

L'importanza di essere significante: Un esempio basato sul test della Torre di Londra

Ottavia M. Epifania, Luca Stefanutti, Pasquale Anselmi, Andrea Brancaccio, Debora de Chiusole



Dipartimento di Filosofia, Sociologia, Pedagogia e Psicologia Applicata,
Università di Padova

La psicometria tra oggi e domani:
Sfide e nuovi orizzonti

20 Giugno 2024

The ratio between the measures of a and b is constant and independent of the measurement unit:

$$\frac{\varphi(a)}{\varphi(b)} = \frac{\varphi'(a)}{\varphi'(b)},$$

where φ and φ' are two different scales of measurement of the same variable¹.

¹ Strictly referring to physical measures

The ratio between the measures of a and b is constant and independent of the measurement unit:

$$\frac{\varphi(a)}{\varphi(b)} = \frac{\varphi'(a)}{\varphi'(b)},$$

where φ and φ' are two different scales of measurement of the same variable¹.

Meaningful comparisons

The comparison between a and b is meaningful if it is invariant under all the unit transformations.

¹ Strictly referring to physical measures

The ratio between the measures of a and b is constant and independent of the measurement unit:

$$\frac{\varphi(a)}{\varphi(b)} = \frac{\varphi'(a)}{\varphi'(b)},$$

where φ and φ' are two different scales of measurement of the same variable¹.

Meaningful comparisons

The comparison between a and b is meaningful if it is invariant under all the unit transformations.

Meaningful comparisons 2.0

Given that there is a difference between a and b , is this difference significant (or not) regardless of the scales of measurement?

¹ Strictly referring to physical measures

Admissible and non-admissible transformations

$$\varphi(P) = [0, 1, 2, 3]$$

$$\varphi'(P) = [0, 2, 4, 10]$$

$$\varepsilon(P) = [0, 2, 2, 3]$$

Admissible and non-admissible transformations

$$\varphi(P) = [0, 1, 2, 3]$$

$$\varphi'(P) = [0, 2, 4, 10]$$

$$\varepsilon(P) = [0, 2, 2, 3]$$

	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9
φ									
Joe	0	1	2	2	2	3	3	3	3
Jane	0	2	2	2	3	3	3	3	3
Max	0	1	0	2	3	3	3	3	3
φ'									
Joe	0	2	4	4	4	10	10	10	10
Jane	0	4	4	4	10	10	10	10	10
Max	0	2	0	4	10	10	10	10	10
ϵ									
Joe	0	2	2	2	2	3	3	3	3
Jane	0	2	2	2	3	3	3	3	3
Max	0	2	0	2	3	3	3	3	3

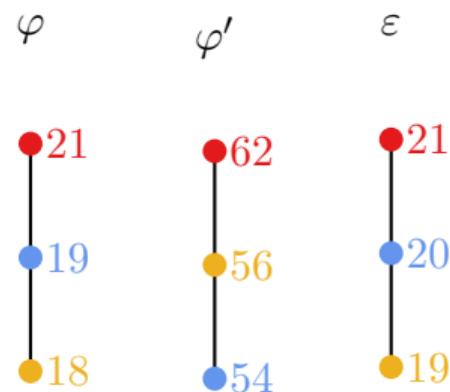
Admissible and non-admissible transformations

$$\varphi(P) = [0, 1, 2, 3]$$

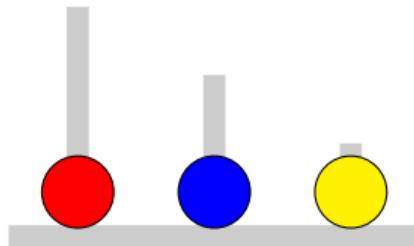
$$\varphi'(P) = [0, 2, 4, 10]$$

$$\varepsilon(P) = [0, 2, 2, 3]$$

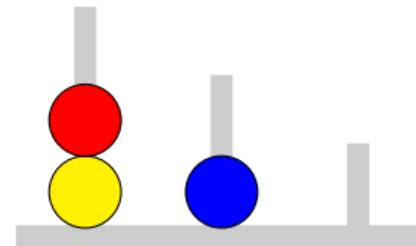
	q_1	q_2	q_3	q_4	q_5	q_6	q_7	q_8	q_9
φ									
Joe	0	1	2	2	2	3	3	3	3
Jane	0	2	2	2	3	3	3	3	3
Max	0	1	0	2	3	3	3	3	3
φ'									
Joe	0	2	4	4	4	10	10	10	10
Jane	0	4	4	4	10	10	10	10	10
Max	0	2	0	4	10	10	10	10	10
ε									
Joe	0	2	2	2	2	3	3	3	3
Jane	0	2	2	2	3	3	3	3	3
Max	0	2	0	2	3	3	3	3	3



The Tower of London Test (ToL Test)

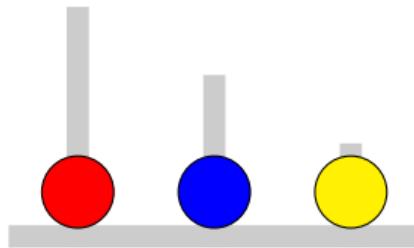


Starting configuration

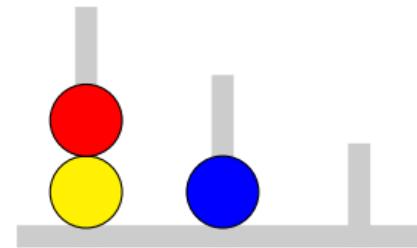


Goal configuration

The Tower of London Test (ToL Test)



Starting configuration



Goal configuration

Problem Example	Minimum moves	Alternative paths
1	2	1
2	2	1
3	3	2
4	3	1
5	4	2
6	4	1
7	4	1
8	4	1
9	5	2
10	5	1
11	5	1
12	5	2

Attempt-based SMs

Scoring system	First attempt	Second attempt	Third attempt	Fourth on	Total sum score
KR	3	2	1	0	0 – 36
SH1	1		0		0 – 12

Attempt-based SMs

Scoring system	First attempt	Second attempt	Third attempt	Fourth on	Total sum score
KR	3	2	1	0	0 – 36
SH1	1		0		0 – 12

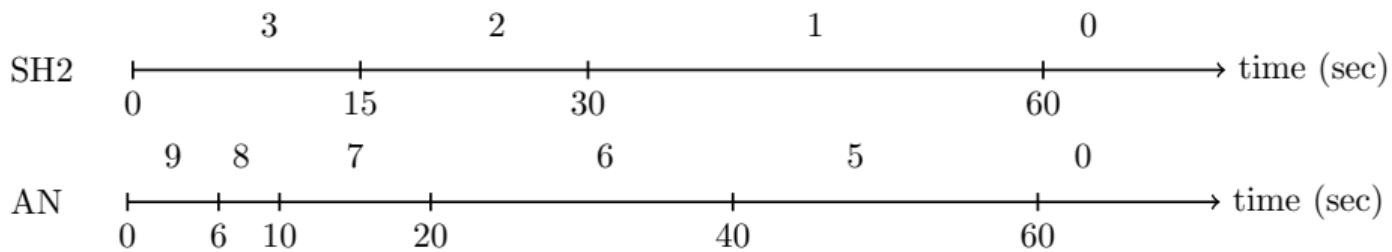
Scoring system	First attempt	Second attempt	Third attempt	Fourth on	Total sum score
P1	3		2	0	0 – 36
P1'	3		1	0	0 – 36

Attempt-based SMs

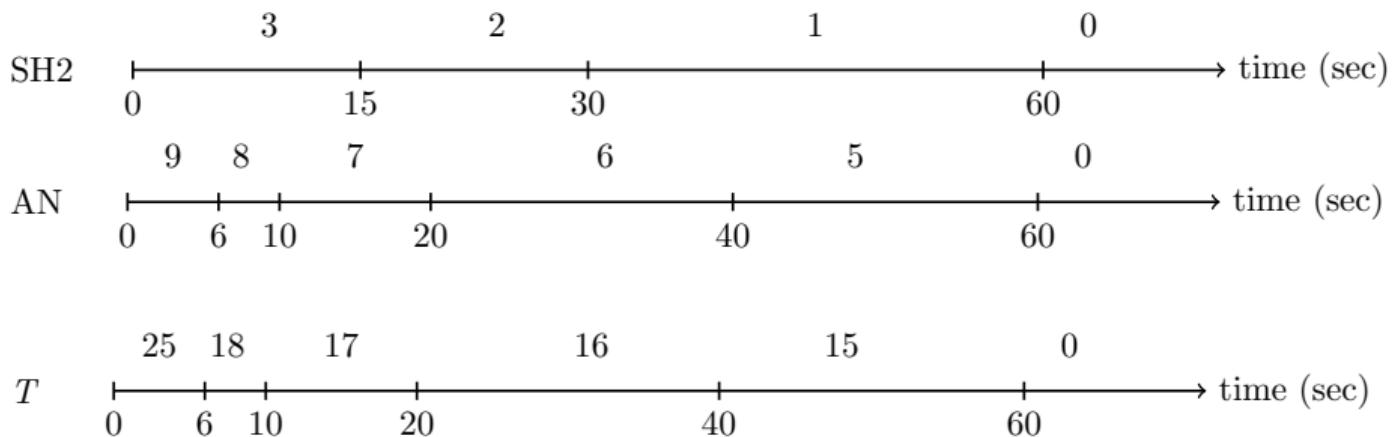
Scoring system	First attempt	Second attempt	Third attempt	Fourth on	Total sum score
KR	3	2	1	0	0 – 36
SH1	1		0		0 – 12

Scoring system	First attempt	Second attempt	Third attempt	Fourth on	Total sum score
P1	3		2	0	0 – 36
P1'	3		1	0	0 – 36

Latency-based SMS

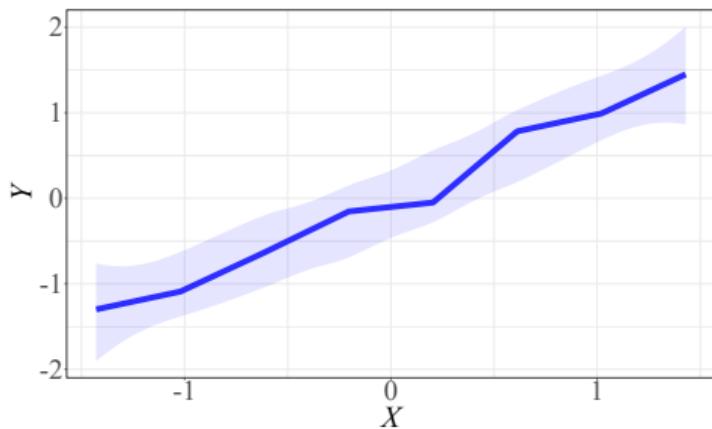


Latency-based SMS



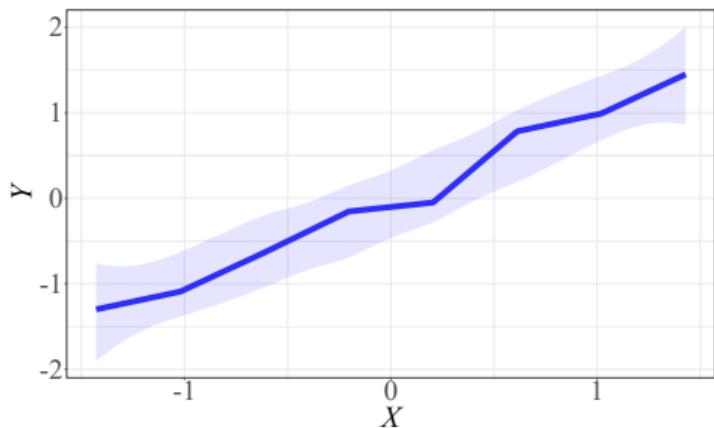
Methods: Individual differences

Monotonic relation

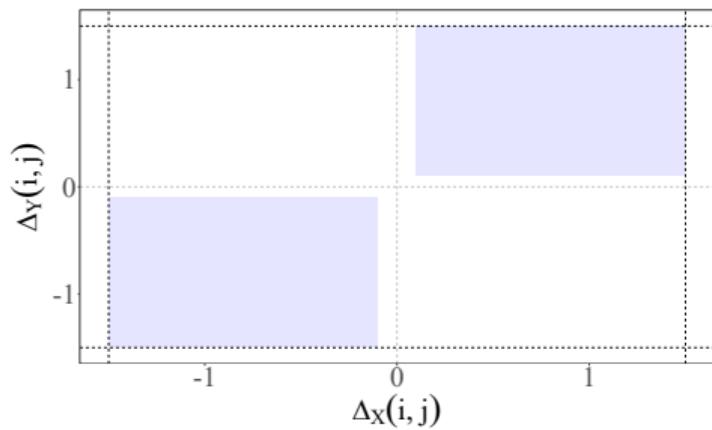


Methods: Individual differences

Monotonic relation

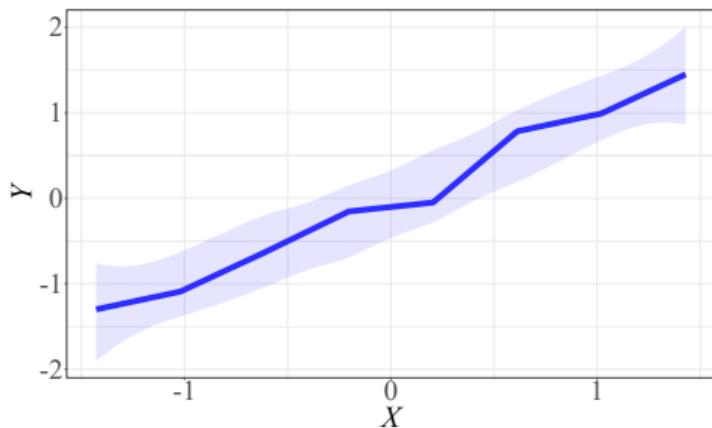


Distances and inversions

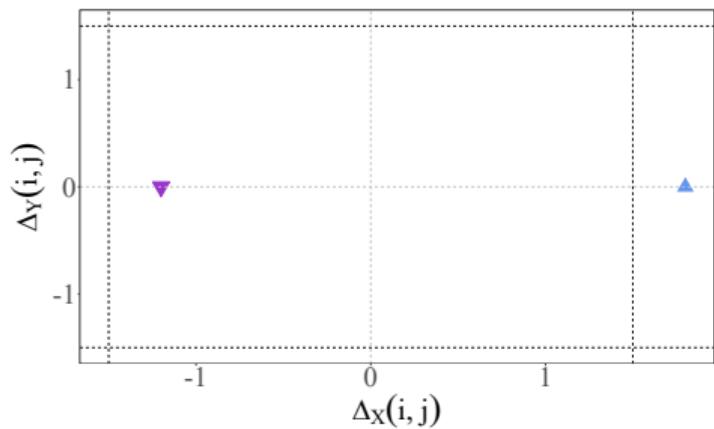


Methods: Individual differences

Monotonic relation

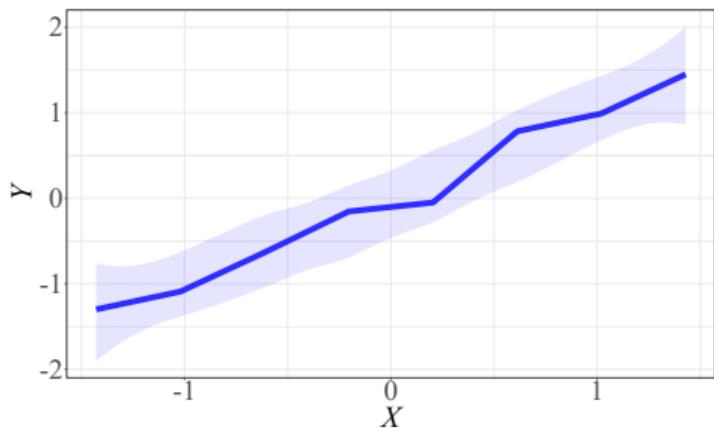


Distances and inversions

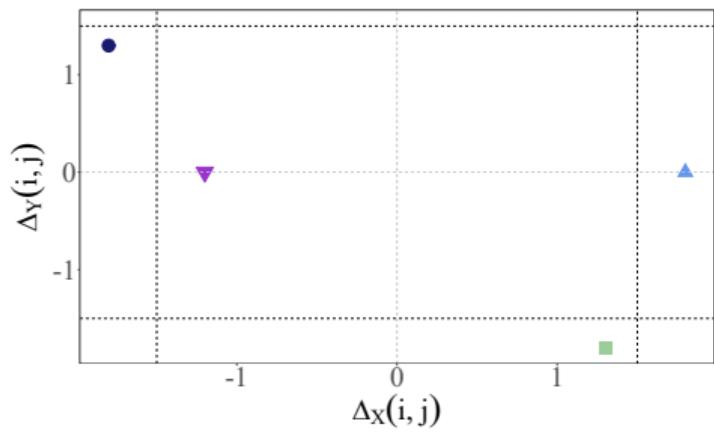


Methods: Individual differences

Monotonic relation

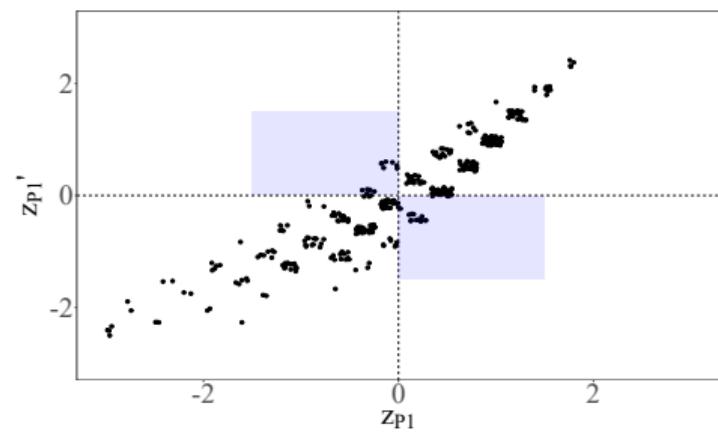
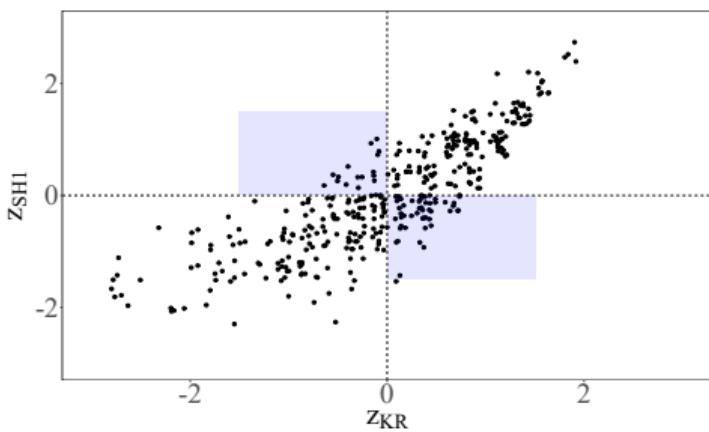


Distances and inversions



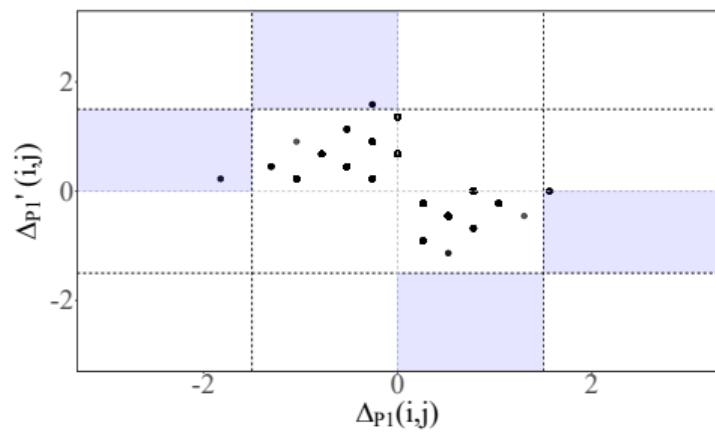
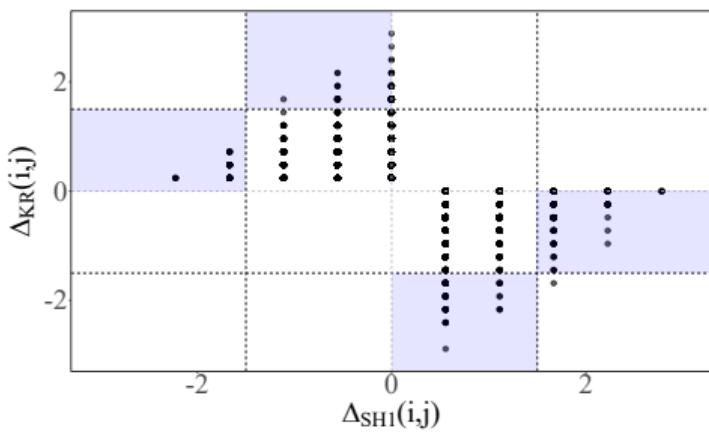
Results: Individual differences

Attempt-based SM: Monotonic relation



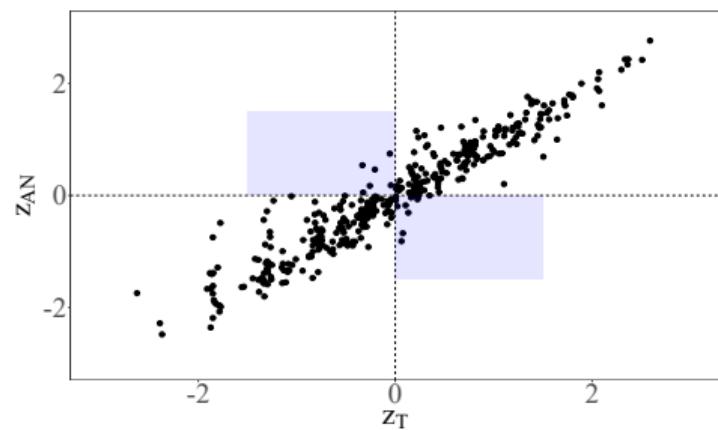
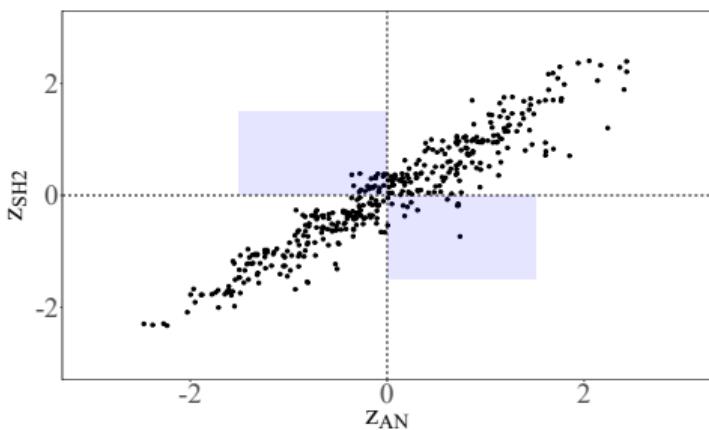
Results: Individual differences

Attempt-based SM: Differences and distances



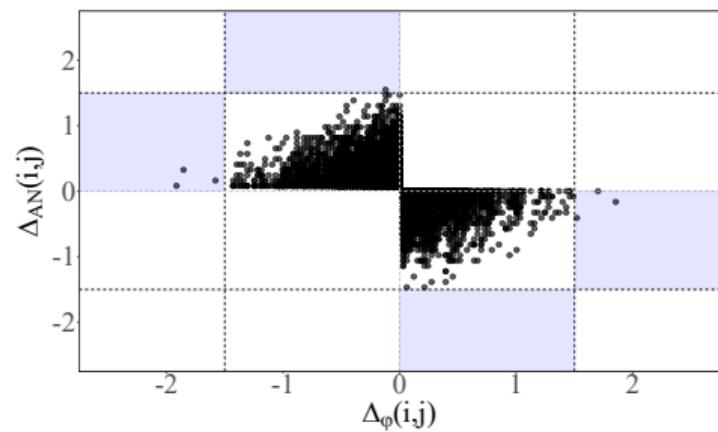
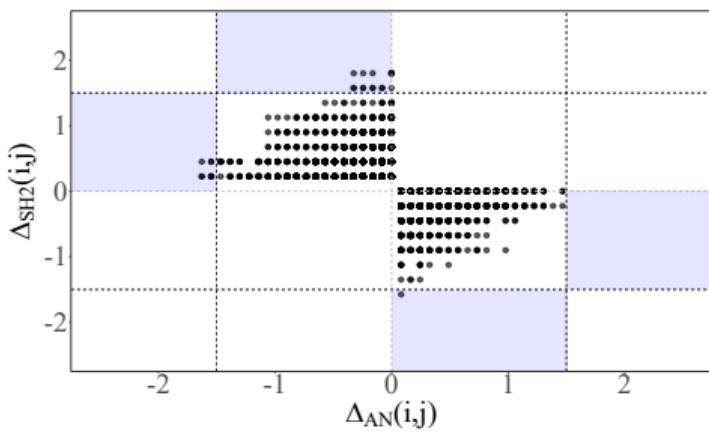
Results: Individual differences

Latency-based SM: Monotonic relation



Results: Individual differences

Latency-based SM: Differences and distances



Methods: Group differences

$$H_0: \mu_{g1} - \mu_{g2} = 0$$

$$H_1: \mu_{g1} - \mu_{g2} \neq 0$$

t-test on the standardized scores considering different grouping variables:

Grouping variable	n_1	n_2
Gender	199	196
Administration order	202	193
Administration modality	211	184
Schooling years	171	224

Results: Group differences

Attempt-based SM

	KR	SH1	P1	P1'
	<i>d</i>	<i>d</i>	<i>d</i>	<i>d</i>
Gender	1.84	2.11*	1.69	2.03*
	0.19	0.21	0.17	0.20
Test order	-0.15	0.80	-0.48	0.28
	-0.01	0.08	-0.05	0.03
Adm. Modality	-2.85**	-1.93	-2.69**	-2.35*
	-0.29	-0.19	-0.27	-0.24
Schooling	3.95***	3.56***	3.82***	3.85***
	0.39	0.36	0.38	0.39

Results: Group differences

Attempt-based SM

	KR <i>d</i>	SH1 <i>d</i>	P1 <i>d</i>	P1' <i>d</i>
Gender	1.84	2.11*	1.69	2.03*
	0.19	0.21	0.17	0.20
Test order	-0.15	0.80	-0.48	0.28
	-0.01	0.08	-0.05	0.03
Adm. Modality	-2.85**	-1.93	-2.69**	-2.35*
	-0.29	-0.19	-0.27	-0.24
Schooling	3.95***	3.56***	3.82***	3.85***
	0.39	0.36	0.38	0.39

Results: Group differences

Attempt-based SM

	KR <i>d</i>	SH1 <i>d</i>	P1 <i>d</i>	P1' <i>d</i>
Gender	1.84	2.11*	1.69	2.03*
	0.19	0.21	0.17	0.20
Test order	-0.15	0.80	-0.48	0.28
	-0.01	0.08	-0.05	0.03
Adm. Modality	-2.85**	-1.93	-2.69**	-2.35*
	-0.29	-0.19	-0.27	-0.24
Schooling	3.95***	3.56***	3.82***	3.85***
	0.39	0.36	0.38	0.39

Results: Group differences

Attempt-based SM

	KR	SH1	P1	P1'
	<i>d</i>	<i>d</i>	<i>d</i>	<i>d</i>
Gender	1.84	2.11*	1.69	2.03*
	0.19	0.21	0.17	0.20
Test order	-0.15	0.80	-0.48	0.28
	-0.01	0.08	-0.05	0.03
Adm. Modality	-2.85**	-1.93	-2.69**	-2.35*
	-0.29	-0.19	-0.27	-0.24
Schooling	3.95***	3.56***	3.82***	3.85***
	0.39	0.36	0.38	0.39

Results: Group differences

Attempt-based SM

	KR	SH1	P1	P1'
	<i>d</i>	<i>d</i>	<i>d</i>	<i>d</i>
Gender	1.84	2.11*	1.69	2.03*
	0.19	0.21	0.17	0.20
Test order	-0.15	0.80	-0.48	0.28
	-0.01	0.08	-0.05	0.03
Adm. Modality	-2.85**	-1.93	-2.69**	-2.35*
	-0.29	-0.19	-0.27	-0.24
Schooling	3.95***	3.56***	3.82***	3.85***
	0.39	0.36	0.38	0.39

Results: Group differences

Attempt-based SM

	KR	SH1	P1	P1'
	<i>d</i>	<i>d</i>	<i>d</i>	<i>d</i>
Gender	1.84	2.11*	1.69	2.03*
	0.19	0.21	0.17	0.20
Test order	-0.15	0.80	-0.48	0.28
	-0.01	0.08	-0.05	0.03
Adm. Modality	-2.85**	-1.93	-2.69**	-2.35*
	-0.29	-0.19	-0.27	-0.24
Schooling	3.95***	3.56***	3.82***	3.85***
	0.39	0.36	0.38	0.39

Results: Group differences

Latency-based SM

	SH2	AN	T
	<i>d</i>	<i>d</i>	<i>d</i>
Gender	1.64	1.88	2.10*
	0.17	0.19	0.21
Test order	0.37	0.99	0.95
	0.04	0.10	0.10
Adm. Order	-2.90**	-2.33*	-2.84**
	-0.29	-0.23	-0.29
Schooling	5.52***	5.32***	5.13***
	0.56	0.54	0.52

Results: Group differences

Latency-based SM

	SH2	AN	T
	<i>d</i>	<i>d</i>	<i>d</i>
Gender	1.64	1.88	2.10*
	0.17	0.19	0.21
Test order	0.37	0.99	0.95
	0.04	0.10	0.10
Adm. Order	-2.90**	-2.33*	-2.84**
	-0.29	-0.23	-0.29
Schooling	5.52***	5.32***	5.13***
	0.56	0.54	0.52

Results: Group differences

Latency-based SM

	SH2	AN	T
	<i>d</i>	<i>d</i>	<i>d</i>
Gender	1.64	1.88	2.10*
	0.17	0.19	0.21
Test order	0.37	0.99	0.95
	0.04	0.10	0.10
Adm. Order	-2.90**	-2.33*	-2.84**
	-0.29	-0.23	-0.29
Schooling	5.52***	5.32***	5.13***
	0.56	0.54	0.52

Are we sure sum scores are a good idea...?

PSYCHOMETRIKA—VOL. 89, NO. 1, 84–117
MARCH 2024
<https://doi.org/10.1007/s11336-024-09964-7>



RECOGNIZE THE VALUE OF THE SUM SCORE, PSYCHOMETRICS' GREATEST
ACCOMPLISHMENT

KLAAS SIJTSMA^{id}

TILBURG UNIVERSITY

JULES L. ELLIS^{id}

OPEN UNIVERSITY OF THE NETHERLANDS

DENNY BORSBOOM^{id}

UNIVERSITY OF AMSTERDAM



Are we sure sum scores are a good idea...?

PSYCHOMETRIKA—VOL. 89, NO. 1, 84–117
MARCH 2024
<https://doi.org/10.1007/s11336-024-09964-7>



RECOGNIZE THE VALUE OF THE SUM SCORE, PSYCHOMETRICS' GREATEST
ACCOMPLISHMENT

KLAAS SIJTSMA^{id}

TILBURG UNIVERSITY

JULES L. ELLIS^{id}

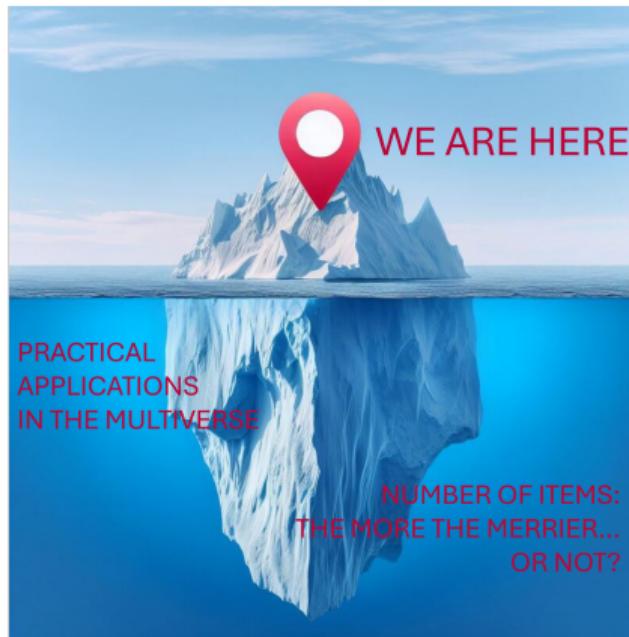
OPEN UNIVERSITY OF THE NETHERLANDS

DENNY BORSBOOM^{id}

UNIVERSITY OF AMSTERDAM



Sum scores of ordinal data bring to a multiverse of contrasting results





Sum scores of ordinal data bring to a multiverse of contrasting results

Increasing the number of items does not solve the issue.... it worsens it!

Meaningfulness of psychological measures and reproducibility are interlaced

Research founded by the project “Computerized, Adaptive and Personalized Assessment of Executive Functions and Fluid Intelligence” (PRIN 2020, Prot. 20209WKCLL, P.I. Prof. Luca Stefanutti)



Sum scores of ordinal data bring to a multiverse of contrasting results

Increasing the number of items does not solve the issue.... it worsens it!

Meaningfulness of psychological measures and reproducibility are interlaced

Bright side:

Sum scores of truly dichotomous data (i.e., true vs. false, correct vs. incorrect) are meaningful

Research founded by the project “Computerized, Adaptive and Personalized Assessment of Executive Functions and Fluid Intelligence” (PRIN 2020, Prot. 20209WKCLL, P.I. Prof. Luca Stefanutti)