengths and Weaknesses in the Intellectual Profile of Different Subtypes of Specific Learning Disorder: A Study on 1,049 Diagnosed Children

Enrico Toffalini, David Giofrè, Cesare Cornoldi

First Published February 13, 2017 | Brief Report | Check for updates
https://doi.org/10.1177/2167702616672038



Research in Developmental Disabilities 129 (2022) 104306

Contents lists available at ScienceDirect

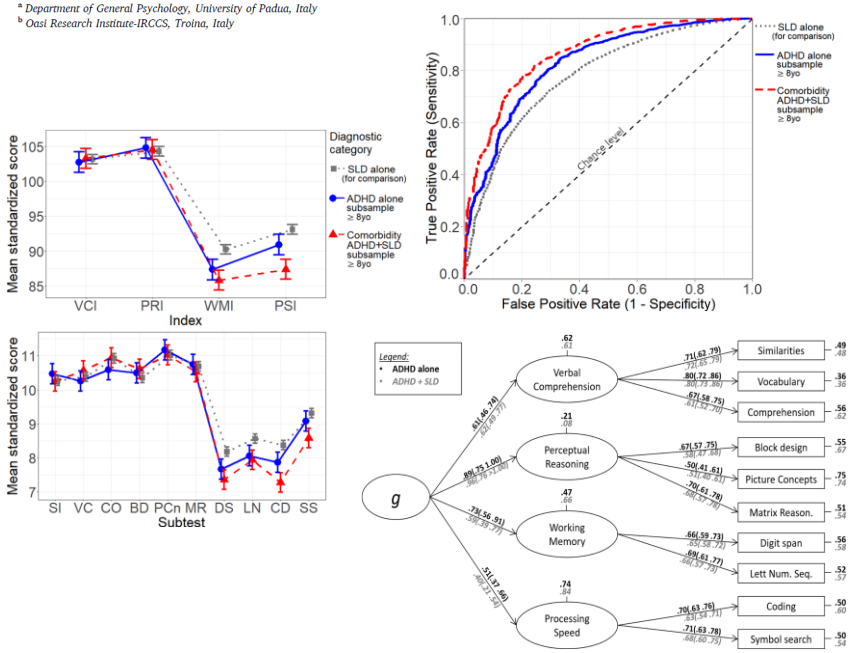
Research in Developmental Disabilities

journal homepage: www.elsevier.com/locate/redevdis

The structure, profile, and diagnostic significance of intelligence in children with ADHD are impressively similar to those of children with a specific learning disorder

Enrico Toffalini [a,*,1], Serafino Buono [b,2], Cesare Cornoldi [a,*,3]

[a] Department of General Psychology, University of Padua, Italy
[b] Oasi Research Institute-IRCCS, Troina, Italy



→ widely inconsistent cut-offs in LD literature

The Journal of Child Psychology and Psychiatry

Journal of Child Psychology and Psychiatry **:* (2021), pp **–** doi:10.1111/jcpp.13397

No evidence for a core deficit in developmental dyscalculia or mathematical learning disabilities

Irene C. Mammarella,[1] Enrico Toffalini,[2] Sara Caviola,[1,3] Lincoln Colling,[4] and Denes Szücs[5]

[1]Department of Developmental and Social Psychology, University of Padova, Padova, Italy; [2]Department of General Psychology, University of Padova, Padova, Italy; [3]School of Psychology, University of Leeds, Leeds, UK; [4]School of Psychology, University of Sussex, Sussex, UK; [5]Department of Psychology, University of Cambridge, Cambridge, UK

Trends in Neuroscience and Education 17 (2019) 100115

Contents lists available at ScienceDirect

Trends in Neuroscience and Education

journal homepage: www.elsevier.com/locate/tine

Are specific learning disorders truly specific, and are they disorders?

Lien Peters*, Daniel Ansari

Numerical Cognition Laboratory, Department of Psychology, Faculty of Education & Brain and Mind Institute, University of Western Ontario, Western Interdisciplinary Research Building, 1151 Richmond Street North, London, ON N6A 5B7, Canada

ARTICLE INFO

Keywords:
Categorical

ABSTRACT

Specific learning disorders, such as dyslexia and dyscalculia, are frequently studied to inform of cognitive development, genetic mechanisms and brain function. In this Opinion Paper, we

Table 1 Summary of the characteristics of MLD samples in the studies included in two recent meta-analyses (Peng et al., 2018; Schwenk et al., 2017)

	MLD samples with previous clinical diagnosis	MLD samples with no previous clinical diagnosis
(...)		
Math criteria for selecting MLD groups		
Math scores ≤ 10th percentile (or 1.5 *SD*)	4 /11 (37%)	14/79 (18%)
Math scores ≤ 15th percentile (or 1 *SD*)	0/11	20/79 (25%)
Math scores ≤ 25th percentile	5/11 (45%)	29/79 (37%)
Other criteria	2/11 (18%)	16/79 (20%)
Other abilities controlled for		
Reading skills	10/11 (90%)	59/79 (75%)
IQ	11/11 (100%)	55/79 (69%)

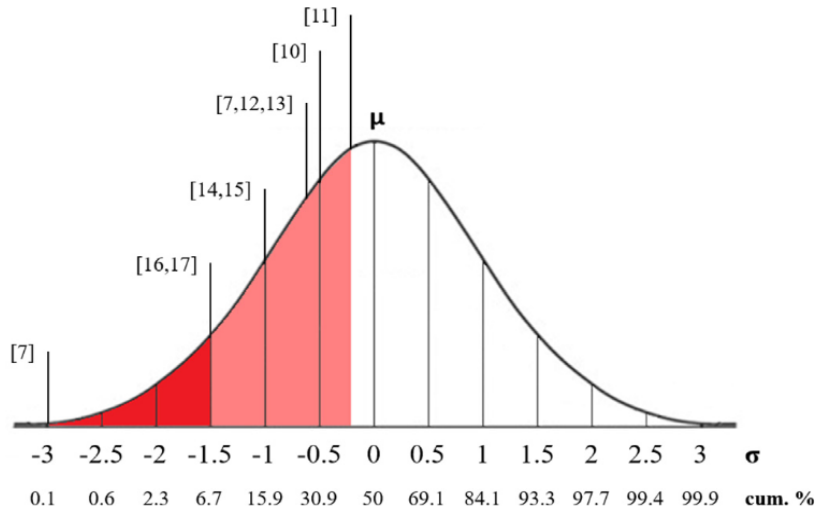


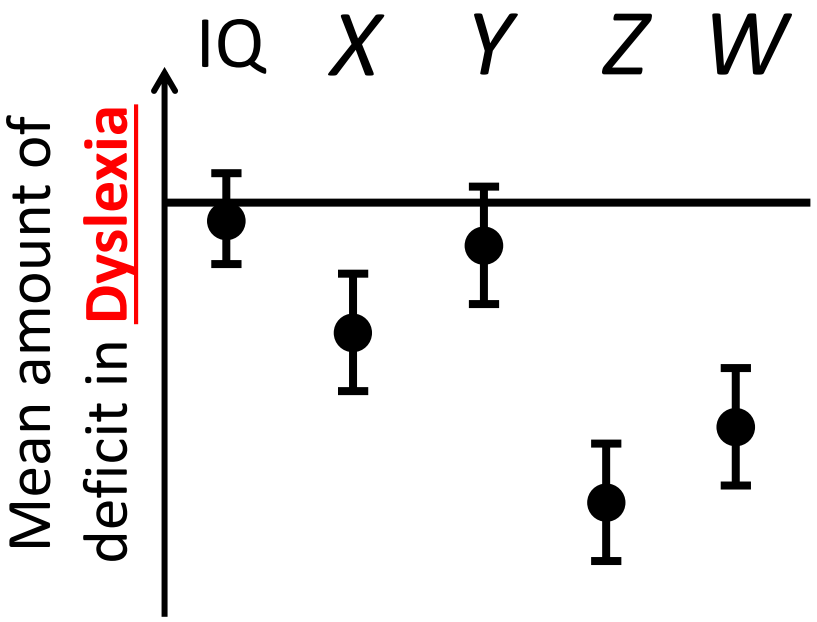
Fig. 1. Visualization of the variation in cut-off scores that have been used in a limited subset of studies of dyslexia and dyscalculia. Children scoring below 1.5 standard deviations of the population mean, and who therefore would be classified as having an SLD according to the DSM 5 criteria, fall within the dark red area of the distribution. More lenient cut-off criteria that have been used in research would result in overestimations of up to 37 percent of children being labeled as having SLDs, indicated in pink [12,14,15,17]. See [22] for a similar figure depicting the variability in selection criteria for dyscalculia.

2. How the dimensional framework can be tested in studies on learning disorders?

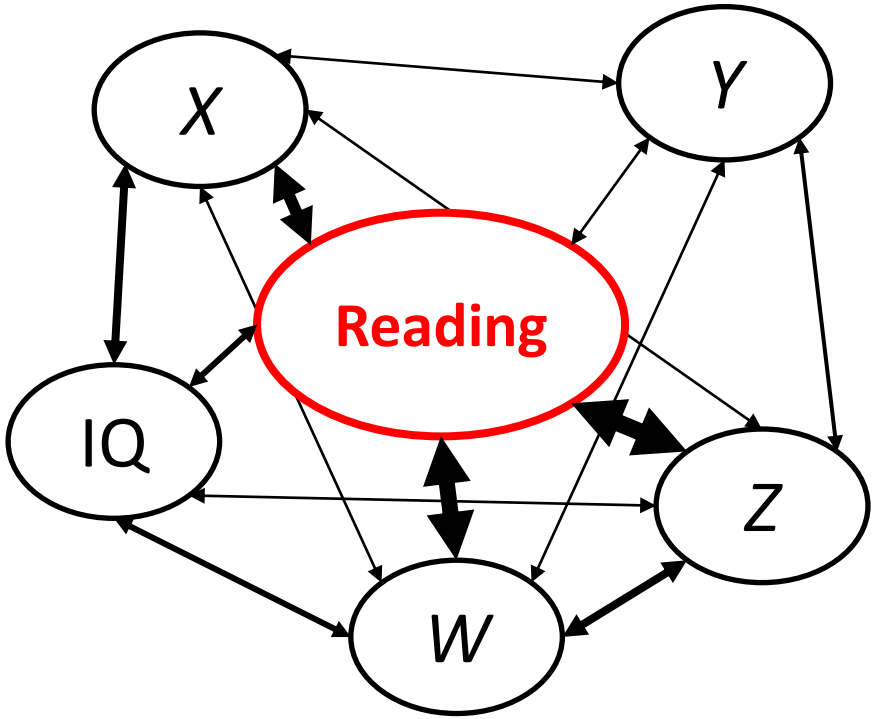
from category → to trait

the focus of our research shifts

Traditional case-control designs focus on differences between children with vs without DYSLEXIA in *X, Y, Z, W (candidate "**core deficits**")*



Once dyslexia is regarded as the tail of a distribution, you focus on READING decoding (and intelligence) instead



from category → to trait

the focus of our research shifts

- *Dyslexia* is (causally?) associated with a deficit in cognitive areas X and Y
- *Dyscalculia/MLD* is associated with a deficit in cognitive area Z
- *ADHD* is associated with dysfunction in cognitive area W as well as motivational area M

- *In the general population*, there is a *network* of (causal?) associations between reading, math abilities, global intelligence, working memory, attentional capacities, inhibitory control, and specifically areas X, Y, Z, W, M

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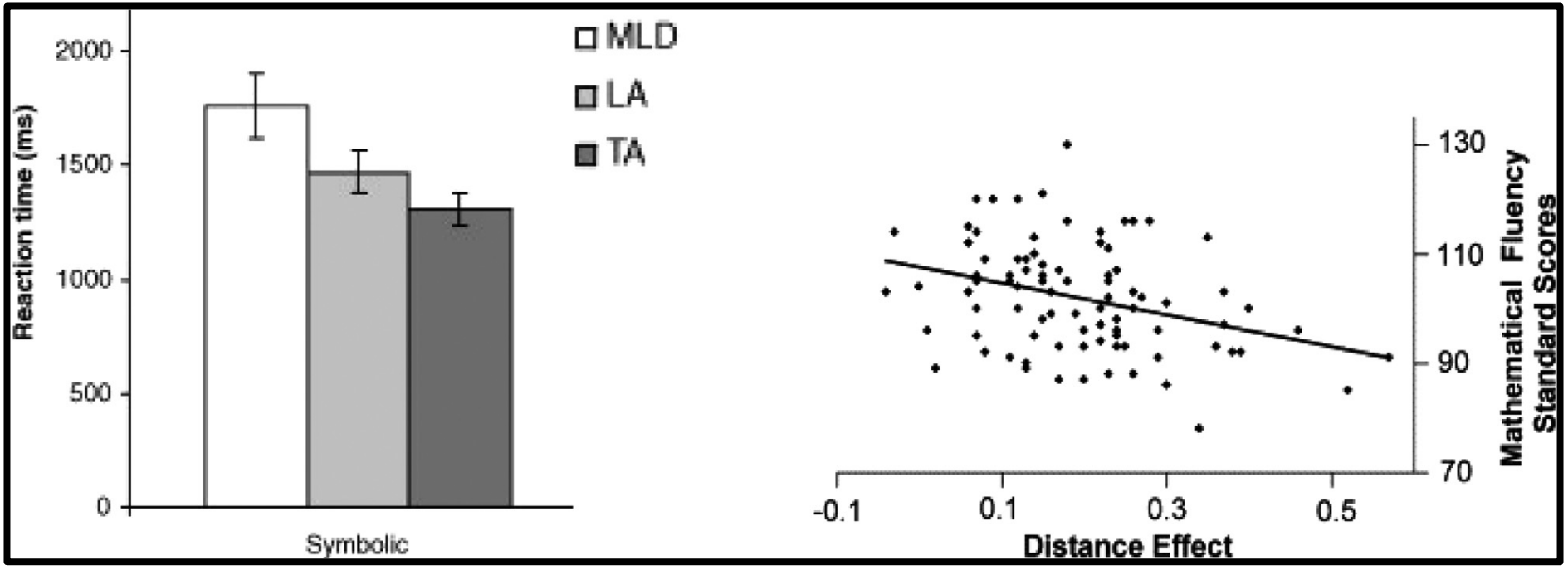
ARTICLE INFO

Keywords:
Categorical
Dimensional
Dyslexia
Dyscalculia
Genetics
Neuroimaging

ABSTRACT

Specific learning disorders, such as dyslexia and dyscalculia, are frequently studied to inform our understanding of cognitive development, genetic mechanisms and brain function. In this Opinion Paper, we discuss limitations of this research approach, including the use of arbitrary criteria to select groups of children, heterogeneity within groups and overlap between domains of learning. By drawing on evidence from cognitive science, neuroscience and genetics, we propose an alternative, dimensional framework. We argue that we need to overcome the problems associated with a categorical approach by taking into account interacting factors at multiple levels of analysis that are associated with overlapping rather than entirely distinct domains of learning. We conclude that this research strategy will allow for a richer understanding of learning and development.

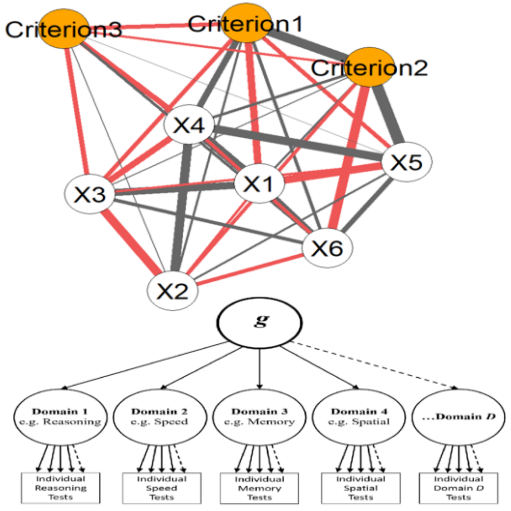


is disorder «nothing but» the lower/upper end of a distribution?

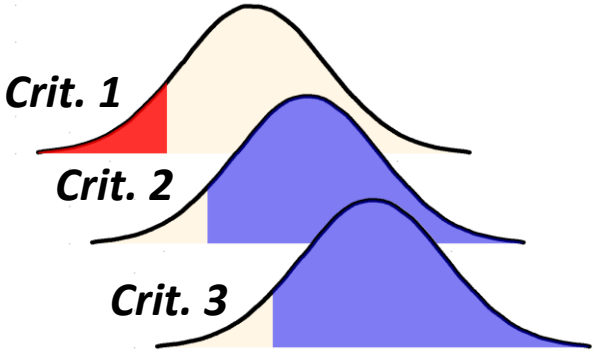
from a model of the *general* population, we can make precise quantitative predictions on what is supposed to happen in its «tails». Quantitative predictions can then be tested. If difficult analytically, do it simulatively

---

(1) **Simulate population**, via global parameters (covariances, distributions, asymmetries...) / Model



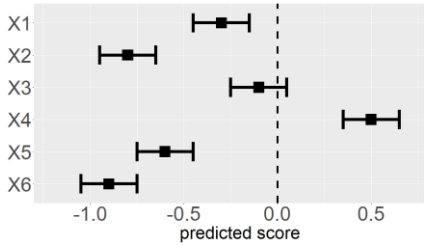
→ (2) **Simulate diagnostic process**, via psychometric (and «clinical») cut-offs →



may include persistence of the condition, poor response to treatment, simulating individual trajectories if possible

(3) **Compare simulated data with real data**

- Average profiles/scores



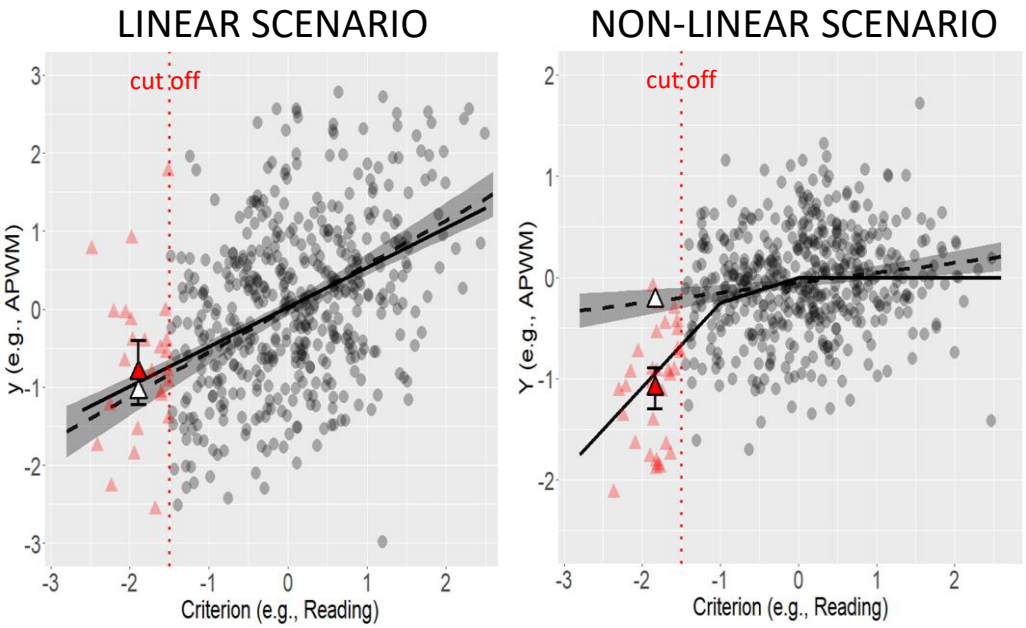
- Prevalence

- Comorbidity
- Variability of scores

→ ***DEDUCTIVE PROCESS*** →

is disorder «nothing but» the lower/upper end of a distribution?

→ *Predicted-vs-observed discrepancies* suggest **non-linearities** in the effects along the continuum = possible need for categories



→ **Not** necessarily all-or-nothing scenarios: a condition could present dimensional characteristics in some aspects (e.g., cognitive) but behave like cluster in others (e.g., emotional, motivational perhaps after receiving a diagnosis)

The Journal of Child Psychology and Psychiatry

Journal of Child Psychology and Psychiatry **:* (2021), pp **–** doi:10.1111/jcpp.13397

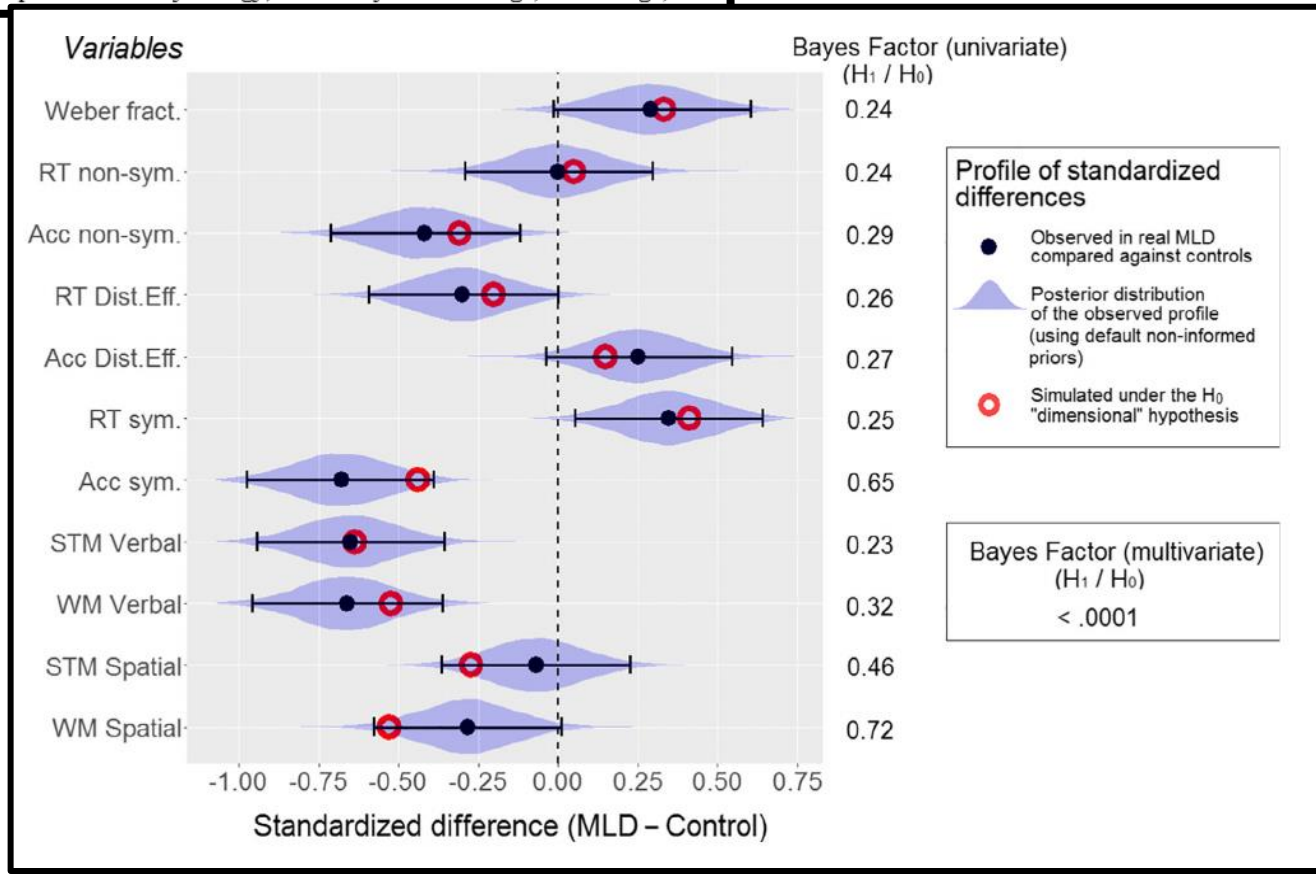
No evidence for a core deficit in developmental dyscalculia or mathematical learning disabilities

Irene C. Mammarella,[1] Enrico Toffalini,[2] Sara Caviola,[1,3] Lincoln Colling,[4] and Denes Szűcs[5]

[1]Department of Developmental and Social Psychology, University of Padova, Padova, Italy; [2]Department of General Psychology, University of Padova, Padova, Italy; [3]School of Psychology, University of Leeds, Leeds, UK; [4]School of Psychology, University of Sussex, Sussex, UK; [5]Department of Psychology, University of Cambridge, Cambridge, UK

47 children with psychometric criteria for «pure dyscalculia»

had an average cognitive profile that was closely predictable from the population multivariate continuum of math-cognitive abilities



SCIENTIFIC STUDIES OF READING
https://doi.org/10.1080/10888438.2021.1897596
Routledge
Taylor & Francis Group

Inferring the Performance of Children with Dyslexia from that of the General Population: The Case of Associative Phonological Working Memory

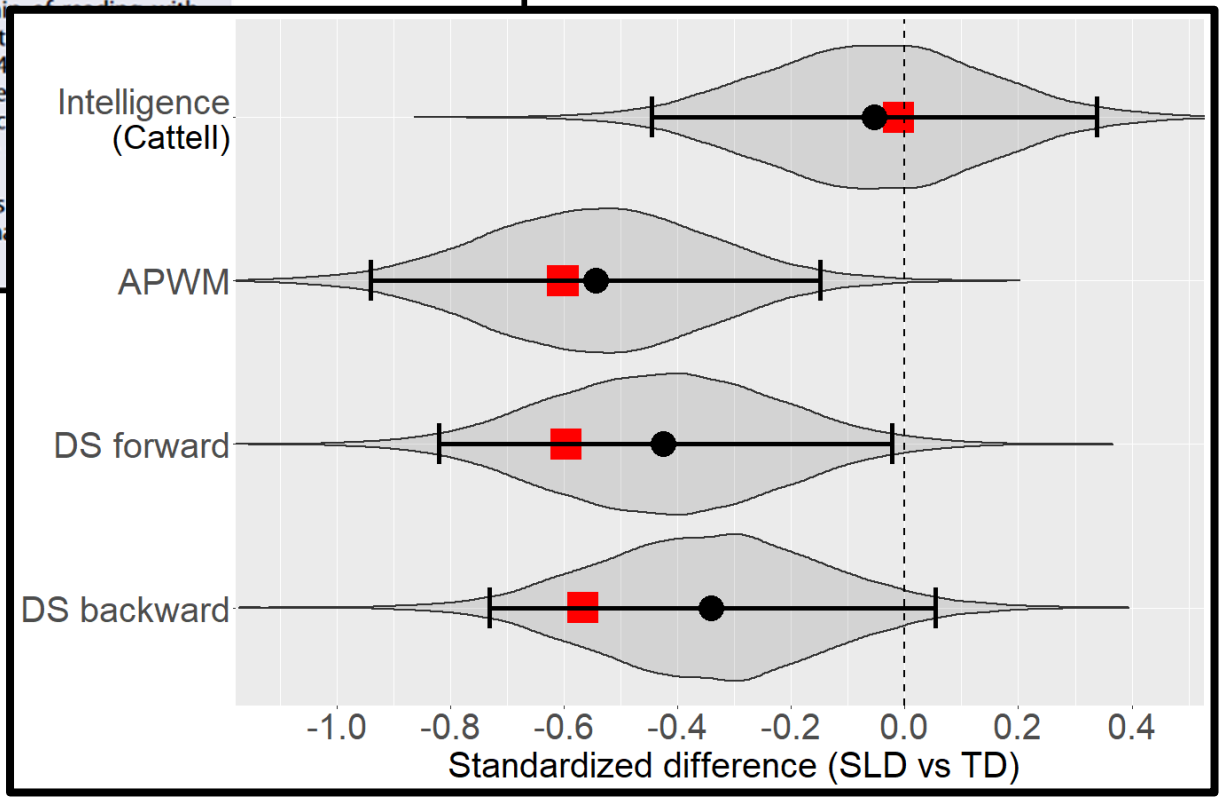
Barbara Carretti, Cesare Cornoldi, Arianna Antonello, Laura Di Criscienzo, and Enrico Toffalini

Department of General Psychology, University of Padua, Padua, Italy

ABSTRACT

The study examines whether the average performance of the population with dyslexia in a working memory measure can be inferred dimensionally from the characteristics of the typical population. Specifically, we focused on Associative Phonological Working Memory (APWM), an ability that we predicted being impaired in dyslexia due to the relationship of reading with both associative learning and working memory (WM). St linear relationship between APWM and reading ability in 4 oping (TD) children, after accounting for fluid intelligence WM. In Study 1b a simulation procedure was used to calc APWM expected in children with dyslexia, based on the found in Study 1a. This prediction was compared with mance of 26 children with dyslexia. A deficit in APWM was extent was in line with that simulated from the correlation the TD population.

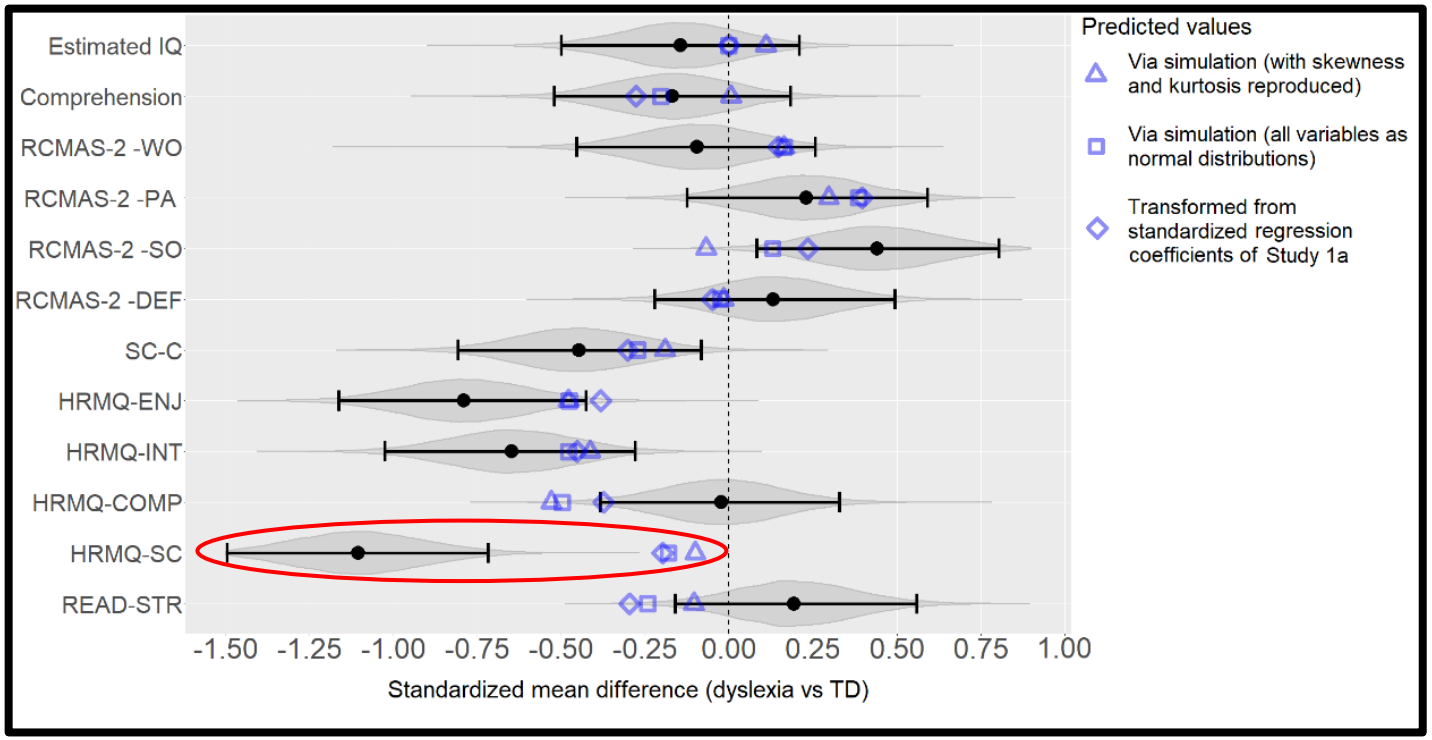
Similar example on 26 children diagnosed with dyslexia



their deficits in verbal WM (focus was on verbal binding WM), closely reflected global parameters from the TD sample (438 children)

In Donolato et al. (under review) we looked at **emotional and motivational** aspects, which may present «unique» profiles in learning disorders ***triggered*** by: *1. receiving a diagnosis, and/or 2. failing to meet average school requests due to difficulties exceeding a given threshold*

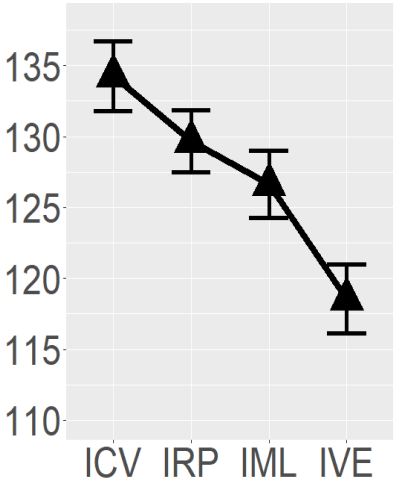
- → In fact, most of the profile is predicted pretty well dimensionally *(anxiety, interest/pleasure in reading, self-concept as a student)*
- → Only big violation is *self-concept as reader*: weakly related with actual reading decoding ability in TD sample, but strongly negative in dyslexia, |Cohen's d| > 1; effect of the diagnosis?



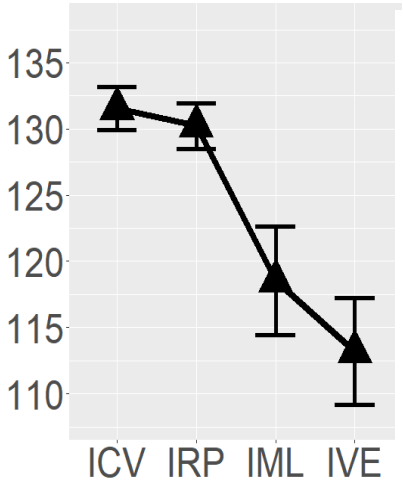
OTHER RESEARCH

Average intellectual profile in so-called **«Giftedness»** (IQ≥130) has peaks and throughs… *But that's obvious!*

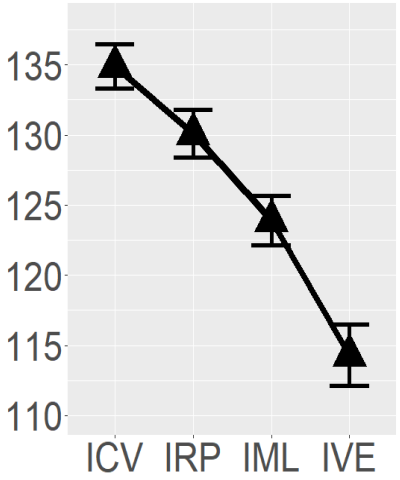
Morrone et al. (2019) N = 90



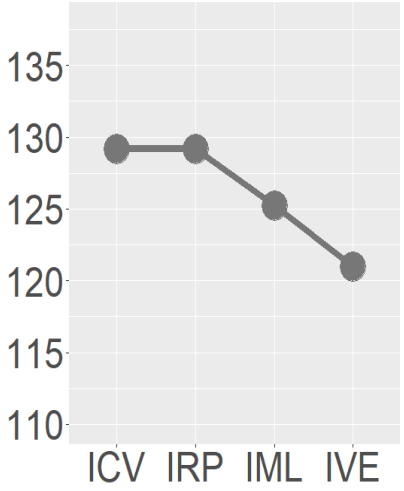
WISC-IV ITA N = 40



WISC-IV USA N = 157



Expected / Simulated



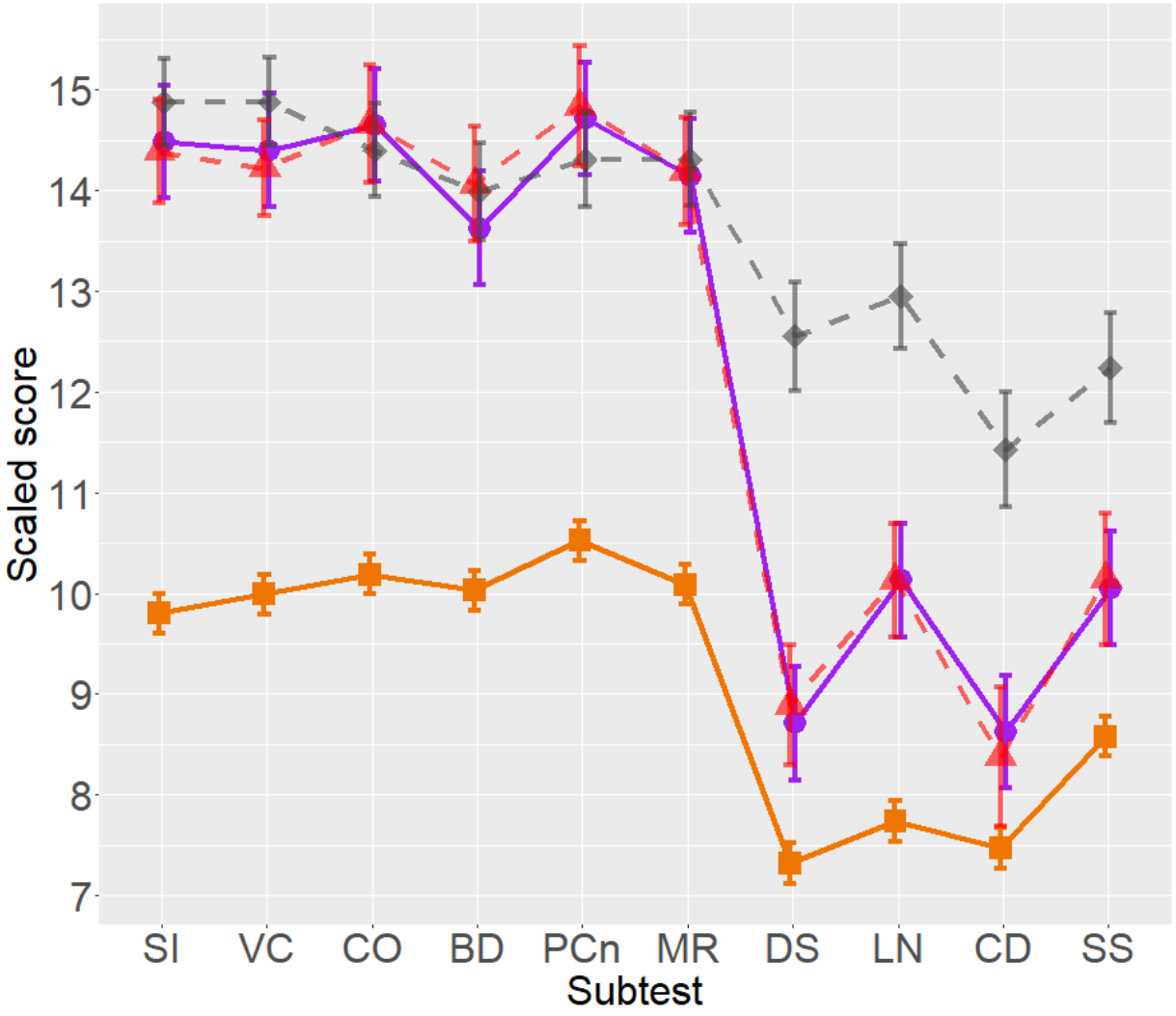
Gifted children excel *(obviously)* in areas:

1) more strictly related with *g*, AND
2) measured by more subtests → Thus, in VCI and PRI

→ BUT, the observed discrepancy appears quantitatively larger than predicted (VCI higher than expected [verbal scores more sensitive to higher levels of ability?]; PSI lower than expected [speed scores not sensitive to high ability?])

OTHER RESEARCH

ADHD + GIFTEDNESS (2e), profile (Cornoldi et al., under review)



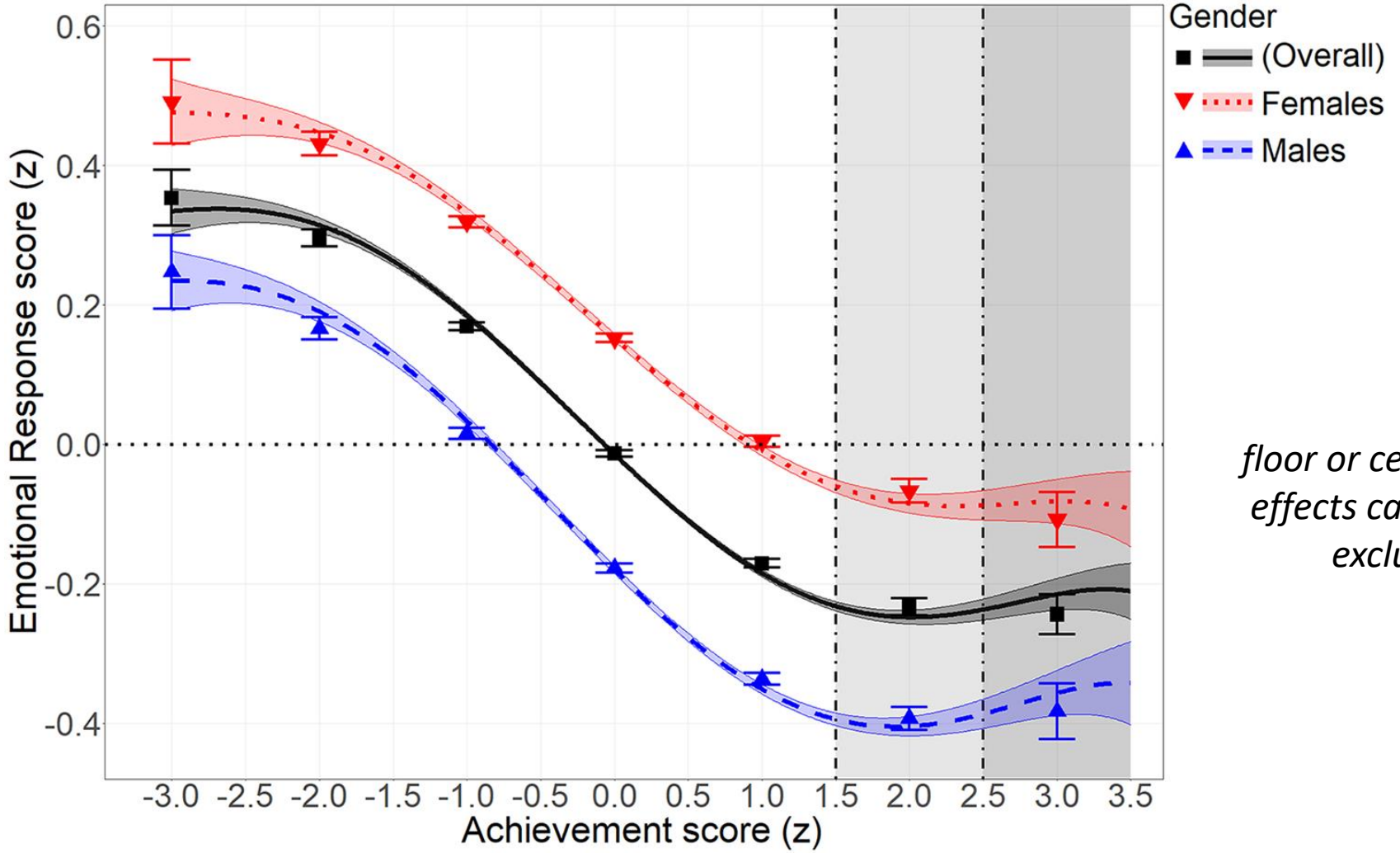
Both ADHD and Giftedness have non-homogenous profiles; 2e (IAG≥125; N = 83) emphasize the effect

2e profile is exactly inferable dimensionally, knowing: 1. general ADHD profile + 2. structure of covariances in ADHD + 3. cut-offs for «giftedness»

OTHER RESEARCH

Non-linear relationships between achievement score and emotional response to testing, with «gifted» pupils being less «emotional» than others, but more than linearly expected

Cornoldi et al. (2021)



floor or ceiling effects can be excluded

3. Pros and cons of a dimensional framework for neurodevelopmental disorders

Do we need categories?

in **Clinical field** might facilitate communication, and allow us to *impose policies* *(but also a risk related with labelling?)*

And in **Research**?

Focus directly on the «condition» of interest

Risk of interpreting largely overlapping conditions, with common underlying cognitive basis, as discrete clusters / largely overlapping dimensions as being orthogonal.
→ Reduced generalizability in knowledge, treatments

Limited *power* (many case-control studies N < 30), reduced credibility and replicability, combined with *publication bias* leads to overestimation of the effect sizes ("type M error"; Gelman & Carlin, 2014)

Do we need categories?

Parsimony principle in science → Explain phenomena using fewer (rather than more) assumptions, parameters, categories, if possible without losing accuracy

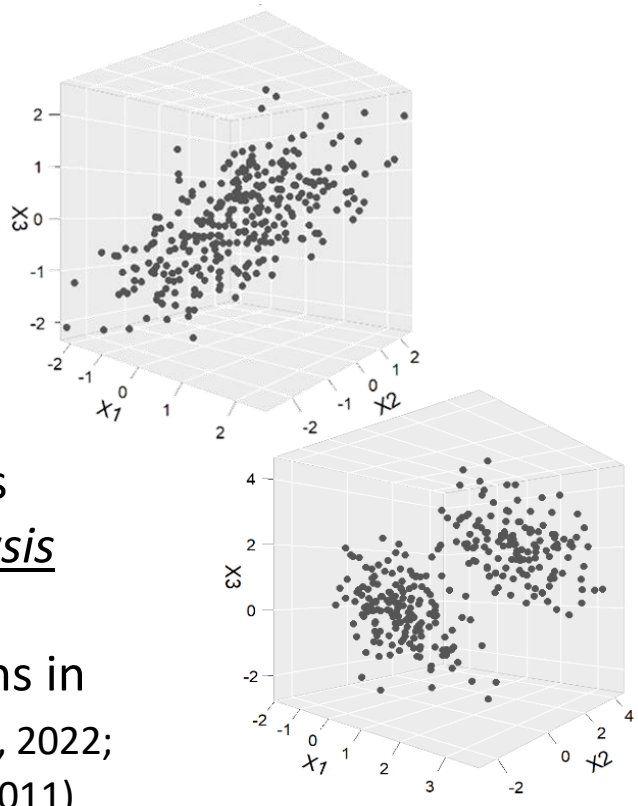
«Entia non sunt multiplicanda sine necessitate»

For many disorders discussed above → **if we can frame them in terms of INDIVIDUAL DIFFERENCES (in ONE population) it is better than presenting them as distinct categories**

Take home messages

- I suggest a focus on learning disorders as continuous individual difference / traits for *parsimony, power, generalizability*
- OK to study disorders as categories… but know risks
- Always start from the general population for dimensional predictions, as a benchmark / prior (even for possible *disconfirmations* of those predictions!)
- Recent studies suggest that learning disorders behave just like the lower ends of the ability distributions (at least from the cognitive point of view)

*Note on **cluster analysis*** (for researchers):



Unsupervised *machine learning* methods may be ideal to detect discontinuities → discrete sub-populations with «unique» combinations of deficits

... yet these exploratory methods may require conditions difficult to attain in psychological research! *Cluster analysis* and *Latent profile analysis* → N > 500, many orthogonal indicators (e.g., k ≥ 6), and implausible cluster separations in psychology (Cohen's d >> 0.80) (Tein et al., 2013; Toffalini et al., 2022; similar requirements may apply for *taxometric analysis*, Ruscio et al., 2011)

PLOS ONE

OPEN ACCESS PEER-REVIEWED RESEARCH ARTICLE

Entia Non Sunt Multiplicanda ... Shall I look for clusters in my cognitive data?

Enrico Toffalini, Paolo Girardi, David Giofrè, Gianmarco Altoè

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Thank you for listening

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