The Inverse Base-Rate Effect

Sixty Years of Partial Progress

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A patient has the following symptoms:

- Sore throat
- Rash

Do they have Jominy Fever or Phipp’s Syndrome?

They have Jominy Fever

A patient has the following symptoms:

- Rash
- Sore throat

Do they have Jominy Fever or Phipp’s Syndrome?

They have Jominy Fever

A patient has the following symptoms:

- Nausea
- Sore throat

Do they have Jominy Fever or Phipp’s Syndrome?

They have Phipps Syndrome.

A patient has the following symptoms:

- Sore throat
- Rash

Do they have Jominy Fever or Phipp’s Syndrome?

They have Jominy Fever

A patient has the following symptoms:

- Nausea
- Rash

Do they have Jominy Fever or Phipp’s Syndrome?

?

The inverse base-rate effect

3 x Sore throat + Rash → Jominy fever

1 x Sore throat + Nausea → Phipp's syndrome

Rash + Nausea → ? (Phipps?)

3 x AB → 1

1 x AC → 2

	1	2
BC	.35	**. 65**

Phenomenon first reported: Binder & Estes (1966)

Novel stimulus → (relatively) rare outcome?

3 x AB → 1

1 x AC → 2

	1	2
A	**.70**	.30
BC	.35	**. 65**

Phenomenon first reported: Medin & Edelson (1988)

Bias towards rare cue within compound?

3 x AB → 1

1 x AC → 2

3 x FD → 1

1 x GE → 2

	1	2
BC	.35	**.65**
DE	.55	.45

Phenomenon first reported: Medin & Robins (1971)

More certain about C than B?

3 x AB → 1

1 x AC → 2

	1	2
BC	.36	**.64**
B	**.88**	.12
C	.33	**.67**

e.g. Wills et al. (2014)

Enter EXIT (Kruschke, 2001)

- AB → 1 is learned first.
- This causes errors in response to AC, due to common cue A.
- These errors are avoided by directing attention away from A and towards C.
- This **error-driven, effortful attentional re-allocation** persists into the test phase.
- Thus: BC → 2, even though B > C.

Heritage: Mackintosh (1974)

Predictions of EXIT

3 x AB → 1

1 x AC → 2

3 x FD → 1

1 x GE → 2

- ✓ IBRE requires a common cue
- C more attended than B (but not E vs. D)
- IBRE mediated by prediction error
- IBRE requires **effortful** attentional reallocation.

C more attended than B

3 x AB → 1

1 x AC → 2

3 x FD → 1

1 x GE → 2

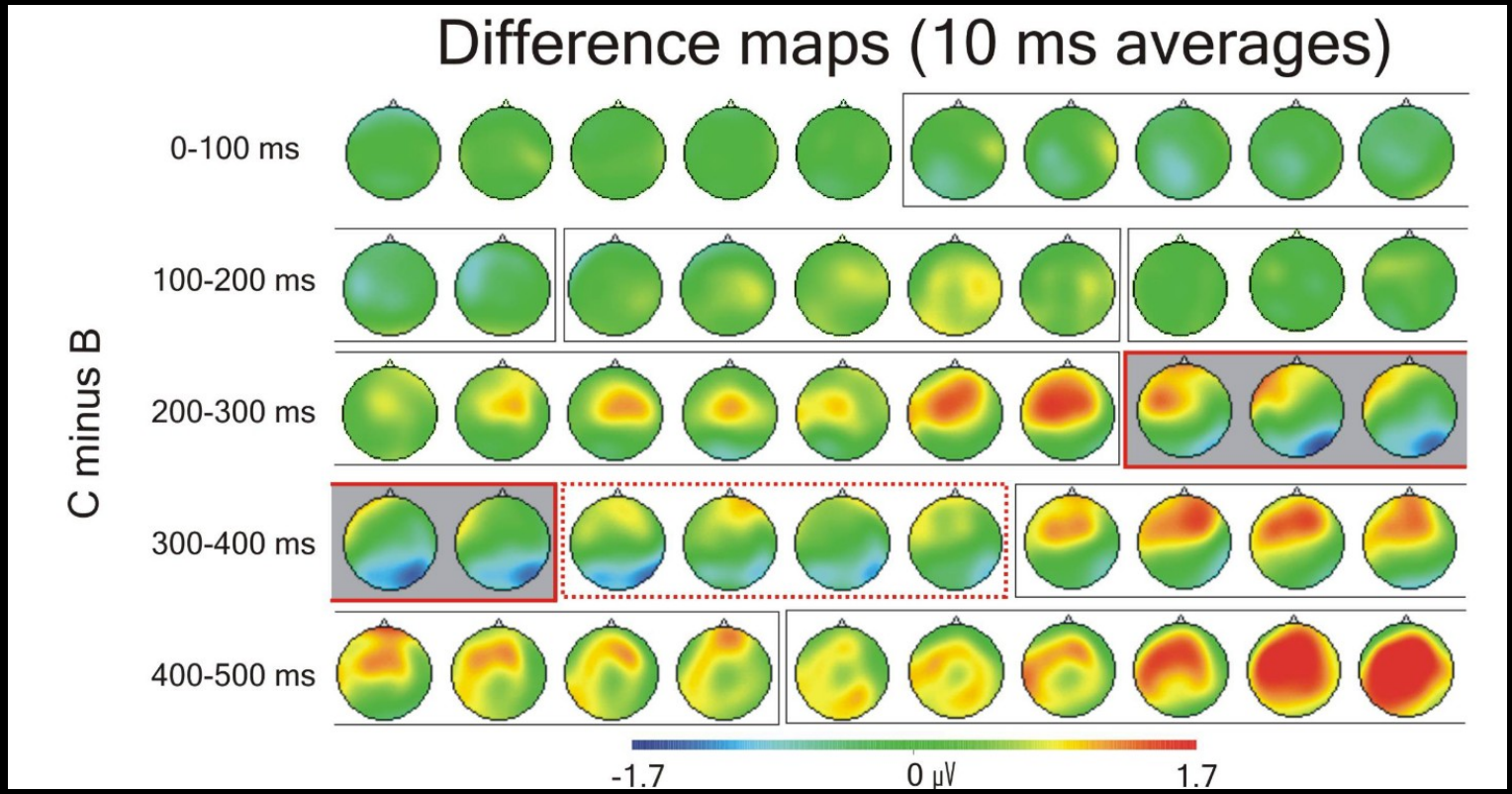
Wills et al. (2014)

C more attended than B

		1	2
3 x AB → 1	BC	.36	**.64**
1 x AC → 2	DE	.95	.05
3 x FD → 1	B	**.88**	.12
1 x GE → 2	C	.33	**.67**

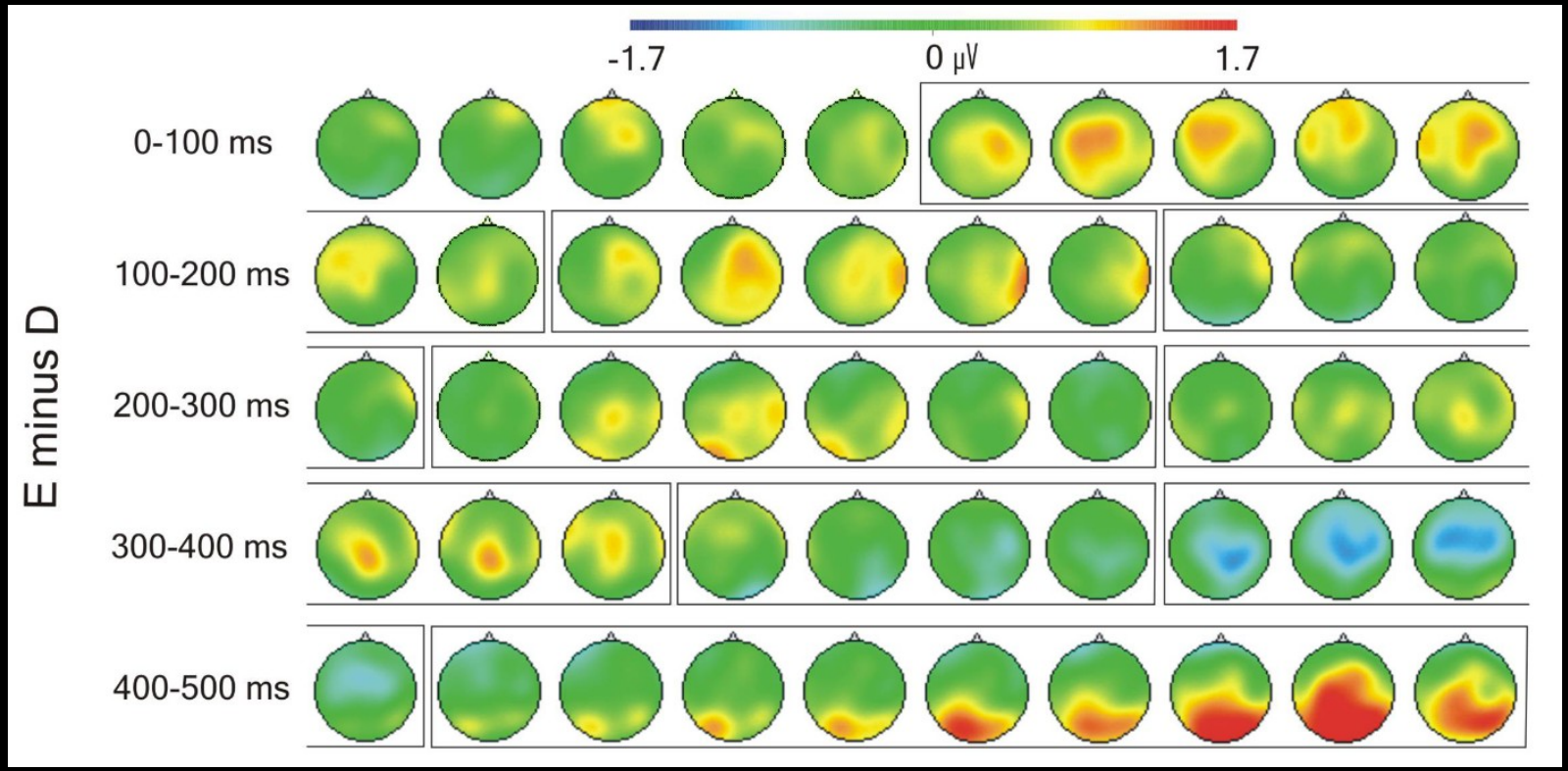
Wills et al. (2014)

C more attended than B



Wills et al. (2014)

E **not** more attended than D



Wills et al. (2014)

Predictions of EXIT

3 x AB → 1

1 x AC → 2

3 x FD → 1

1 x GE → 2

✓IBRE requires a common cue

✓C more attended than B

✓(but not E vs. D)

- IBRE mediated by prediction error
- IBRE requires **effortful** attentional reallocation.

IBRE mediated by prediction error

3 x AB → 1

1 x AC → 2

3 x FD → 1

1 x GE → 2

Inkster, Milton, Edmunds, Benattayallah, Wills (2022)

IBRE mediated by prediction error

ROI for prediction error from previous meta-analysis (e.g. Fouragnan et al., 2018):

- Striatum
- Anterior cingulate
- Medial anterior prefrontal cortex
- Right dorsolateral prefrontal cortex

	1	2
BC	.33	**.65**
DE	.44	.56
B	**.92**	.08
C	.15	**.85**

Inkster, Milton, Edmunds, Benattayallah, Wills (2022)

IBRE mediated by prediction error

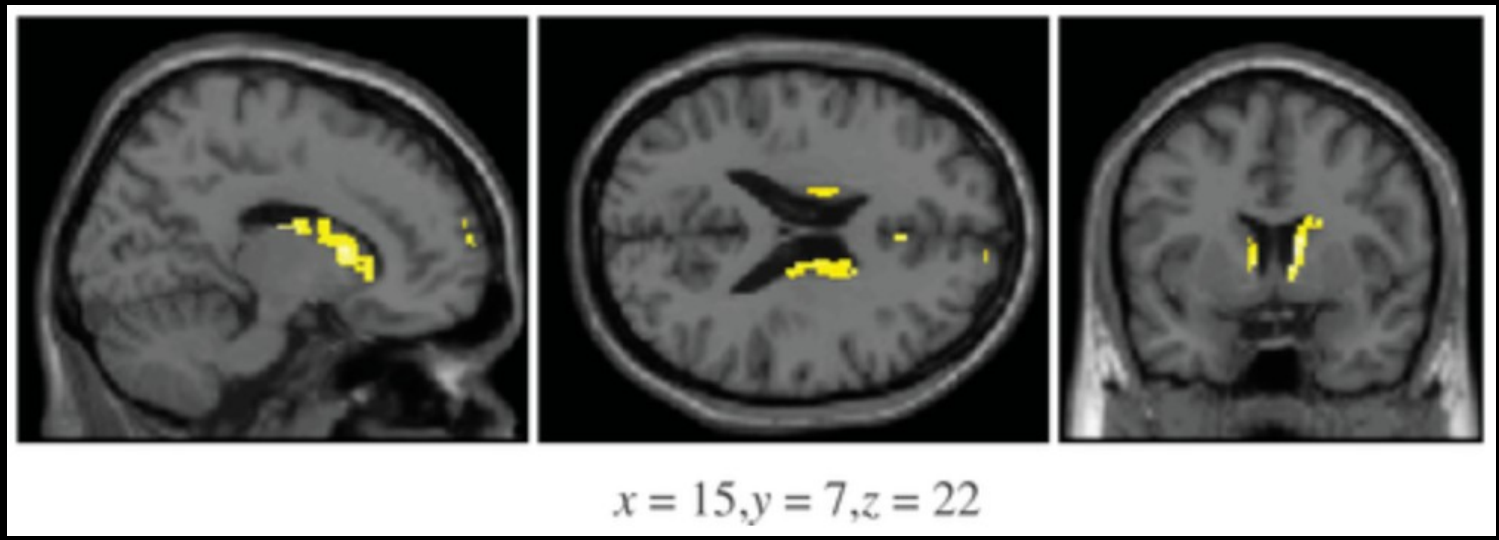
3 x AB → 1

1 x AC → 2

3 x FD → 1

1 x GE → 2

(C-B) – (E-D)



- Caudate body
- Anterior cingulate
- Right superior prefrontal cortex

Inkster, Milton, Edmunds, Benattayallah, Wills (2022)

Predictions of EXIT

3 x AB → 1

1 x AC → 2

3 x FD → 1

1 x GE → 2

✓IBRE requires a common cue

✓C more attended than B

✓(but not E vs. D)

✓IBRE mediated by prediction error

- IBRE requires **effortful** attentional reallocation.

IBRE requires **effortful** attentional reallocation

3 x AB → 1

1 x AC → 2

- Concurrent **digit load** during training and test.
- Trained to criterion.
- Two previous investigations inconclusive (Medin & Bettger, 1991; Lamberts & Shanks, 2007)

	1	2
BC (control)	.35	**.65**
BC (load)	.50	.50

Dome & Wills (in prep.)

Predictions of EXIT

3 x AB → 1

1 x AC → 2

3 x FD → 1

1 x GE → 2

✓IBRE requires a common cue

✓C more attended than B

✓(but not E vs. D)

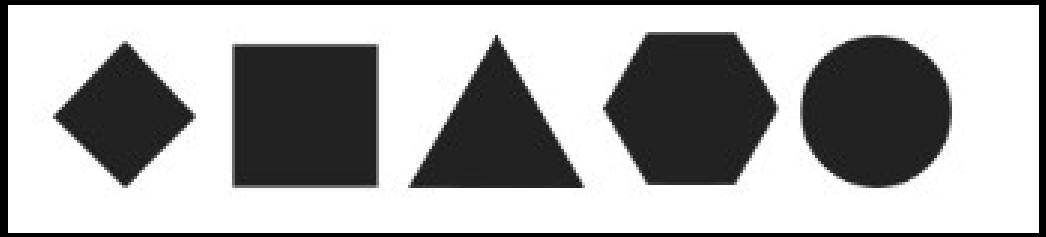
✓IBRE mediated by prediction error

✓IBRE requires **effortful** attentional reallocation.

Challenges for EXIT

- IBRE without errors?
- Human and model hetereogeneity

IBRE without prediction error



3 x ABX

1 x ACY

BC : X or Y?

	X	Y
BC	.35	**.65**
B	**.92**	.08
C	.08	**.92**

Dome & Wills (in prep.)

Heterogeneity in IBRE

3 x AB → 1

1 x AC → 2

Long test: A, B, C, BC

Large N (>300)

Most common result:

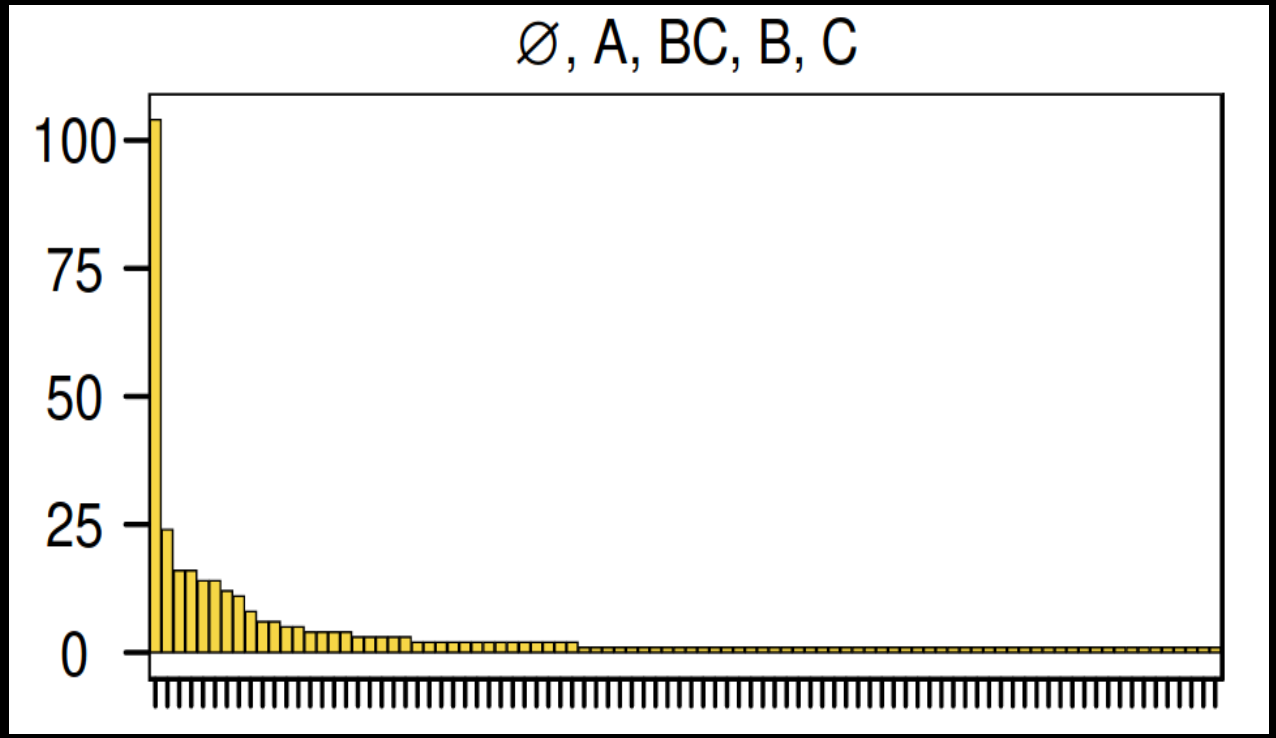
P(1):

[A, B] > .5 > [BC, C]

(about a third of participants)

Dome & Wills (in prep.)

Heterogeneity in IBRE



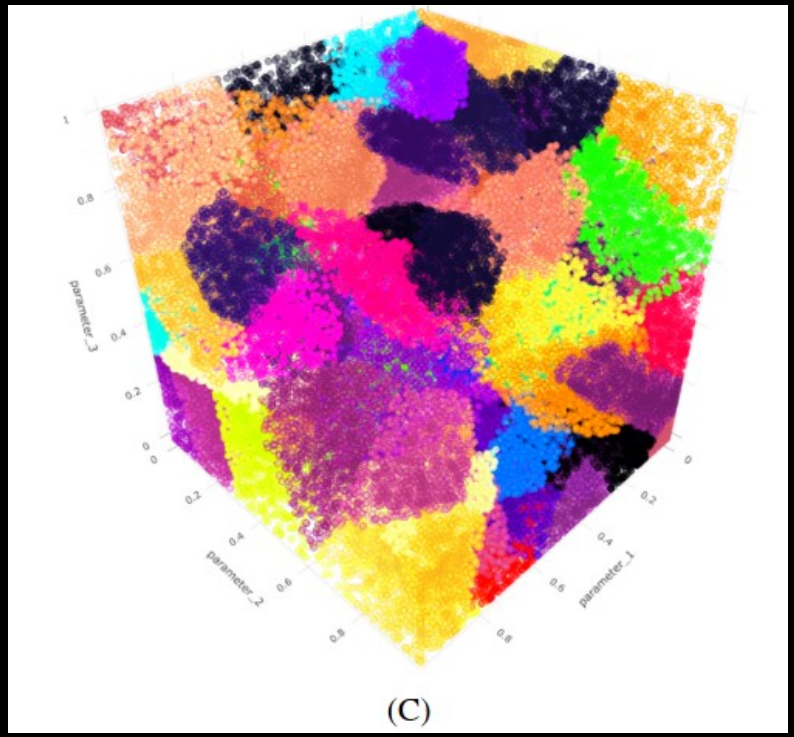
90 distinct patterns

(2,131 in the universal set)

Dome & Wills (in prep.)

Heterogeneity in EXIT

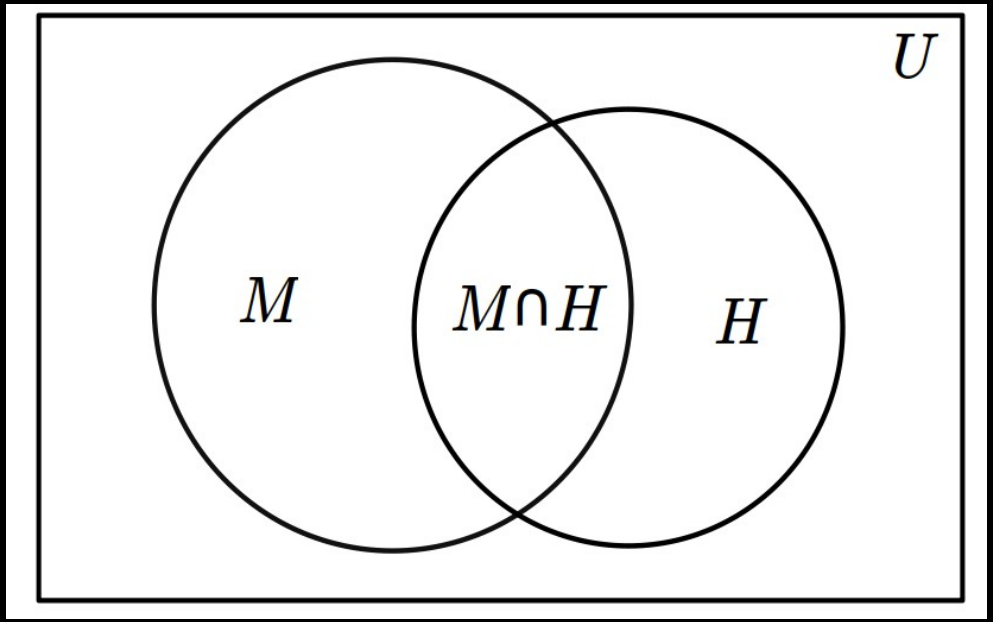
- EXIT is a formal model with several free parameters.
- It can also produce many different patterns.
- This can be investigated with Parameter Space Partitioning (see my other talk...)



Dome & Wills (in prep.)

Accommodation and prediction

- **Accommodation:** Pattern observed in both human and model.
- **Prediction:** Pattern observed in model but not (yet) in human.



Dome & Wills (in prep.)

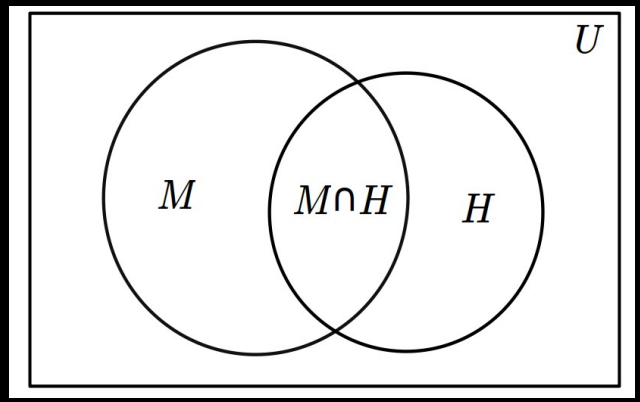
Accommodation and prediction

- **Accommodation:** Pattern observed in both human and model.

$$\alpha = \frac{|M \cap H|}{|H|}$$

- **Prediction:** Pattern observed in model but not (yet) in human.

$$\beta = \frac{|M \cap H'|}{|H'|}$$



Dome & Wills (in prep.)

Formal models of the IBRE

	α	β
Ideal model*	1	0
EXIT		
Full	.09	.17
CAG	.03	.03
RAS	.05	.08
DGCM		
(2007)	.38	.92
(2018)	.12	.12
Known weak model **	.01	0

* Under conditions of complete information

** Gluck & Bower (1988), does not capture group-level IBRE effect.

Dome & Wills (in prep.)

Sixty Years of Partial Progress

- IBRE first reported in 1966
- We’re clearer than we were about necessary and sufficient conditions
  - A → 1
  - Common cue effect
  - Sequential presentation
  - Overt errors not required
- We’re clearer about underlying processes (at least in the standard procedure)
  - Attentional re-allocation
  - Involvement of prediction error

Sixty Years of Partial Progress

- We have a clear informal account, with a formal implementation (EXIT)
- But…
  - IBRE still occurs in situations informal-EXIT would not predict
  - Formal EXIT (and all other accounts) have both poor accommodation at an individual-participant level, and are overly flexible

Thanks for listening!