Multiple Exemplar Training and Derived Stimulus Relations in Animals and People

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WHERE DO NOVEL STIMULUS RELATIONS COME FROM?

• How can we account for the fact that a stimulus will sometimes evoke a reaction to which it has never been conditioned?

          Hull (1939)
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• How can we account for the fact that a stimulus will sometimes evoke a reaction to which it has never been conditioned?

  Hull (1939)

• “Something clearly connects the dissimilar stimuli, and the nature of this connection, which may be referred to as a stimulus relation, is one of Holy Grails of psychological inquiry.”

WHERE DO NOVEL STIMULUS RELATIONS COME FROM?

• Sidman & Tailby (1982) demonstrated emergence of reflexivity, symmetry and transitivity relations in children

STIMULUS EQUIVALENCE: BASIC PROPERTIES

Arbitrary Conditional Discrimination
Training

Train A \rightarrow B

Train B \rightarrow C

Emergent Relations

- Reflexivity: A \rightarrow A, B \rightarrow B, C \rightarrow C
- Symmetry: B \rightarrow A, C \rightarrow B
- Transitivity/Equivalence: A \rightarrow C/C \rightarrow A
STIMULUS EQUIVALENCE: BASIC PROPERTIES

**Arbitrary Conditional Discrimination Training**

- Green $\rightarrow$ "Green"
- Blue $\rightarrow$ "Blue"
- "Green" $\rightarrow$ "Verde"
- "Blue" $\rightarrow$ "Azul"

**Emergent Relations**

**Reflexivity** $A = A$

- "Green" $\rightarrow$ "Verde" $\rightarrow$ ?

**Symmetry** If $A = B; B = A$

- "Green" $\rightarrow$ ?

**Transitivity** If $A = B \& B = C; A = C$

- ? $\rightarrow$ "Verde" $\rightarrow$ ?
STIMULUS EQUIVALENCE AND THE SEARCH FOR SYMMETRY

- Sidman et al. (1982) replicated emergent symmetry in children, but not in monkeys or baboons

UNIQUELY HUMAN?

• Tool use
• Language
• Tabasco?
AFTER SIDMAN & TAILBY (1982)

- Explosion of basic human research

- New theoretical approaches to complex emergent relations
  - Sidman—Classes include all elements of reinforcement contingencies
  - Hayes—Relational Frame Theory—Arbitrarily Applicable Relational Responding as a higher order operant developed by multiple exemplar training
APPLICATIONS

• Numerous educational applications from the college classroom to teaching basic verbal relations in non-verbal clients


WHAT HAPPENED TO THE SEARCH FOR EMERGENT RELATIONS IN NON-HUMANS?

• Some demonstrations of transitivity, but symmetry? Not so much...
  • Lionello-DeNolf (2009) reviewed 24 studies in non-humans—only two showed consistent evidence of symmetry
  • Galizio & Bruce (2018)—dozen more studies, but still only two successful procedures...


TWO SUCCESSES IN NON-HUMANS

- Urcuioli (2008) Pigeons
- Schusterman & Kastak (1993) Sea Lions

URCUIOLI (2008)

• Urcuioli (2008) Pigeons
  • Go, No-Go (successive discrimination)—all responses on a single key

  • Trained identity relations for the stimuli used in the arbitrary conditional discrimination

• Generality across species

- Trained arbitrary “go, no-go” conditional discriminations in rats along with identity relations

- Symmetry probe tests following Urcuioli

- No evidence of symmetry in any of 7 animals tested

- Replicated in a recent MA (Dyer, 2017) and no evidence of symmetry in 5 rats—we’re now 0 for 12!

- Cross-species generality is open to question

• Success with multiple exemplar training

• 30 AB relations trained

• No symmetry obtained until MET with 6 pairs: A→B, B→A both trained

• Perhaps a history of MET is what’s missing in animals?
MULTIPLE EXEMPLAR TRAINING

- But multiple exemplar training with symmetry has not been successful in most other studies with
  - Pigeons — (Velasco et al. 2010)
  - Capuchins (Brino et al. 2014)
  - Or rats–MA theses: Katie Dyer; Tiffany Phassukan
    - Acquisition of symmetrical relation was slower than initial relation!
But evolution science itself suggests that human symbolic behavior has unique properties... No nonhuman animal has yet shown the defining features of relational framing, and the centrality of relational framing to complex human behavior is very evident...p. 125.

(Unlike Tabasco sauce...)

• “Animal laboratories were immediately less important”?  
  • Hayes (2016, p. 14)

• But can the origins of derived stimulus relations be discerned in humans?  
  • Pelaez et al. (2000), Barnes-Holmes et al. (2004), Luciano et al. (2007) trained such relations through multiple exemplar training in young (but verbal) children

• Animals can learn Non-Arbitrarily Applicable Relations (NAARR)—presumptively the prerequisite process for AARR in RFT
GENERALIZED MTS AND MULTIPLE EXEMPLAR TRAINING

• Set size expansion studies across several species (Katz & Wright; 2006)
  • Training begins with few exemplars; number of exemplars expanded after each transfer test

• Training with many stimulus examples is generally required to produce generalized identity matching in monkeys and pigeons

Katz & Wright (2006) Same-different abstract concept learning in pigeons.
*JEP:ABP, 32*, 80-86.
GENERALIZED MTS AND MULTIPLE EXEMPLAR TRAINING

• Set Size Expansion: A model paradigm for studying multiple exemplar training and relational responding?

• Katz, Wright and colleagues results consistent with RFT

• Premack and colleagues (1988) found above chance transfer in young chimps with only 2 exemplars.

GENERALIZED MATCHING IN RODENTS?

• Stimulus control literature largely based on pigeons and monkeys

• Previous studies with traditional modalities have often been discouraging (e.g., Iversen, 1993; 1997).
EMERGENT RELATIONS IN RODENTS
• Prichard et al. (2015) failed to show symmetry using Urcuioli procedure with olfactory stimuli in rats

• But, followed up with a second experiment to assess transfer of identity matching using similar training and testing procedures


Automated Olfactometer
• Houselight and centerport light on
• Observing response initiates sample odor
• Sample Odor: FI 5 s, 1 s blackout
• Comparison Odor:
  • S+ FI 5 s → sugar pellet; S- 5 s response period
• 30 s ITI with blackout
• Identity matching with 4 odor stimuli
TRAINING CRITERION

- Discrimination Ratio (DR) >.8 on all trial types for 2 consecutive sessions

DR = RR matching (positive)/RR matching (positive) + non-matching (negative) trial types
IDENTITY PROBE DESIGN

- When criterion was met, (DR = .80 on each trial type)—probe sessions were conducted.
- On probe sessions, 4 matching (positive) and 4 non-matching (negative) probe trials with novel (Set 2) odors (all unreinforced) were interspersed with 40 Set 1 BL trials.
- 8 generalized identity probe sessions (as per Urcuioli, 2008).
- Baseline sessions followed each probe session until criterion was met again.

Set 1
Cinnamon, Apricot, Bubblegum, Root Beer

Set 2
Brandy, Vanilla Butternut, Almond, Licorice
The graph shows the relationship between Trial Type (Positive, Negative) and Nosepokes/sec. It indicates a decrease in nosepokes/sec from Positive to Negative, with a baseline represented by a line with two data points.
Prichard et al. (2015)  
Exp 2
Prichard et al. (2015)  
Exp 2

![Graphs showing鼻poke per second across positive and negative trials for different K and L groups with lines representing baseline, probe, and first probe conditions.](image)
Prichard et al. (2015)
Exp 2

The graphs illustrate the data from Prichard et al. (2015) for Experiment 2. Each graph shows the nosepokes per second for different trial types (Baseline, Probe, First Probe) across positive and negative trial conditions for different subjects (K7, K34, K8, L23, K9, L25). The data suggests a decrease in nosepokes for negative trials compared to positive trials.
SUMMARY/FOLLOW-UP

• Evidence for generalized MTS in 5/6 rats

• Bruce et al (2018) replicated with non-matching task

• Generalized matching/non-matching obtained after training with only four exemplars!

ARE TWO EXEMPLARS ENOUGH FOR RATS?

- Train with just two odors
  - Set 1
    - Cinnamon, Apricot
  - Set 2
    - Brandy, Vanilla Butternut, Almond, Licorice

- Test with 4 novel odors

ARE TWO EXEMPLARS ENOUGH FOR RATS?

• NO (mostly)!

![Graphs showing positive and negative responses per second for different conditions and exemplars.](image-url)
ARE FOUR EXEMPLARS ENOUGH?

- Train with four odors (add two more)
  
  Set 1
  Cinnamon, Apricot, Bubblegum, Root Beer

- Test with 4 novel odors
  
  Set 2
  Brandy, Vanilla Butternut, Almond, Licorice

FOUR ARE ENOUGH!

- 2 Exemplar
- 4 Exemplar

- N35
- O4
FOUR ARE (MORE OR LESS) ENOUGH......
FOUR ARE (MORE OR LESS) ENOUGH……

4 Exemplar Training

Discrimination Ratio

N25  N35  O2  O4

BL  Probe
ARE RATS THAT SMART?

- Rats appear to show generalized identity matching after training with only 4 exemplars—compared to the 30-60 that appear to be required in pigeons and monkeys.

- Note that successive discrimination used with rats—simultaneous with most other studies.

- Are they cheating? Might something other than identity be controlling responding?
IDENTITY OR STIMULUS CHANGE?

- The possibility of temporal control—stimulus change, not identity

- Long duration odor signals reinforcement; odor change after 5 s signals non-reinforcement

IDENTITY OR STIMULUS CHANGE?

• The possibility of temporal control—stimulus change, not identity

• Masking odor→stimulus change on matching AND non-matching trials

• 5 rats; 4 from previous study and 1 new
IDENTITY OR STIMULUS CHANGE?

• Masking odor:
  (e.g., pistachio)

New Stimulus Sets for ID training and probes:
- Apple, Grass, Coconut, Sandalwood
- Clove, Honey, Blueberry, Geraniol

Sample (5s)  Mask (1s)  Comparison (5s)  30 s ITI
IDENTITY OR STIMULUS CHANGE?

A BIT OF BOTH?

GENERALIZED IDENTITY EMERGED DESPITE LOWER RESPONSE RATES

- Mask reduced response rates to novel stimuli relative to baseline
- Still, significantly more responding on matching than non-matching probe trials—evidence for generalized identity

![Discrimination Ratio Graph](graph-image.png)

**With 1-s Mask**

<table>
<thead>
<tr>
<th>Location</th>
<th>Discrimination Ratio</th>
</tr>
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<tbody>
<tr>
<td>N25</td>
<td>~0.8</td>
</tr>
<tr>
<td>N35</td>
<td>~0.6</td>
</tr>
<tr>
<td>O2</td>
<td>~0.8</td>
</tr>
<tr>
<td>O4</td>
<td>~0.6</td>
</tr>
<tr>
<td>O10</td>
<td>~0.8</td>
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</tbody>
</table>
GENERALIZED IDENTITY EMERGED DESPITE LOWER RESPONSE RATES

- Mask reduced response rates to novel stimuli relative to baseline.
- Still, significantly more responding on matching than non-matching probe trials — evidence for generalized identity.
- Why lower rates?
  - Competing control by mask may require more exemplar training.....
SET SIZE EXPANSION IN RATS WITH A MASKING STIMULUS

- Rats trained on go, no-go MTS procedure as before with 1-sec neutral odor (mask) between sample offset and comparison onset
- Initial training with two exemplar odors (2EX) followed by probe test with four novel odors
- Addition of two more exemplar odors (4EX), transfer test
- Addition of four more exemplar odors (8EX), transfer test

- Galizio, Dyer, Wagner, Westrick, Shaw, Guidone, Lowe & Bruce (in progress)
Full transfer after training with eight exemplars
Nearly full transfer with 1-s mask after training with only two exemplars
SUMMARY

- Most rats show above chance MTS or NMTS with novel stimuli after training with as few as 4-8 exemplars—but in some cases 2 exemplars were sufficient

- Masking studies suggests transfer is based on generalized identity, not change detection or temporal control
CONCLUSIONS

• Findings from our laboratory and others confirm that MET enhances (but perhaps surprisingly) may not always be necessary for, relational responding in non-humans.

• Origins of relational responding remain poorly understood and very difficult to study in humans (although research with non-verbal clients could make a very significant contribution!!)

• Research with both animals and humans is needed and can play an important role in the understanding and application of complex stimulus relations.
THANKS!

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