# Measuring spatial ability at a distance:
# Who goes into STEM

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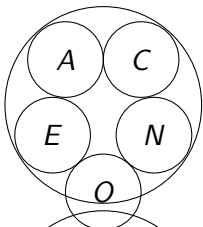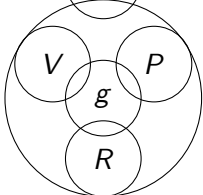Evanston, Illinois USA

NORTHWESTERN
UNIVERSITY

December, 2011

## Outline

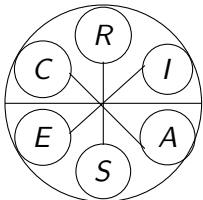## Three domains: Temperament, Abilities, and Interests



Temperament

Abilities

Interests

### Temperament

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

### Ability

① g

② $g_f g_c$

### Interests

2 broad dimensions organizing 6-8 specific interests

① People vs. Things

② Facts vs Ideas

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**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)

**Synthetic Aperture Personality Assessment (SAPA)**

- Using the web to collect data on temperament, ability and interests
    - Synthetically form large covariance matrices from smaller subsets of items
    - Each subject given $\approx$ 50 personality, 10 interest, and 16 ability items sampled from the larger pool.
    - Total pool of items $> 600$
        - $\approx$ 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 $\approx$ 30,000 participants (Sept 2010-December 2011).

## SAPA: what the subject sees

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

**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 $=>$ 40,000 subjects per year
   - 700-1000 subjects/week
   - By varying p, one can prototype items rapidly.

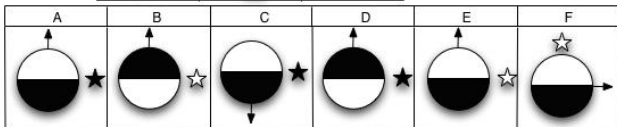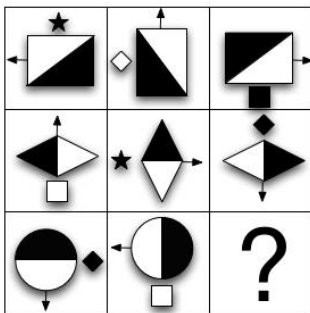**Types of ability items**

1. Alpha/Numeric reasoning ($\approx 14$)

2. General knowledge ($\approx 14$)

3. Abstract matrix reasoning (14 of varying characteristics)

4. Unclassified ($\approx 14$)

5. Spatial (cube) rotation (24 underdevelopment)

## Matrix reasoning
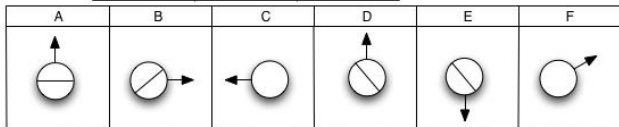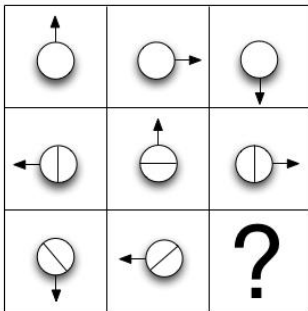
## Matrix reasoning

## 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.

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Select the choice that represents a rotation of the cube labeled X.

## 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 colums
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**
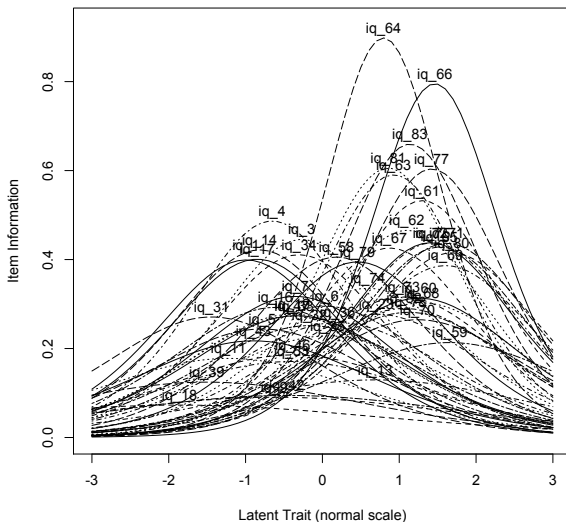
**Validity studies**

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

## College major by Temperament, Ability and Interests



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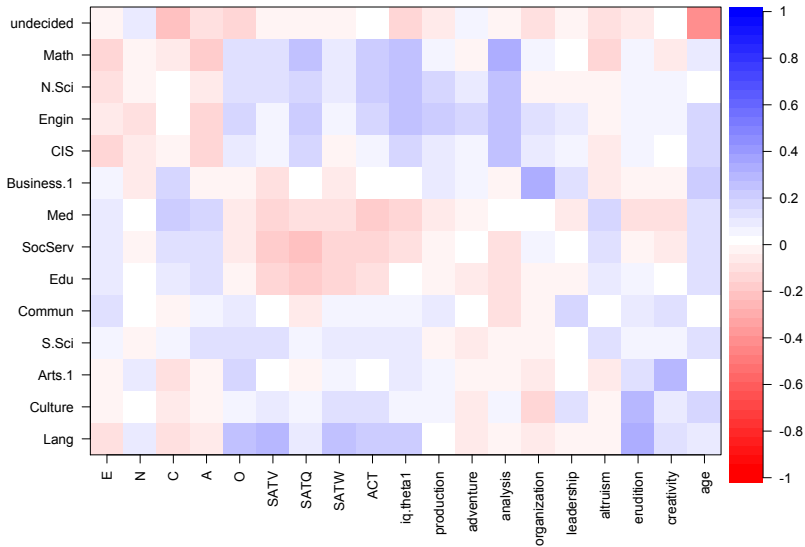
## College major by Temperament, Ability and Interests- Females only



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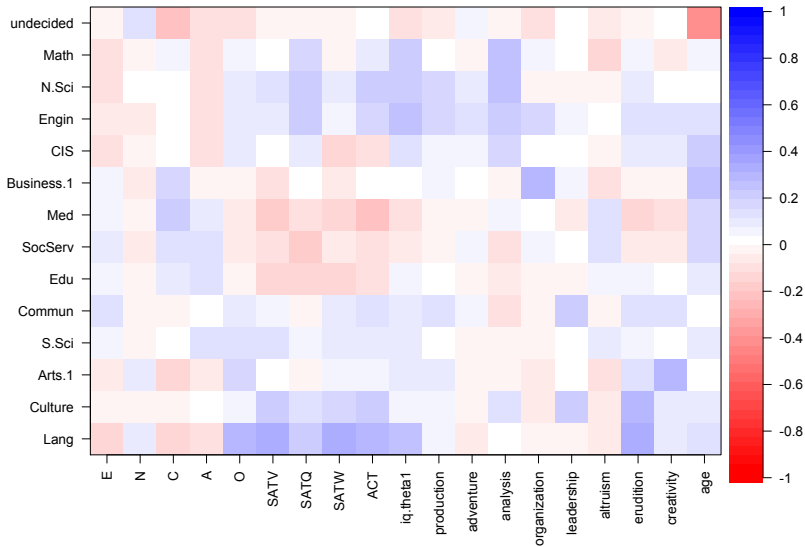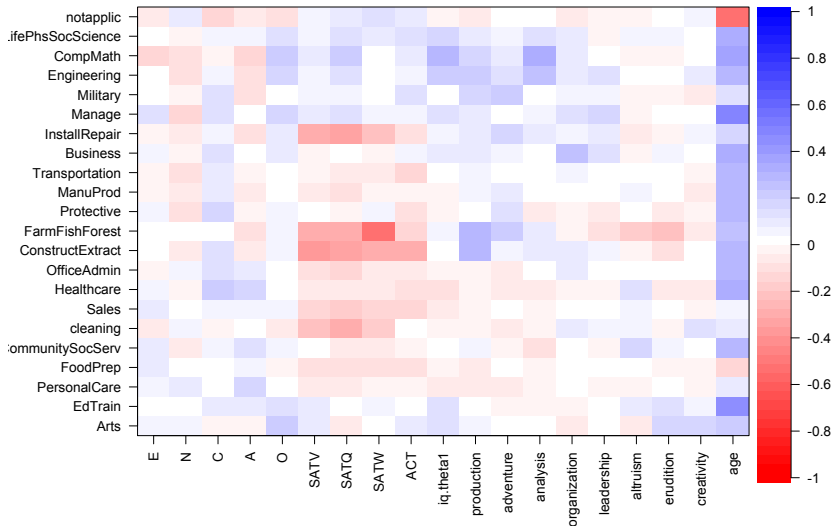
# College major by Temperament, Ability and Interests- Females only



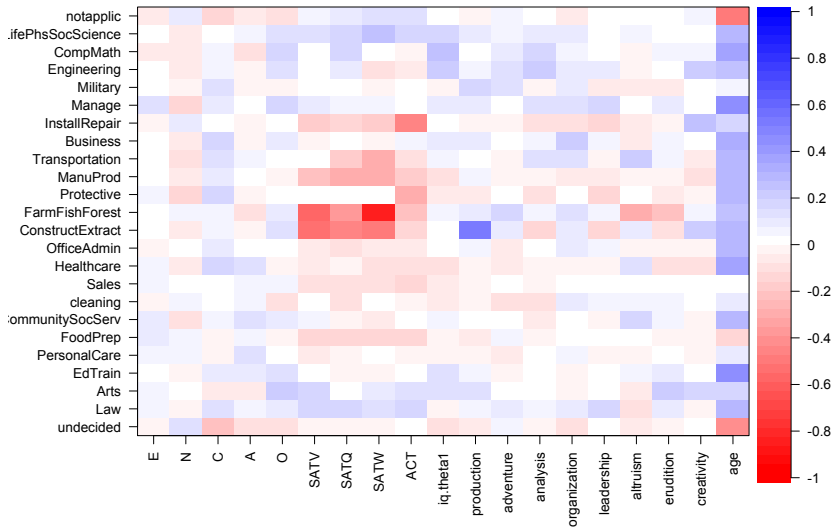Temperament, Ability and Interest: College major  -- Male only
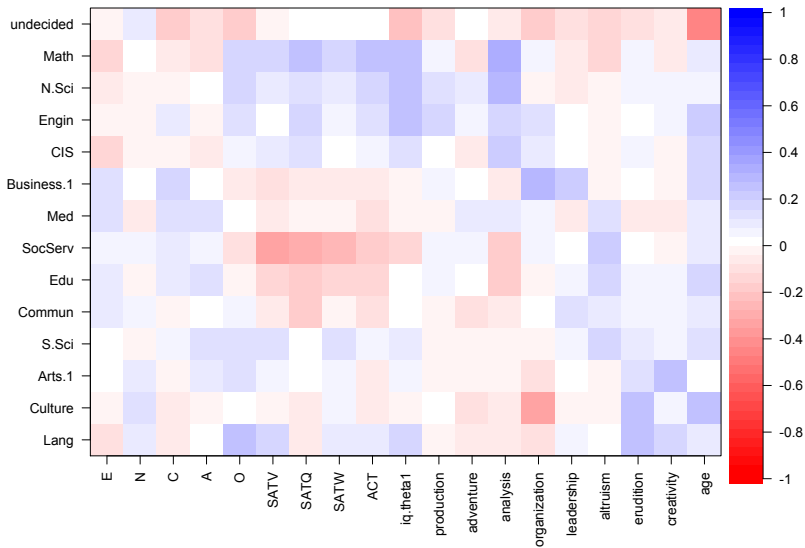
## Occupation by Temperament, Ability and Interests – All participants
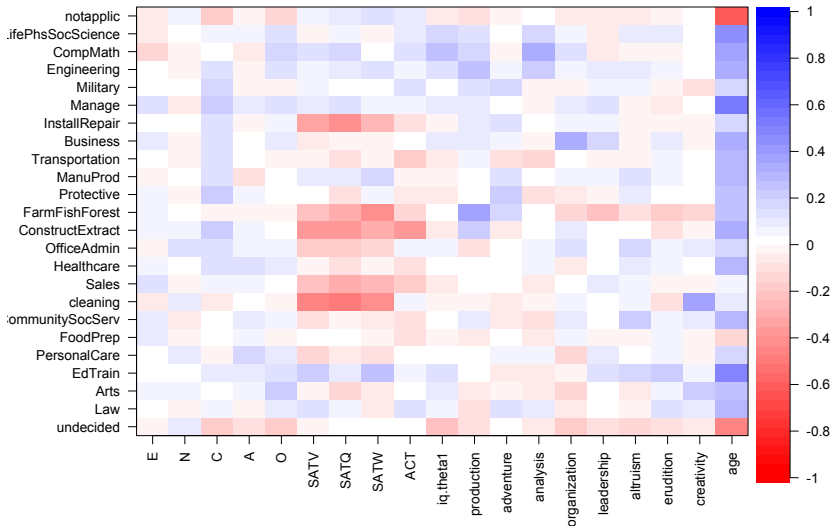


Temperament, Ability and Interest: Occupation

# Occupation by Temperament, Ability and Interests- Females only



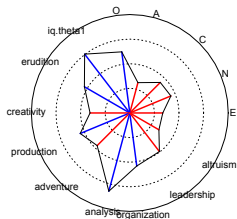Females only --Temperament, Ability and Interest: Occupation

# Occupation by Temperament, Ability and Interests- Males only



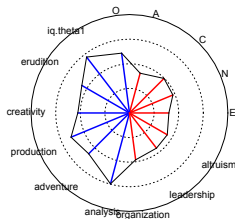Males only --Temperament, Ability and Interest: Occupation
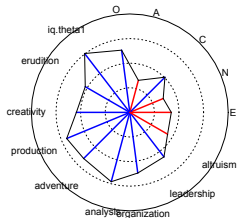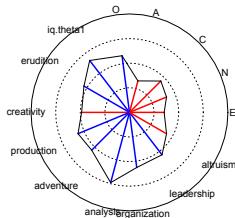
## STEM majors

## Business/Education/Social Services
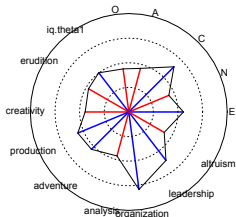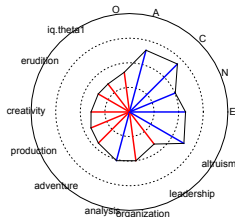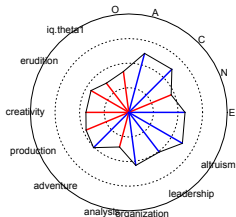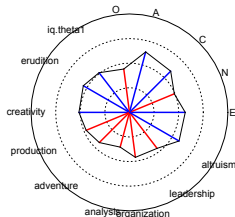
## Social Sciences and the Arts
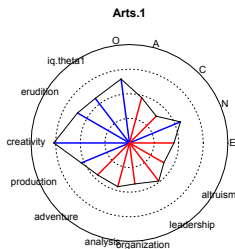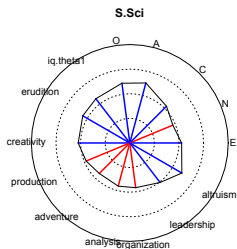
**Summary and Conclusion**

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)
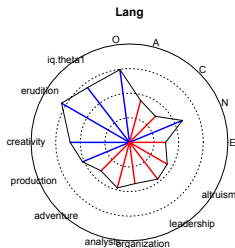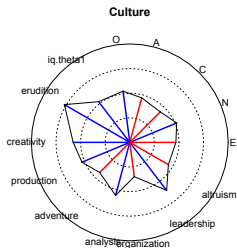2. These constructs may be measured in large scale, telemetric studies
   - The SAPA methodology does not make it onerous on the subject
   - SAPA techniques allow for rapid prototyping of measures
3. These constructs relate to the choice of STEM majors and careers

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