

# Comparative studies of categorization

Andy J. Wills

*University of Exeter*

With thanks to: Stephen Lea, Lisa Leaver, Fraser Milton, Catherine Bryant, Sue Chapman, Chris Longmore, Lou Millar, Britta Osthaus, Catriona Ryan, Mark Suret.

Funded by: European Commission.

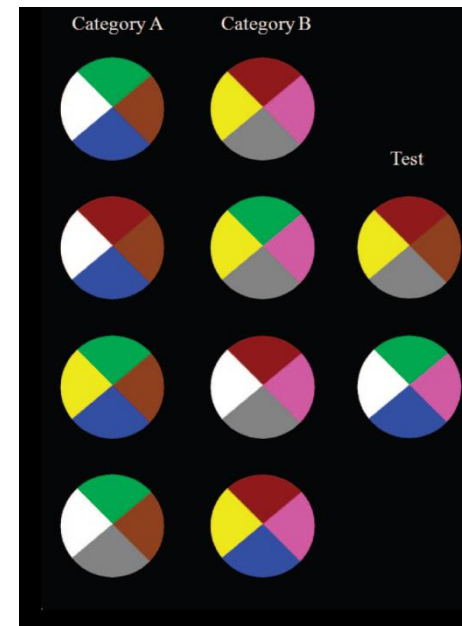
# What are the characteristics of rule-based processing?

- “A rules process is considered to be a similarity one where only a single or a small subset of an object’s properties are involved” (Pothos, 2005).
- Unidimensional categorization and rule use:
  - Adults vs. children (e.g. Smith & Kemler, 1977)
  - Humans vs. monkeys (Couchman et al., 2010).
  - Concurrent load, and incidental training, in adults (Kemler Nelson, 1984; Smith & Shapiro, 1989).

Category A	Category B
0 0 0 0	1 1 1 1
0 1 0 0	1 0 1 1
0 0 1 0	1 1 0 1
0 0 0 1	1 1 1 0

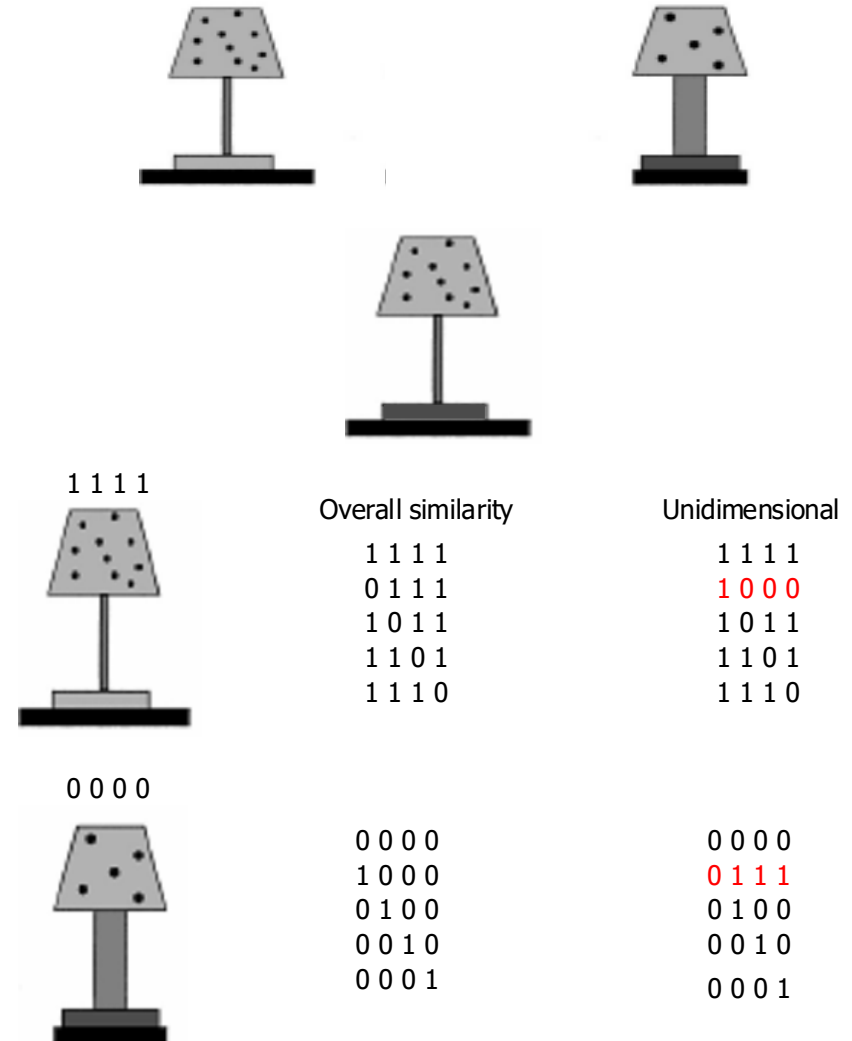
  

Test
0 1 1 1
1 0 0 0



# Critique – Lea & Wills (2008)

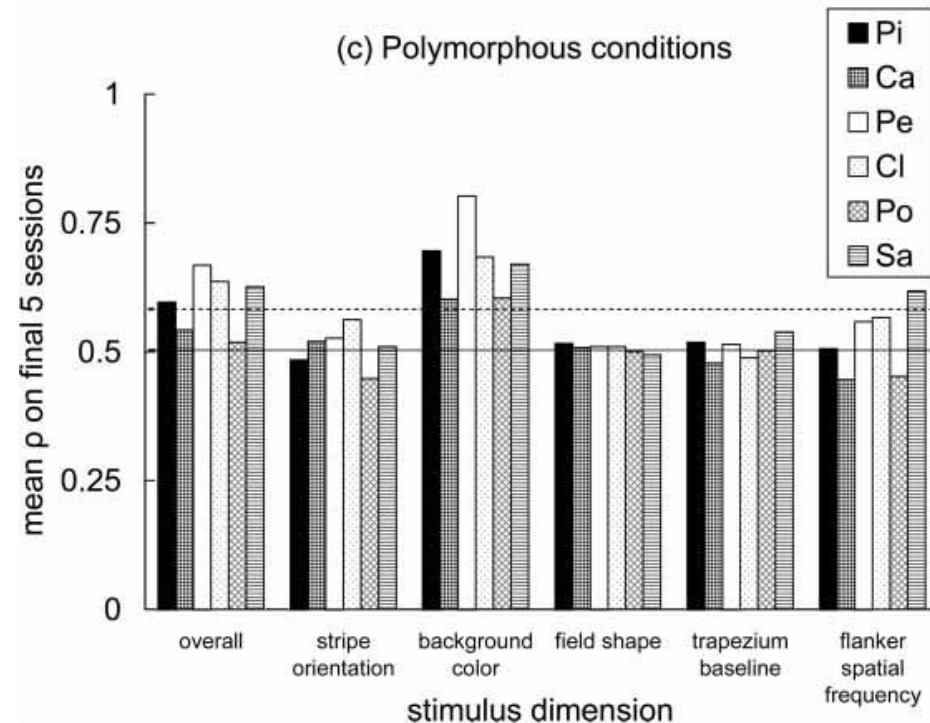
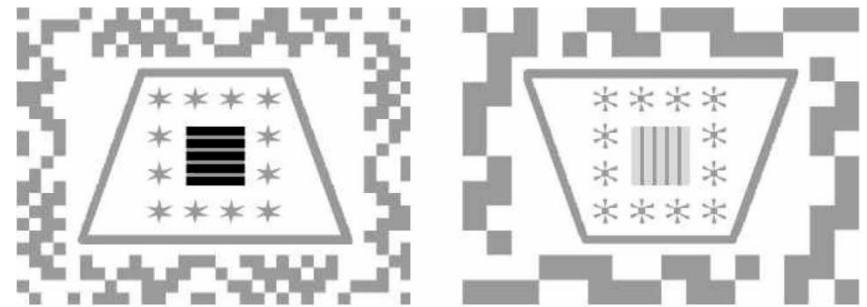
- Human data
  - Time pressure and concurrent load sometimes *increase* single-dimension responding (Milton, Wills & Longmore, 2008)
  - Overall similarity responding is sometimes associated with a reflective personality, a large working memory, and instructions to respond meticulously (Wills, Longmore & Milton, under review).



# Critique – Lea & Wills (2008)

- Birds

- Under the assumption  
**UD = deliberative**  
**OS = non-deliberative**  
 OS classification might be assumed to be prevalent in birds  
 (cf. Couchman's argument).
- Across many experiments in our bird lab over the last 20 years, bird behaviour in multi-dimensional classification is best characterized as single- or low-dimensional  
 (e.g. Lea, Wills & Ryan, 2006).

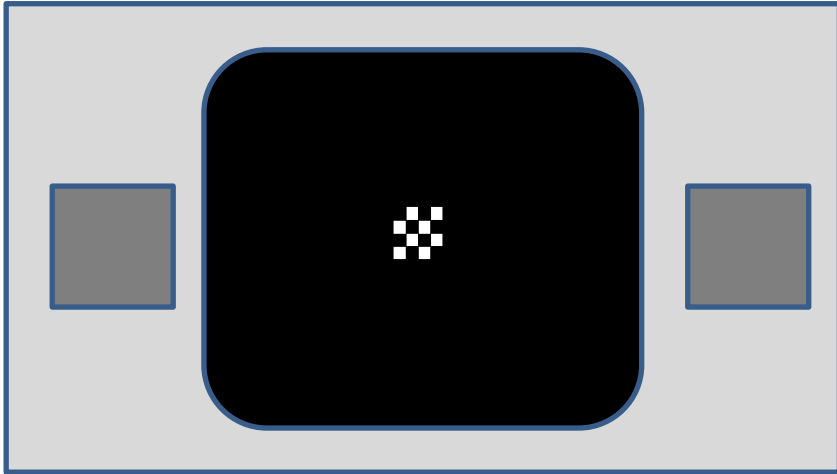


# Contrasting hypotheses

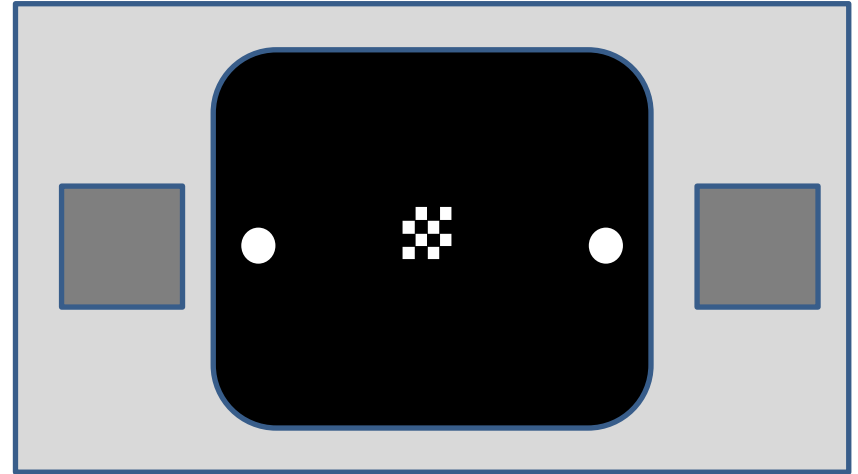
- *Single-dimension classification is the product of deliberative processing of information.*
  - > Humans will show a greater tendency to single-dimension responding than pigeons or squirrels.
  - > This should be observable across multiple procedures.
- *Single-dimension classification is the product of procedural factors*
  - > ... and at least some procedural factors will affect different species in the same way.

# Experiment 1a - Pigeons

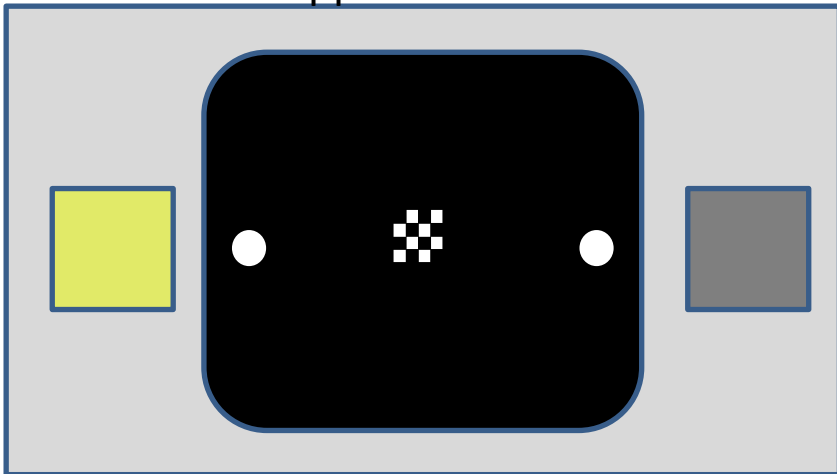
1. Peck stimulus (*tand* FT 10s VI 5s)



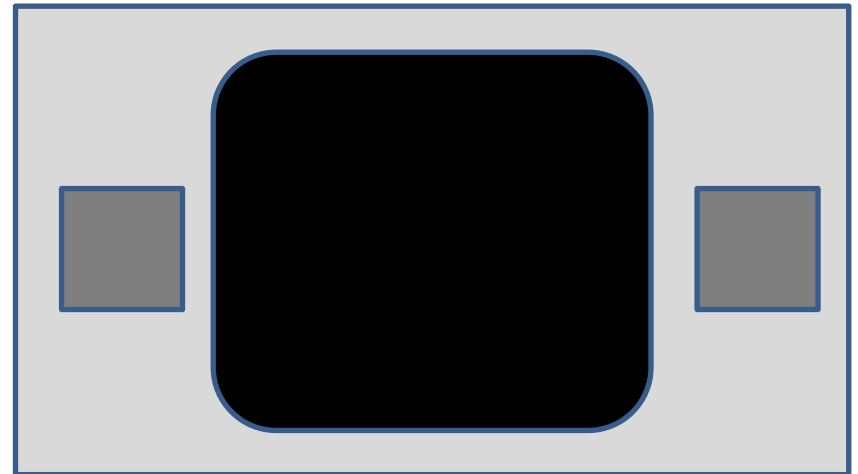
2. Peck choice disk (*incorrect ignored*)



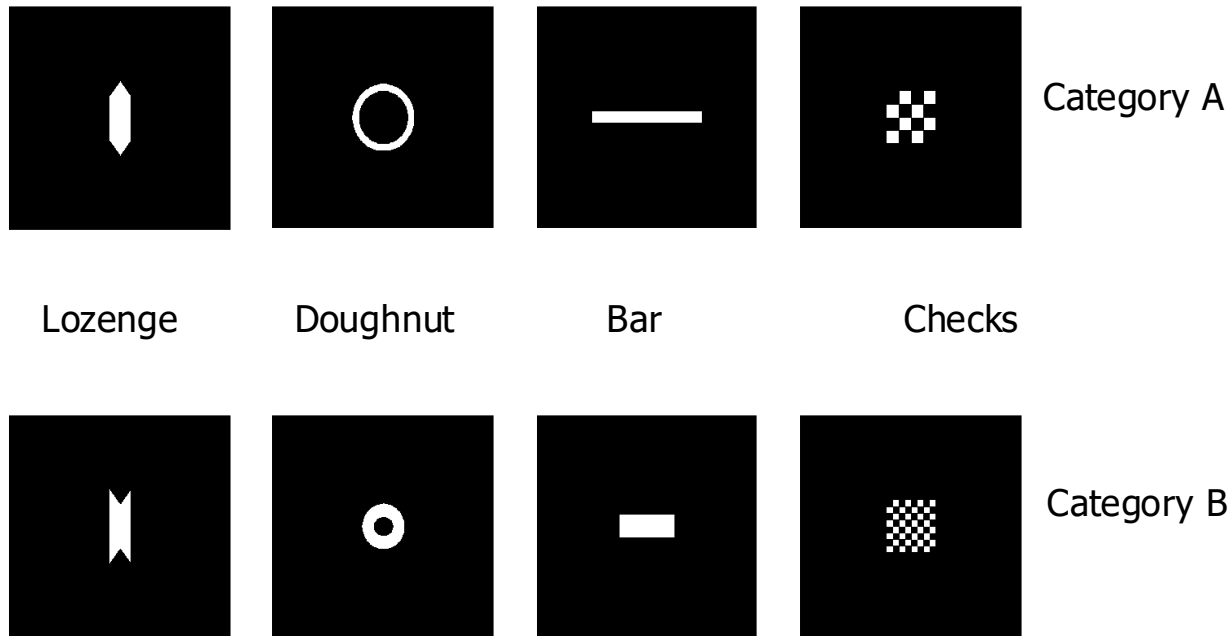
3. Three-second access to grain from illuminated hopper.



4. ITI ( 10-15 seconds )

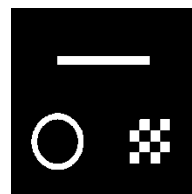


# Training and test

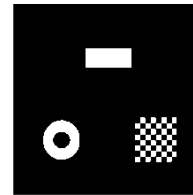


- Phase 1: 8 presentations of each of the 8 stimuli shown above. 64 trials per session. 1 session per day. Trained to criterion (75% correct on each of the 8 stimuli).

# Training and test



Category A

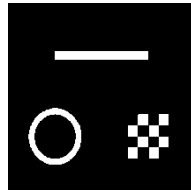


Category B

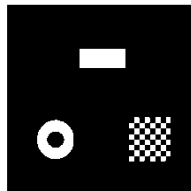
- Phase 2: “Prototype” patterns made up of the three dimension on which the bird was best. Trained to criterion (87.5% correct). 64 trials per session. 1 session per day.

# Training and test

Prototypes

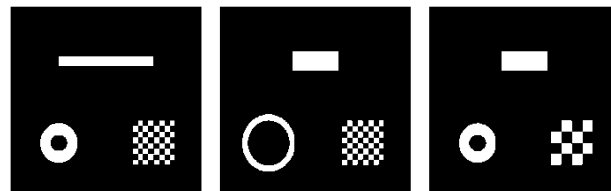
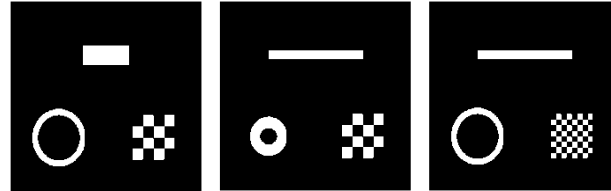


Category A



Category B

One-away stimuli



**Phase 3:** 60 trials per test session.

Trials 1-20: Prototype stimuli (training contingencies).

Trials 21-60: 24 prototypes (training contingencies), 4 prototypes (test contingencies), 12 one-away stimuli (2 x 6, test contingencies).

*Test contingencies* = Non-differential reinforcement.

Re-acquisition: Each test session followed by training session(s) on prototypes to 87.5% criterion.

Six test sessions in total – one for each of the six ways of spatially ordering the elements of the prototypes.

# Results

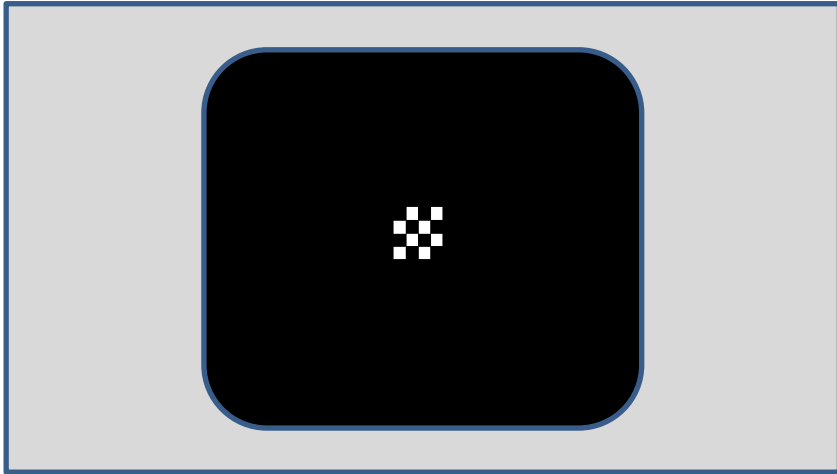
- Eight pigeons tested.
- Slow phase 1 training: About 40-50 sessions.
- Relatively quick phase 2 training: About 2-5 sessions.
- Test phase:
  - 4 pigeons classified on **overall similarity**
  - 4 pigeons classified on a **single dimension** (2 checks, 1 bar, 1 doughnut).

# Experiment 1b - Undergraduates

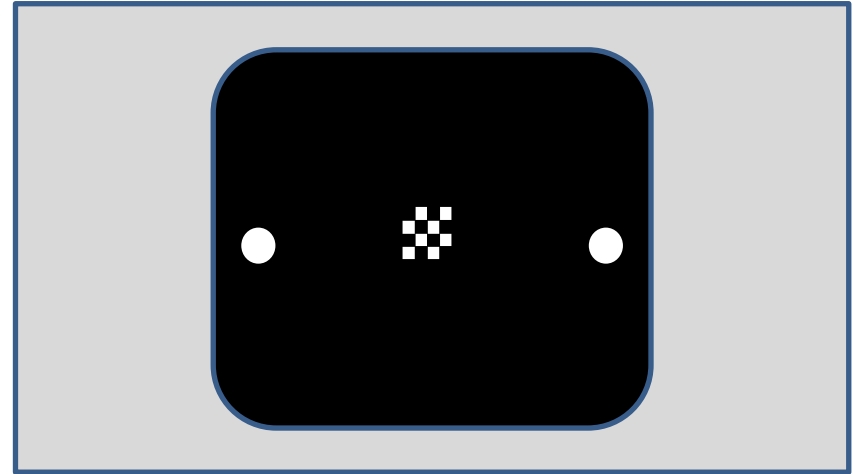
Same stimuli, same visual angle (cf. Goto, Wills & Lea, 2004).

Faster acquisition (one session). Similar trial procedure:

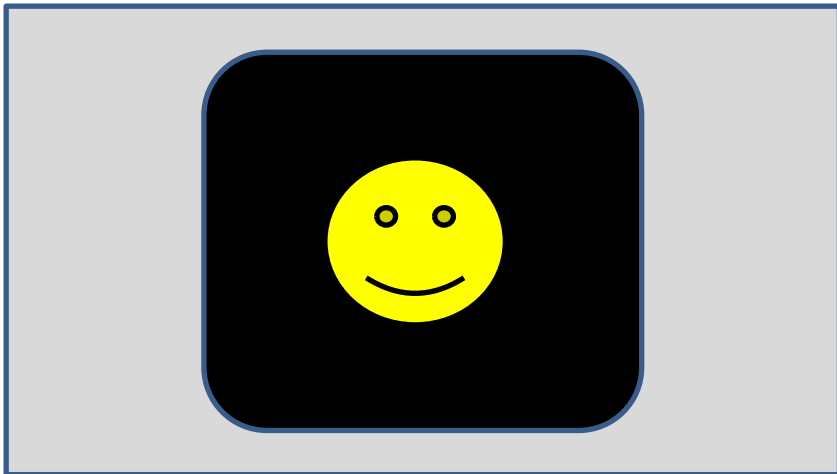
1. Peck stimulus (*tand* FT 10s VI 5s)



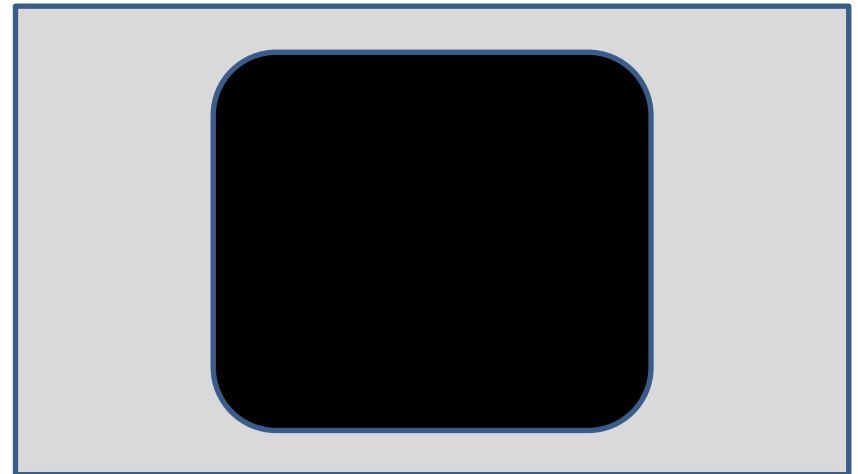
2. Peck choice disk (*incorrect ignored*)



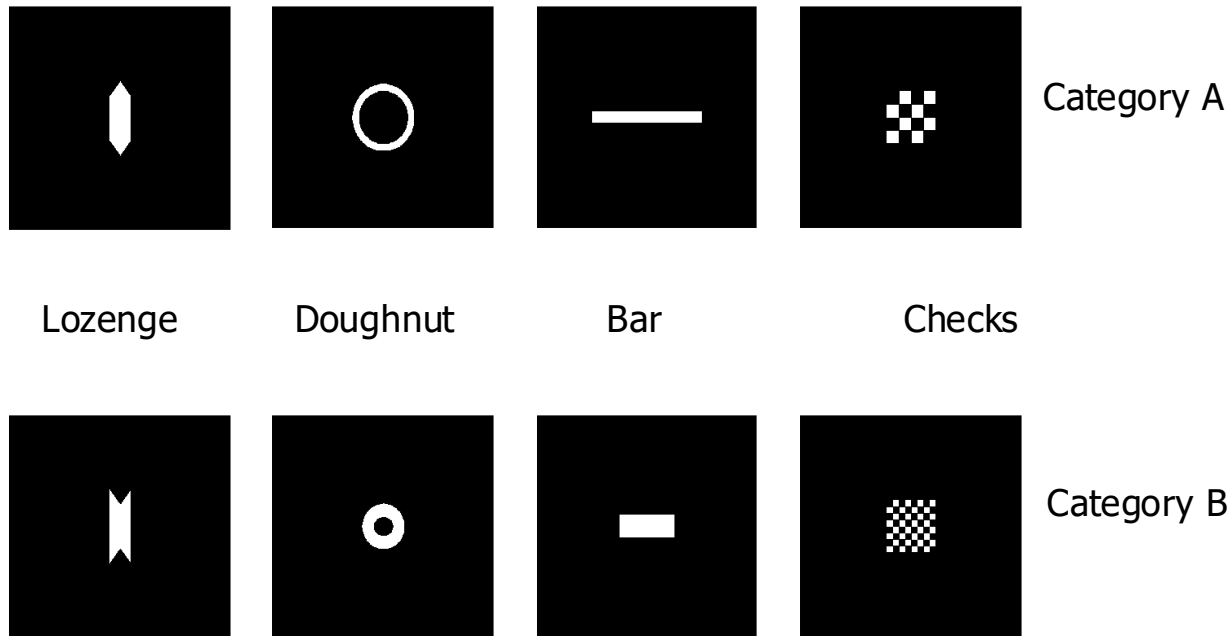
3. One-second "smiley".



4. ITI ( 1 second)

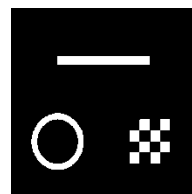


# Training and test

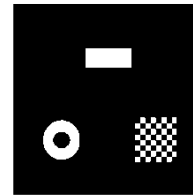


- Phase 1: 8 presentations of each of the 8 stimuli shown above. 64 trials per block. Up to 3 blocks. Trained to criterion (75% correct).

# Training and test



Category A

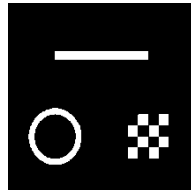


Category B

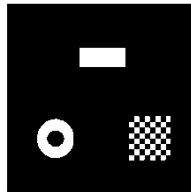
- Phase 2: “Prototype” patterns made up of the three dimension on which the UG was best. 64 trials per block. Trained to criterion (75% correct).

# Training and test

Prototypes

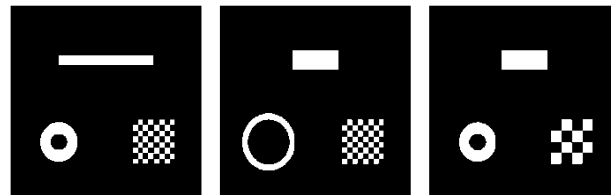
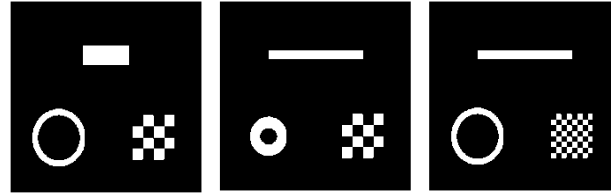


Category A



Category B

One-away stimuli



## Phase 3: 40 trials

24 prototype trials (training contingencies)

4 prototype trials (test contingencies)

12 one-away trials (test contingencies)

# Results

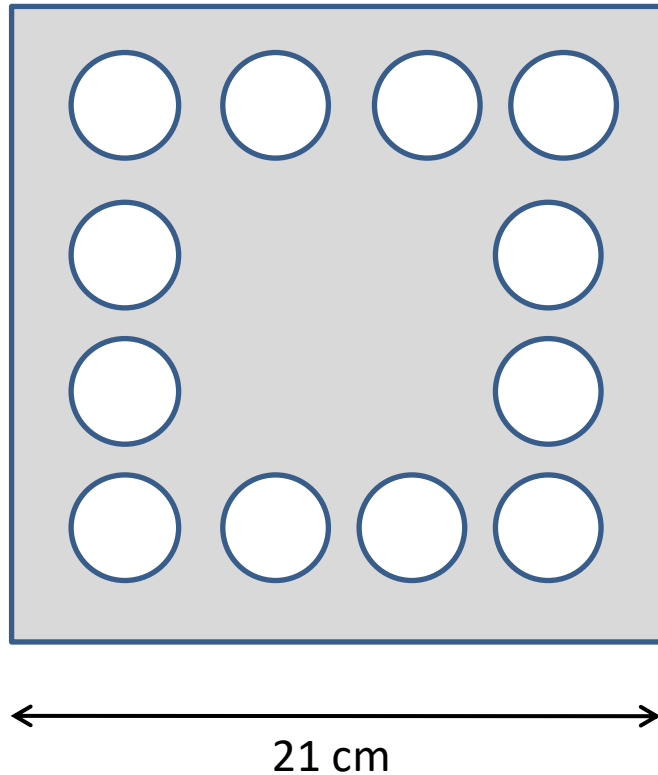
- 14 undergraduates tested; 2 excluded (N=12).
- Test phase:
  - 7 UGs classified on **overall similarity**
  - 3 UGs classified on a **single dimension** (doughnut).
  - 2 UGs did neither.
- Comparison to Exp 1a: Proportion of participants showing overall similarity classification did not differ by species. In terms of a trend, the prevalence of OS classification is higher in UG than in pigeons.

# Aims of Experiment 2

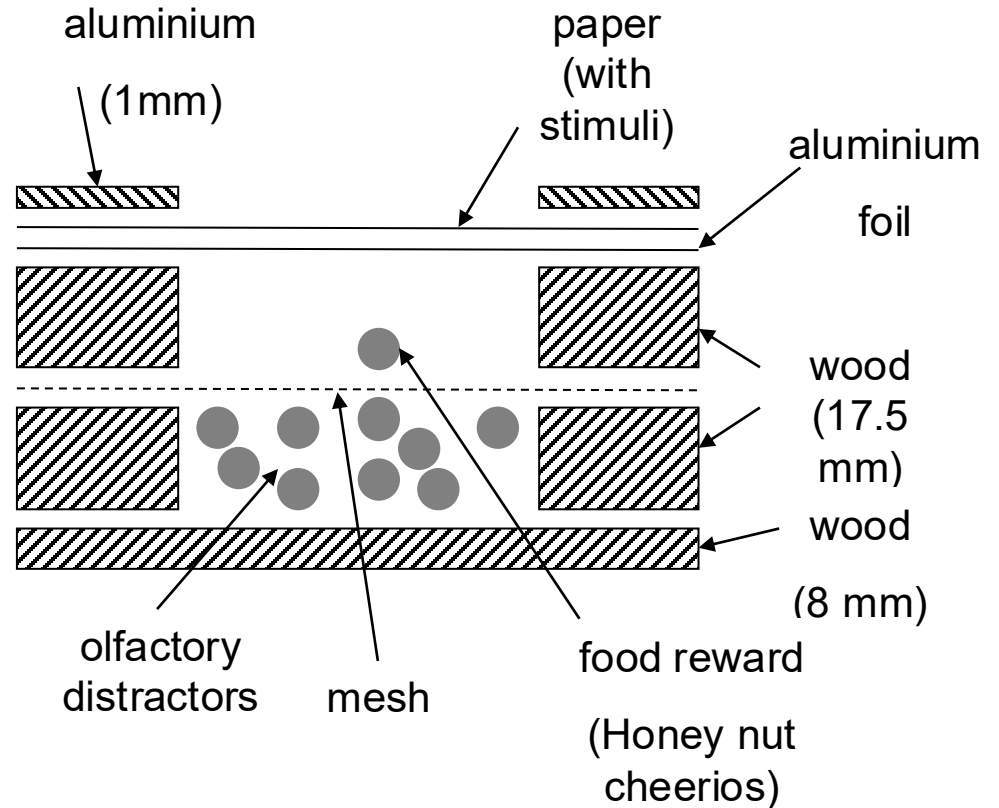
- Investigate statistical power explanation
  - Make procedural changes we expect (on the basis of our previous work, e.g. Milton & Wills, 2004) to increase single-dimension responding in humans.
  - If a comparison of Experiments 1 and 2 reveals a significant effect of procedure, but no species effect, this suggests our procedure had the power to detect at least a large species difference (obviously, a small species difference might remain undetected).
- Investigate generality
  - Will species difference still be found under different procedures?
  - Spatially integrated stimuli (Milton & Wills, 2004) and array rather than sequential presentation (Rehr & Brooks, 1995) increase single-dimension classification in humans.
  - Hence, we used spatially integrated stimuli and an array procedure.
- If we find a pigeon/human difference in Experiment 2, is that better characterized as a general animal / human difference, or a mammal / non-mammal difference?
  - Hence, a third non-human mammalian test species: **grey squirrels**.

# Experiment 2a - Squirrels

Poke board – aerial view



Poke board – cross-section of one cell

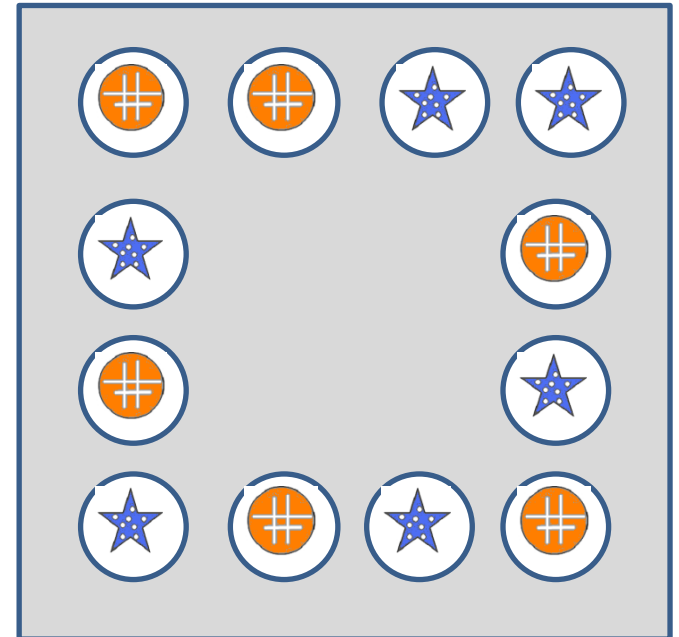


- Lab-based procedure

# Training

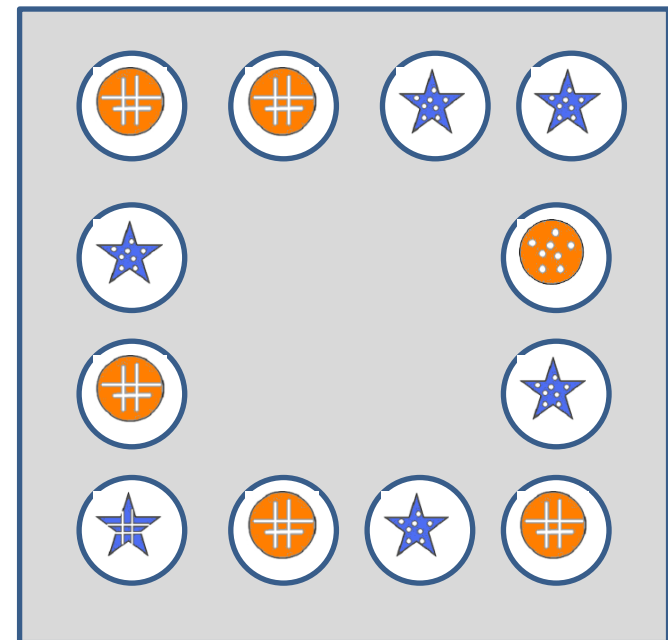
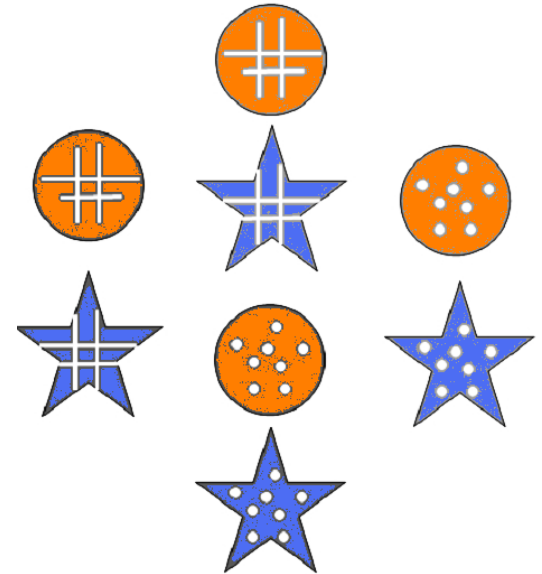
Training proper was preceded by a number of stages of apparatus familiarization, tests for control of behaviour by olfaction (no evidence it was), and pre-training with a simpler stimulus (black hexagon)

- Food under ★ but not under ⚡ (counter-balanced)
- Symbol location varied randomly by trial.
- Performance indexed by Herrnstein et al. (1976) rho applied to order of visitation. Rho of 1.0 means all food cells visited before any non-food cells. Random search order results in a mean rho of 0.5
- Trained to a rho = 0.8 criterion.



# Test

- As training, except two training stimuli replaced by two one-away stimuli.
- Six trials per test session. Across six trials, all one-aways presented twice (once with food; once without).
- A test stimulus is treated as positive if amongst the first six symbols selected. Otherwise, it's treated as negative.
- Three test sessions; interspersed by training to criterion.



# Results

- Four squirrels tested.
- 2-10 training sessions required (4 trials per session).
- Test phase:
  - All 4 squirrels classified on a **single dimension** (3 colour, 1 shape).

# Experiment 2B - Pigeons

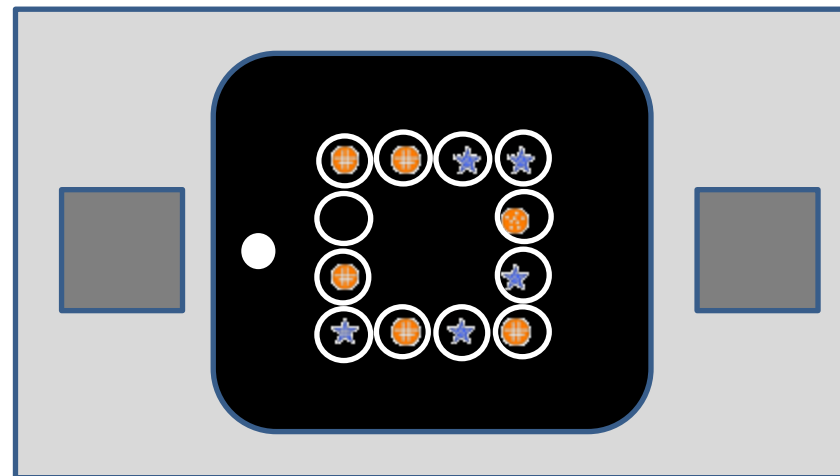
Training proper was preceded by pre-training on simpler stimuli (black hexagons)

Train to criterion ( $\rho = 0.8$ )

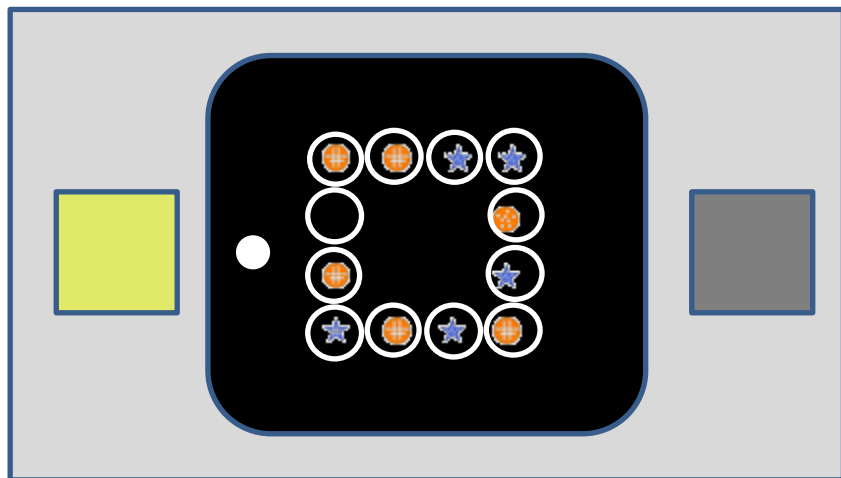
1. Peck stimulus twice



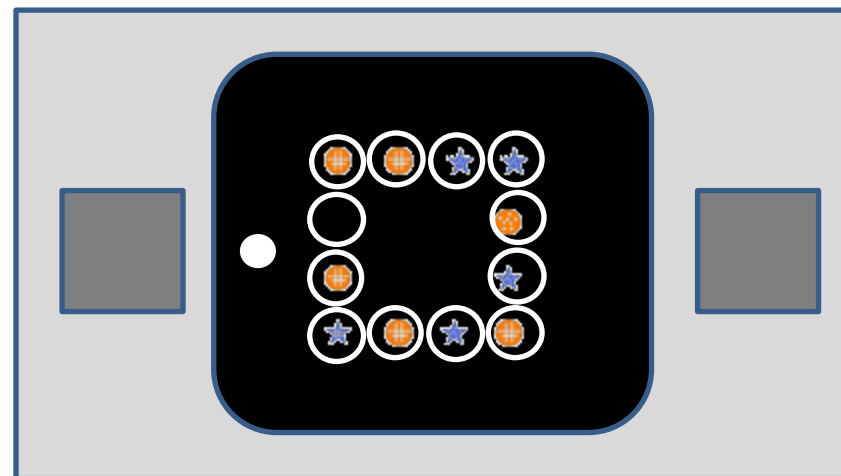
2. Stimulus disappears; single peck to circle.



3a. 2.5 second operation of food hopper (food present) or...



3b. no consequence (food absent)



Repeat 1-3, until all stimuli have gone. Pecking empty circles -> 2.5s where pecks ineffective.

# Results

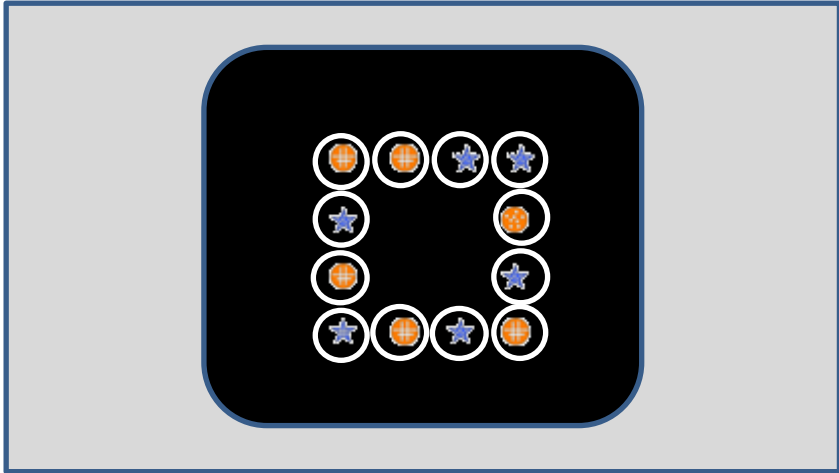
- Six pigeons tested.
- Rapid learning (cf. Huber et al., 2005) – took 3-6 sessions (4 trials per session).
- Test phase:
  - 5 pigeons classified on a **single dimension** (Colour).
  - 1 pigeon classified on **overall similarity**.

# Experiment 2C - Undergraduates

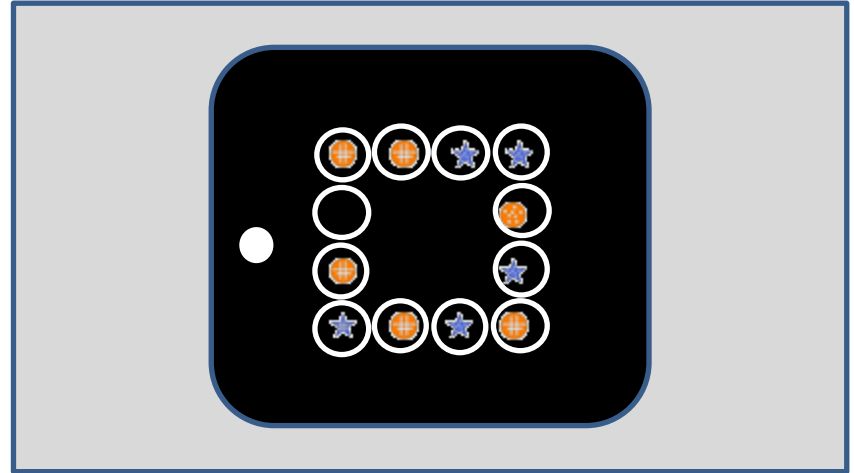
Single session with training phase followed by test phase.

Train to criterion ( $\rho = 0.8$ )

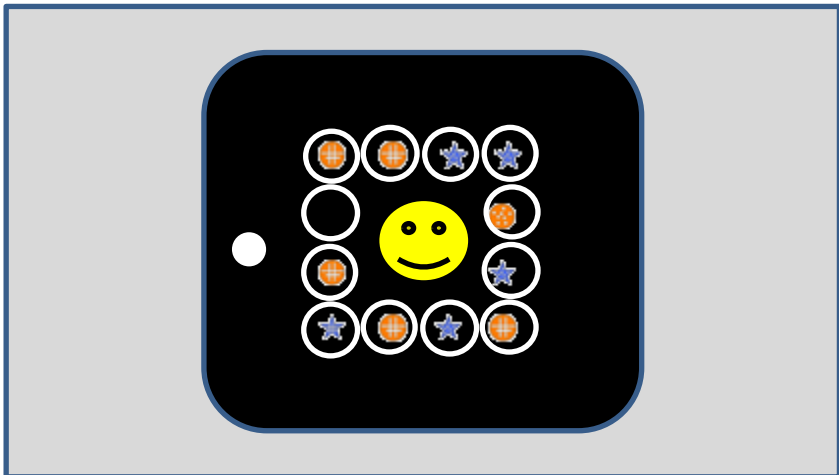
1. Touch stimulus



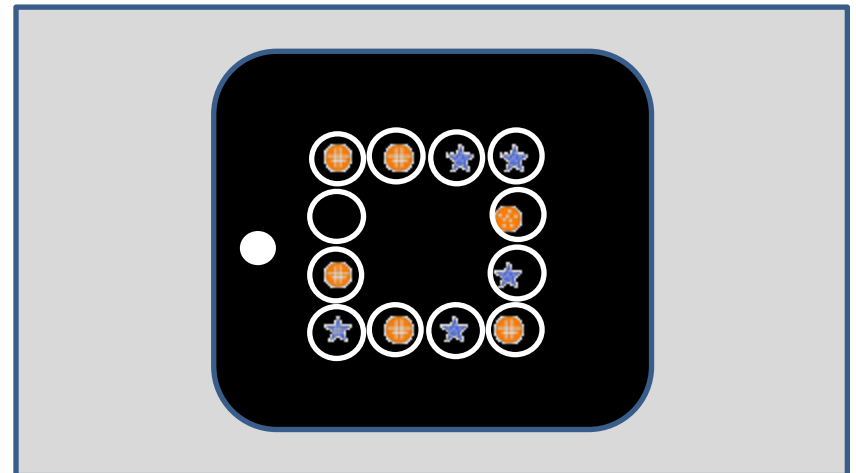
2. Stimulus disappears; touch circle.



3a. 1 second smiley (+ve trial) or...



3b. no consequence (-ve trial)



Repeat 1-3, until all stimuli have gone.

# Results

- 24 undergraduates tested; 21 passed criterion.
- Test phase
  - 2 UGs classified by **overall similarity**.
  - 7 UGs classified by a **single-dimension**. (3 shape, 4 colour).
  - 12 UGs did something else.
- Procedure comparisons
  - Pigeons: Significantly greater proportion of UD in Experiment 2 than in Experiment 1.
  - Undergraduates: Significantly greater proportion of UD in Experiment 2 than in Experiment 1.
- Species comparison
  - Even collapsing across Experiments 1 and 2, no significant difference between pigeons and undergraduates in prevalence of UD classification. Trend is towards more OS in undergraduates.

# Discussion

- What are the cognitive differences between humans and other animals?
- Use of a single dimension in classification, as opposed to overall similarity classification, has been repeatedly associated to deliberative thought in humans.
- On that basis, one might expect higher prevalence of OS classification in non-human animals.
- Some evidence consistent with this within primates (Couchman), but our previous experience of pigeons suggested they seldom classify on an OS basis.
- In the current studies, we found that humans and pigeons were affected in similar ways by procedural manipulations (simultaneous, integrated vs. sequential, separated), but no species difference emerged.
- Similar results in pigeons, squirrels and humans in Experiment 2 suggest this is not specifically an avian issue.
- Closely similar procedures are essential – comparing Exp 1a and 2c would have been very misleading, for example.

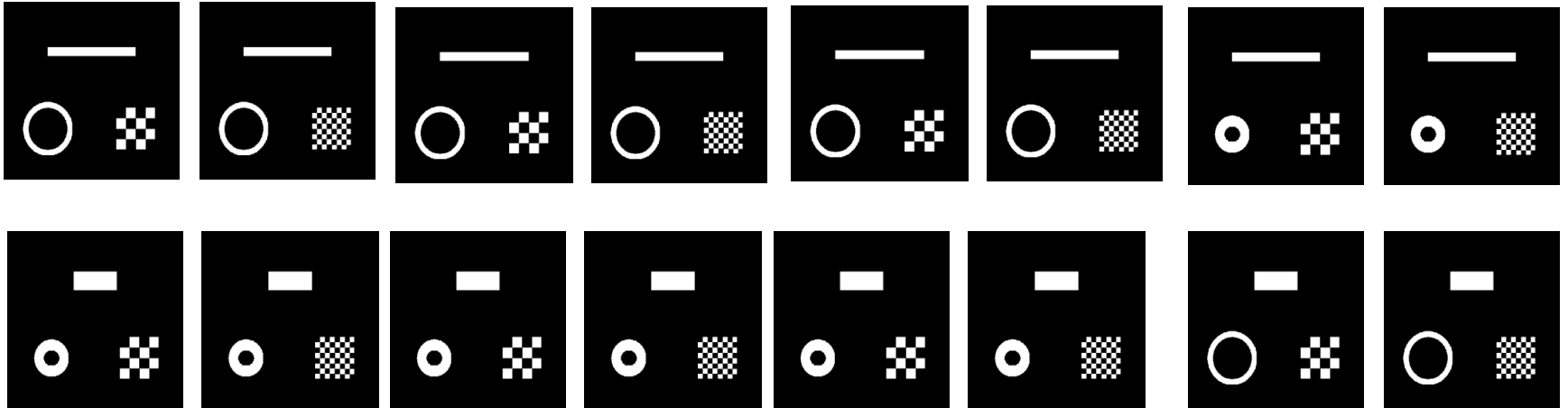
# Single-dimension classification is characteristic of deliberative thought?

- Option #1: Assert that the hypothesis is correct.  
**Consequence**: Humans, pigeons and squirrels have similar access to deliberative thought processes (at least in this procedure).
- Option #2: Reject this consequence as implausible, and hence reject the hypothesis.
- Option #3: Assert, post-hoc, that humans approach this particular task non-deliberatively. But work with humans on very similar tasks (Milton et al., 2008, 2009; Wills et al., submitted) implicates deliberative thought.

# Strategic information use

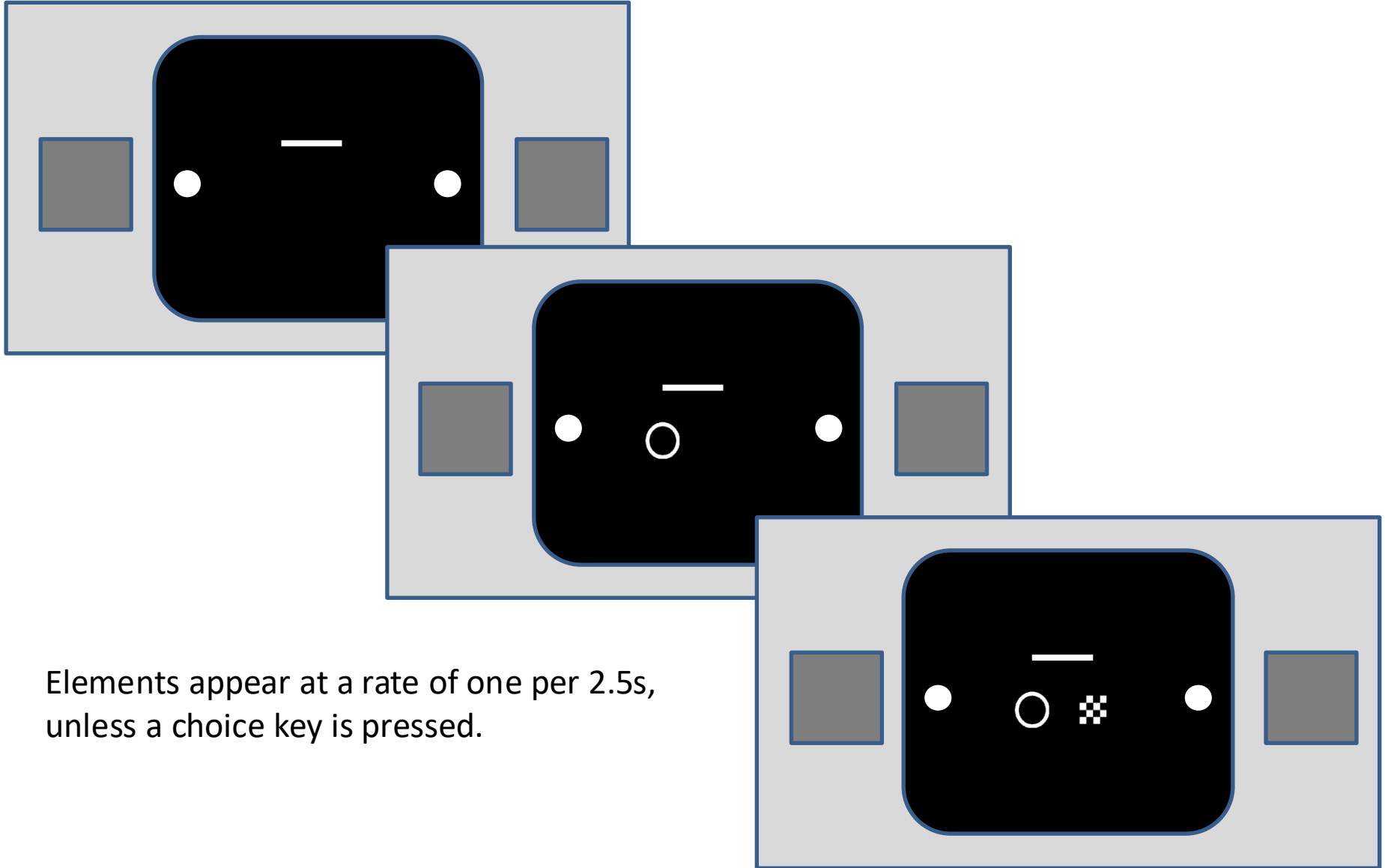
- Perhaps species differences are to be found, not in the amount of information employed in a categorization decision, but in the extent to which the available information is used – and sought – strategically?
- Two things needed to investigate this:
  - A procedure where the dimensions are differentially useful.
  - Procedures to assess strategic information use across species.

# Differential cue validity



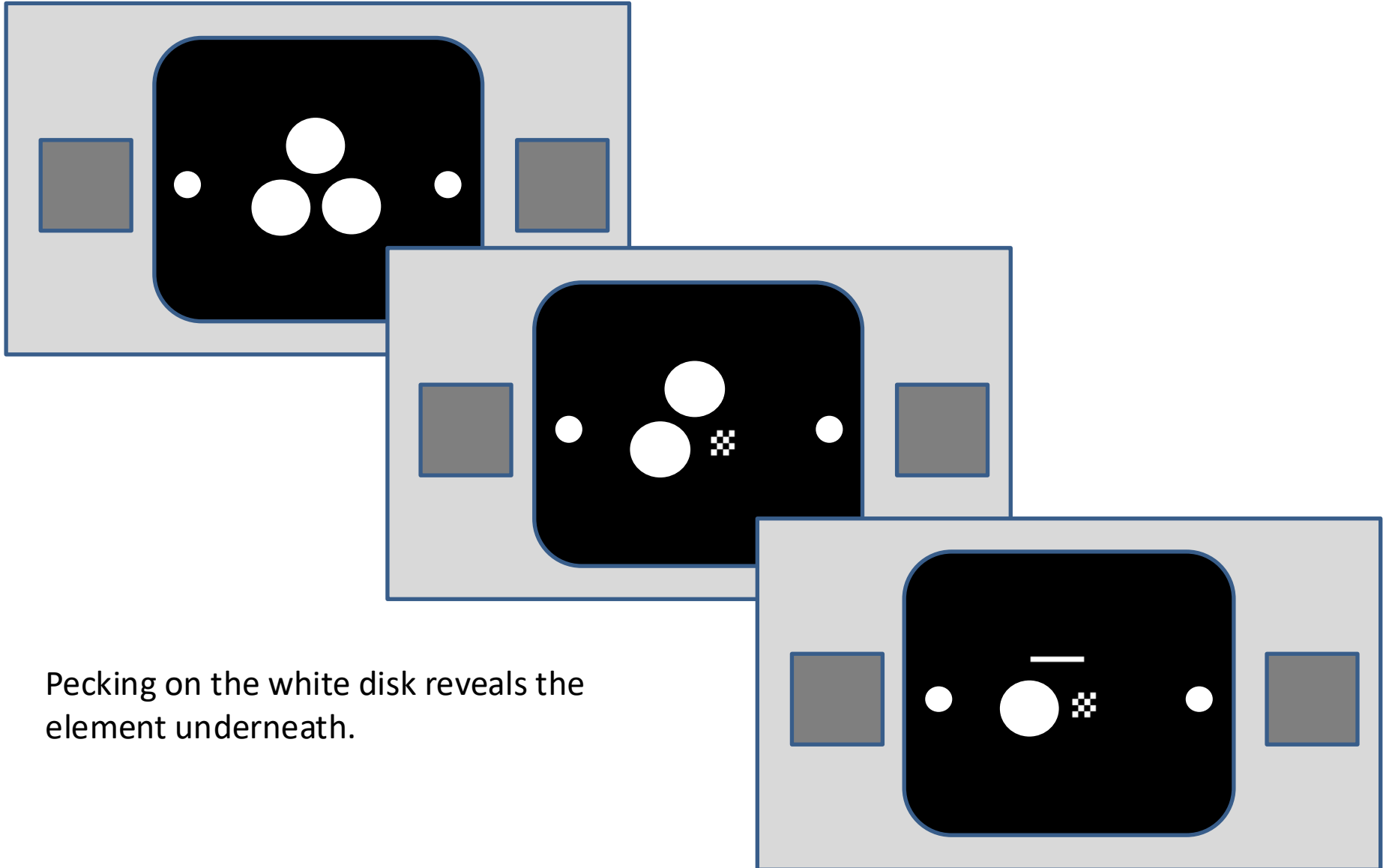
- Using a similar stimulus set to our first experiments, make one dimension perfectly predictive of category membership, one partly predictive, and one non-predictive.
- In the above example, validities are: bar length 100%; doughnut 75%; checks 50%

# Wait-to-reveal



Elements appear at a rate of one per 2.5s, unless a choice key is pressed.

# Choose-to-reveal

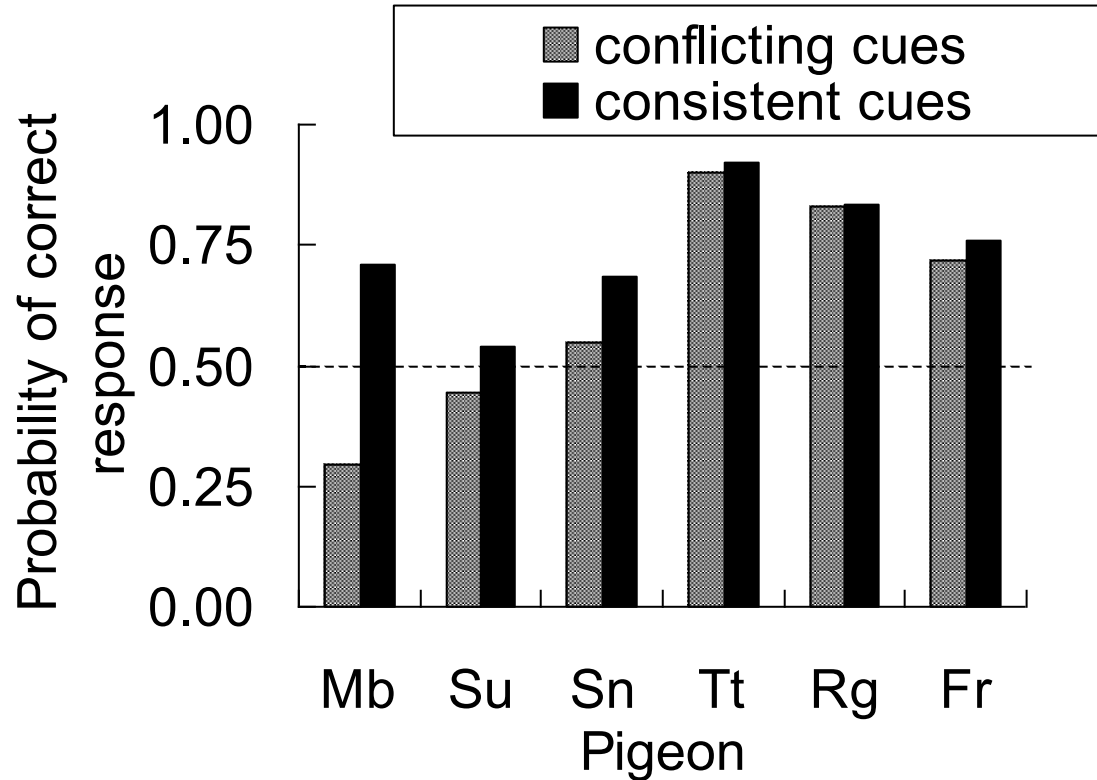


Pecking on the white disk reveals the element underneath.

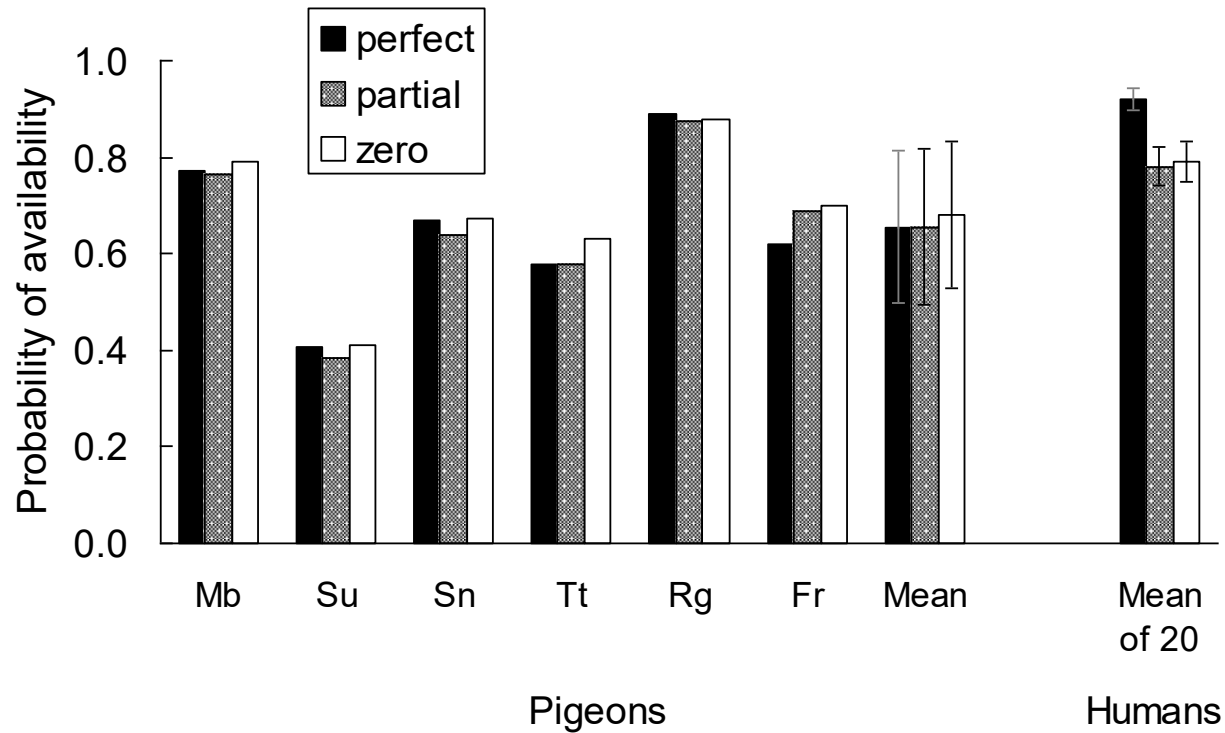
# Experiment

- Wait-to-reveal, and choose-to-reveal, sessions interspersed amongst standard full reveal sessions (2 full reveal sessions for each non-standard session).
- Will pigeons come to wait for the most valid cue before responding?
- Will pigeons come to choose the most valid cue?
- Same questions for undergraduates tested in a closely similar procedure.

# Full information trials

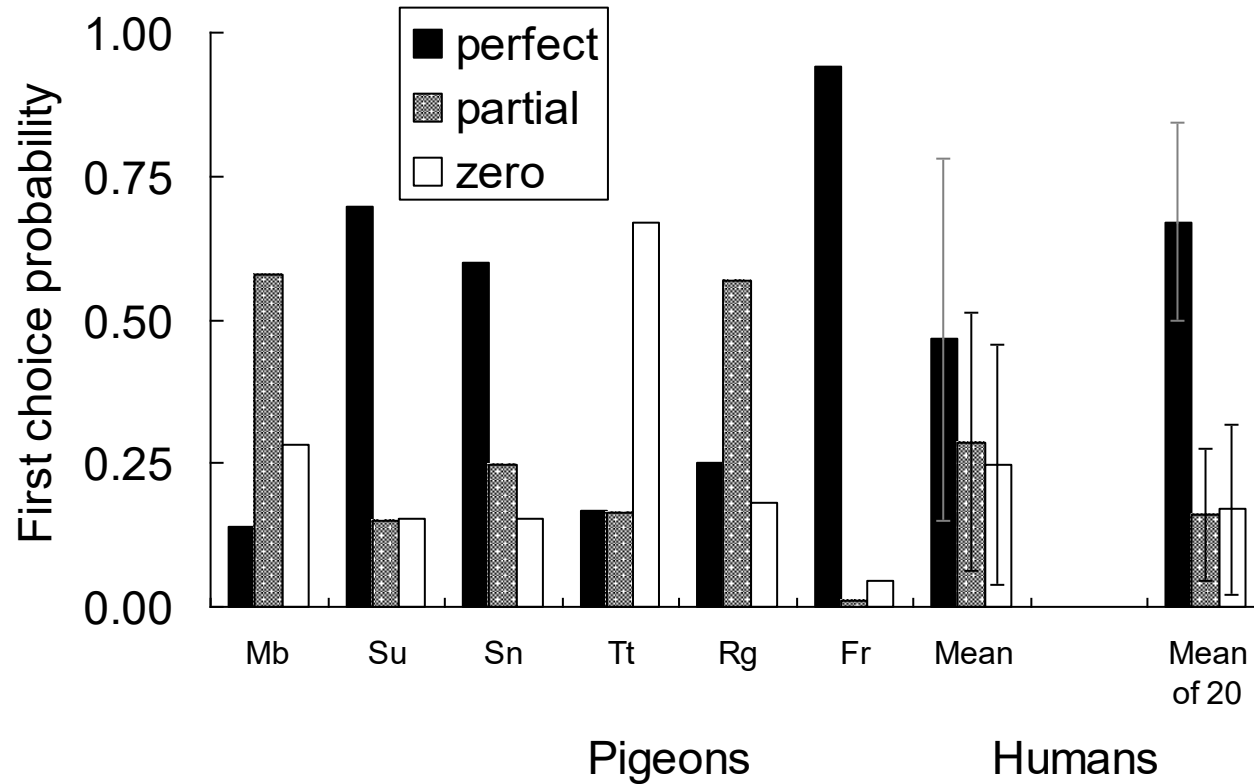


# Wait-to-reveal



- Probability that dimension is available at point of choice.
- Pigeons no more likely to wait for the perfect predictor than the non-valid predictor.
- Nearly all humans more likely to wait for the perfect predictor than the others.

# Choose-to-reveal



- Probability that a dimension is the first to be selected.
- Humans more likely to select the perfect predictor first. This is seen individually in nearly all humans.
- Numerical trend in the pigeons, but not significant. Trend seems to be driven by just two pigeons out of six (Su, Sn).

# Strategic use

- Pigeons seem less willing to wait for, and less likely to select, the most diagnostic information.