Predictive learning, prediction errors and attention: Evidence from event-related potentials and eye-tracking

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Predictive learning

- Bell → Food
- “A+”
- Learning by contiguity?
  - Pavlov (1927)
  - Thorndike (1898)

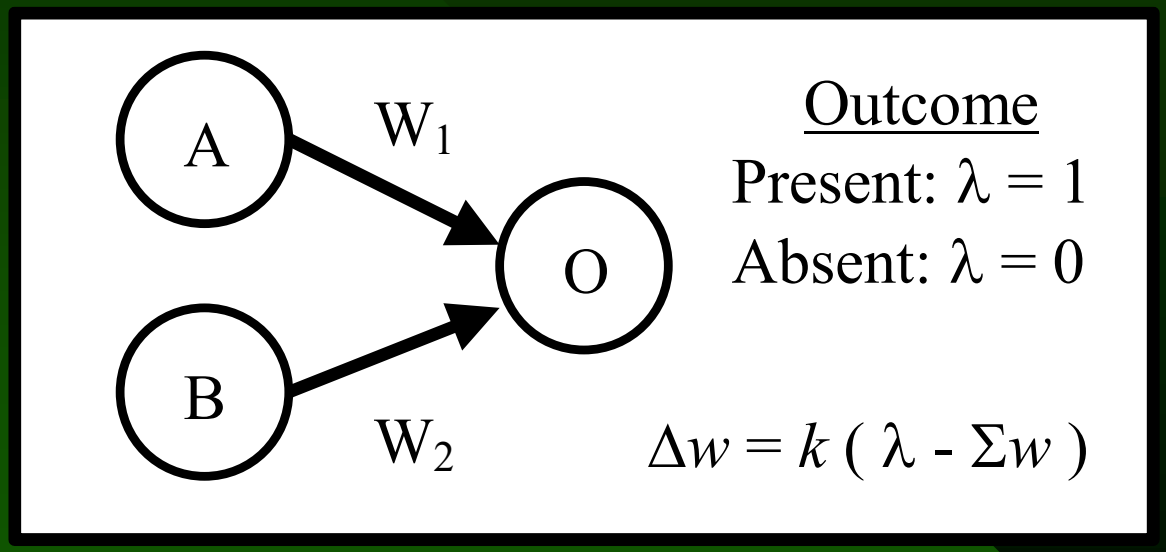
Surprise-dependent learning

	Phase 1	*Phase 2*	*Test*
Exp.	A+	AB+	B?
Ctrl.		AB+	B?

- “Blocking” (Kamin, 1969)
- Prediction errors

Learning and prediction errors

- Direct associative theories
  - Rescorla-Wagner (1972)



A+ AB+ B?

AB+ B?

Learning and prediction errors

- Learning via attention induced by prediction errors
  - Pearce-Hall (1980); Mackintosh (1975); Kruschke (1992, 2001).

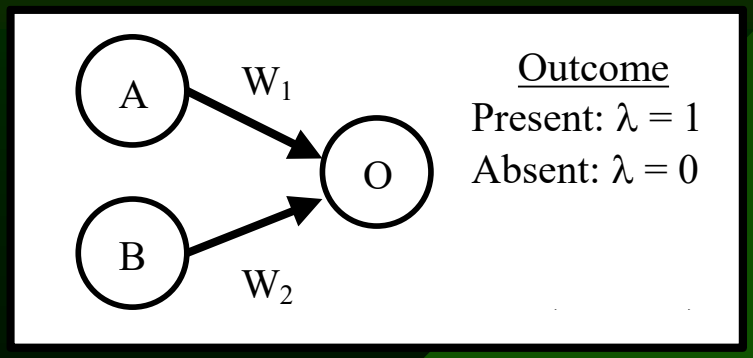
Learning and prediction errors

$\Delta V_A = \alpha_A(\lambda - V_A)$

$\Delta\alpha_A$ is positive if $|\lambda - V_A| < |\lambda - V_x|$

$\Delta\alpha_A$ is negative if $|\lambda - V_A| > |\lambda - V_x|$

A+	AB+	B?
	AB+	B?



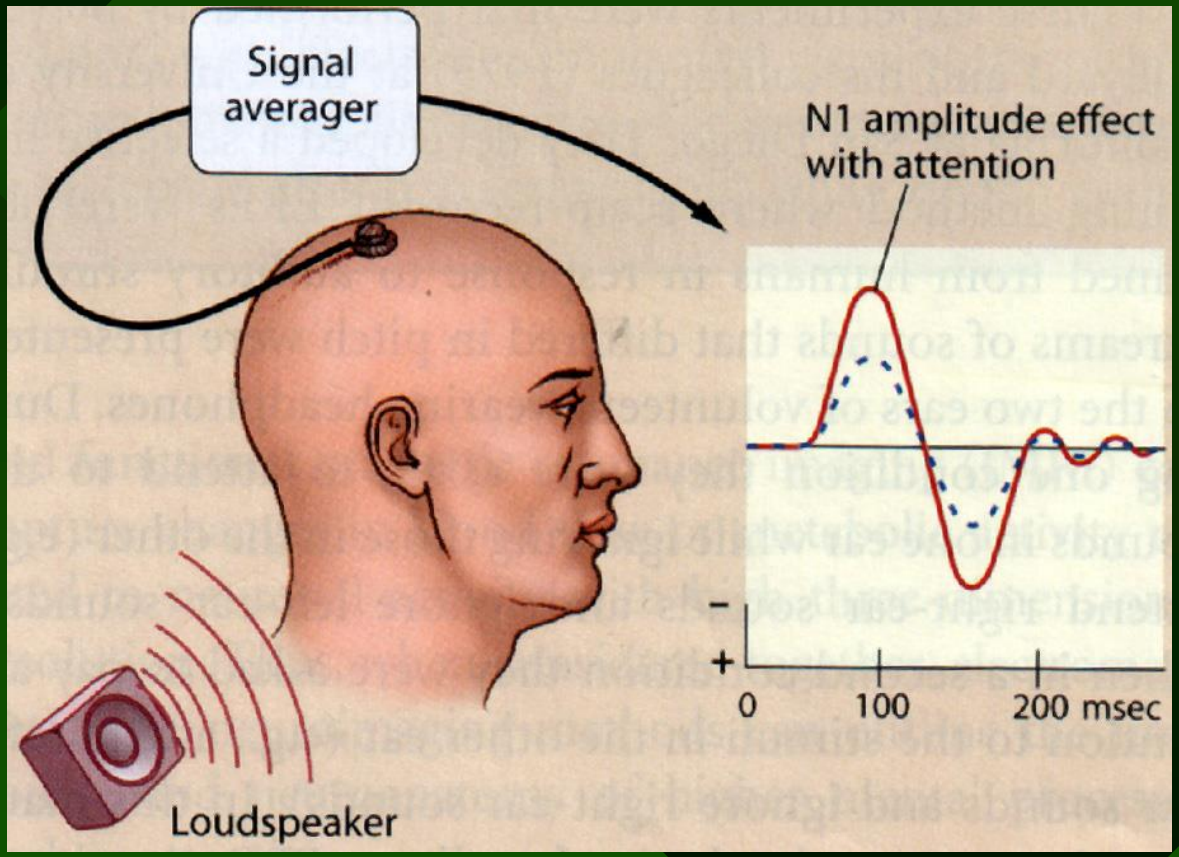
Learning and prediction errors

- High-level reasoning processes
  - De Houwer et al. (2005), Lovibond (2003).

Experiment 1

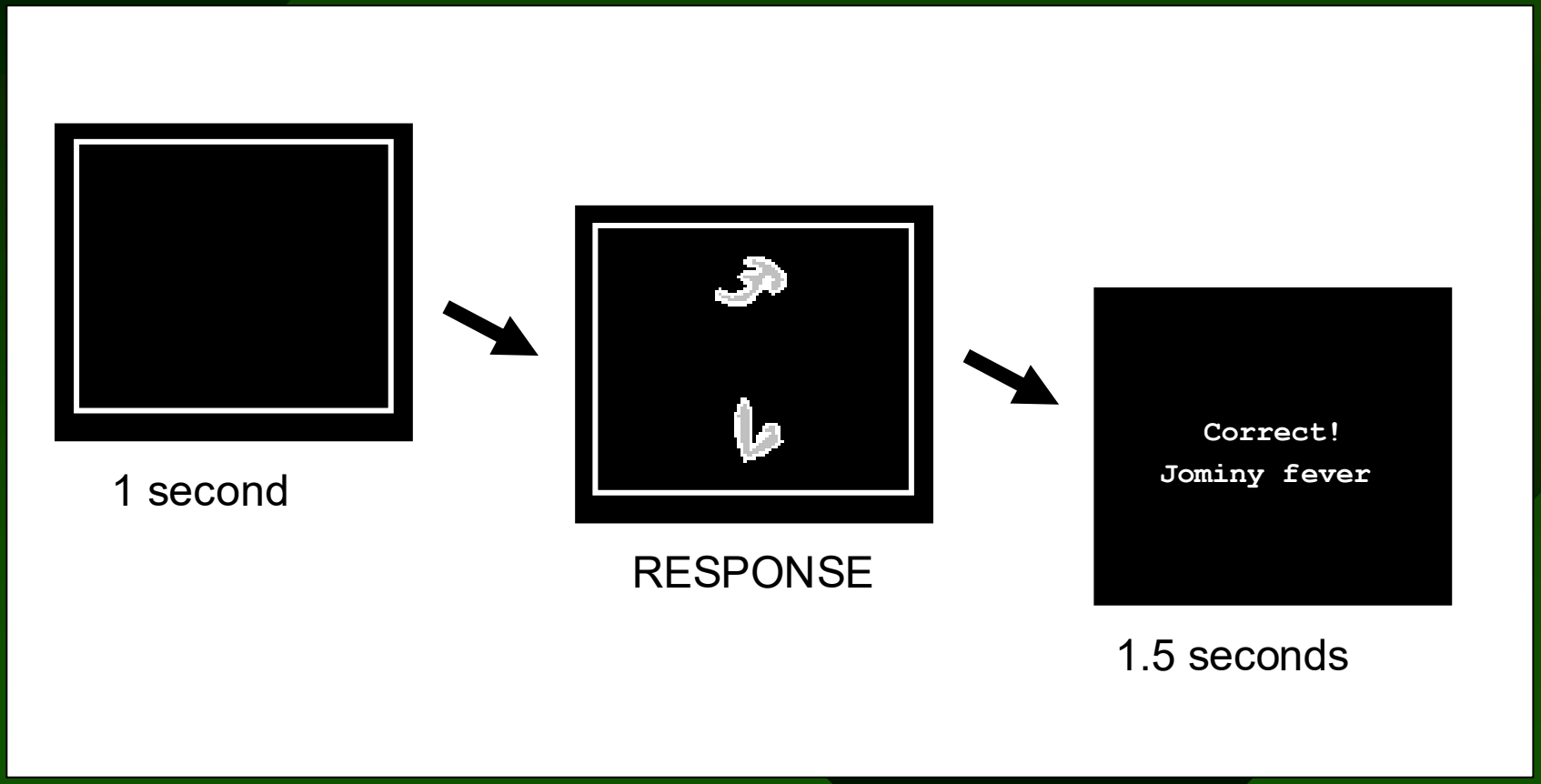
- ERP evidence for attentional processes in a predictive learning task with adult humans.

ERP and attention



- Hillyard et al. (1973) … Luck *et al*. (2000)

Trial structure



- 2 second time-out (0.3% trials terminated)

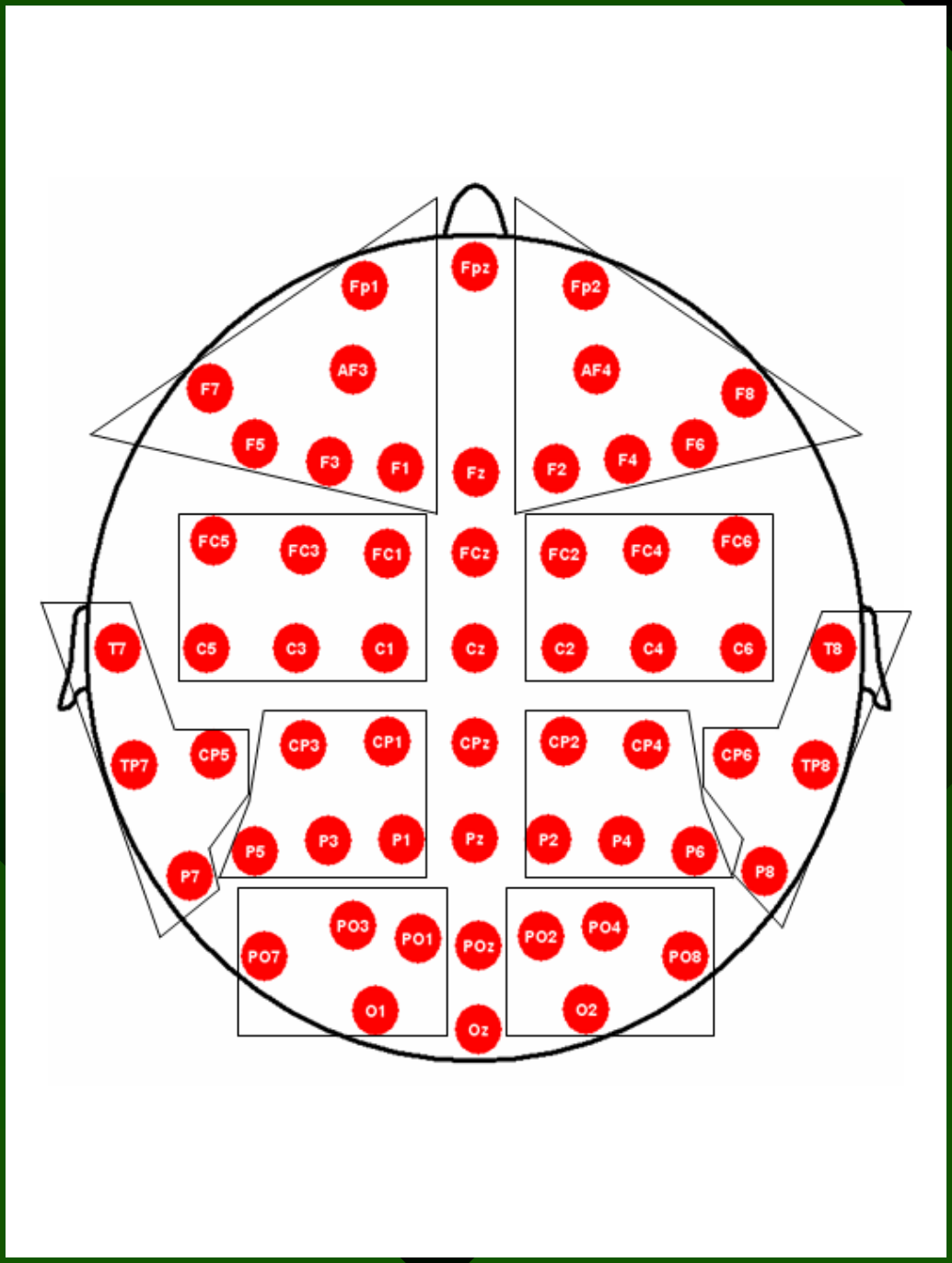
Experimental design

Phase 1	Phase 2	Phase 3
A+	AX+	X: “No data”
B-	BY+	Y: “No data”
I-	IJ-	A+, B-, AX+, BY+
(192)	(144)	(288)

- Each letter represents 4 icons

Prediction

- Larger N1 for Y than for X
- High-density EEG array allows cortical localisation.



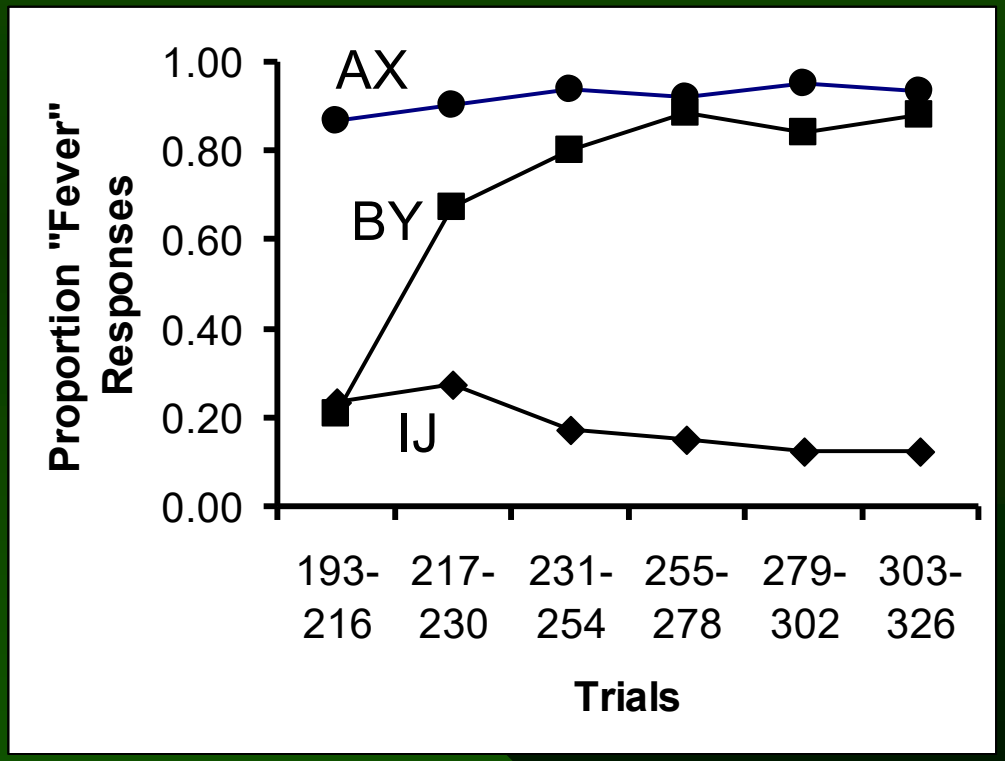
Behavioural results

Phase 1

A – 0.90

B – 0.03

I – 0.03



Phase 3

X – 0.45

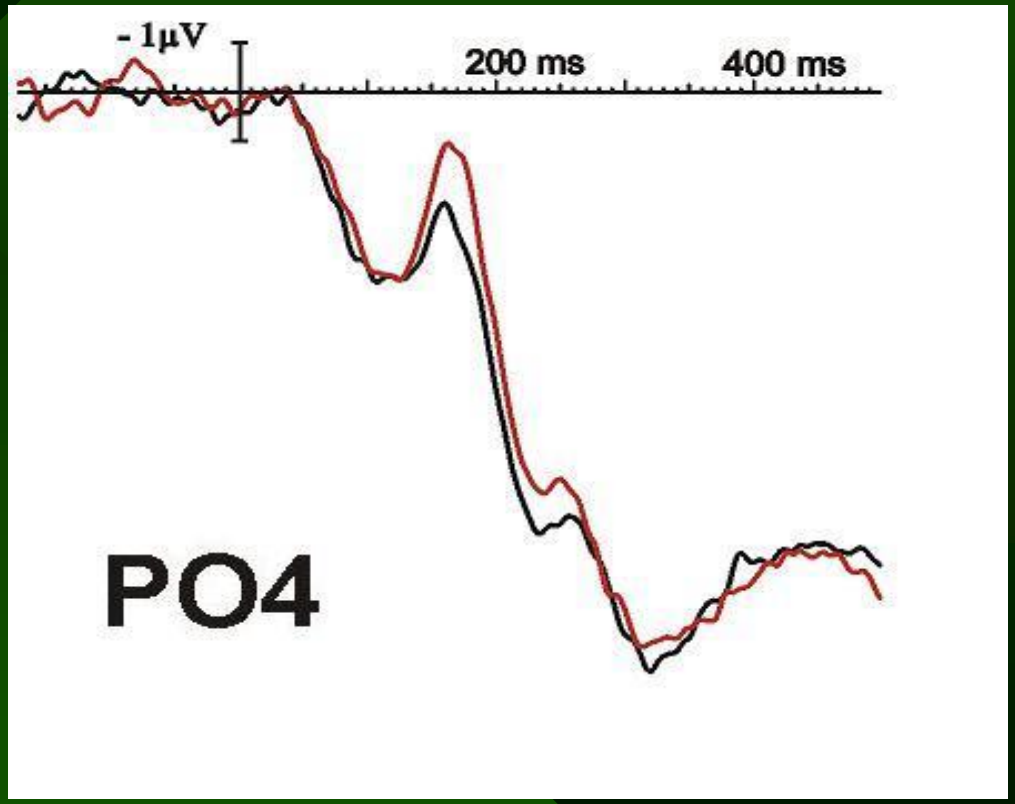
(807ms)

Y – 0.72

(767ms)

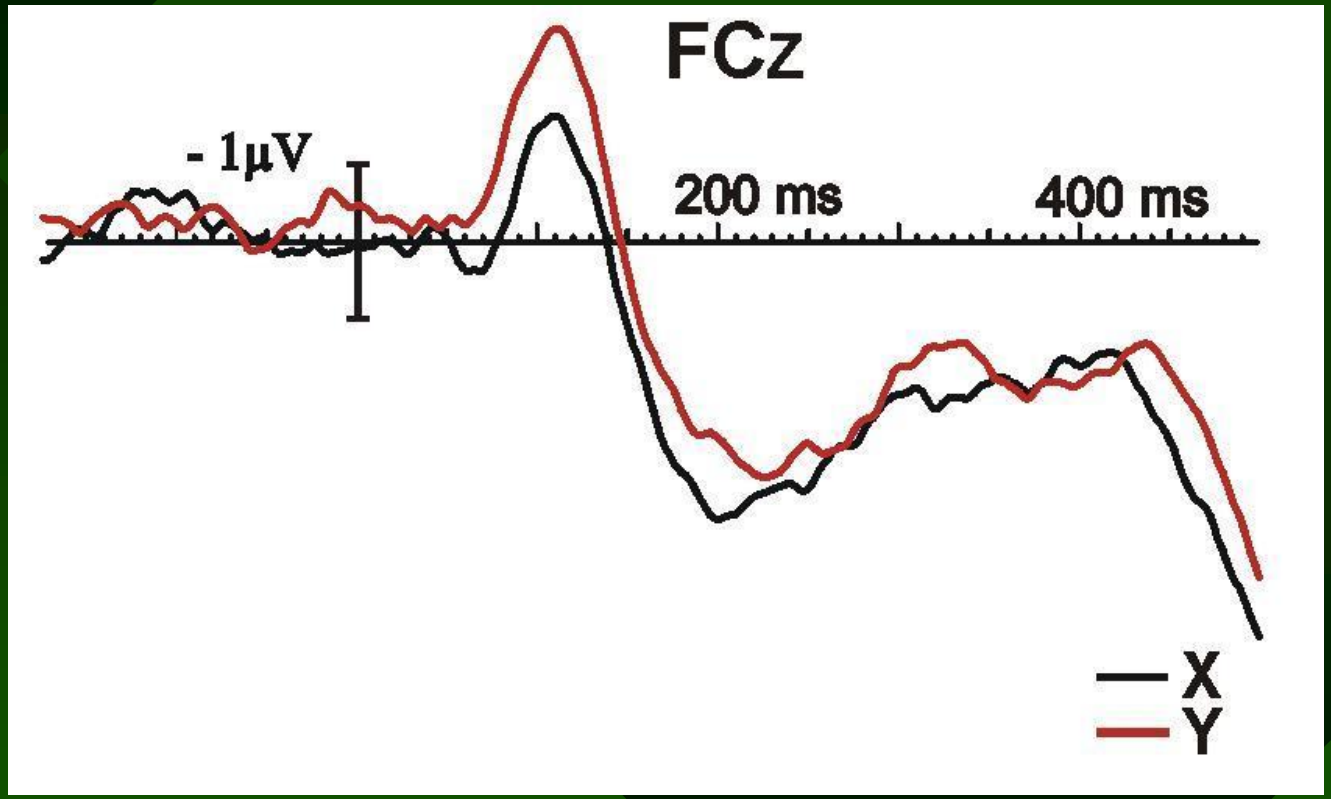
- Other phase 3 trial types:
  A:0.96; AX: 0.98; BY: 0.91; B: 0.18

Predicted N1 difference



- Posterior scalp regions

Earlier AN1 difference

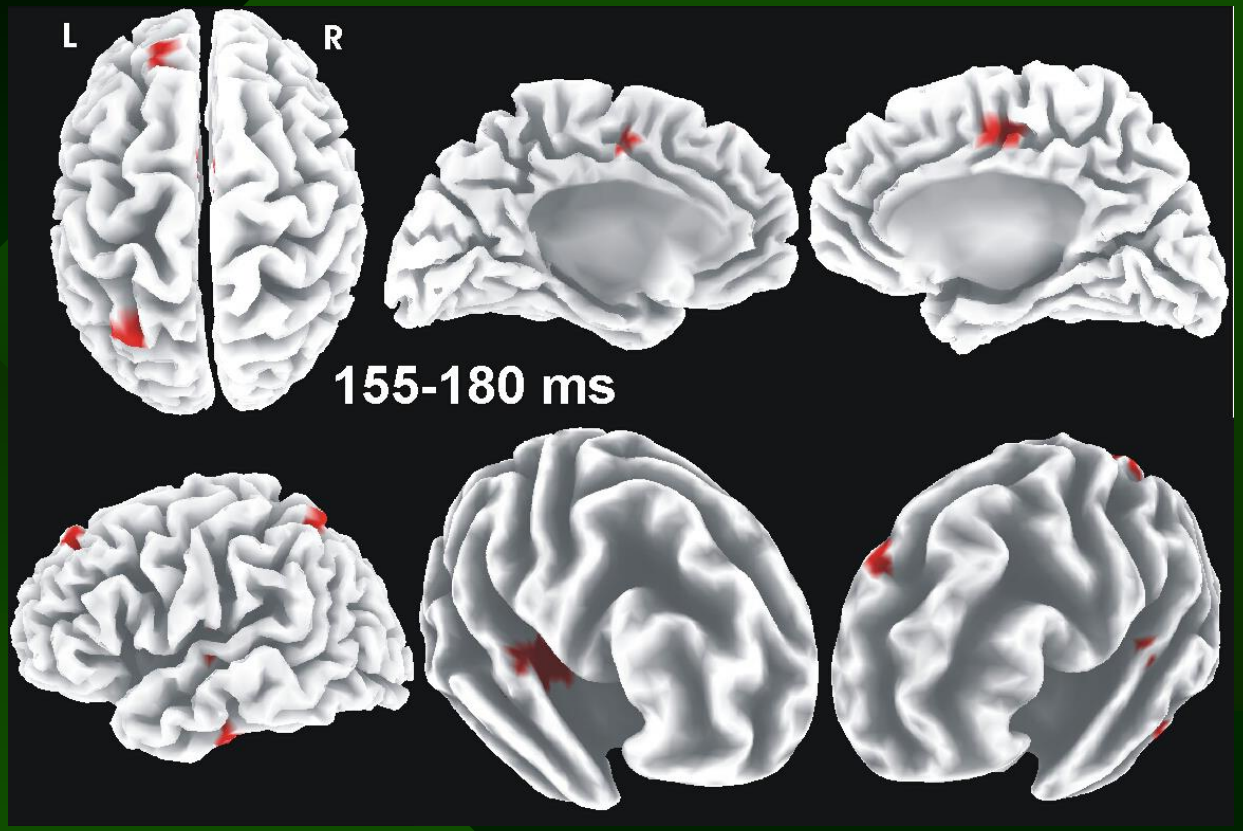


- Anterio-central scalp regions

Cortical localisation

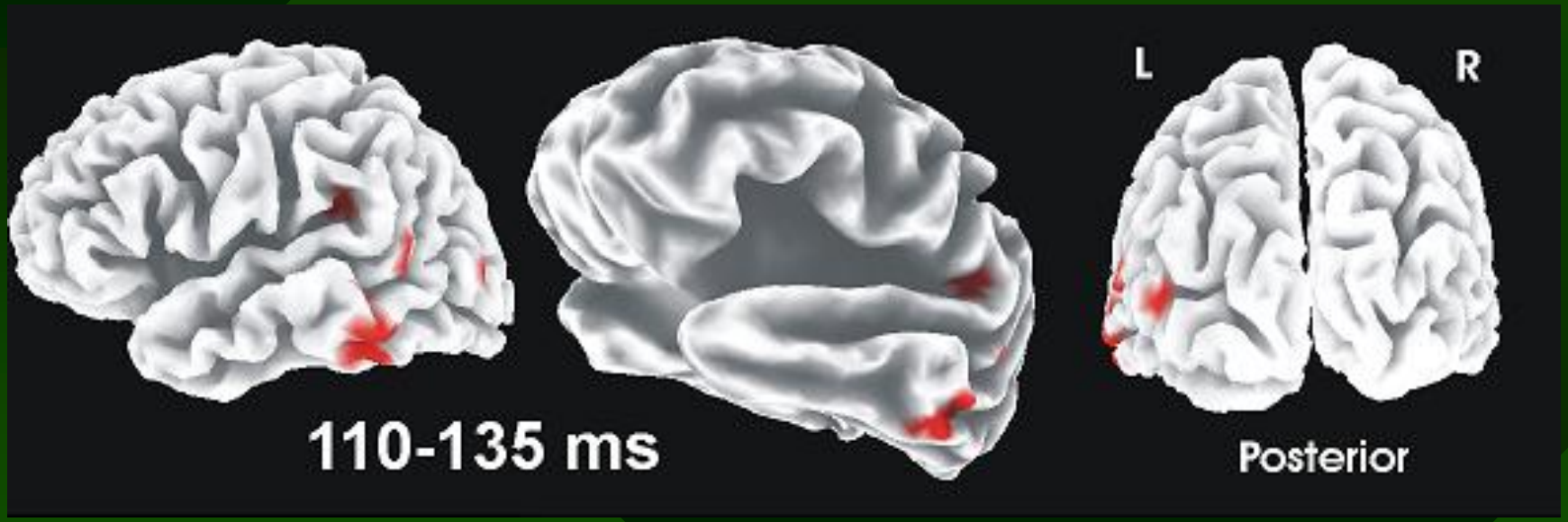
- **LO**w-**R**esolution **E**lectromagnetic **T**omography **A**nalysis
  - "LORETA"
  - Computes 3D intracerebral current density
  - Solves the "inverse problem" through a smoothness assumption
  - Extensively validated
  - Computations restricted to cortical gray matter and hippocampi
  - Spatial resolution: 7mm

N1 time window



- **Posterior parietal**
- Posterior region of **anterior cingulate**
- **Supplementary eye field**
- Temporal (more anterior, inferior)
- Anterior insula

AN1 time window



- **Occipital**
- **Inferior temporal**
- Posterior insula

Localisation summary

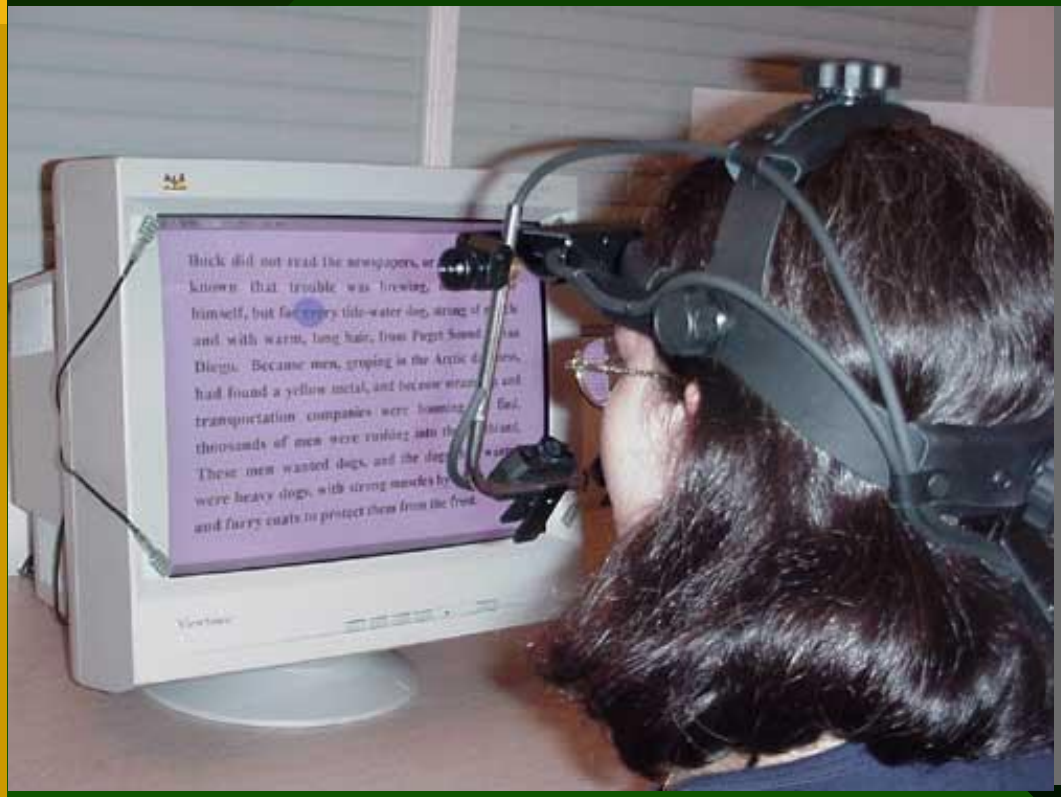
- Early time window
  - Temporal-occipital
    - Endogenous attention shifts (Kim et al. 1999)
- N1 time window
  - Posterior parietal, supplementary eye-fields
    - Selective visual analysis (Nobre et al. 2000)
  - Posterior region of anterior cingulate
    - Attention shifts (Kim et al. 1999)
- Insular activity
    - Attention? (Kim et al. ; Nobre et al)
    - Language processing? (Fylnn et al, 1999)

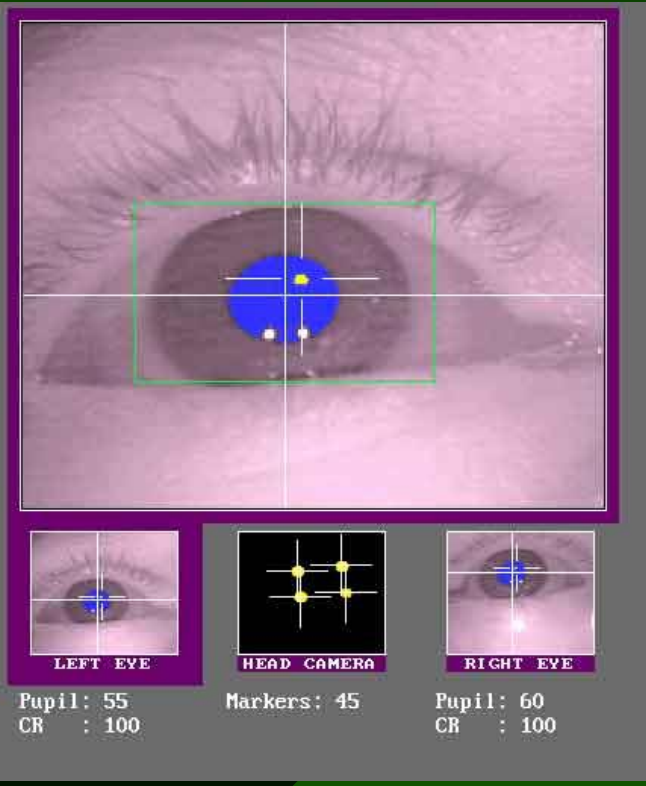
Exp. 2 – Eye-tracking

- Exp. 1 limitation:
  - It's a post-learning effect

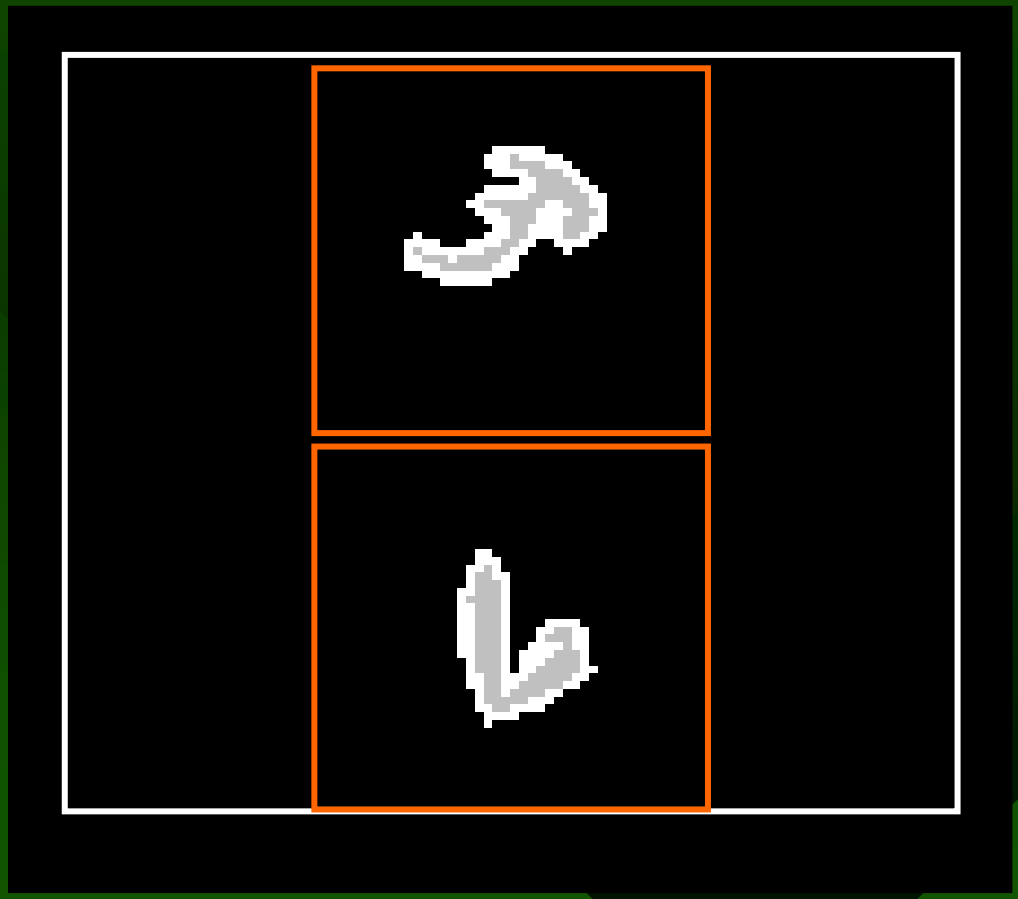
Phase 1	Phase 2	Phase 3
A+	AX+	X: "No data"
B-	BY+	Y: "No data"
I-	IJ-	A+, B-, AX+, BY+

Eye-tracking methodology





Regions of interest



Results

	Dwell	X / (X + A)
X	337ms	37%
Y	435ms	46%

Conclusion

- Subjects distinguish very rapidly (135ms) between events that differ in their previous involvement in prediction errors.
- Nature and localisation of ERP differences implicates attentional processes.
- Human asssociative learning not entirely the product of high-level reasoning processes.