

# Automatic Item Generation of Figural Analogy Problems: A Review and Outlook

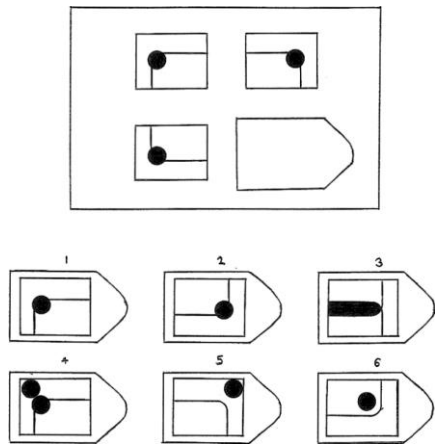
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And Maithilee Kunda

Vanderbilt University

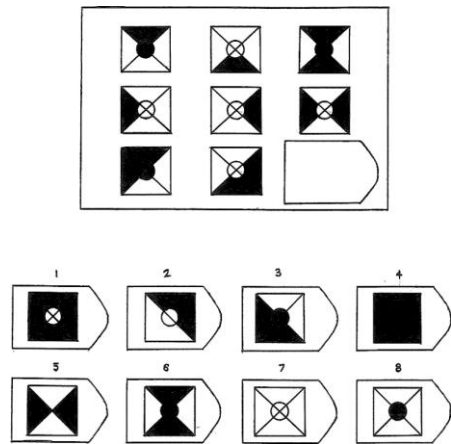
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# Examples

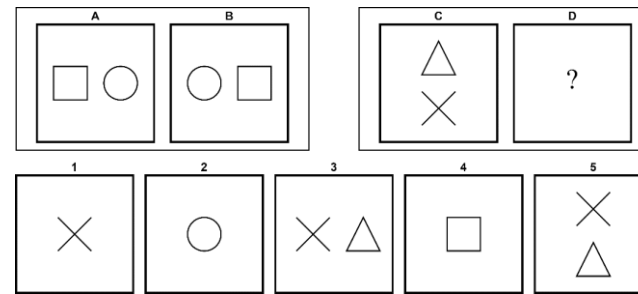
- Figural Analogy Problem (FAP)
- Automatic Item Generation (AIG)



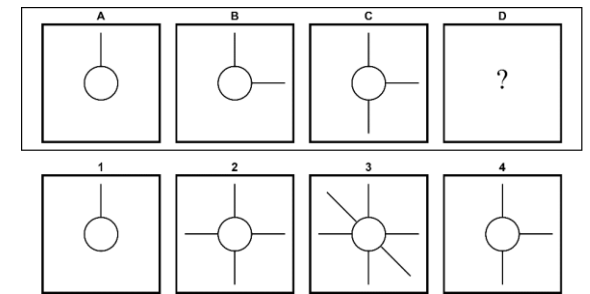
2x2 Progressive Matrix  
(Kunda et al., 2013)



3x3 Progressive Matrix  
(Kunda et al., 2013)



2+2 Geometric Analogy  
(Lovett et al., 2009)



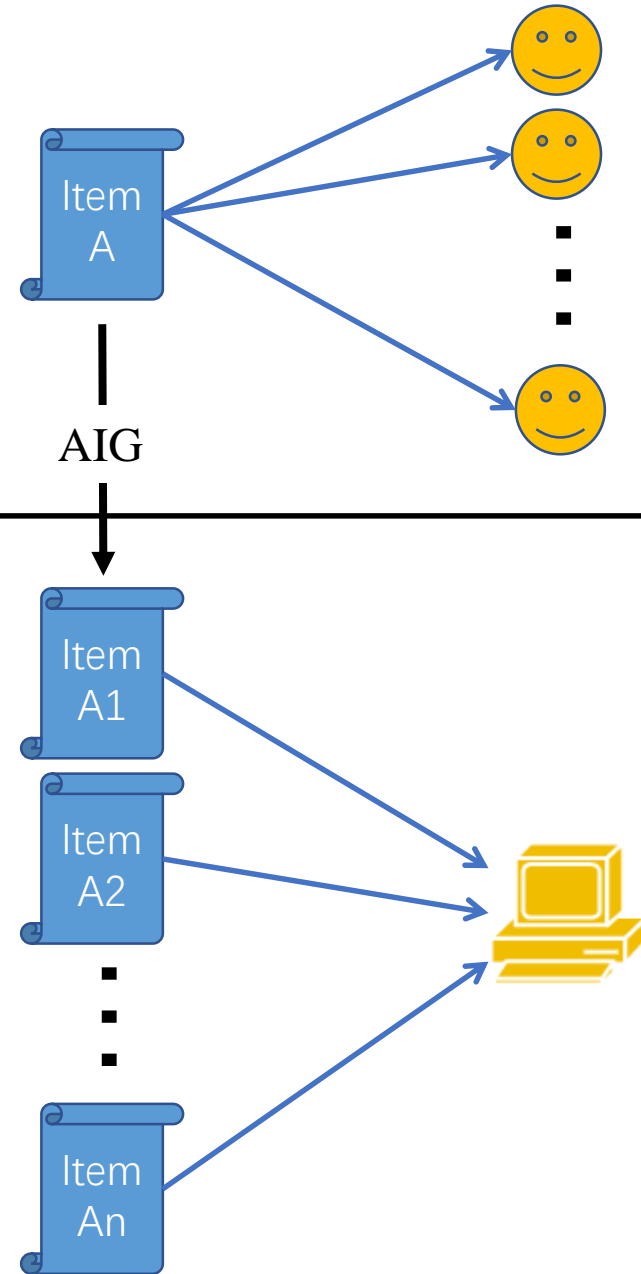
4x1 Figural Series  
(Sekh et al., 2020)

# Motivation of our work

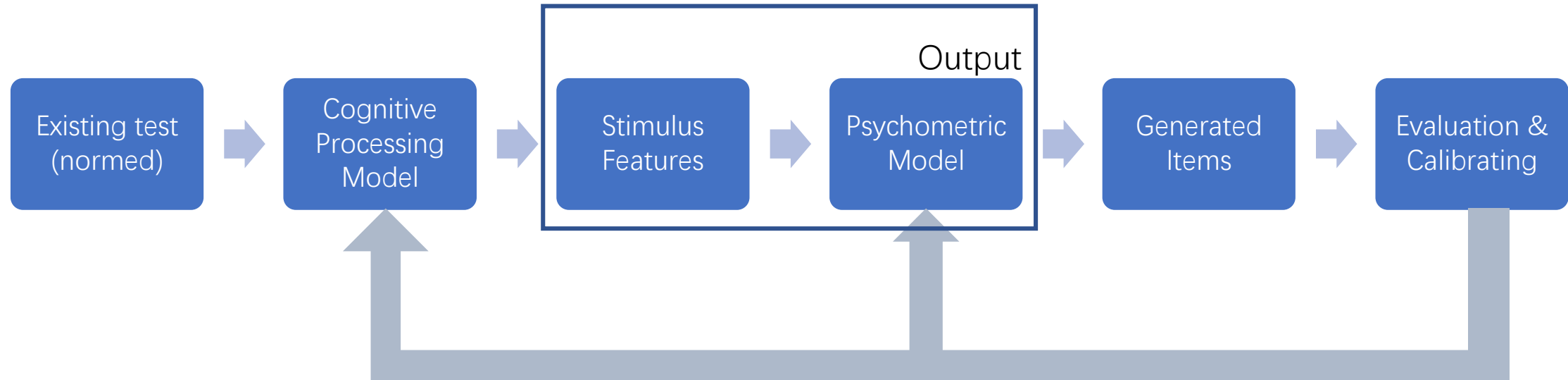
Human Intelligence Tests



Training and Testing  
Data-Driven AI Models

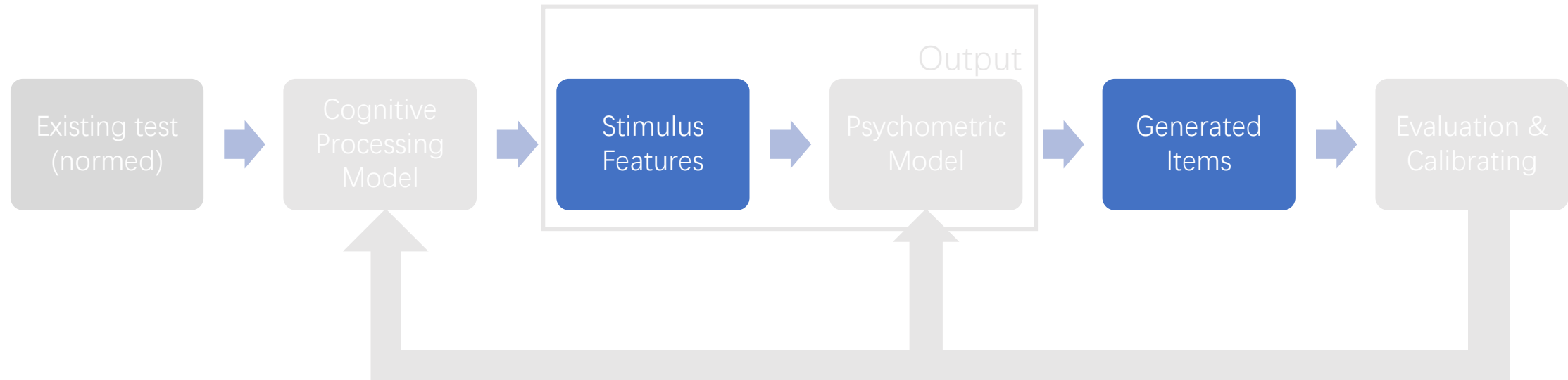


# AIG of FAP For Human Intelligence Tests



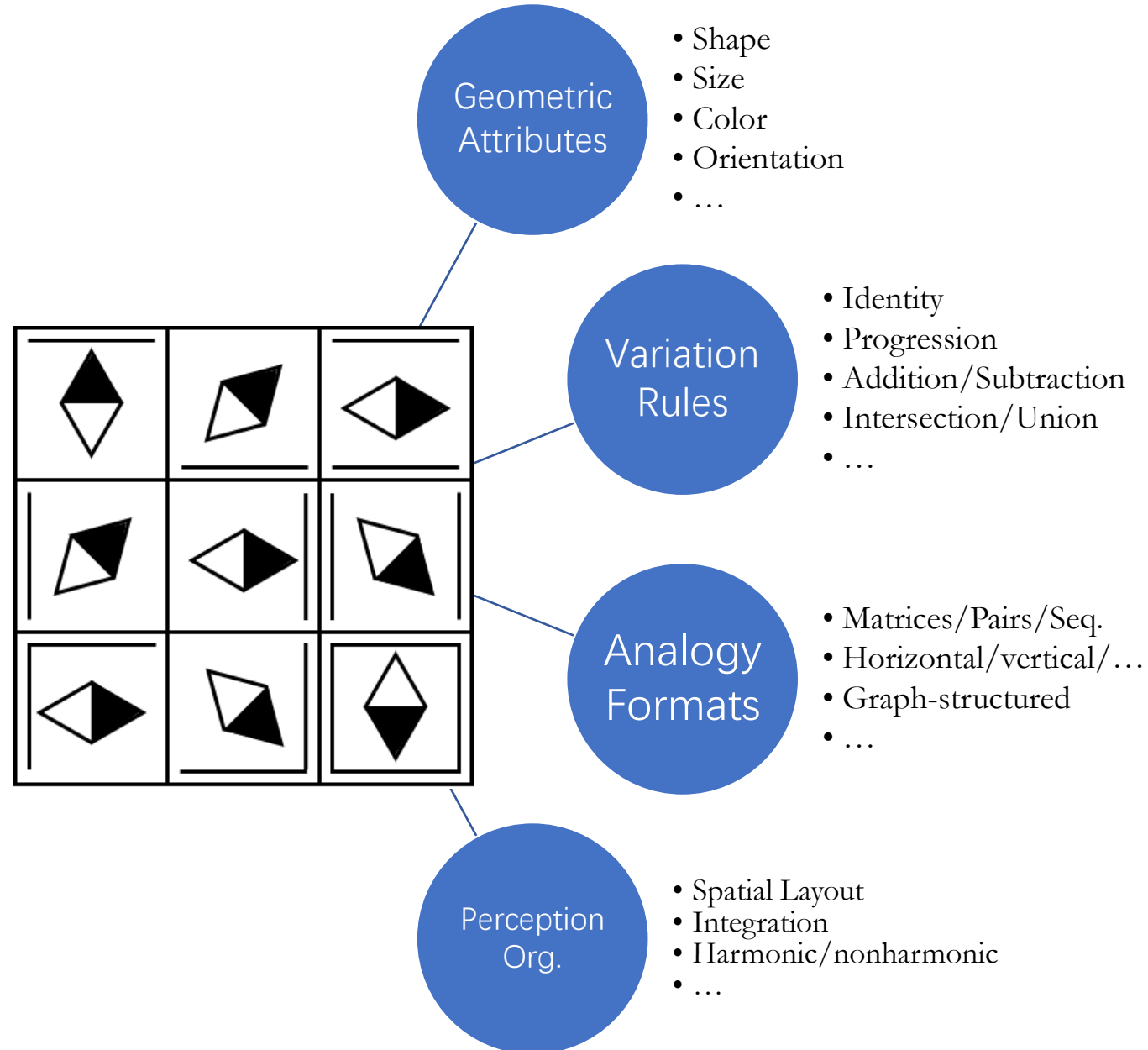
Cognitive Design System Approach (Embretson, 2004)

# AIG of FAP For Human Intelligence Tests

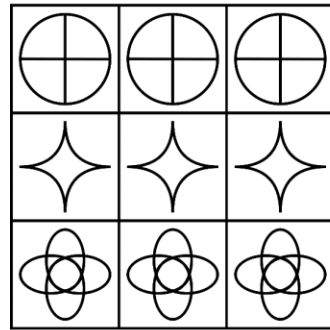


Cognitive Design System Approach (Embretson, 2004)

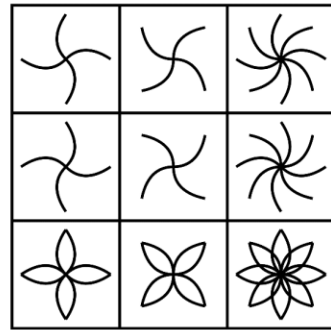
# Rule-Based Item Construction



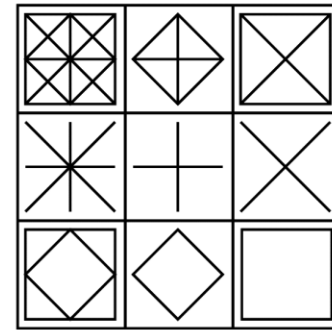
# Rule-Based Item Construction



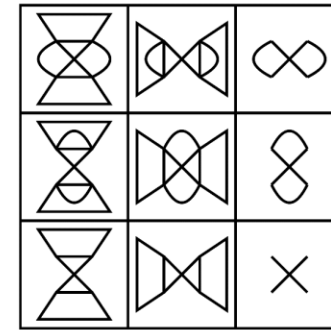
Identity



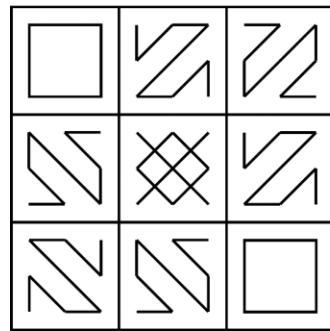
Addition



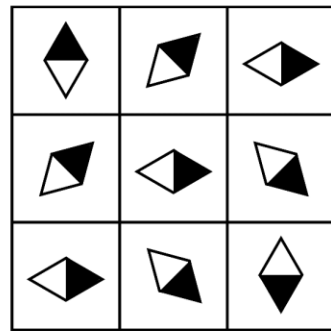
Subtraction



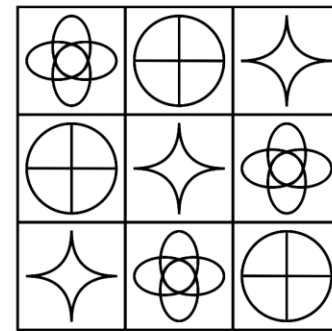
Intersection



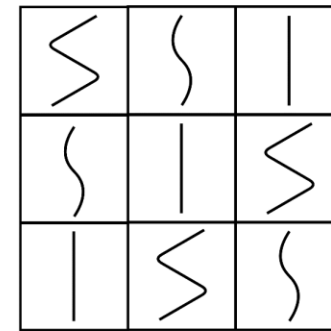
XOR



Orientation Progression

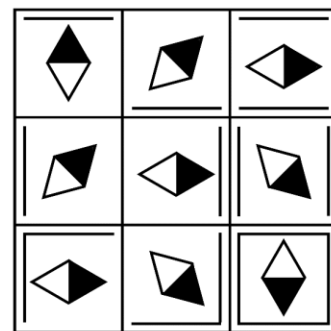


Closed Shape Variation

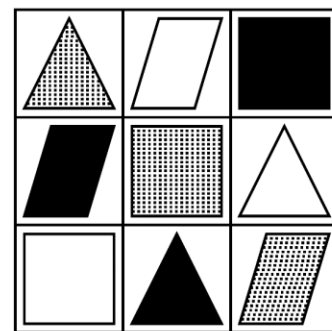


Open Shape Variation

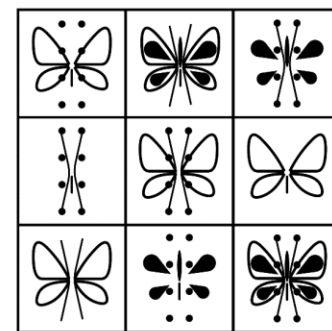
**Variation Rule  
Examples**



Separation



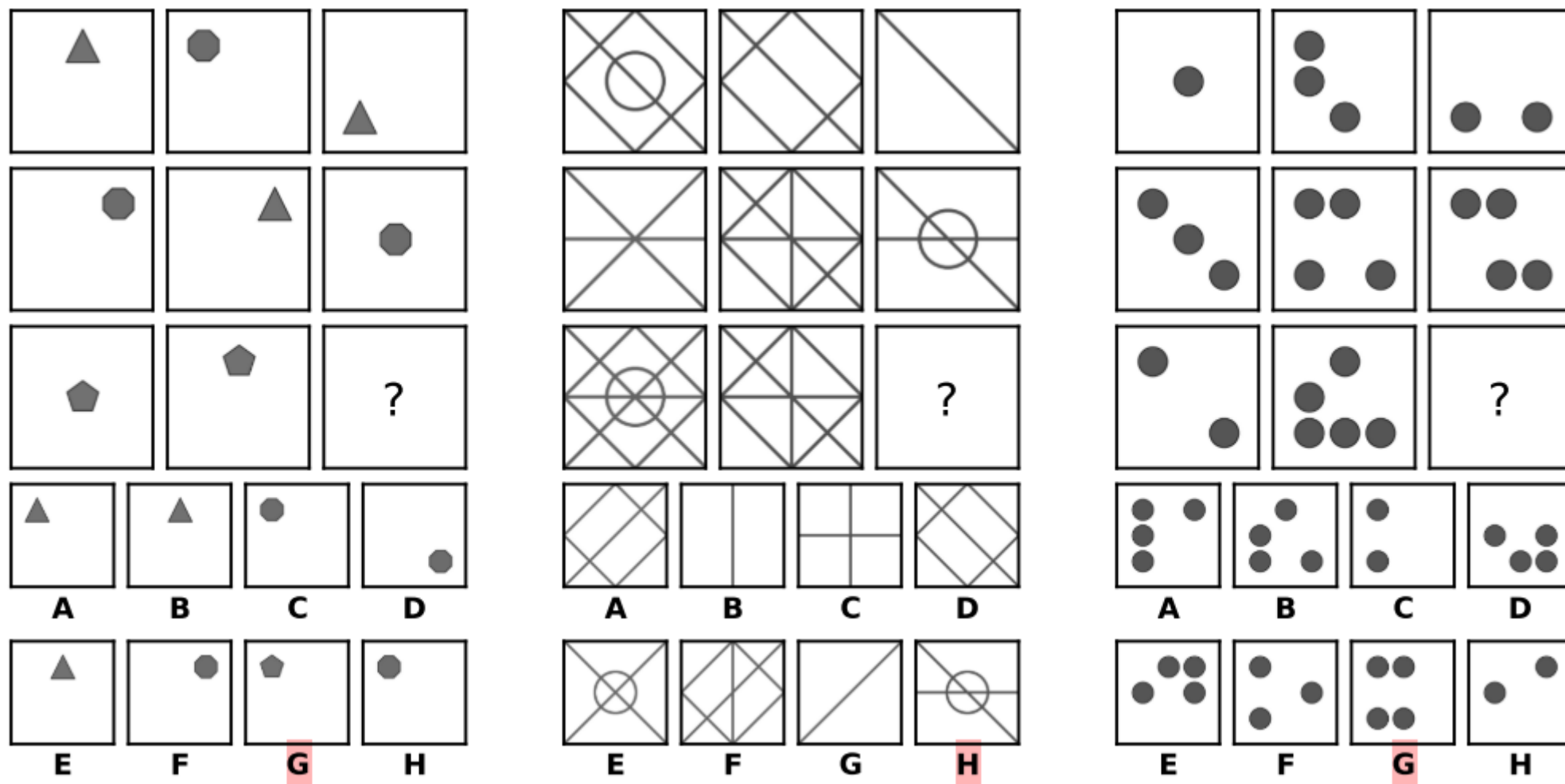
Integration



Embedding

**Perception Org.  
Examples**

# AIG of FAP For Data-Driven AI Models

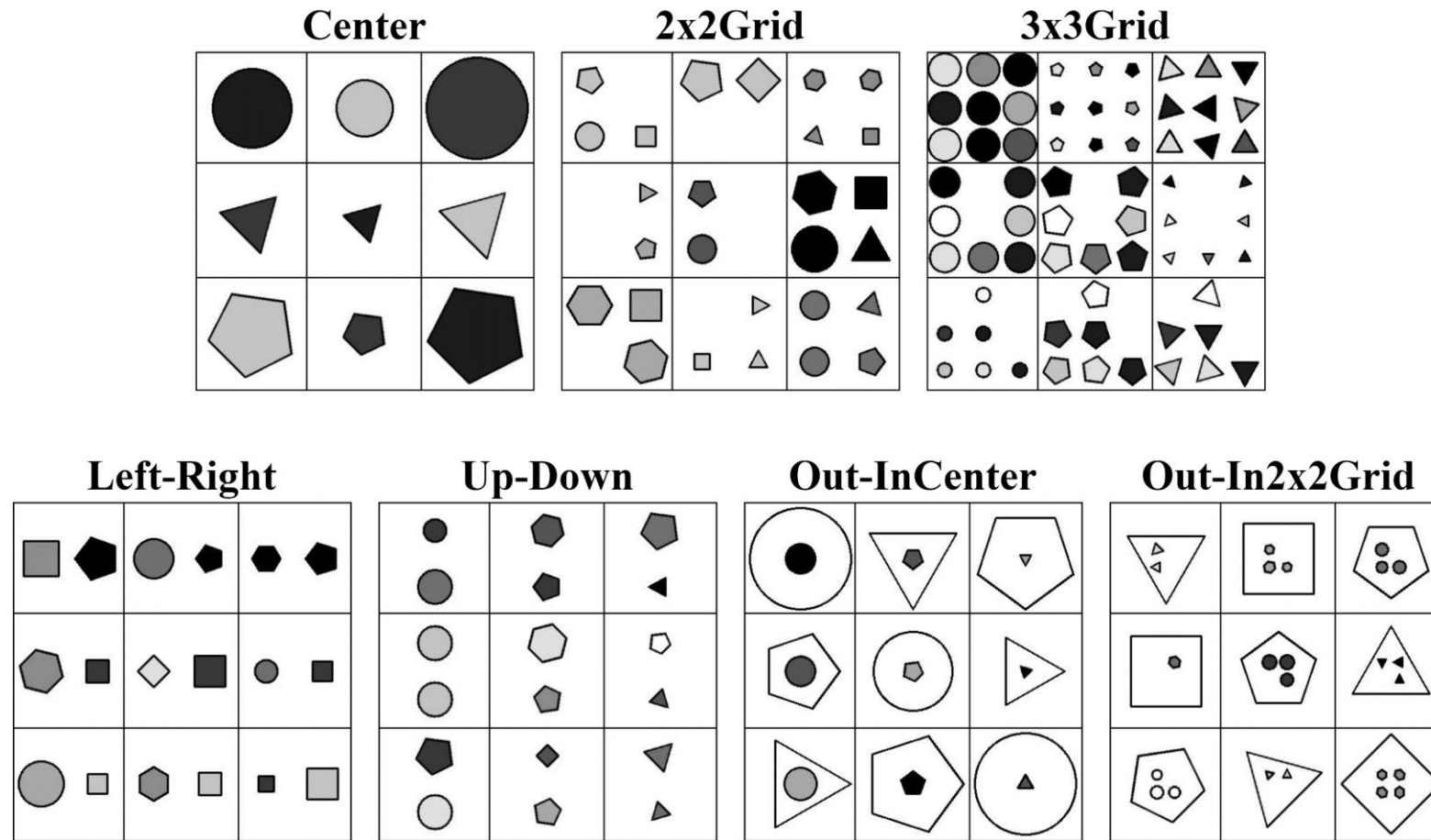


- 1.2M items for training
- 20K items for validation
- 200K items for testing

Procedurally Generated Matrices  
(PGM)



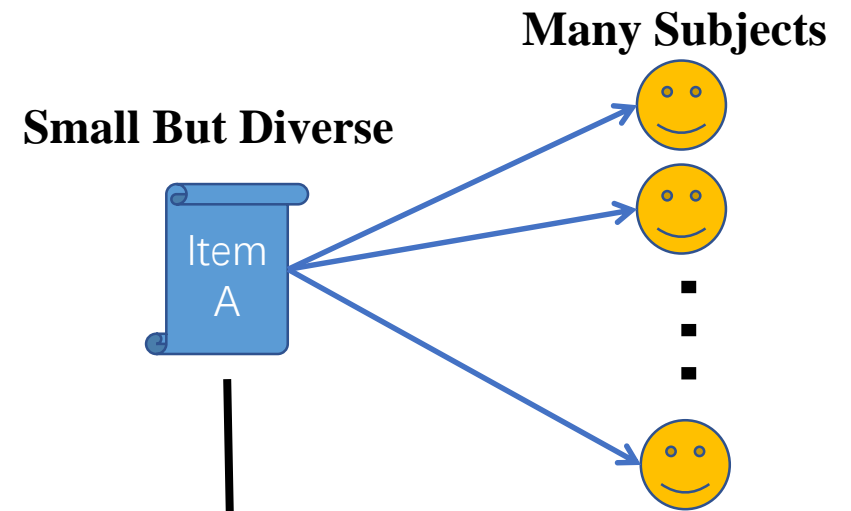
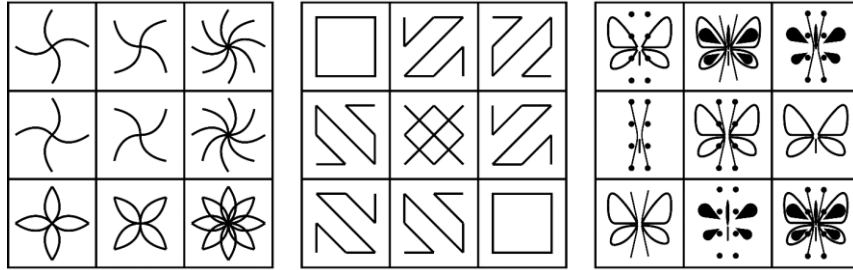
# AIG of FAP For AI Models



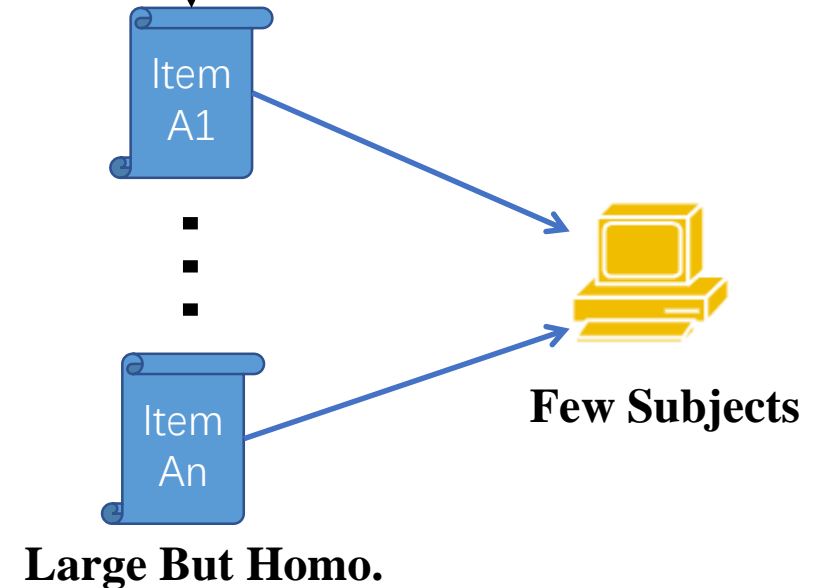
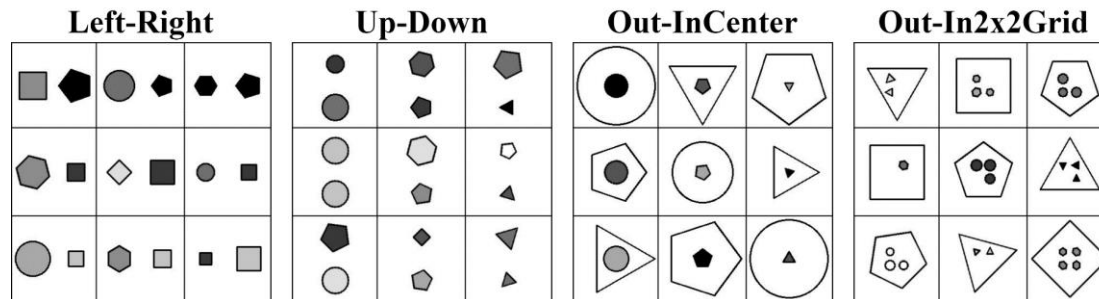
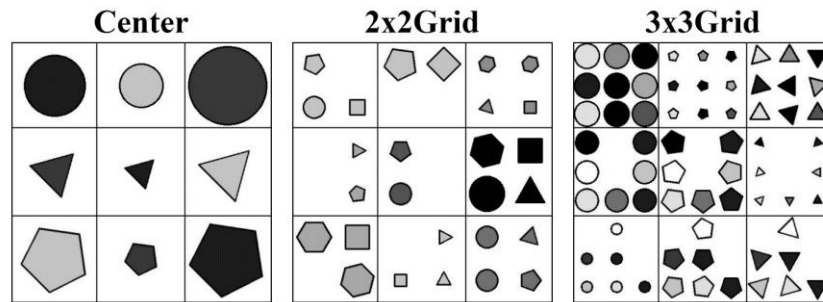
➤ 70,000 items << PGM

## Relational and Analogical Visual Reasoning (RAVEN)

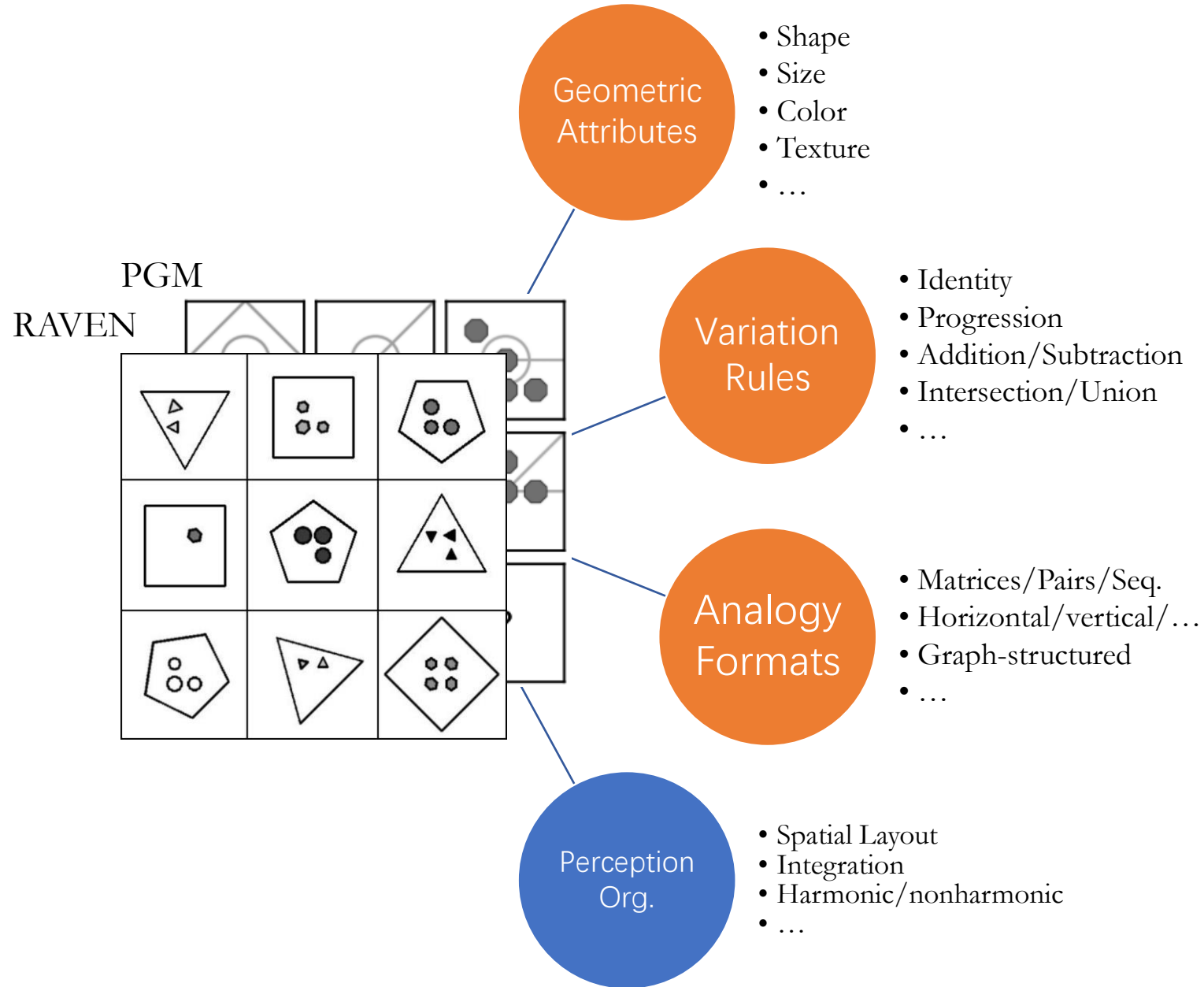
# Contextual Comparison



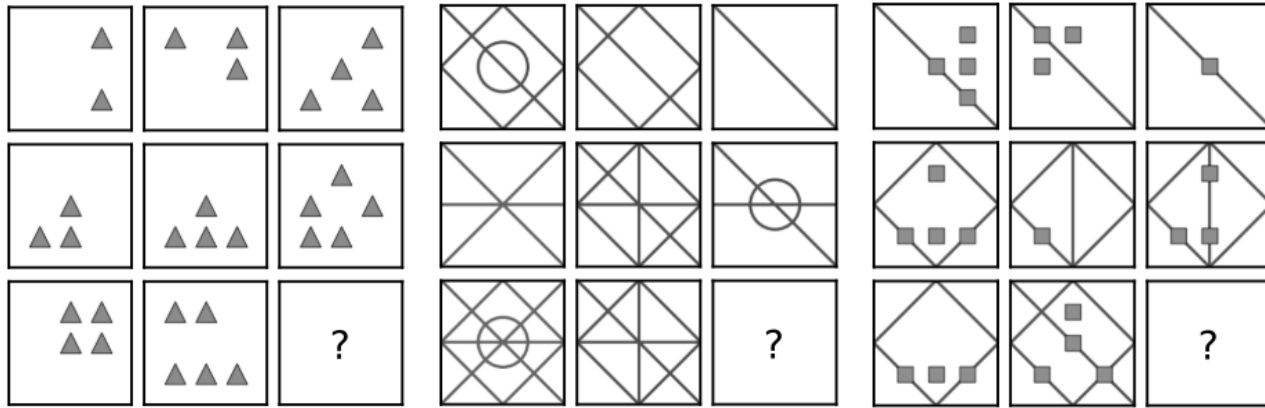
AIG



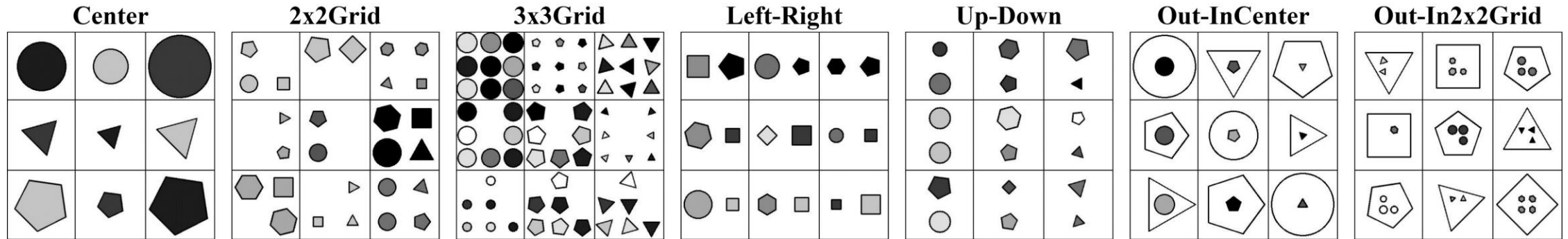
# Item Generation of PGM and RAVEN



# Perception Organization



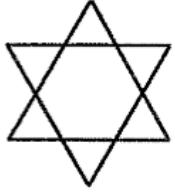
- PGN: 3 hardcoded layouts
- RAVEN: 7 hardcoded layouts



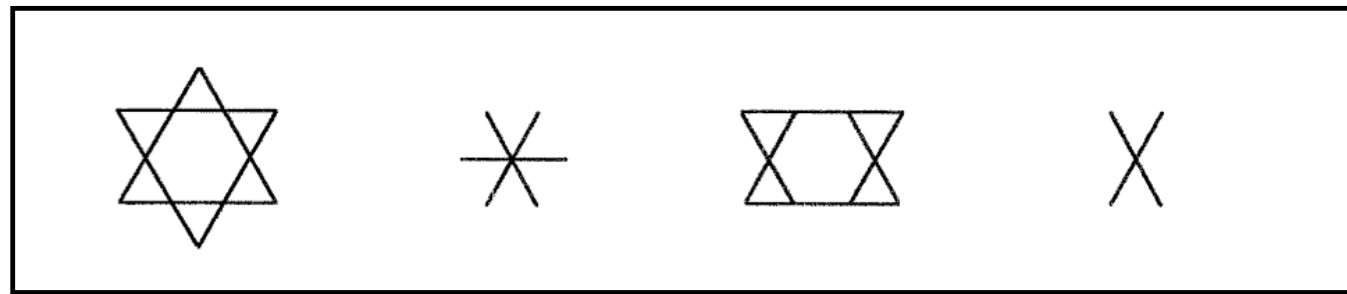
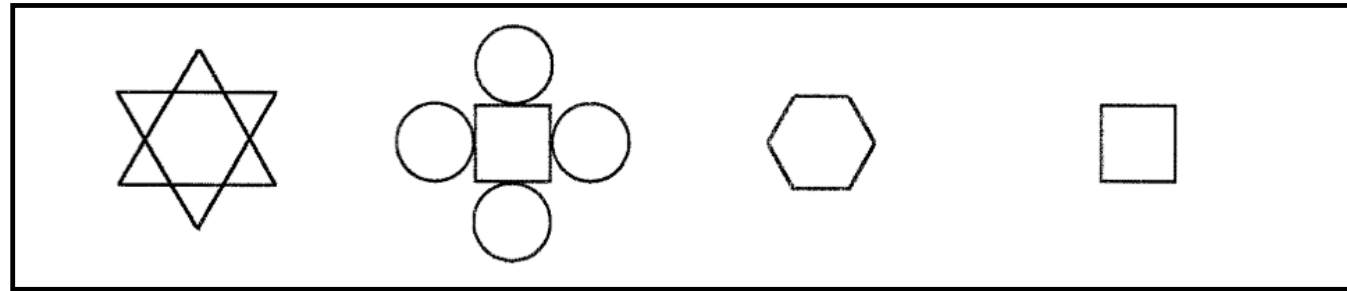
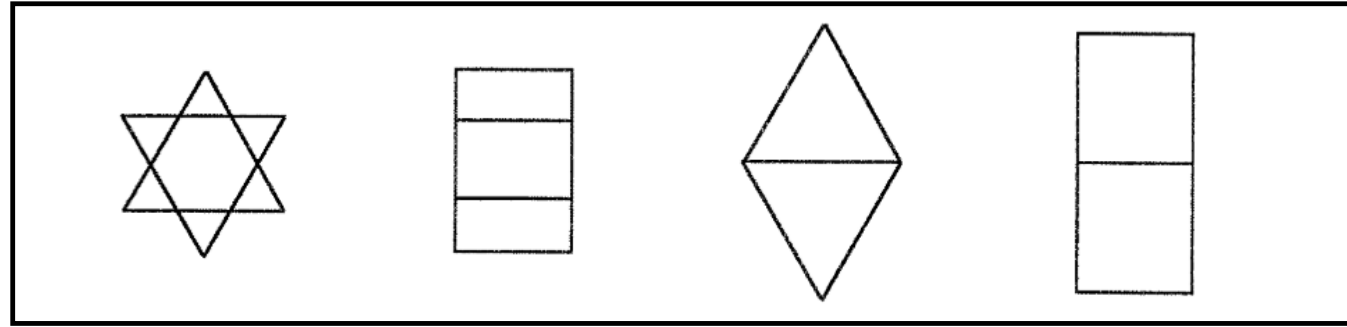
Perception Organization is hard to predefine:

- Integration
- Gestalt grouping/mapping
- dependency on other factors and the context

# Perception Organization



# Perception Organization

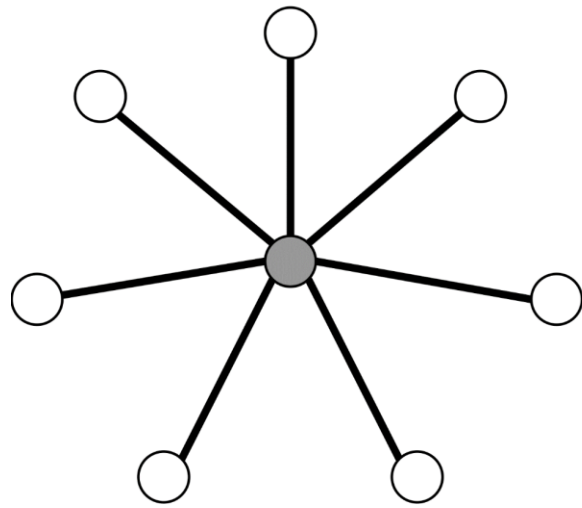


**A**    **:**    **B**    **::**    **C**    **:**    **D**

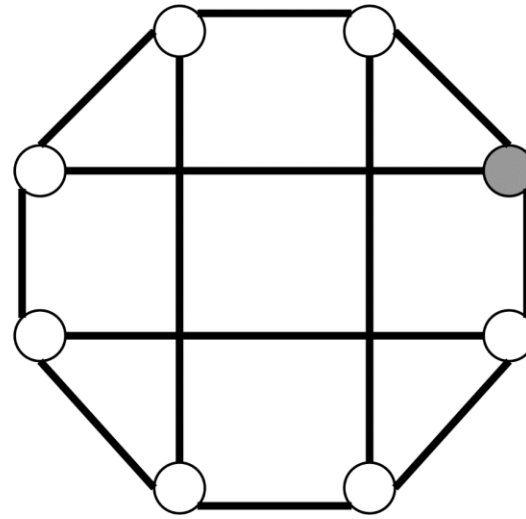
Analogy: A is to B as C is to D

# Other issues in AIG of FAP For AI Models

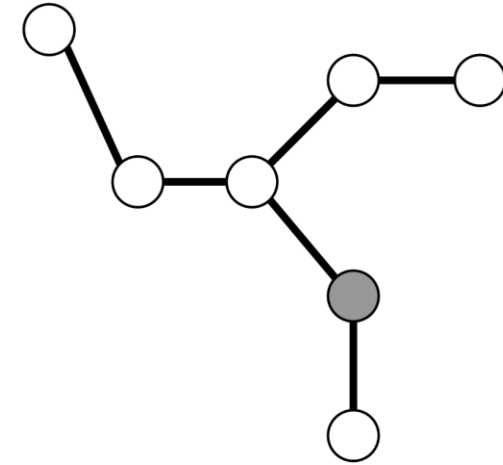
- learning analogies versus learning irrelevant statistical regularities. (Hu et al., 2021; Benny et al., 2021)



**Star**  
**(RAVEN)**



**3-Regular**  
**(IMPARTIAL-RAVEN)**



**Tree**  
**(RAVEN-FAIR)**

# Other issues in AIG of FAP For AI Models

- learning analogies versus learning irrelevant statistical regularities. (Hu et al., 2021; Benny et al., 2021)
- “Universal Psychometrics” (Hernandez-Orallo et al., 2014)
  - despite solving the same type of problems, hard to compare human subjects and Data-Driven AI models.
  - Human subjects did well on human tests but failed “machine” tests.
  - “Machine” did well on “machine” tests but failed human tests.



Q&A

Thank you for your time!