Development and Validation of a Measure of Two-Dimensional Rotation Ability

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Introduction

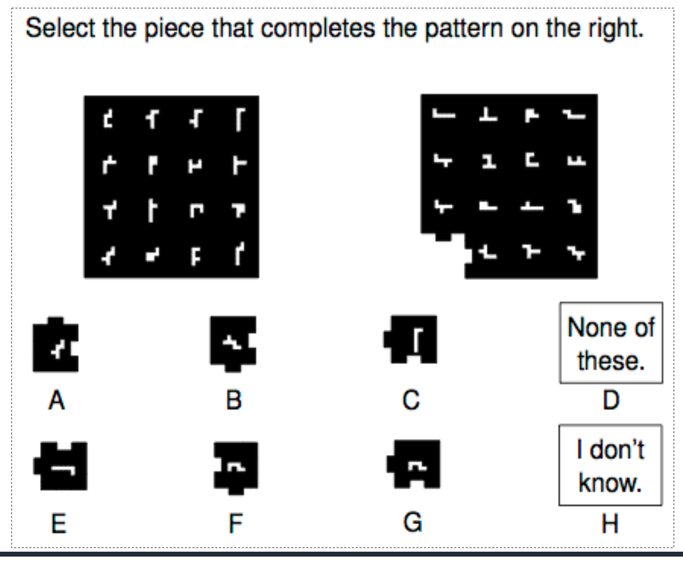
- Spatial ability is an important but relatively neglected aspect of intelligence in educational settings (Lubinski, 2010)
- Mental rotation is one specific spatial ability that has been linked to success and creative breakthroughs in STEM (Uttal & Cohen, 2013)

Objectives

- Develop and validate a set of public-domain 2D-rotation items using automatic item generation methods
- Compare 2D- and 3D- rotation ability across a wide range of occupational contexts

Items

Participants identify the missing piece in the figure. Correct answers require matching with stimuli where both the stimuli and answers are rotated (up to 180 degrees).



Method

Sample

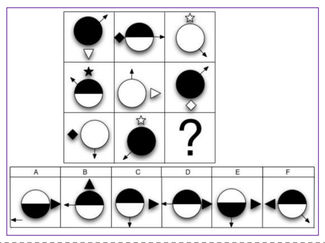
- N = 1,395,181 Participants from the SAPA project (https://www.sapa-project.org/)
- Mean age 26.41 (SD = 12.58); 67.5% female

Measures

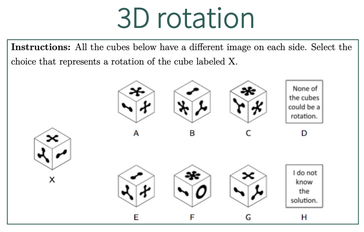
- **Abilities :** 3D rotation, Matrix reasoning, Verbal ability, Compound Remote Associates problem-solving, Letter-number series, and propositional reasoning (ICAR; Revelle & Condon, 2014)

Example items

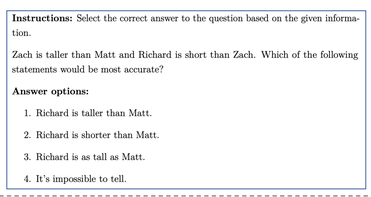
Matrix reasoning



3D rotation



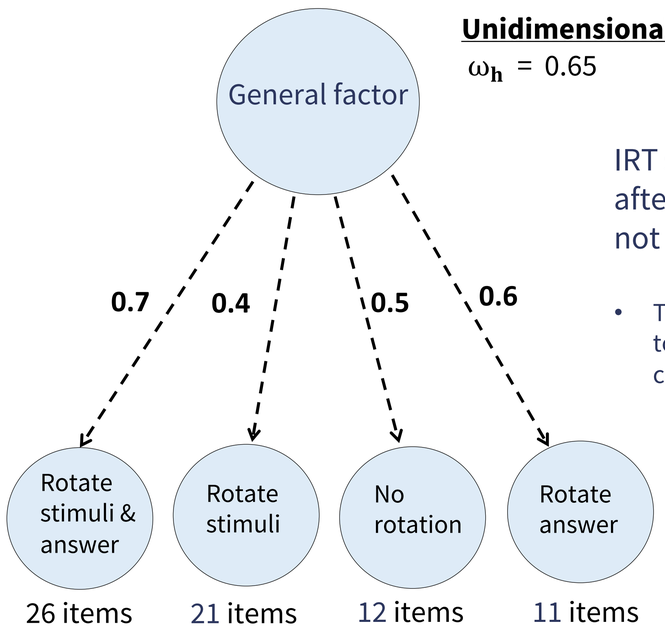
Verbal ability



- **Temperament:** SAPA Personality Inventory (SPI; Condon, 2017)

Results

Structure and dimensionality



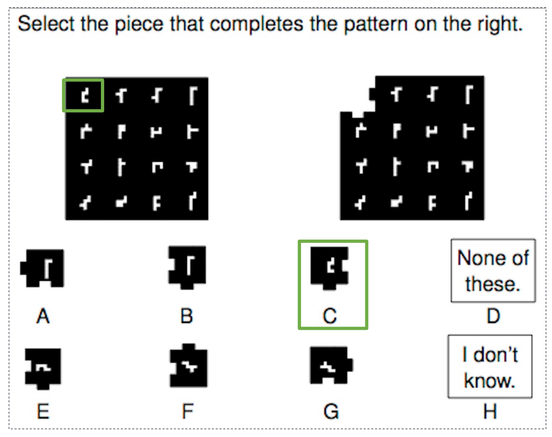
Unidimensionality ω_h = 0.65

Internal consistency: ω_t = .97 α = 0.94

IRT scored on the general factor after excluding 12 items that do not require mental rotation…

- These items only require participants to identify the missing piece that completes the pattern

Lower-order factors reflect differences across items in mental rotation demands



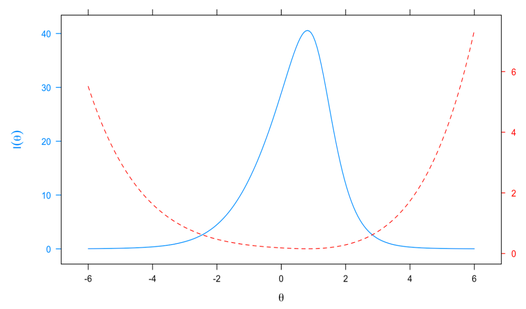
Unidimensionality after excluding items:

ω_h = .74

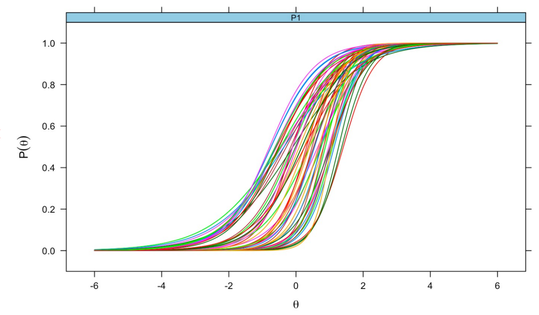
Item Response Theory Analysis

- For the full set of 58 items, measurement is most precise at slightly above average 2D rotation ability levels
- Item parameters suggest that the set of items covers a wide range of difficulty (-0.79 – 1.41)
- More complex items involving rotation of both the stimuli and answer option tended to be more difficult.

Test information



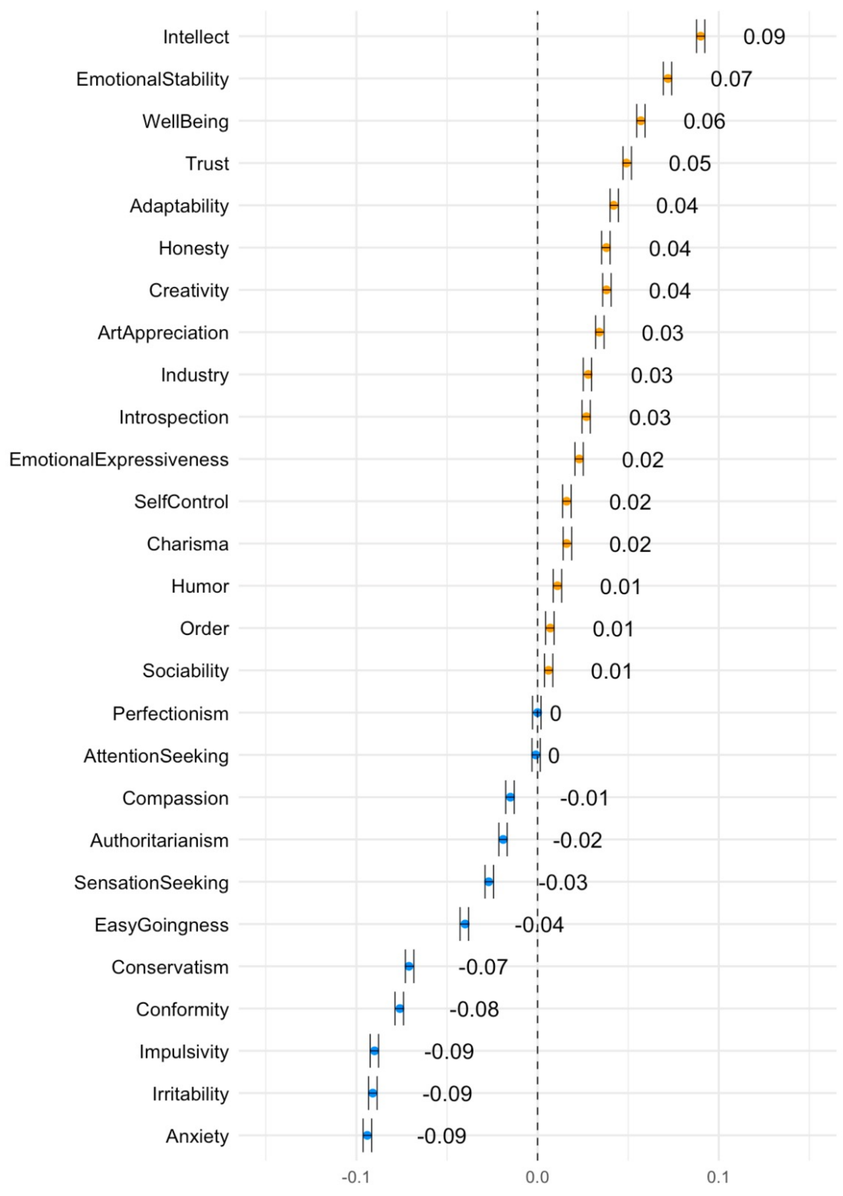
Item probability functions



Relationships with other individual differences

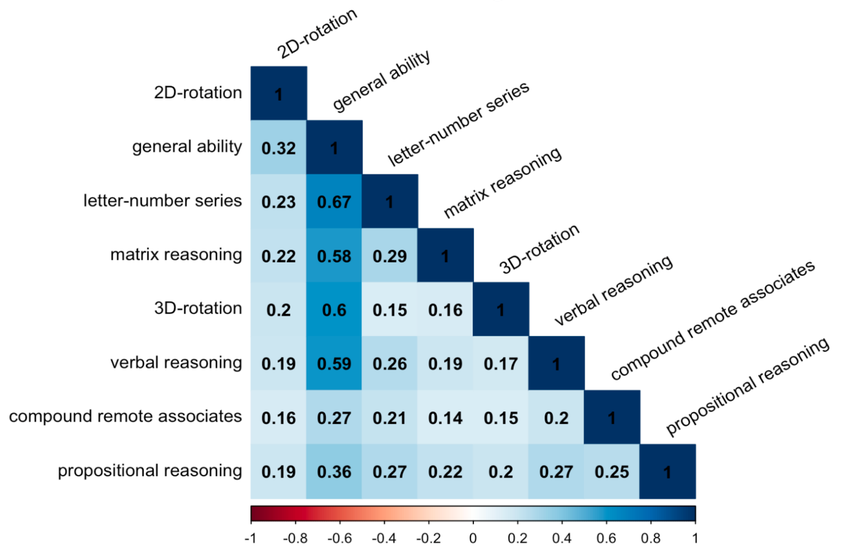
Temperament

Correlations with the 27 SAPA Personality Inventory traits



Cognitive abilities

Correlations with other cognitive abilities



Top scoring occupations

		Ability and percentile	
Occupation	**N**	**2D**	**3D**
Biological Technician	223	.96	.96
Physicist	268	.96	.99
Postsecondary Teacher-Engineering	294	.94	.91
Energy Engineer	228	.94	.92
Molecular and Cellular Biologist	331	.93	.95
Aerospace Engineer	515	.91	.96
Chemical Engineer	545	.91	.92
Radar and/or Sonar Technician	208	.91	.70
Computer Systems Engineers/Architect Statisician	1639	.90	.94
Statistician	303	.90	.94
Manufacturing Engineer	329	.90	.91
Biologist	654	.90	.89
Chemist	558	.90	.93

r_s = .82

O*NET Job Characteristics

O*NET job characteristics most strongly correlated with 2D rotation, identified using the BISCUIT statistical learning technique

r = 0.47 to 0.55

Skills and abilities most highly demanded by the occupations held by those with high spatial ability

"Mathematical reasoning", "science", "mathematics knowledge", "Engineering and technology", "Investigative", "Physics knowledge", "Mathematics skills", "Analytical thinking", "Systems analysis", "Technology design", "Information ordering"

r = -0.32 to -0.42

Skills and abilities least demanded by the occupations held by those with high spatial ability

"Dealing with unpleasant or angry people", "Customer and personal service", "Performing or working directly with the public", "Social orientation", "Self control", "Concern for others", "Relationships", "Dealing with external customers"

BISCUIT (Best Items Scale that is Cross-validated, Unit-weighted, Informative, and Transparent) is a correlation-based statistical learning technique that retains the items most strongly correlated with a criterion (Elleman et al., 2021).