

# IMITATION LEARNING IN PROBLEM SOLVING TASKS: MEMORIZING OR UNDERSTANDING?

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# Problem solving

- Many activities in life involve planning and solving problems
- People learn to solve problems
  - By trial-and-error
  - Social learning
    - By teaching
    - By observation of skilled people (e.g., experts)

# Gizmo problem solving task

- Previous experiment: Manipulated learning
  - Trial-and-error learning (reinforcement)
  - Learning by observation (imitation)
- Task
  - Find, with **three uses of a scale**, the one gizmo that is either **heavier** or **lighter** than the rest of a set of 12 gizmos
  - Variant used in psychology experiments (Simmel, 1953)
  - Well-defined problem
  - Complex enough to avoid ceiling effects

# Reinforcement learning

**Learning:** told if answers are correct or not

ExperimentApplet.ExperimentApplet

Info Start Stop Exit

Level 2: Find the gizmo with a different weight (lighter or heavier) in no more than 3 trials

Color Selector Tool

- U Unknown: Heavy, Light or Normal
- HL Heavy or Light weight
- HN Heavy or normal weight
- LN Light or normal weight
- H Heavy weight
- L Light weight
- N Normal weight

Weight Scale was used 0 time(s) out of a maximum of 3 Answer Time Left: 29:00 Problems Completed: 0 Exit

# Imitation learning

**Learning:** shown five demonstrations

The screenshot shows a Java applet window titled "ExperimentApplet.ExperimentApplet". At the top, there are buttons for "Info", "Start", "Stop", and "Exit". The main area contains a puzzle instruction: "Level 2: Find the gizmo with a different weight (lighter or heavier) in no more than 3 trials".

At the top left of the puzzle area, there is a 2x6 grid of gizmo icons, each labeled with a letter 'U'. To the right of this grid is the text "Demonstration Mode". Below the grid is a balance scale with two pans, each divided into three sections. A message box is overlaid on the scale, displaying "Demo: 3" and an "OK" button.

On the right side of the applet, there is a "Color Selector Tool" panel. It lists several weight categories with corresponding colored boxes:

- U** (blue): Unknown: Heavy, Light or Normal
- HL** (grey): Heavy or Light weight
- HN** (red): Heavy or normal weight
- LN** (green): Light or normal weight
- N** (dark grey): Normal weight

At the bottom of the applet, there is a status bar with the following information:

- Weight: [ ]
- Scale was used 3 time(s) out of a maximum of 3
- Answer: [ ]
- Time Left: ---
- Problems Completed: -
- Exit button

# Results

- Imitation learning group was more accurate (more correct answers) than reinforcement learning group

Dandurand, F., Bowen, M., & Shultz, T. R. (2004). *Learning by Imitation, Reinforcement and Verbal Rules in Problem Solving Tasks*. Paper presented at the Third International Conference on Development and Learning (ICDL'04) Developing Social Brains, La Jolla, California, USA.

# Open research questions

- Is explicit feedback better than nothing?

- Task can be solved using pen and paper

- Explicit feedback not available
- Uses reasoning only



- Why did imitation outperform reinforcement?

- Does imitation involve understanding?

- Or is memorizing sufficient?



- Does familiarization with task prior to demonstrations improve accuracy?

# Is imitation about memorizing or understanding?

- Contradiction in the literature
- **Problem solving → memorizing**
  - Classical area of cognitive science (Newell, 1972)
    - Research interests: search, heuristics and hints
  - Imitation dismissed as rote memorizing (e.g., Katona, 1940)
- **Imitation learning → understanding**
  - Vast and active research area (human, animal, machine)
  - Understanding mentor's goals (Carpenter, Call, & Tomasello, 2002)
  - Complex, hierarchical problem representations (Byrne & Russon, 1998)



# How to study understanding?

- Operational definition
  - Understanding = ability to generalize what was learned by observation to novel, more difficult problems
- Remove possibility of memorizing full solution
  - Use task in which demonstration problems are different from problems to-be-solved

# Generalized imitation group

Watch 9 gizmo demos - solve 12 gizmo problems

The screenshot shows a Java applet window titled "ExperimentApplet.ExperimentApplet". At the top, there are buttons for "Info", "Start", "Stop", and "Exit". The main area contains a puzzle titled "Level 2: Find the gizmo with a different weight (lighter or heavier) in no more than 3 trials".

The puzzle consists of a 2x6 grid of gizmos. The top row has six blue gizmos, each with a white 'U' on it. The bottom row has three blue gizmos with white 'U's, followed by three empty slots. To the right of the grid is the text "Demonstration Mode".

Below the grid is a balance scale with two pans. The left pan is empty and the right pan is empty. A "Message" dialog box is open in the center, displaying "Demo: 2" and an "OK" button.

On the right side, there is a "Color Selector Tool" with a legend:

- U: Unknown: Heavy, Light or Normal
- HL: Heavy or Light weight
- HN: Heavy or normal weight
- LN: Light or normal weight
- H: Heavy weight
- L: Light weight
- N: Normal weight

At the bottom of the applet, there are several status fields: "Weight" (empty), "Scale was used 3 time(s) out of a maximum of 3", "Answer" (empty), "Time Left: ---", "Problems Completed: -", and "Exit".

# General experimental setup

- Familiarization
  - 5 min. practice before watching demonstrations
- Demonstrations
  - Expert solves gizmo problem solving task
- Explicit feedback
  - Told if answers are correct or not

# Experimental groups

- All participants solve 12 gizmo problems
- 5 Learning conditions

Learning condition:	Control	Reinforcement *	Imitation *	Generalized imitation	Delayed generalization
Familiarization	No	No	No	No	Yes
Demonstrations	None	None	12 gizmos	9 gizmos	9 gizmos
Explicit Feedback	No	Yes	No	No	No

\* replication groups

# Design

- Two independent variables
  - *Learning condition*: 5 levels
  - *Quartile*: for each subject, 1/4 of trials went into each quartile
- Two dependent variables
  - *Elapsed time*: mean time to solve trials
  - *Accuracy*: proportion of correct answers out of total number of trials

# Predictions

## Elapsed Time

faster over quartiles (practice)

## Accuracy

1. If explicit feedback is useful

Reinforcement > Control

Reinforcement will improve more with practice than other groups

2. If imitation involves understanding

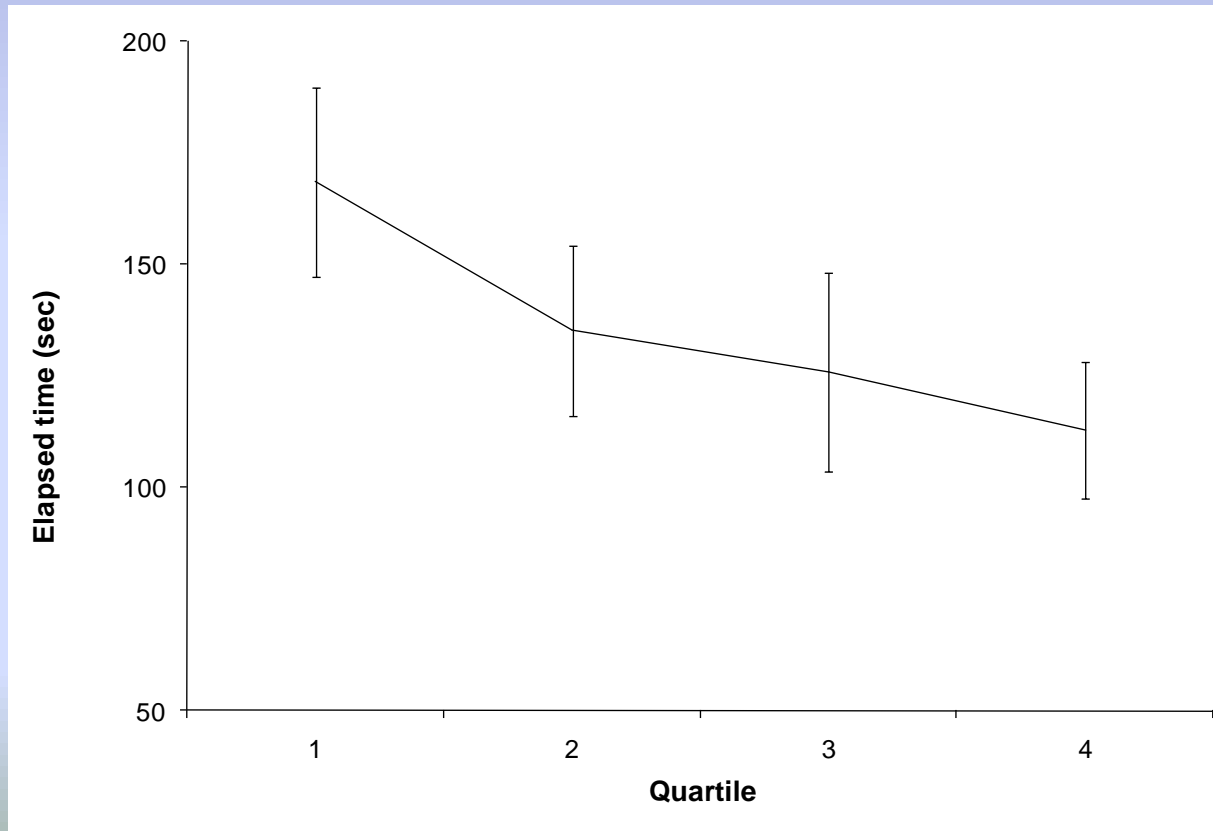
Generalization groups > Control

3. If familiarization improves performance

Delayed generalization > Generalized imitation

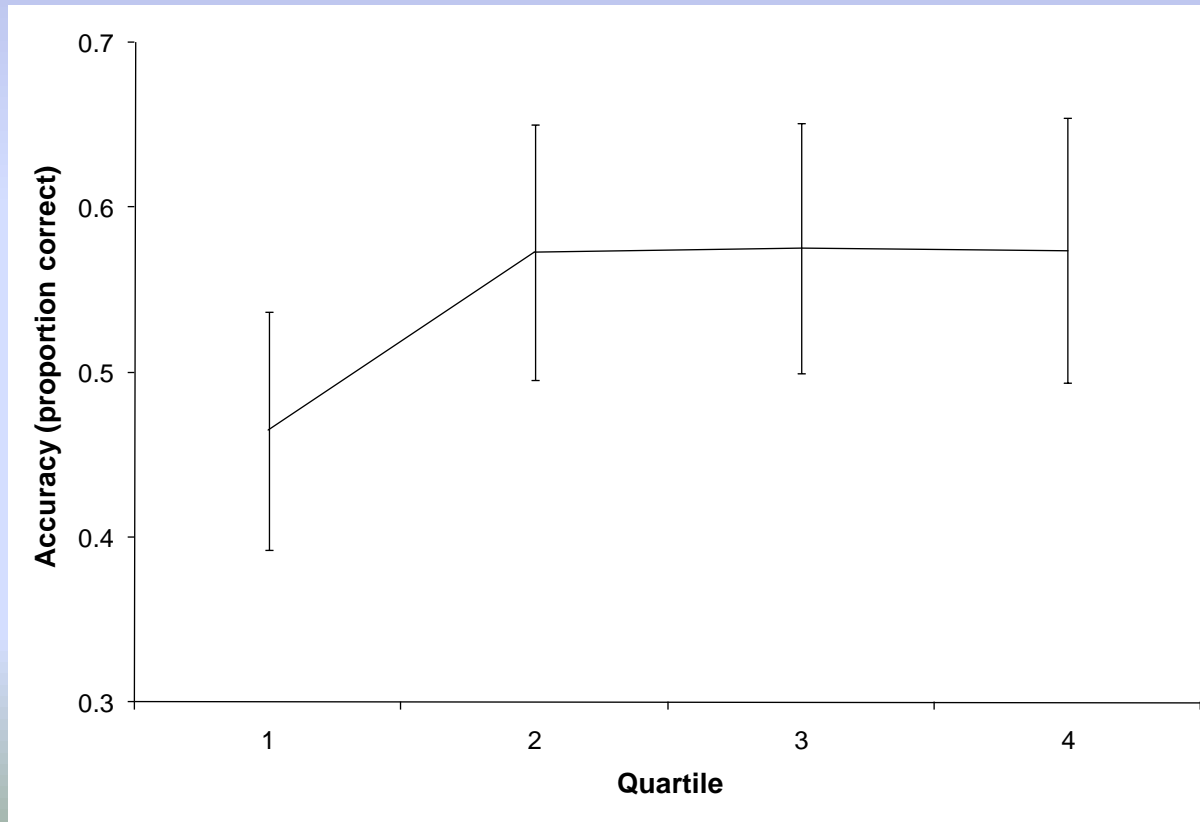
# Results – Elapsed time

- Participants get faster with practice
  - Main effect of *Quartile* only  $F(3, 285) = 41, p < 0.001$



# Results – Accuracy (1)

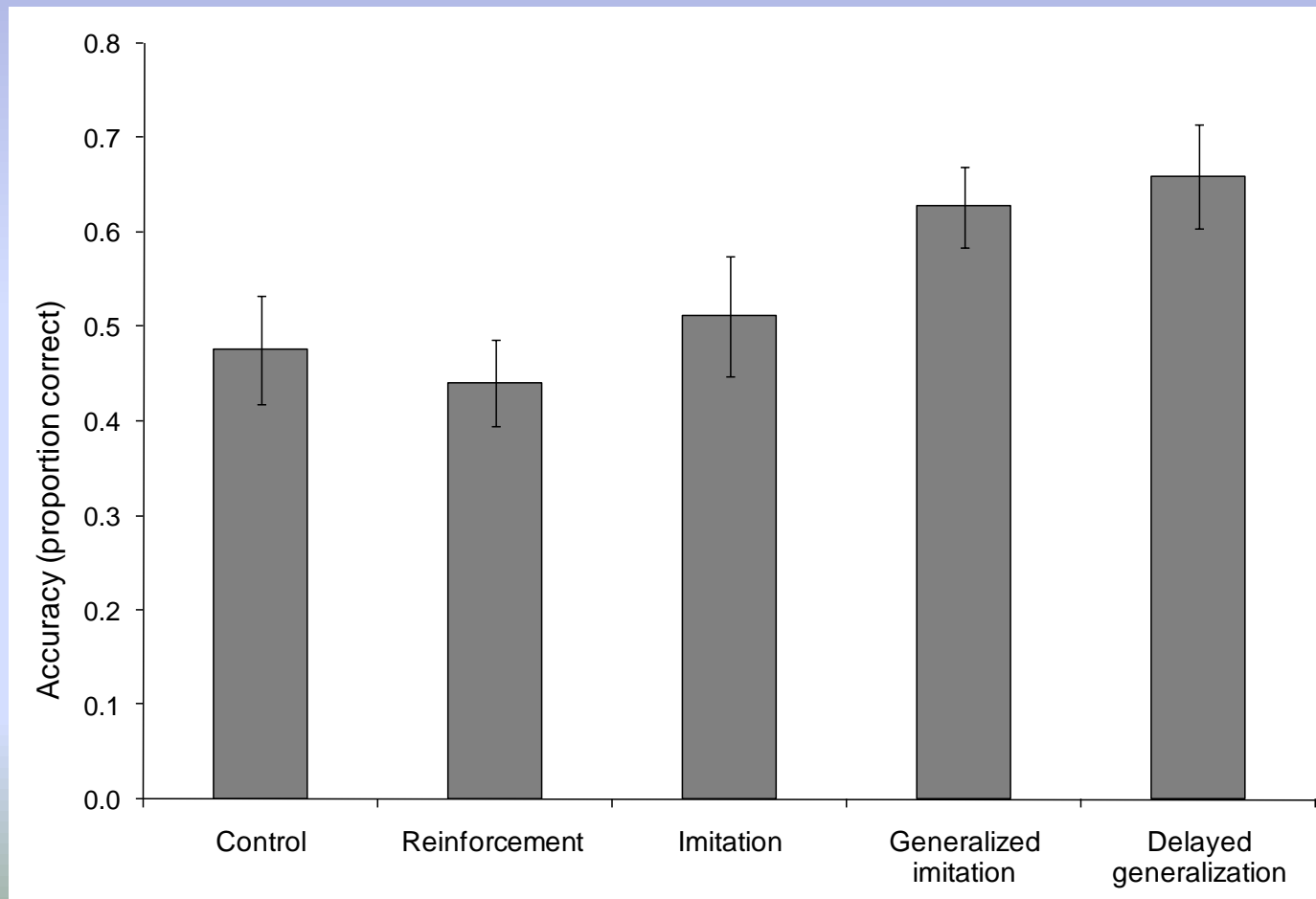
- Participants get more accurate with practice
  - Main effect of *Quartile*  $F(3, 285) = 4.5, p < 0.01$





# Results – Accuracy (2)

- Main effect of *Learning condition*  $F(4, 95) = 3.4, p < 0.05$



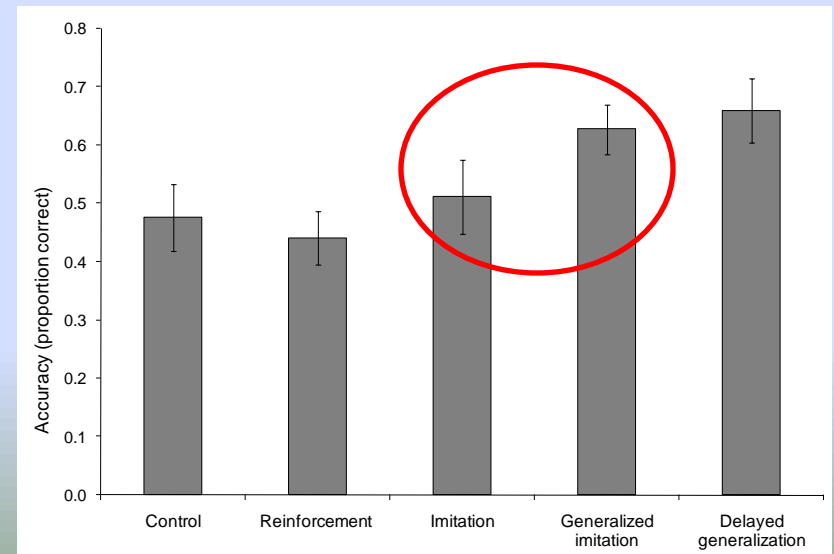
# Q1: Is explicit feedback useful?

- No, feedback not required
- Reinforcement (44.1%) = Control (47.6%) (LSD post-hoc)
  - No *Group x Quartile* interaction



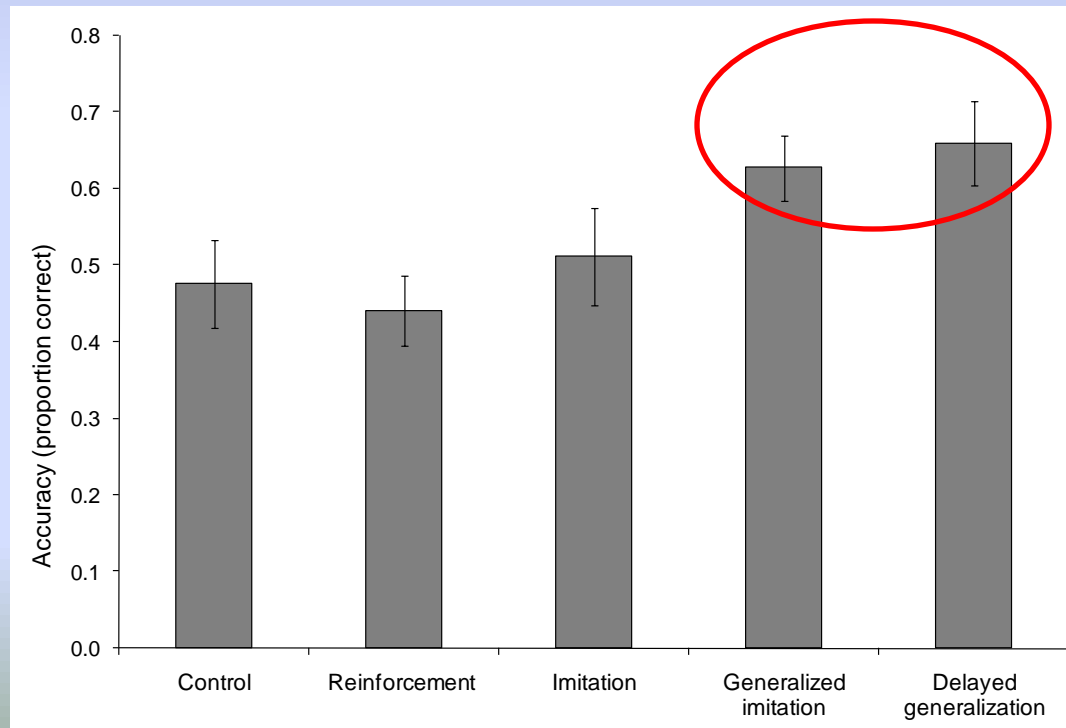
# Q2: Does imitation involve understanding?

- Yes, **Generalized imitation** was at least as accurate as **Imitation**
  - **Generalized imitation** (62.7%) > **Reinforcement** (44.1%)  
(LSD post-hoc)
  - **Generalized imitation** (62.7%) = **Imitation** (51.1%)
  - *Generalized imitation* (62.7%) = *Control* (47.6%) ?
- *Why?*
  - More interesting?
  - More challenging?
  - More motivated?



# Q3: Does familiarization improve performance?

- No, no evidence for a role of familiarization
  - Delayed generalization (65.9%) = Generalized imitation (62.7%)



# Cognitive mechanisms of generalization

- Understanding = Ability to generalize to novel problems
- Generalization mechanisms: Understanding?
  - ☑ Problem-independent encoding of features  
Correct abstraction?
  - ☑ Insight  
Use think aloud protocols
  - ✗ Priming of configurations or steps  
Humans prefer simple and symmetrical solution steps  
(Dandurand, Shultz and Onishi, 2007)

# What did participants learn from the demonstrations?

- Investigate first-weighing strategies
  - Correct rule: use  $1/3$  of gizmos on each side
    - 9 gizmo problem → 3 vs. 3
    - 12 gizmo problem → 4 vs. 4

# First-weighting strategies

Gizmos installed left /right	Experimental group				
	Control	Reinforcement learning	Imitation learning	Generalized imitation	Delayed generalization
1 / 1	13.6%	5.1%	7.5%	0.3%	0.0%
2 / 2	6.2%	12.2%	7.1%	1.0%	0.9%
3 / 3	19.9%	30.2%	17.8%	28.3%	26.9%
4 / 4	49.6%	30.5%	63.9%	67.2%	64.5%
5 / 5	2.7%	3.7%	2.5%	1.0%	6.0%
6 / 6	7.7%	18.3%	1.2%	2.0%	1.7%

- Generalization groups abstracted correct rule
- Control and reinforcement groups explore more

# Next step

- Seek further evidence about cognitive processes involved in gizmo problem solving
- Use think aloud protocols
  - Transcribe and code
- Quantify – Count utterances
  - Understanding (e.g., insight)
  - Reasoning
  - Memorizing, priming





# Take home messages

- Explicit feedback may be redundant
  - Reinforcement = Control
  - Correct self-evaluation of answers (reasoning)
- Participants generalized very well
  - Generalization groups were at least as accurate as imitation group
  - Correct abstractions -- 1/3 rule on 1<sup>st</sup> weighing
- Imitation learning of problem solving tasks: much more than rote memorizing

# Thank you !

- Acknowledgments
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    - Simcha Samuel
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- Comments, questions?

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