Visual Imagination: A View from Artificial Intelligence

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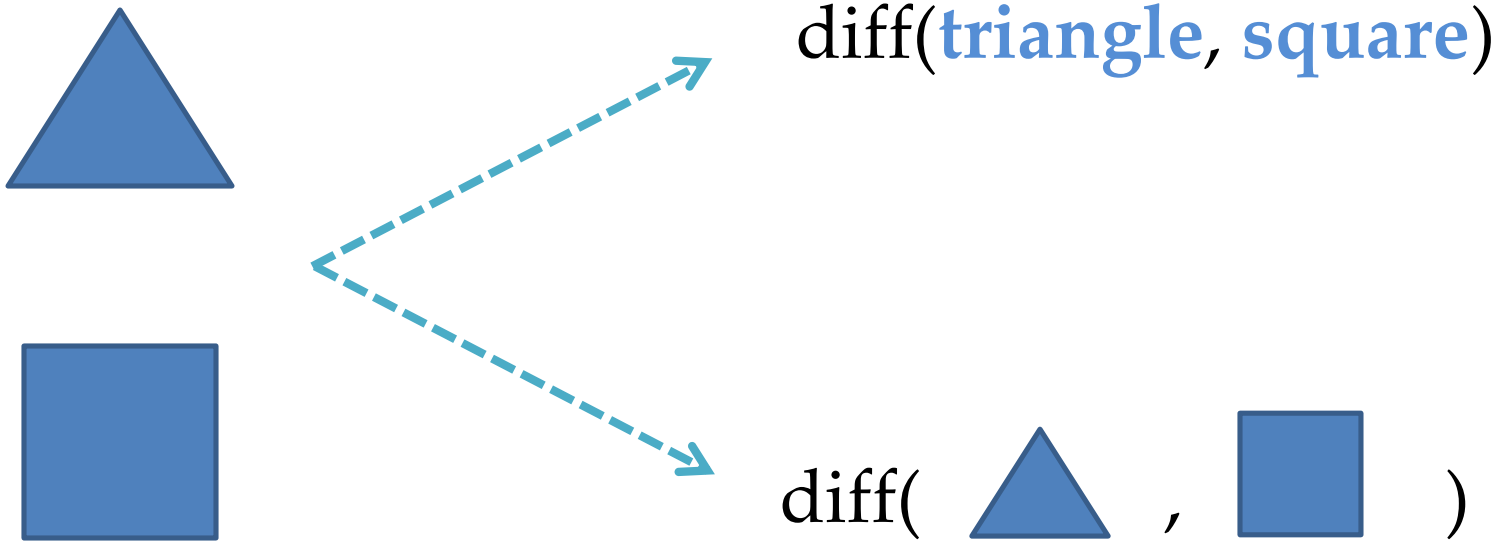
Research Vision

I develop **computational models of visual thinking** to create:

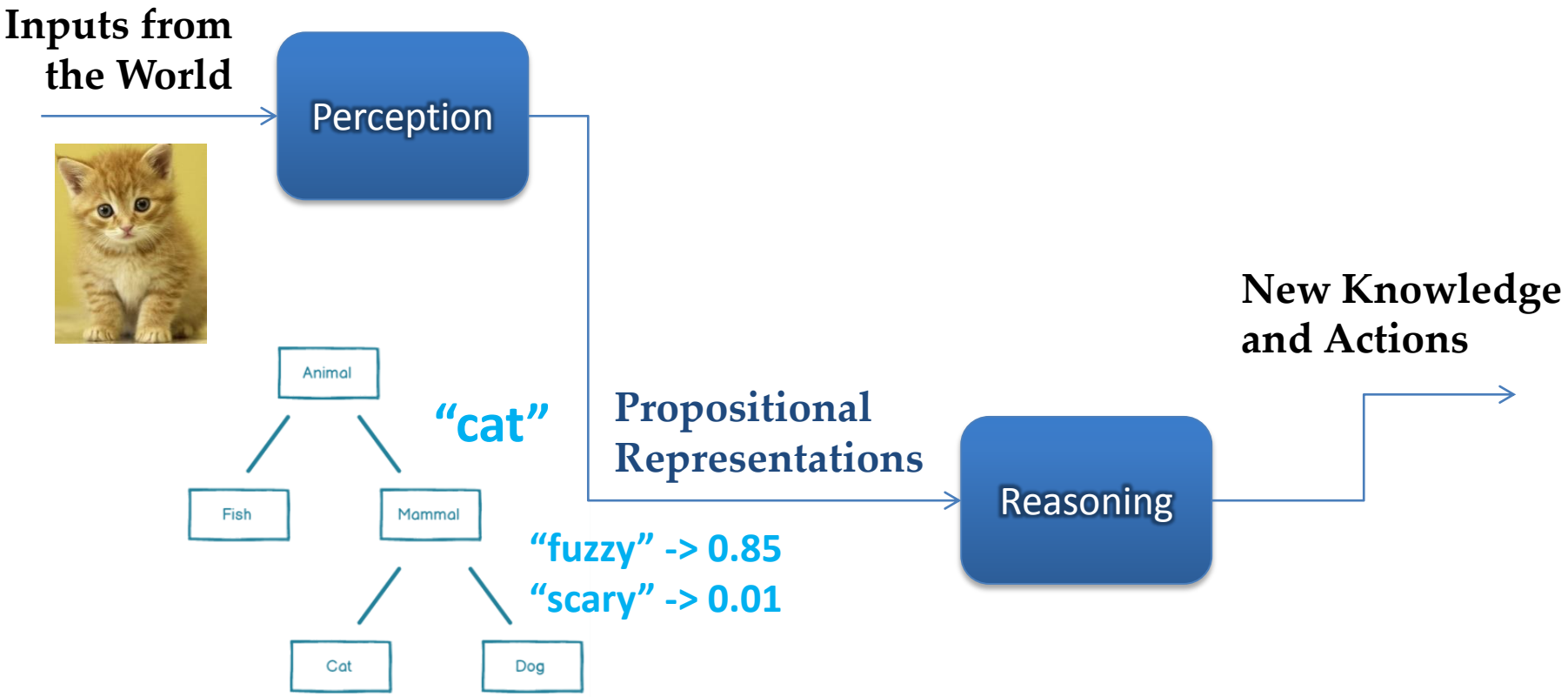
1. New AI techniques for reasoning about information
2. New interactive technologies that leverage human visual thinking

Reasoning with Visual Representations

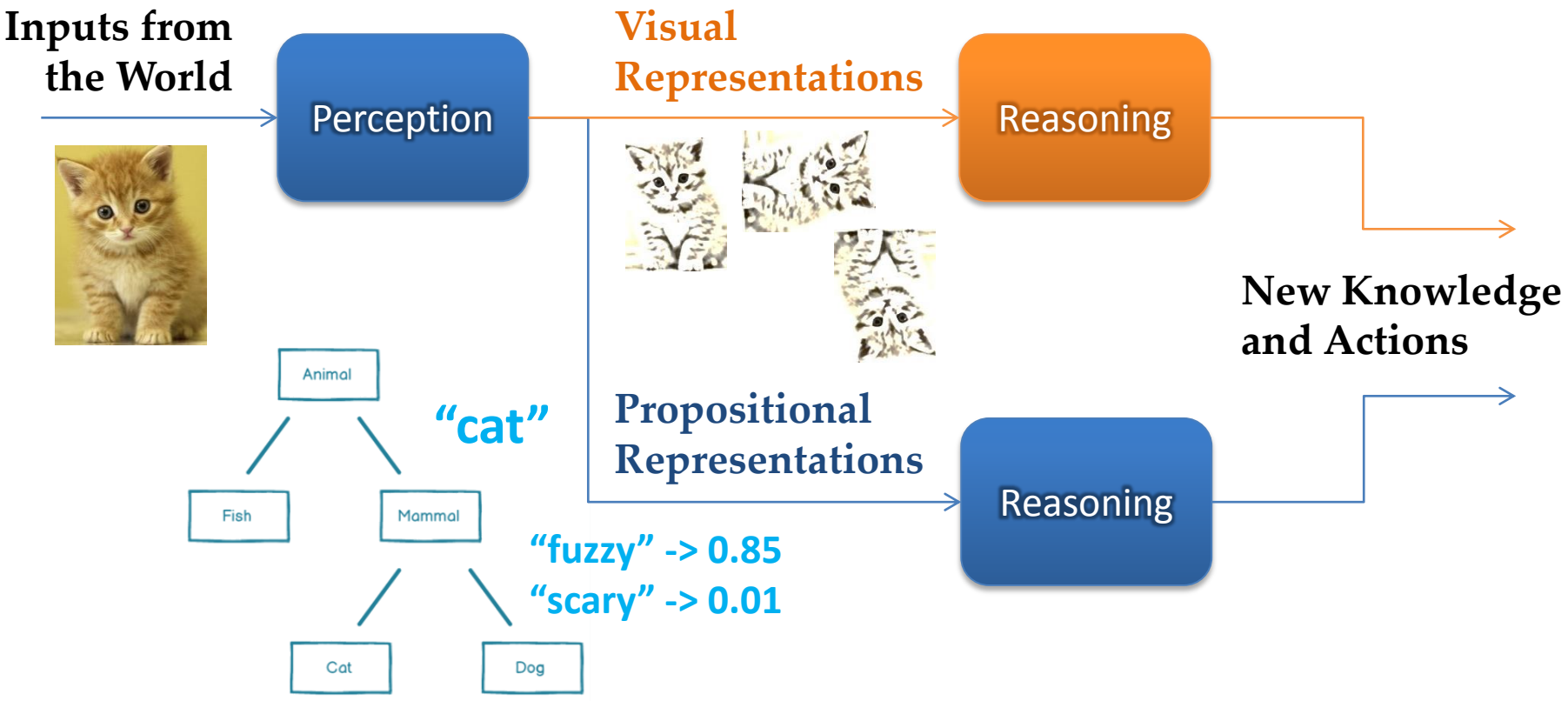
NOT the same as "reasoning about visual things"



The Propositional Thinking Pipeline



Better: A Dual Process Pipeline



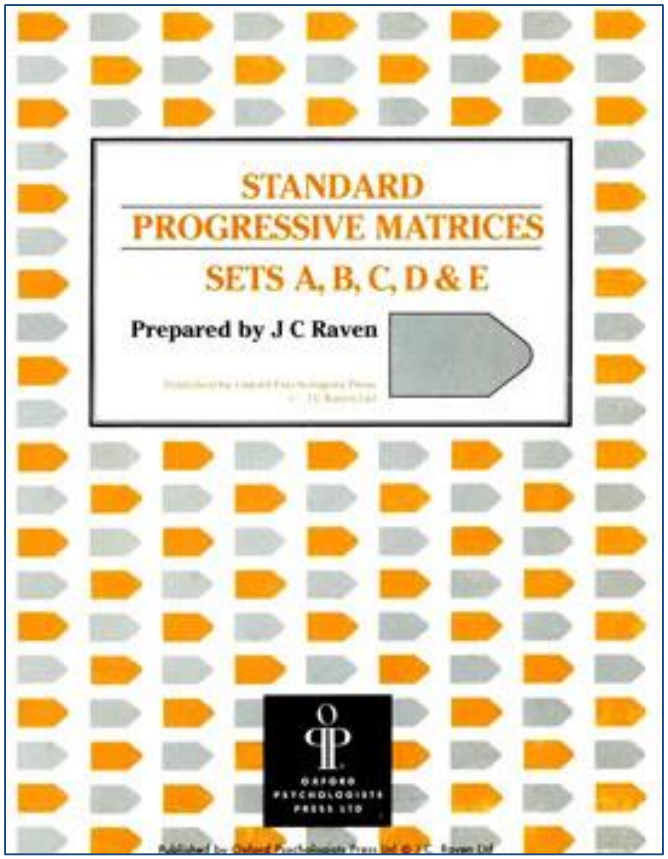
Representational Primitives

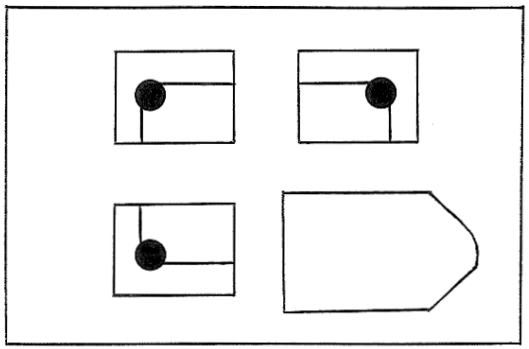
1. **Set S of visual elements with relations isomorphic to the 2D plane**
   - **Excludes diagrammatic representations with verbal labels**
   - **Excludes propositional representations**
   - **Includes pixels as well as non-rectilinear point arrangements**

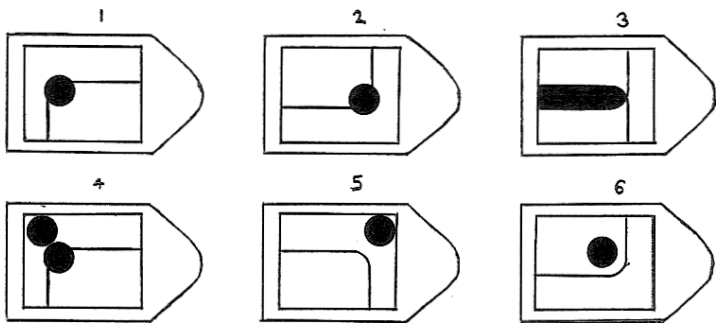
2. **Functionally complete combination operations**
   - **E.g. {intersection, complement}**

3. **Geometric operations**
   - **Translations**
   - **Affine transformations**
   - **Other shape deformations**
   - **Colorimetric transformations**

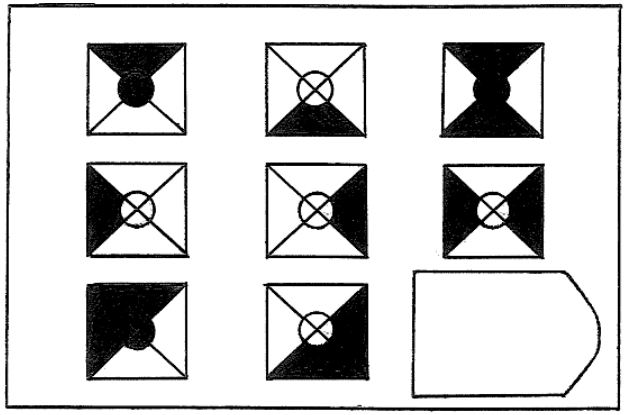
Raven's Progressive Matrices

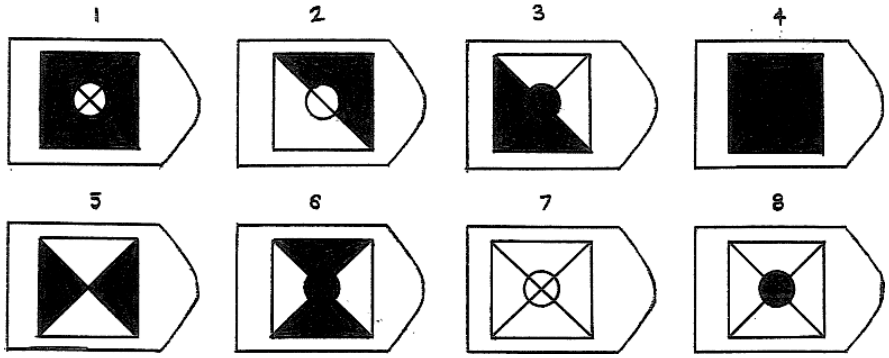




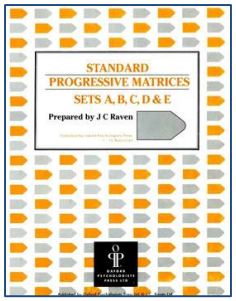


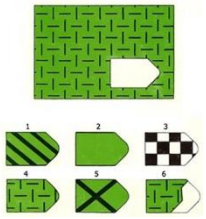
Raven's Progressive Matrices





Conventional Wisdom





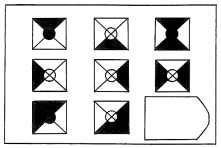
Easy problems

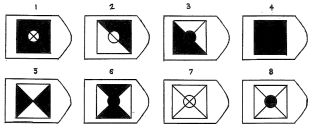
Perception

Visual Representations

Reasoning

New Knowledge and Actions



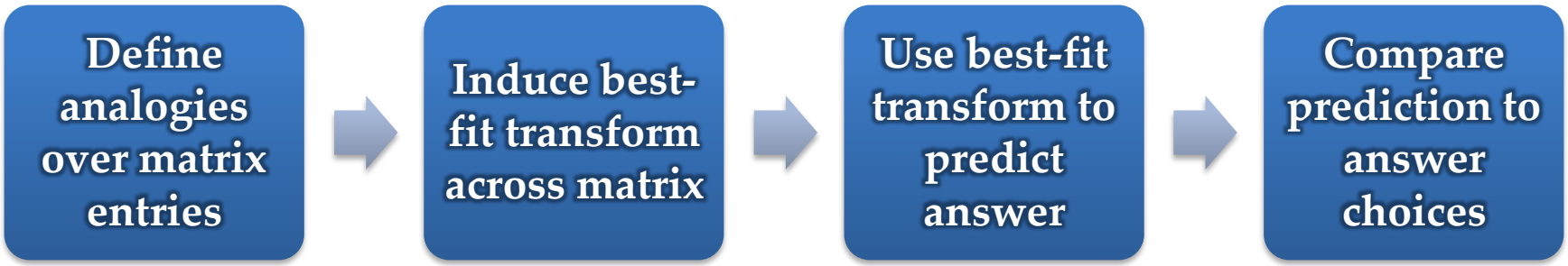


Propositional Representations

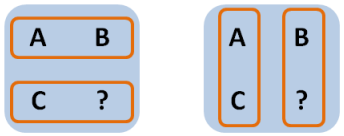
Reasoning

Hard problems

ASTI Reasoning Framework



1. Image Analogies in Matrix



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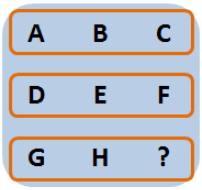

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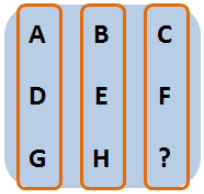

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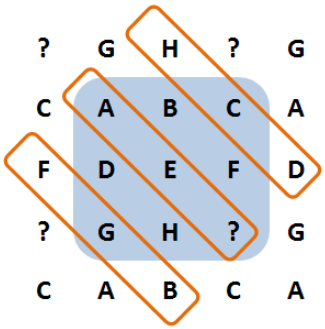
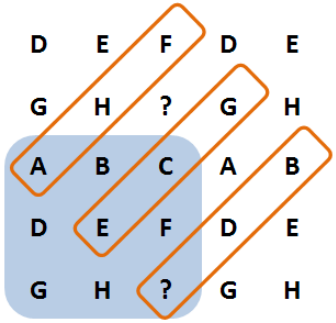


diagonals



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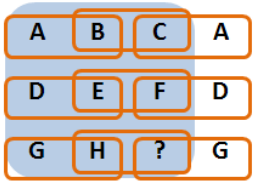

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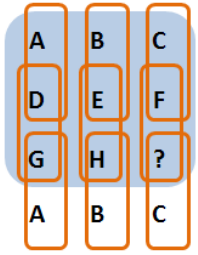

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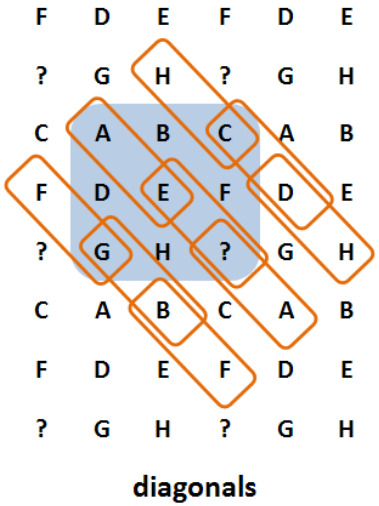
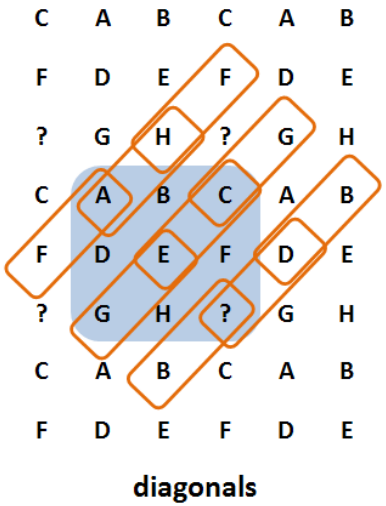


diagonals



diagonals

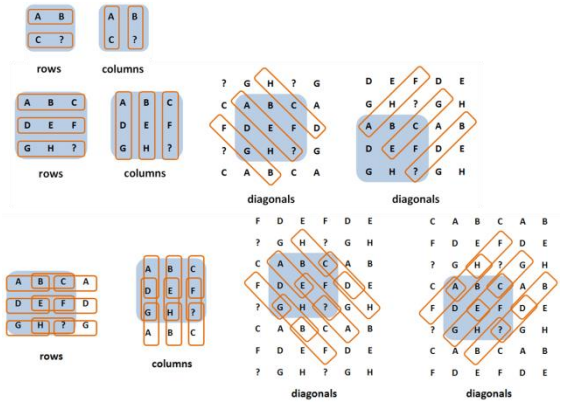
ASTI Reasoning Framework

Define analogies over matrix entries

Induce best-fit transform across matrix

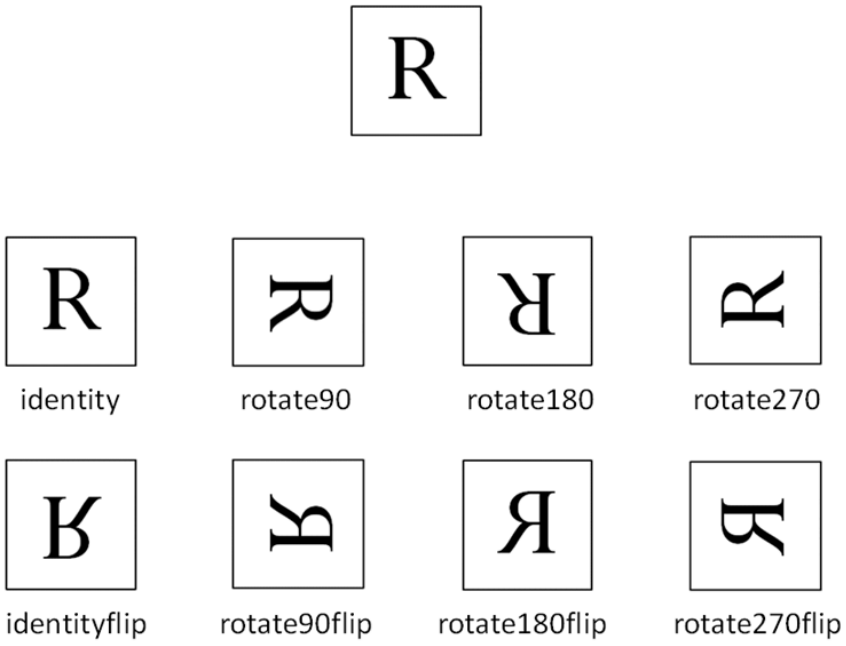
Use best-fit transform to predict answer

Compare prediction to answer choices

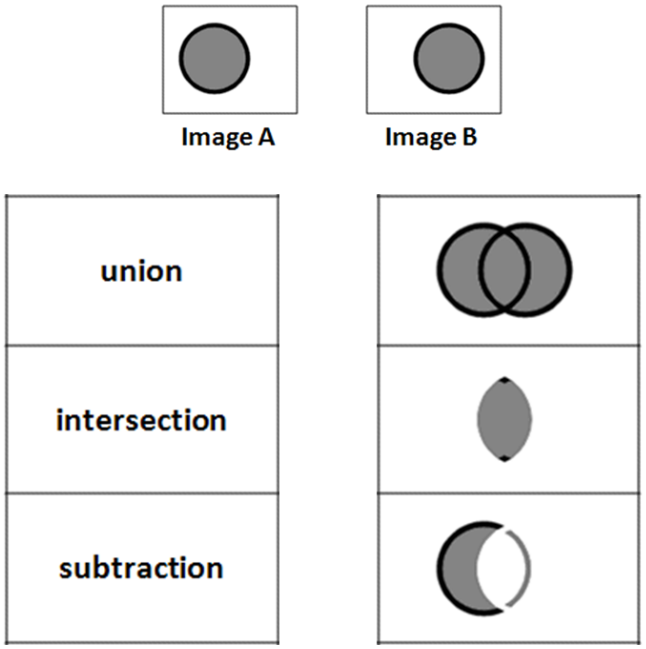


Visual Reasoning Primitives

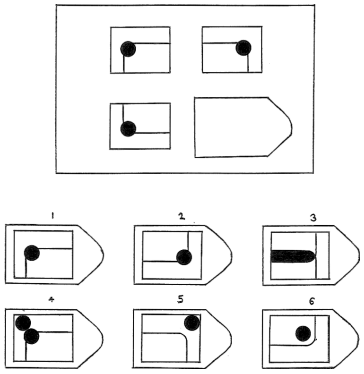
Rectilinear rotation/reflection



Pairwise composition



2. Transformation Induction



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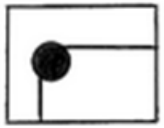
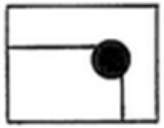
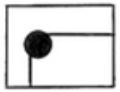
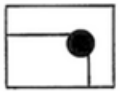
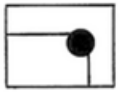
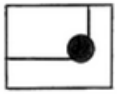
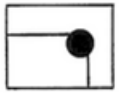
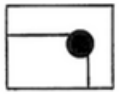
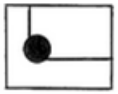
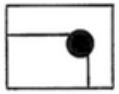
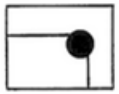
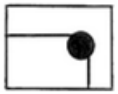
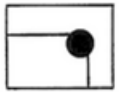
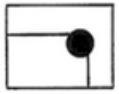
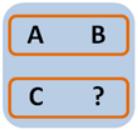
first row:  to 	identity			0.334
	rotate90			0.292
	rotate180			0.536
	rotate270			0.262
	identity-flip			0.318
	rotate90-flip			0.253
	rotate180-flip			0.697
	rotate270-flip			0.259

ASTI Reasoning Framework

Define analogies over matrix entries → **Induce best-fit transform across matrix** → **Use best-fit transform to predict answer** → **Compare prediction to answer choices**



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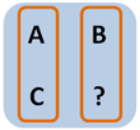

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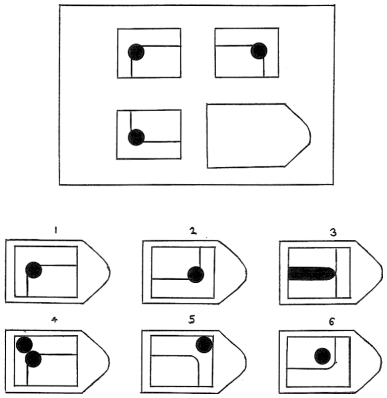
	rotate180			0.536
	rotate270			0.262
	identity-flip			0.318
	rotate90-flip			0.253
	rotate180-flip			0.697
	rotate270-flip			0.259

3. Candidate Prediction

Use best-fit transform and analogy to predict answer:

$$m_{predict} = t_{max}(a_{max}[c_{target}])$$



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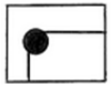
first row:  to 	identity			0.334
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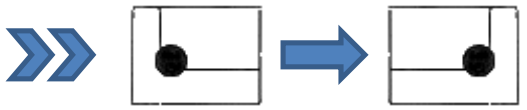

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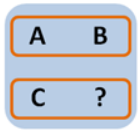

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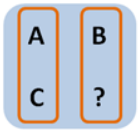

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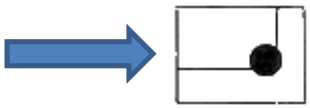
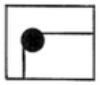
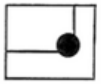
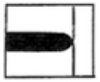
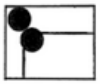
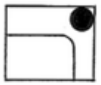
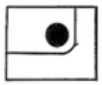


4. Answer Selection

Select most similar answer choice:

predicted answer image	answer choice images	s
		0.257
		0.503
		0.256
		0.211
		0.265
		0.277

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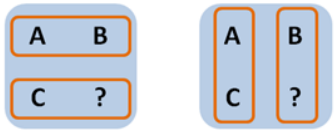
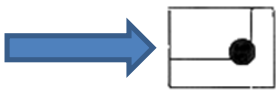
Define analogies over matrix entries → **Induce best-fit transform across matrix** → **Use best-fit transform to predict answer** → **Compare prediction to answer choices**



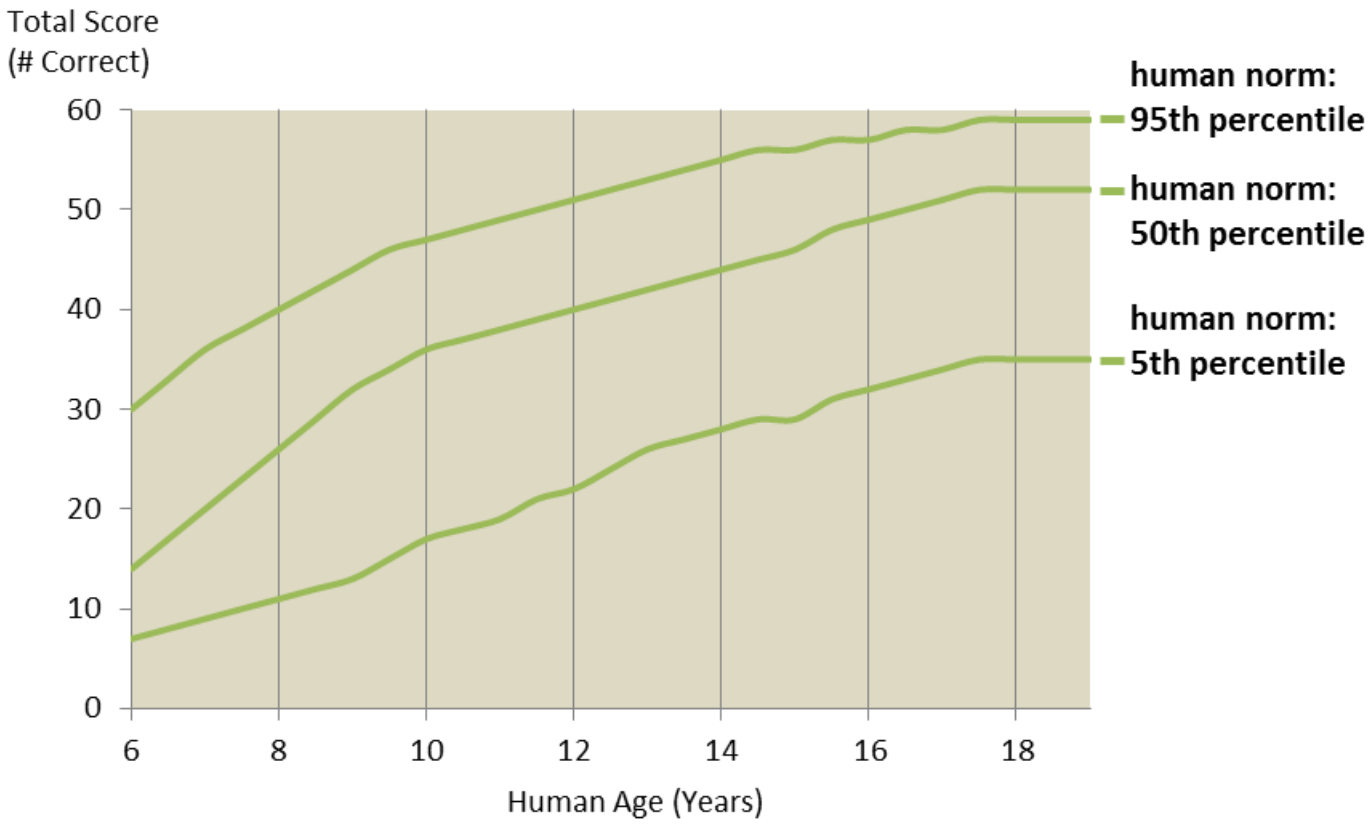
rows columns

original images	base transform	first image transformed	second image	s
first row: / to	identity			0.334
	rotate90			0.292
	rotate180			0.536
	rotate270			0.262
	identity-flip			0.318
	rotate90-flip			0.253
	rotate180-flip			0.697
	rotate270-flip			0.259

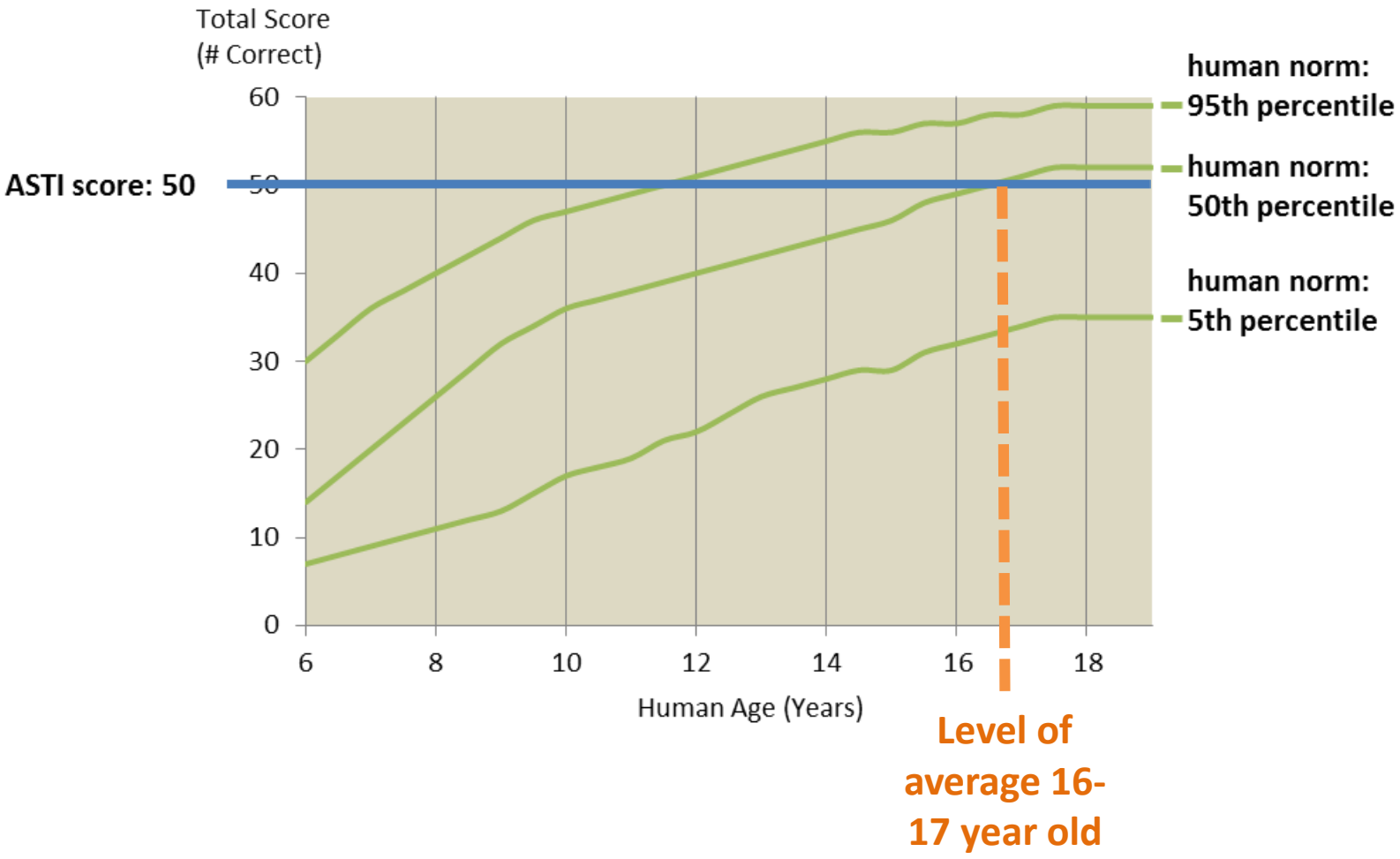


predicted answer image	answer choice images	s
		0.257
		0.503
		0.256
		0.211
		0.265
		0.277

Human Norms on SPM



ASTI Results



Learning about Representational Modality

Knowledge-Based AI : 2010 - present

- Solve Raven's problems using propositional representations
- Solve Raven's problems using visual representations

Ashok Goel

David Joyner

- Over 650 students (undergrad and grad)
- Currently used in KBAI courses as part of GT's OMS-CS program
  - Around 200 students per semester

Neuro-diverse

A Symposium on Autism, Neuroscience, & Perceptual Thinking

Monday, May 23, 2016

Main program (MRB-III 1220) **9:00 am-12:30 pm**
Evening lecture (Sarratt Student Center Cinema) **6:00 pm-7:00 pm**

Free and open to the public - No registration required

Keynote Speakers

Isabelle Soulières | 9:15 am-10:15 am, MRB-III 1220
Psychology Department, University of Quebec in Montreal
Center of Excellence in ASD, University of Montreal
"Autism: From Visuospatial Expertise to Reasoning"

Stephen Shore | 6:00 pm-7:00 pm, Sarratt Cinema
Ruth S. Ammon School of Education, Adelphi University
"Success with Autism: Using our Strengths for Achieving a Fulfilling and Productive Life – Just like Everyone Else"

Additional Speakers

Keivan Stassun, *Department of Physics and Astronomy, Vanderbilt University*
Introduction and Welcome

Frank Tong, *Department of Psychology, Vanderbilt University*
Mechanisms Underlying Imagery and Visual Working Memory

Maithilee Kunda, *Dept. of Electrical Engineering and Computer Science, Vanderbilt University*
Visual Thinking: A View from Artificial Intelligence

Mark Wallace, *Vanderbilt Brain Institute*
The Sensory World and Autism

Rajesh Kana, *Department of Psychology, University of Alabama at Birmingham*
The Impact of Visualizing Reading Intervention on Brain Connectivity in Autism

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Vanderbilt Brain Institute

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VANDERBILT School of Engineering