School of Rocks

Subtyping Enhances Superordinate-Level Learning of Dispersed Category Structures

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Background

- Categories exist at various levels of abstraction
  - e.g. Furniture is a more abstract category than chairs
  - We would say that chairs are a sub-type of furniture
  - We would say that furniture is a superordinate category of chairs
  - More well defined: Scientific Taxonomies
- We still know little about learning functions in such domains

Research Question

- If you want to learn categories at the superordinate level, is easier to learn the superordinate categories alone or should one attempt to simultaneously learn at the subtype level as well?
- Intuitively, learning just the high level categories seams easier
- Suspected there are types of category structure in which this is not always true

Presentation Outline

- Learning involving multiple levels of abstraction
- Geological Taxonomy
- Compactness of Category Structures
- Methods
- Results
- Discussion and Future Work

Previous Findings

Lassaline, Wisniewski, and Medin (1992)

- Used category verification task to see whether level advantages could be obtained in situations where categories lack defining features
- Found that one level or another may be easier to learn even in cases involving fuzzy categories
- Which level is easier to learn may be sensitive to how diagnostic features are distributed across dimensions

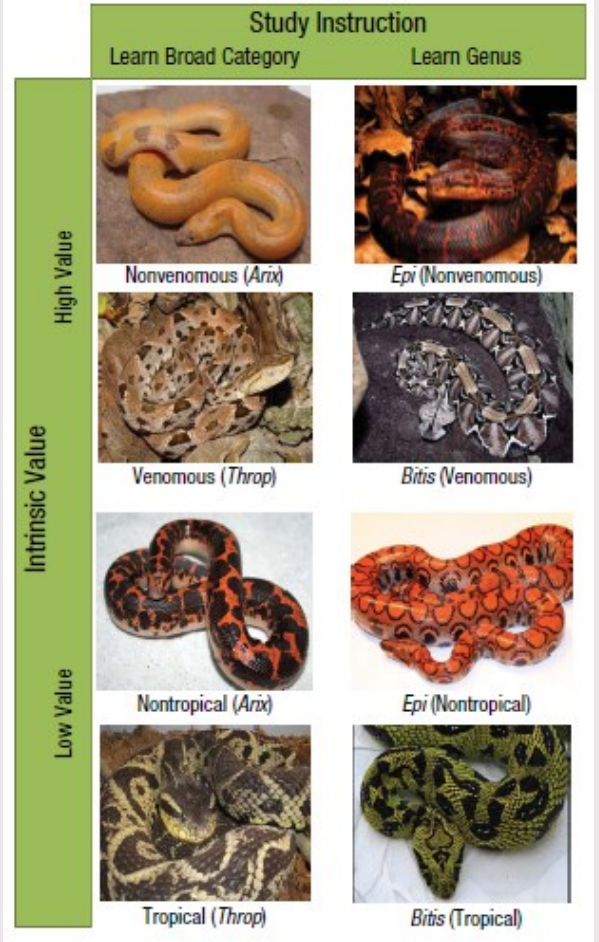
Palmeri (1999)

- Replicated findings under category learning paradigm
- Marked successful attempt to model effects across multiple levels

Previous Findings (Cont.)

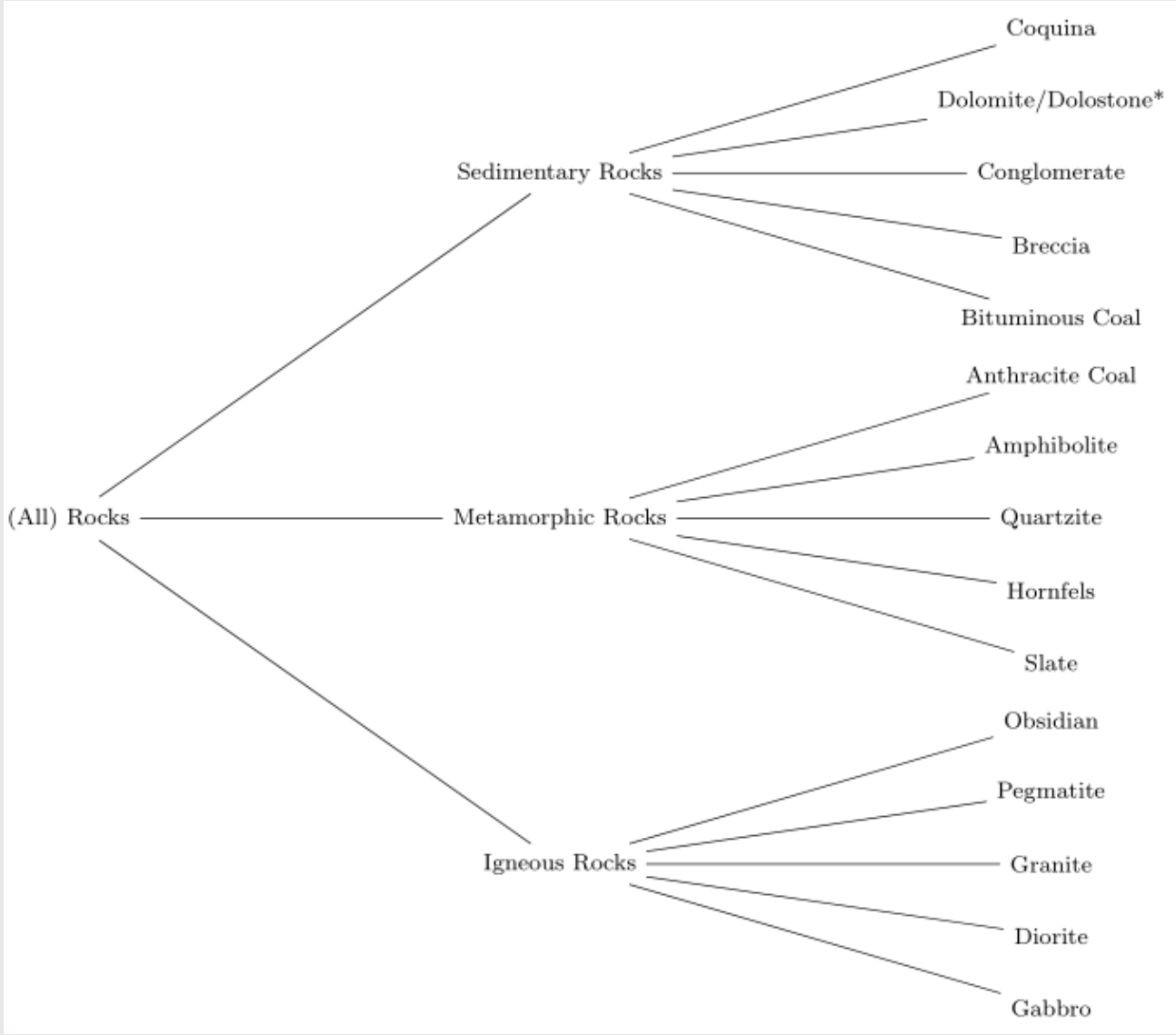
Noh, Yan, Vendetti, Castel, and Bjork (2014)

- Looked at the interactions between attended level, intrinsic value, and ability to learn categories at two levels of specificity
- Design
  - Subjects shown a label with genus of the snake and a high or low value label
  - Instructed to learn either general or specific level labels and tested on both levels
- Findings
  1. Subjects performed better on the level they were instructed to attend to
  2. Specific level performance better for subjects who were instructed to learn at that level if they saw low value labels
  3. High level performance better for subjects who were shown high value labels



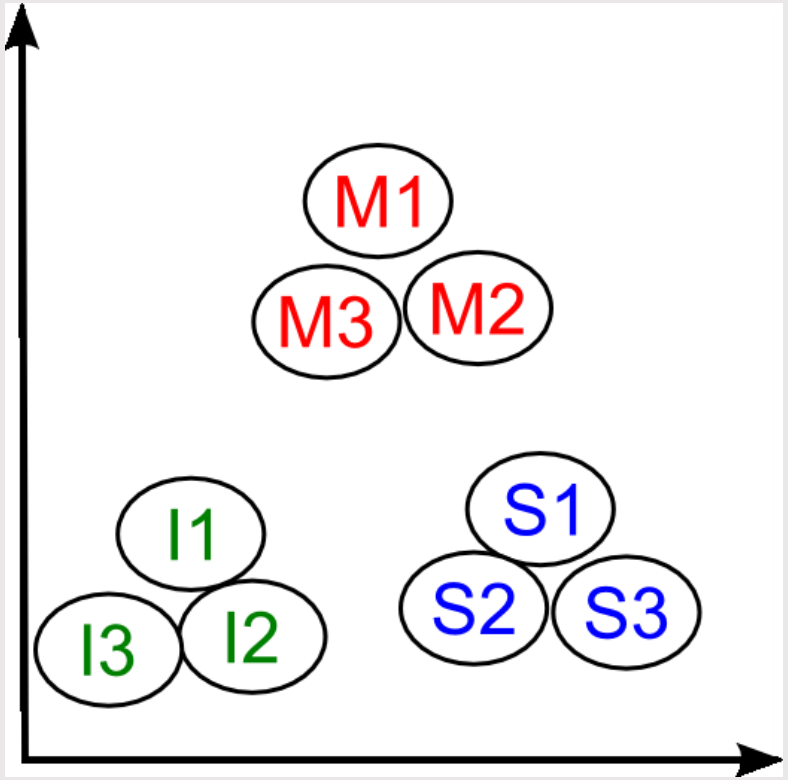
Geological Taxonomy

- 3 primary categories based on mode of formation
- Many subtypes with more nuanced classification schemes

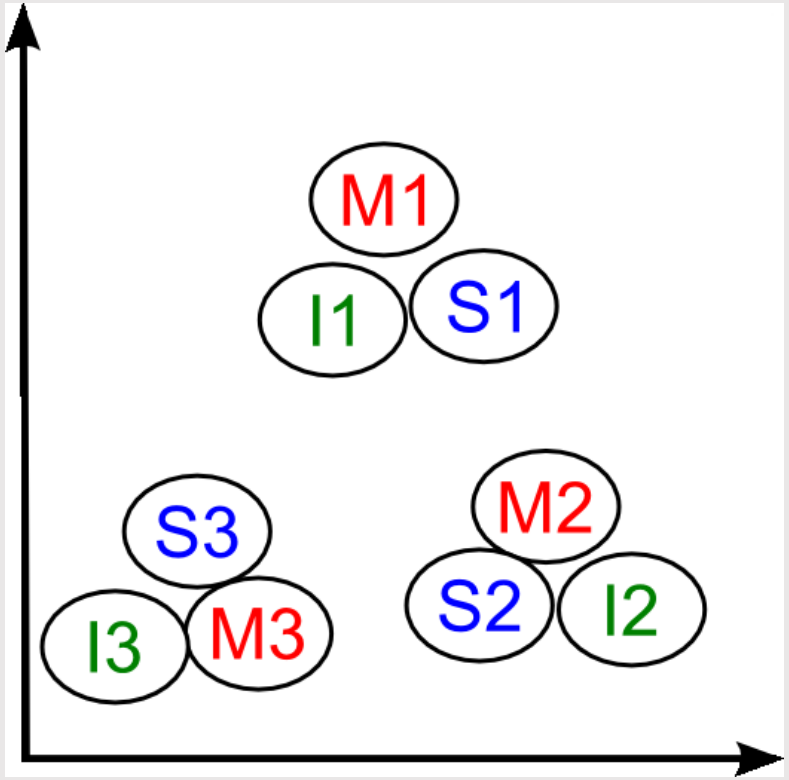


Compactness of category structures

Compact Structure

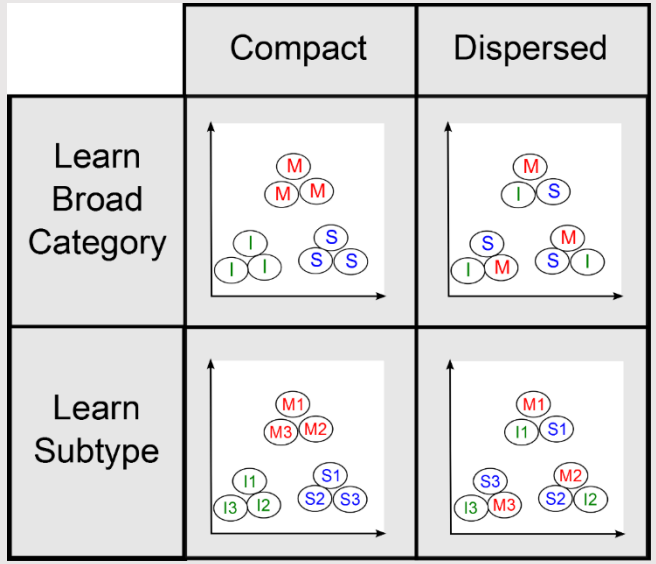


Dispersed Structure



Methods: Experimental Design

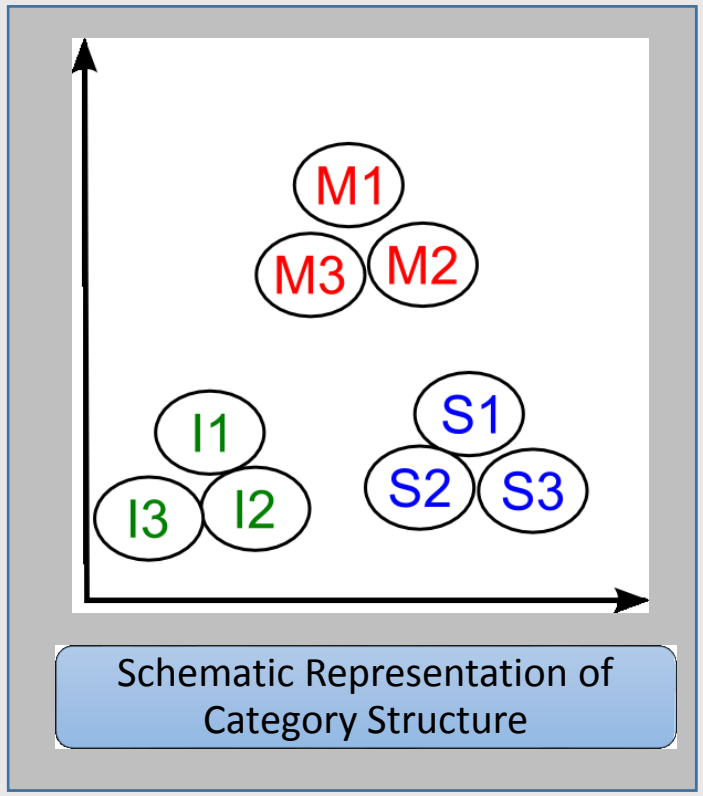
- **Supervised Category Learning Experiment**
  - Shown images of rocks and asked to provide the category
- **4 Blocks**
  - 3 Training Blocks (Feedback Given)
  - 1 Transfer Block (No Feedback, Additional Stimuli)
- **Manipulations**
  - **Stimuli Set** (Between Group)
    - Half of participants received compact stimuli set
    - Half of participants received dispersed stimuli set
  - **Learned Level** (Between Group)
    - Half of participants learn super ordinate categories (Ign., Sed., Meta.)
    - Half of participants learn subtypes (I1, I2, I3, M4, M5, M6, S7, S8, S9)
  - **When stimuli were presented** (Within Group)
    - Half of stimuli presented in Training and Transfer Blocks
    - Half of stimuli presented only in Transfer



Stimulus Sets

- 2 Stimulus Sets
  - 9 subtypes (6 images/subtype)
- Set Construction
  - Assembled a list of candidate subtypes for each of the 3 main categories
  - Collected images from various online geology databases
  - Selected to fit desired category structure
  - Cleaned images to remove distracting features
- Confirmed Category Structures using MDS Scaling Study

Compact Condition

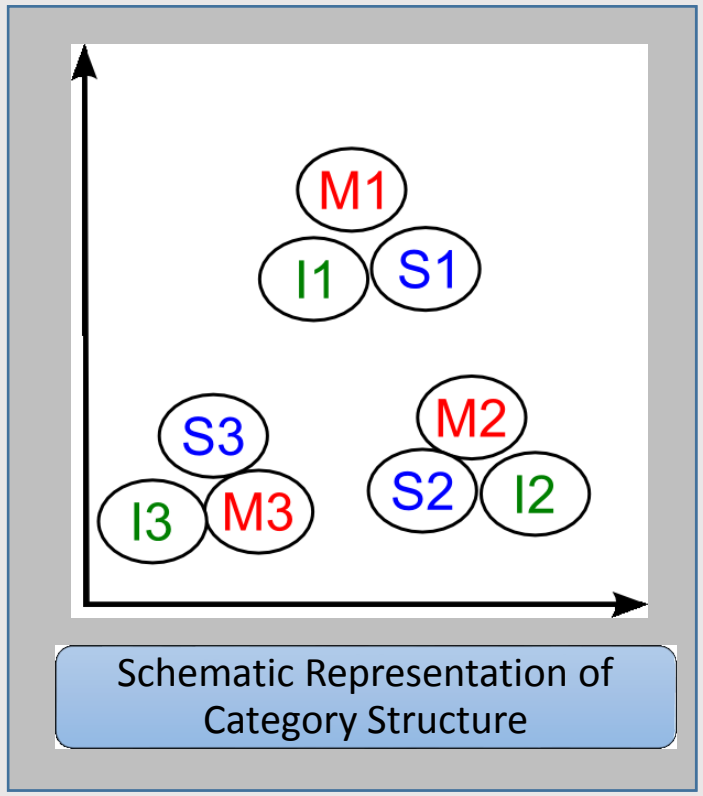


Schematic Representation of Category Structure

Igneous	Metamorphic	Sedimentary
		
		
		

SIMILAR

Dispersed Condition



Schematic Representation of Category Structure

Igneous	Metamorphic	Sedimentary	
			
			
			

Dimensions

Lightness

Average Grainsize

“Sorting”

But was it compact?

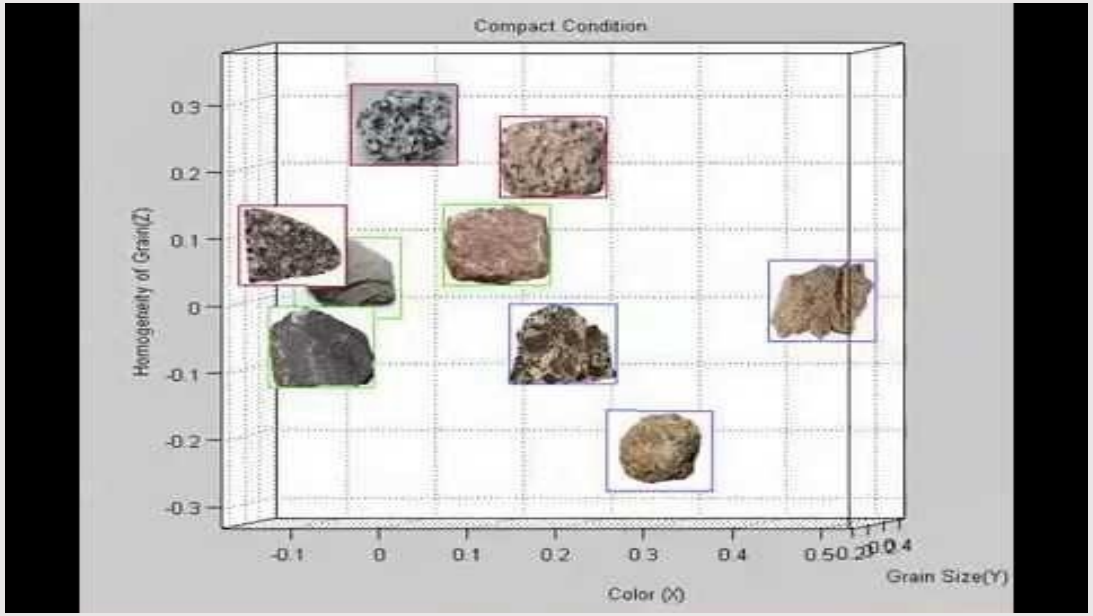
Compact Set

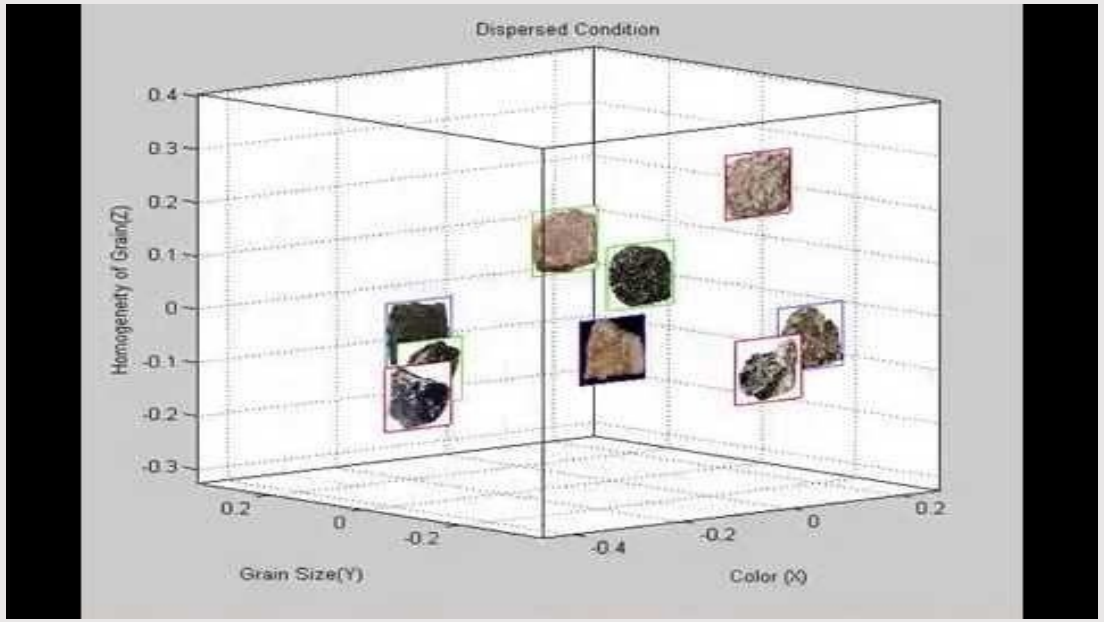
Subtype	I1	I2	I3	M4	M5	M6	S7	S8	S9
Ign.1	0	0.627	0.417	0.798	0.696	0.465	1.045	1.163	0.76
Ign.2	0.627	0	0.343	1.074	0.717	0.896	0.967	0.821	0.626
Ign.3	0.417	0.343	0	0.876	0.657	0.721	1.146	1.054	0.824
Met.4	0.798	1.074	0.876	0	0.462	0.442	1.28	1.205	1.272
Met.5	0.696	0.717	0.657	0.462	0	0.494	0.928	0.758	0.916
Met.6	0.465	0.896	0.721	0.442	0.494	0	1.001	1.112	0.937
Sed.7	1.045	0.967	1.146	1.28	0.928	1.001	0	0.605	0.484
Sed.8	1.163	0.821	1.054	1.205	0.758	1.112	0.605	0	0.758
Sed.9	0.76	0.626	0.824	1.272	0.916	0.937	0.484	0.758	0

Dispersed Set

Subtype	I1	I2	I3	M4	M5	M6	S7	S8	S9
Ign.1	0	0.892	0.948	0.587	1.023	0.92	1.074	0.911	0.39
Ign.2	0.892	0	1.28	0.644	0.717	1.223	1.046	1.112	0.626
Ign.3	0.948	1.28	0	0.723	1.102	0.068	1.285	0.234	1.212
Met.4	0.587	0.644	0.723	0	0.88	0.682	1.167	0.637	0.659
Met.5	1.023	0.717	1.102	0.88	0	1.035	0.462	0.878	0.916
Met.6	0.92	1.223	0.068	0.682	1.035	0	1.227	0.168	1.168
Sed.7	1.074	1.046	1.285	1.167	0.462	1.227	0	1.097	1
Sed.8	0.911	1.112	0.234	0.637	0.878	0.168	1.097	0	1.112
Sed.9	0.39	0.626	1.212	0.659	0.916	1.168	1	1.112	0

How it is distributed



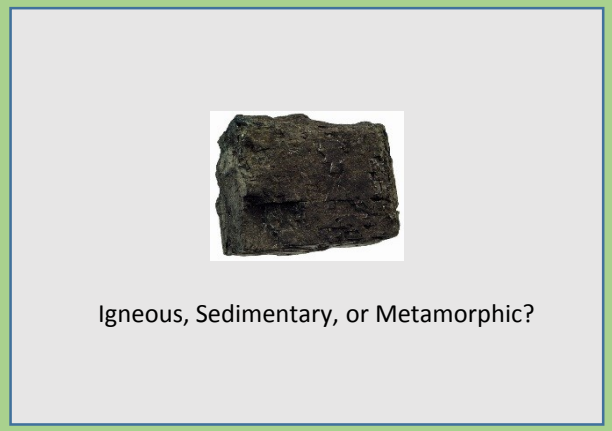


[Link For Compact Solution]

[Link For Dispersed Solution]

Training Block | Training Block | Training Block | Transfer Block

Learn Broad Category



Learn Subtype

- Subjects asked to categorize image
- Receive feedback after each trial

Stimuli

- Half of the stimuli for each subtype presented during each training blocks, with each image appearing twice per block
  - 27 images
  - 54 trials per block

Training Block | Training Block | Training Block | Transfer Block

Learn Broad Category

Igneous, Sedimentary, or Metamorphic?

Okay!

Learn Subtype

Rock Type?

Okay!

- Subjects asked to categorize image
- No feedback given

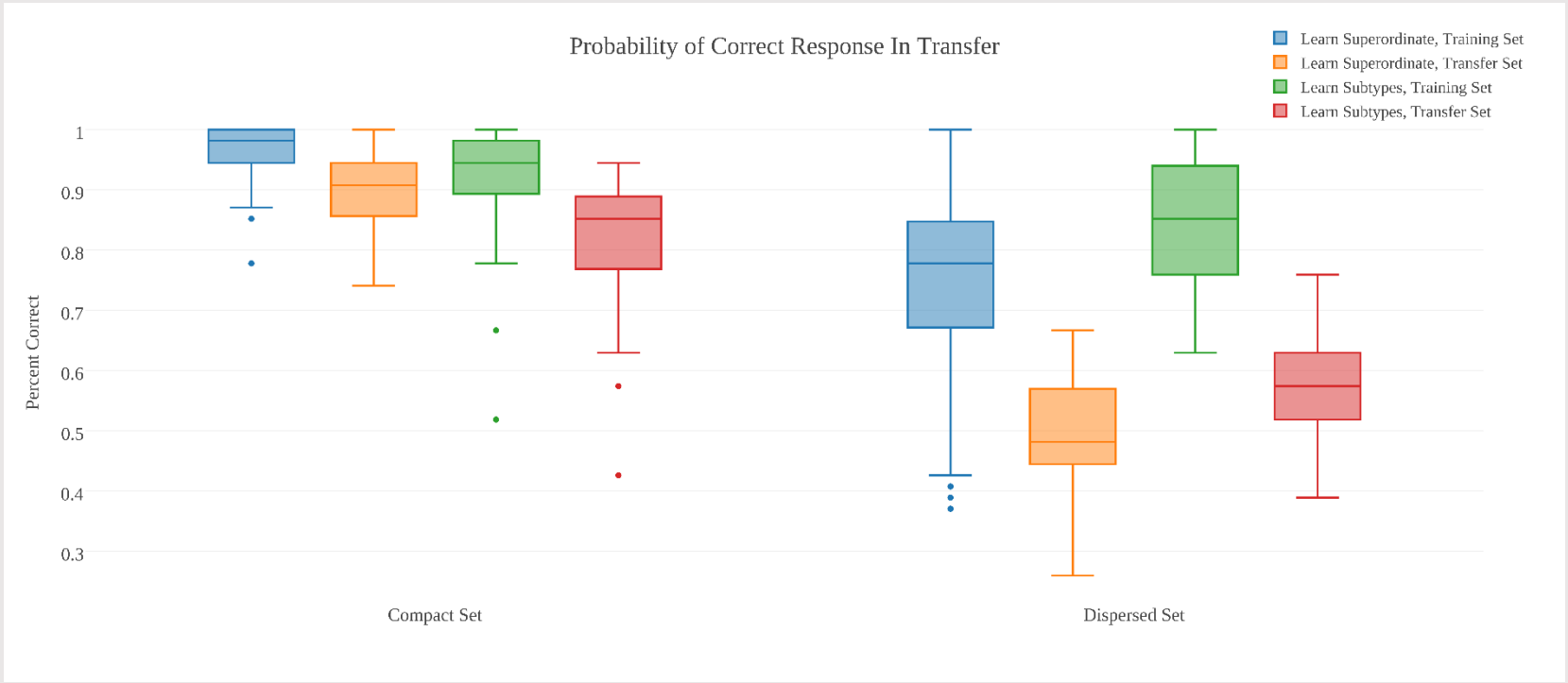
Stimuli

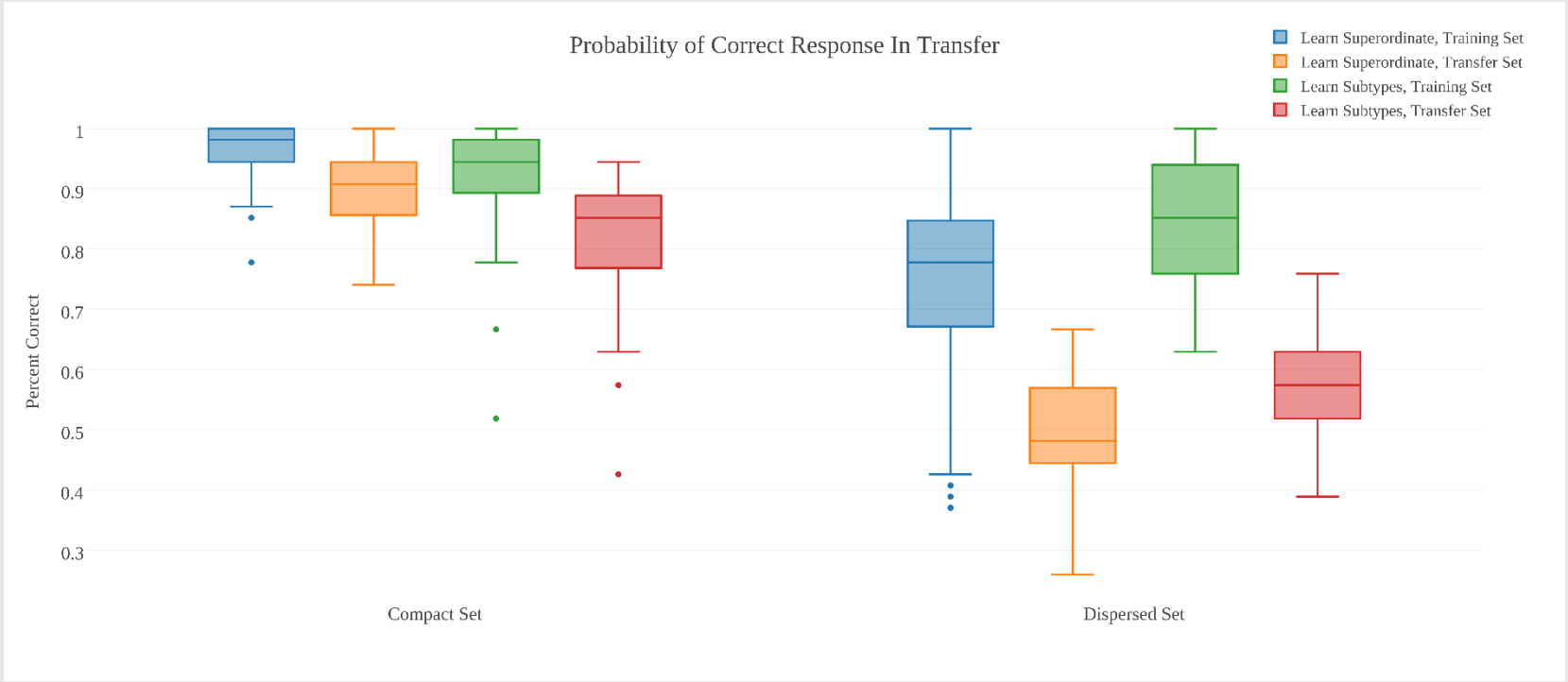
- Images from training blocks + 3 novel stimuli/subtype, each image appears twice
  - 54 images
  - 108 trials

- Measuring correct percentages with regards to superordinate classification, separately for training and novel stimuli

Quick Recap

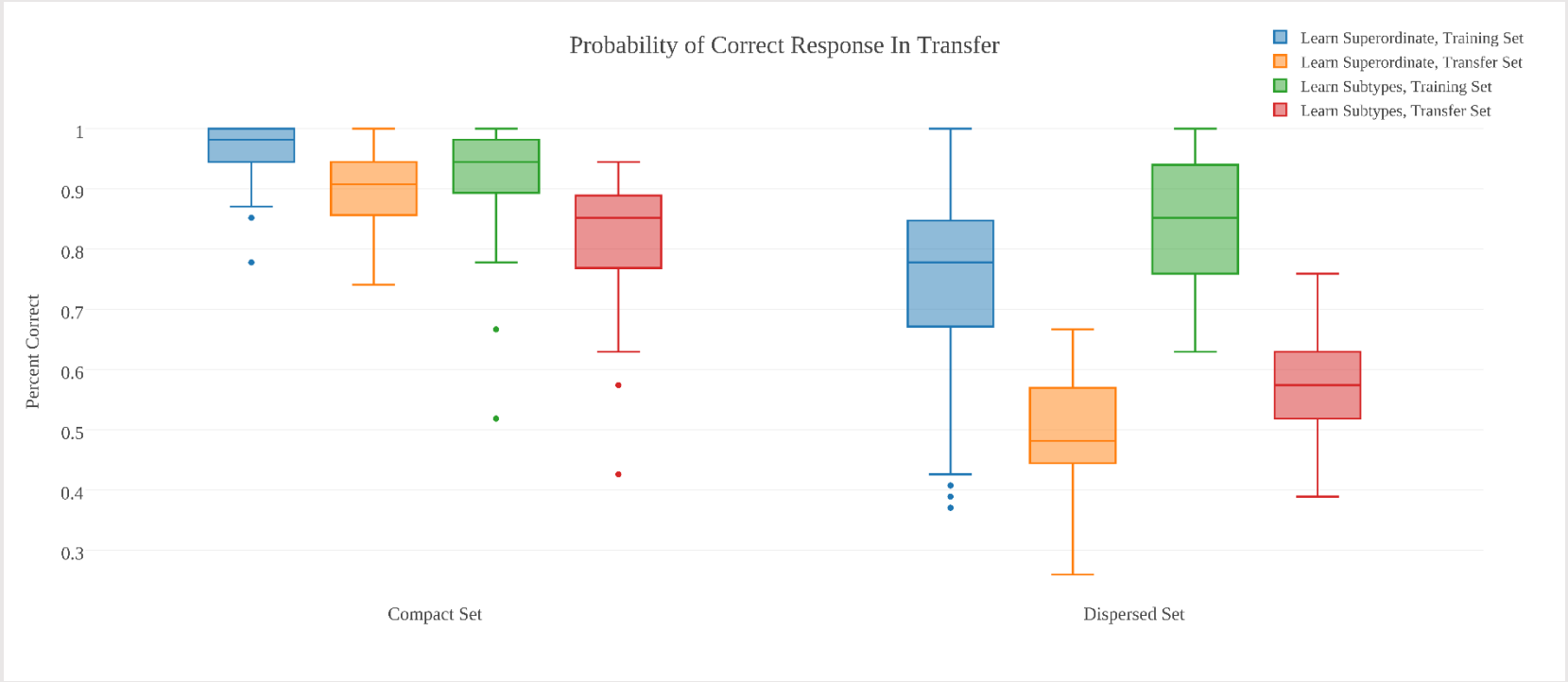
- Question: What level should be learned to maximize learning of superordinate categories?
- 2x2(x2) factorial experiment
  - Between subjects
    - Learned level (learn sub-type or superordinate)
    - Category Structure (learn compact structure or dispersed structure)
  - Within subjects
    - Whether stimuli were old or new
    - Measuring PC with respect to superordinate category separately for old and new stimuli.


Probability of Correct Response In Transfer
Learn Superordinate, Training Set
Learn Superordinate, Transfer Set
Learn Subtypes, Training Set
Learn Subtypes, Transfer Set
Percent Correct
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
Compact Set
Dispersed Set



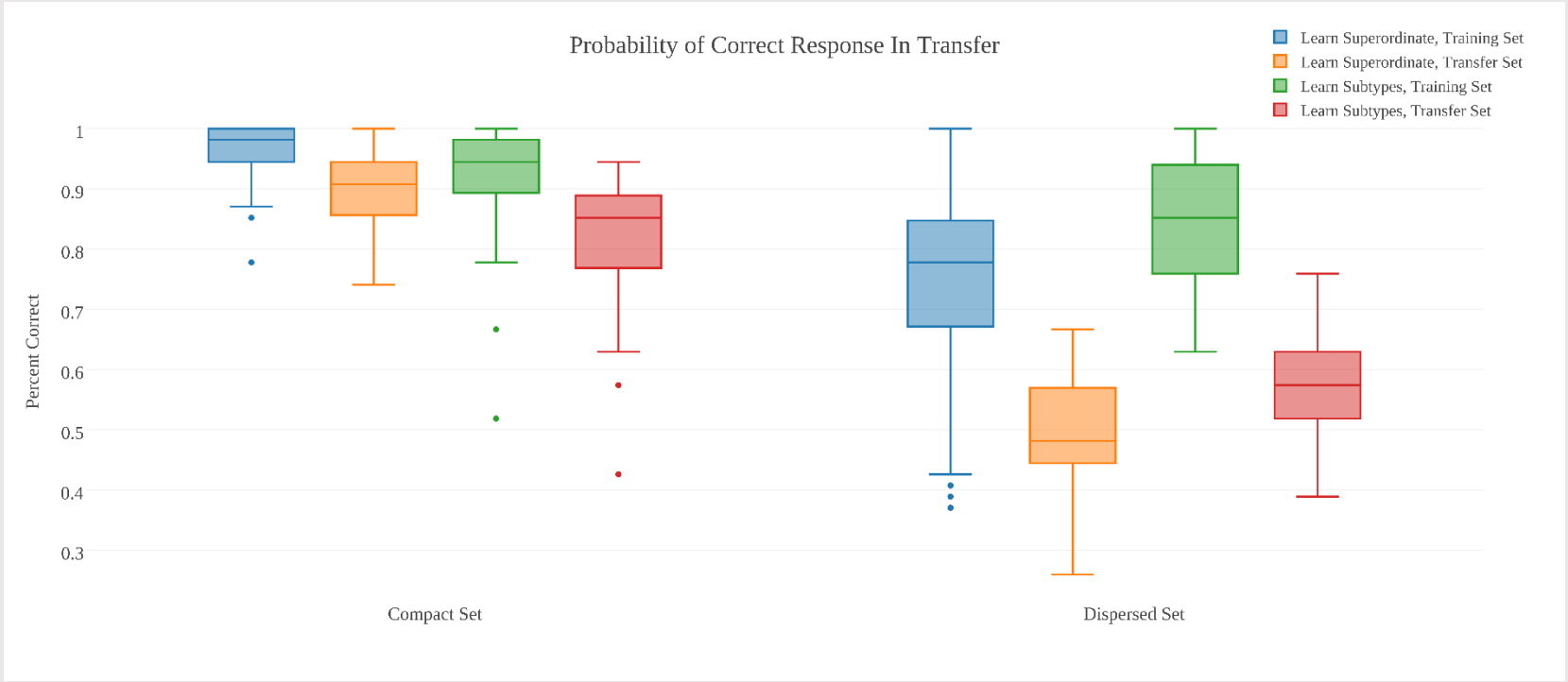
Main Effect of Stimulus Novelty (Training > Transfer)

[F (1,120) = 384.0, p < .001, η_G^2=0.393]



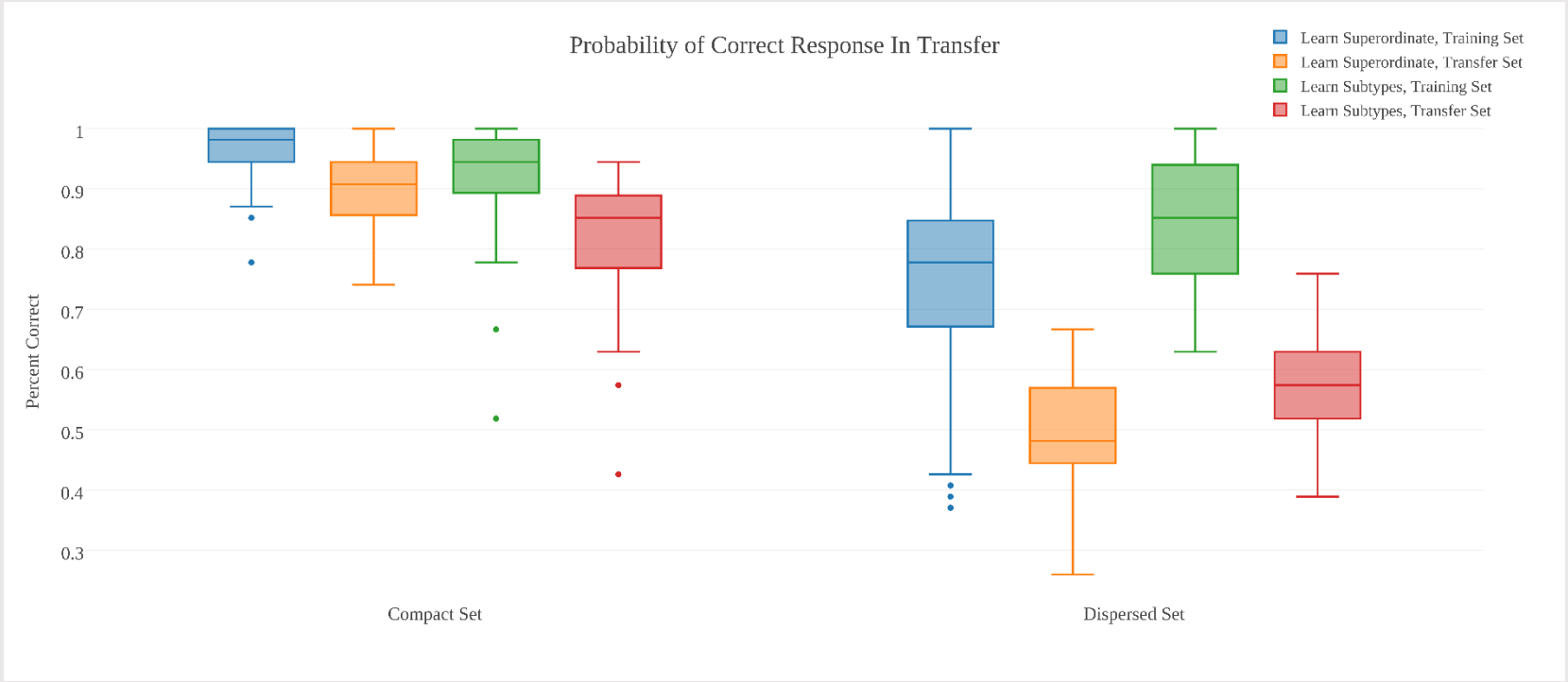
Main Effect of Category Structure (Compact > Dispersed)

$[F\,(1,120) = 182.0,\ p < .001,\ \eta_G^2 = 0.547]$



Interaction Category Structure X Stimulus Novelty

$[F\,(1,120) = 98.7,\ p < .001,\ \eta_G^2 = 0.143]$



Interaction Category Structure X Learned Level

[F (1,120) = 18.6, p < .001, $\eta_G^2 = 0.11$]

Conclusions: Summary

- **Question:** If you want to learn categories at the superordinate level, is easier to learn the superordinate categories alone or should one attempt to simultaneously learn at the subtype level as well?
- **Answer:** It depends on compactness of category structure
  - Compact Structure → (Direct Learning > Indirect Subtype Learning)
  - Dispersed Structure → (Indirect Subtype Learning > Direct Learning)

Implications of Findings

- Learning distinctions that are not relevant for high-level categorizations does not necessarily detract from ability to make those categorizations
- Studies should more frequently look at scenarios involving more than one level of abstraction

Conclusions: Limitations and Unanswered Questions

- Nomenclature
  - What is the difference from learning “Igneous 1” vs “Igneous Gabbro”
- A working hypothesis for mechanism
- To what extent categories in the natural world tend to display compact or dispersed structure?

Questions?