Measuring spatial ability at a distance: Who goes into STEM

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Outline

1. Personality and Differential Psychology

2. Synthetic Aperture Personality Assessment (SAPA): An old methodology with new applications
   - SAPA methodology
   - Sample ability items

3. Some structural and validity studies
   - Structural studies
   - Validity studies
Three domains: Temperament, Abilities, and Interests

Temperament
- 2-5 dimensions reflecting individual differences in Affect, Behavior, Cognition, Desire

Abilities
- 1. g
- 2. gf gc

Interests
- 1. People vs. Things
- 2. Facts vs Ideas
Integrating 3 domains of individual differences to predict STEM

1. Two of the “Big 5” Temperament
   - Openness/Intellect
   - Conscientiousness

2. Ability beyond g
   - Spatial/Rotational
   - Abstract reasoning

3. Two dominant Interests
   - Analytic
   - Production

4. Using Synthetic Aperture Personality Assessment to examine TAI correlates across diverse groups
   - Sampling people from web based assessment
   - Sampling items to synthetically form covariance matrices
   - Prior work studied ability, temperament, attitudes, trust, music preferences: Evans & Revelle (2008); Liebert (2006); Revelle & Laun (2004); Revelle, Wilt & Rosenthal (2010)
Using the web to collect data on temperament, ability and interests

- Synthetically form large covariance matrices from smaller subsets of items
- Each subject given ≈ 50 personality, 10 interest, and 16 ability items sampled from the larger pool.
- Total pool of items > 600
  - ≈ 400 personality items primarily from International Personality Item Pool Goldberg (1999)
  - 92 interest items for Oregon Vocational Interest Scales (Pozzebon, Visser, Ashton, Lee & Goldberg, 2010)
  - 80 ability items (home brewed at NU)
  - Demographic items include age, sex, education, race, country, college major, occupation (if appropriate)
  - Resulting sample sizes > 50,000 – 100,000

College major, occupational status and interest items added in 9/10

Data to be summarized include ≈ 30,000 participants (Sept 2010-December 2011).
**SAPA: what the subject sees**

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**SAPA: what the subject sees**

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**SAPA: what the subject sees**

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SAPA: what the subject sees
SAPA: what the subject sees

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**SAPA: Synthetic Aperture Personality Assessment**

An old methodology with new applications.
SAPA: what the subject sees

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**SAPA: what the experimenter sees: A Synthetic matrix**

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SAPA: Technical overview

1. **n x n synthetic covariance matrices are formed by giving p items to Np subjects**
   - \( N \): Total number of subjects
   - \( n \): Total number of items in synthetic matrix
   - \( p \): Probability of any item being given
   - \( pN \): Number of subjects taking any one item
   - \( p^2N \): Number of subjects for any pair of items

2. **Basic statistics**
   - Data are Massively Missing at Random
   - Means and Variances are based upon \( pN \) subjects
   - Covariances are based upon \( p^2N \) subjects

3. **Power of large samples and sampling of items**
   - 100-150 people per day \( \Rightarrow \) 40,000 subjects per year
   - 700-1000 subjects/week
   - By varying \( p \), one can prototype items rapidly.
Types of ability items

1. Alpha/Numeric reasoning (≈ 14)
2. General knowledge (≈ 14)
3. Abstract matrix reasoning (14 of varying characteristics)
4. Unclassified (≈ 14)
5. Spatial (cube) rotation (24 underdevelopment)
Matrix reasoning

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Matrix reasoning

- A
- B
- C
- D
- E
- F
All the cubes below have a different image on each side. Select the choice that represents a rotation of the cube labeled X.

- A
- B
- C
- D: None of the cubes could be a rotation.
- E
- F
- G
- H: I do not know the solution.
Cube Rotation

All the cubes below have a different image on each side. Select the choice that represents a rotation of the cube labeled X.

A
B
C
D
None of the cubes could be a rotation.

E
F
G
H
I do not know the solution.
Cube Rotation

All the cubes below have a different image on each side. Select the choice that represents a rotation of the cube labeled X.

A B C D
E F G H

None of the cubes could be a rotation.

I do not know the solution.
Cube Rotation

All the cubes below have a different image on each side. Select the choice that represents a rotation of the cube labeled X.

X

A  B  C

D  E  F  G

H

None of the cubes could be a rotation.

I do not know the solution.
Item generation techniques

1. The challenge: to generate new items algorithmically
   - To make many items so items can be open source/shared for research
   - To make items smarter (harder) than we are

2. Two components of a problem
   - Incidentals that do not affect difficulty
   - Radicals that affect difficulty

3. Characteristics of matrix reasoning items
   - Difficulty on matrix reasoning varies by memory load
     Embretson (1998); Mulholland, Pellegrino & Glaser (1980)
   - Number of transformations across rows and columns

4. Characteristics of spatial rotation items
   - Difficulty varies by number of rotations
   - Difficulty varies by number of axes of rotation
Structural studies

1. Item structure based upon tetrachoric and polychoric correlations from synthetic correlation matrices.

2. Classical Test theory
   - Exploratory Factor Analysis of structure
   - Hierarchical Factor Structure

3. Item Response Theory
   - To identify item location (difficulty) and discrimination
   - This has led to some item pruning
   - Ability to construct parallel tests based upon item and test information
Item Information analysis of 28 best old + 24 rotation items

Item information from factor analysis
Validity studies

1. Correlations with self reported SAT/ACT, gender, age
2. Correlations with college major and occupation
   - Classification of major by large groups (Math, Engineering, ...)
   - Classification of occupation by large groups
3. Use of graphical displays rather than significance of correlations (everything is significant)
   - Heat maps of correlations with majors and occupations
   - Spider plots by occupation
Table of Temperament, Ability and Interest: College major

- Undecided
- Math
- N.Sci
- Engin
- CIS
- Business.1
- Med
- SocServ
- Edu
- Commun
- S.Sci
- Arts.1
- Culture
- Lang

E N C A O SATV SATQ SATW ACT

iq.theta1 production adventure analysis organization leadership altruism erudition creativity

age

Legend:

-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1
| Personality and Differential Psychology | Synthetic Aperture Personality Assessment (SAPA): An old methodology with new applications | References |

### College major by Temperament, Ability and Interests - Females only

#### Temperament, Ability and Interest: College major -- Female only

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<th>Interest</th>
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**Correlation Matrix**

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Temperament, Ability and Interest: College major -- Male only

- Temptament: E, N, C, A, O
- Ability: SATV, SATQ, SATW, ACT
- Interest: production, adventure, analysis, organization, leadership, altruism, erudition, creativity, age


Correlation coefficients: -1 to 1
Occupation by Temperament, Ability and Interests – All participants

Temperament, Ability and Interest: Occupation

- ENCA
- SATV SATQ SATW
- ACT
- production adventure analysis
- organization leadership altruism erudition creativity
- age

Temperament, Ability and Interest: Occupation

- notapplic
- LifePhsSocScience
- CompMath
- Engineering
- Military
- Manage
- InstallRepair
- Business
- Transportation
- ManuProd
- Protective
- FarmFishForest
- ConstructExtract
- OfficeAdmin
- Healthcare
- Sales
- cleaning
- communitySocServ
- FoodPrep
- PersonalCare
- EdTrain
- Arts

- E N C A O
- SATV SATQ SATW
- ACT
- iq, theta1
- production adventure analysis
- organization leadership altruism erudition creativity
- age

-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

-1 -0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8 1

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## Occupation by Temperament, Ability and Interests - Females only

### Females only -- Temperament, Ability and Interest: Occupation

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<tr>
<th>Temperament</th>
<th>Ability</th>
<th>Interest</th>
<th>Occupation</th>
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<td>SATW</td>
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<td>ACT</td>
<td>iq, theta1</td>
<td>production</td>
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### Occupation Categories
- Law
- Arts
- Personal Care
- Food Prep
- Community Soc Serv
- Sales
- Healthcare
- Office Admin
- Protective
- Farm Fish Forest
- Construction Extract
- Transportation
- Military
- Engineering
- Comp Math
- Life Phs Soc Science
- Not Applic

### Temperament
- ENC

### Ability
- SATV
- SATQ
- SATW
- ACT
- iq, theta1
- production
- adventure
- analysis
- organization
- leadership
- altruism
- erudition
- creativity
- age

### Interest
- age
- SATV
- SATQ
- SATW
- ACT
- iq, theta1
- production
- adventure
- analysis
- organization
- leadership
- altruism
- erudition
- creativity
- age

### Occupation
- Law
- Arts
- Personal Care
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- Community Soc Serv
- Sales
- Healthcare
- Office Admin
- Protective
- Farm Fish Forest
- Construction Extract
- Transportation
- Military
- Engineering
- Comp Math
- Life Phs Soc Science
- Not Applic

### Correlation Matrix

- ENC (Emotional Stability and Neuroticism): Correlation values range from -1 to 1, indicating the strength and direction of the relationship between temperament and each occupation category.
- SATV (Verbal Reasoning):...
- SATQ (Quantitative Reasoning):...
- SATW (Working Memory):...
- ACT (Critical Thinking):...
- iq, theta1 (General Intellectual Ability):...
- production (Production and Craftsmanship):...
- adventure (Adventurousness):...
- analysis (Analytical Thinking):...
- organization (Organization and Management):...
- leadership (Leadership and Influence):...
- altruism (Altruism and利他):...
- erudition (Erudition and Artistic Expression):...
- creativity (Creativity and Innovation):...
- age (Age):
STEM majors
Business/Education/Social Services

![Graphs for Business, Med, SocServ, and Edu](image-url)
Social Sciences and the Arts

S.Sci

Arts.1

Culture

Lang
Summary and Conclusion

1. Personality and Differential Psychology variables include
   - Temperament (the big 5: CANOE or OCEAN)
   - Ability (g + lower level factors)
   - Interests (People vs. Things, Facts vs. Ideas)

2. These constructs may be measured in large scale, telemetric studies
   - The SAPA methodology does not make it onerous on the subject
   - SAPA techniques allow for rapid prototyping of measures

3. These constructs relate to the choice of STEM majors and careers


Goldberg, L. R. (1999). A broad-bandwidth, public domain, personality inventory measuring the lower-level facets of several five-factor models. In I. Mervielde, I. Deary, F. De Fruyt, & F. Ostendorf (Eds.), Personality psychology in Europe, volume 7 (pp. 7–28). Tilburg, The Netherlands: Tilburg University Press.

