Neural Tracking of Implicit vs Explicit Phonotactic Learning

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The Question

Do implicit and explicit learning lead to different neural commitments?

Implicit and Explicit Learning

Implicit learning

- Cue-based
- Effortless
- Unconscious
- Gradual
- No feedback
- Only positive examples

Explicit learning

- Rule-based
- Effortful
- Conscious
- Abrupt
- Feedback
- Both positive and negative examples

Moreton and Pertsova (2016)

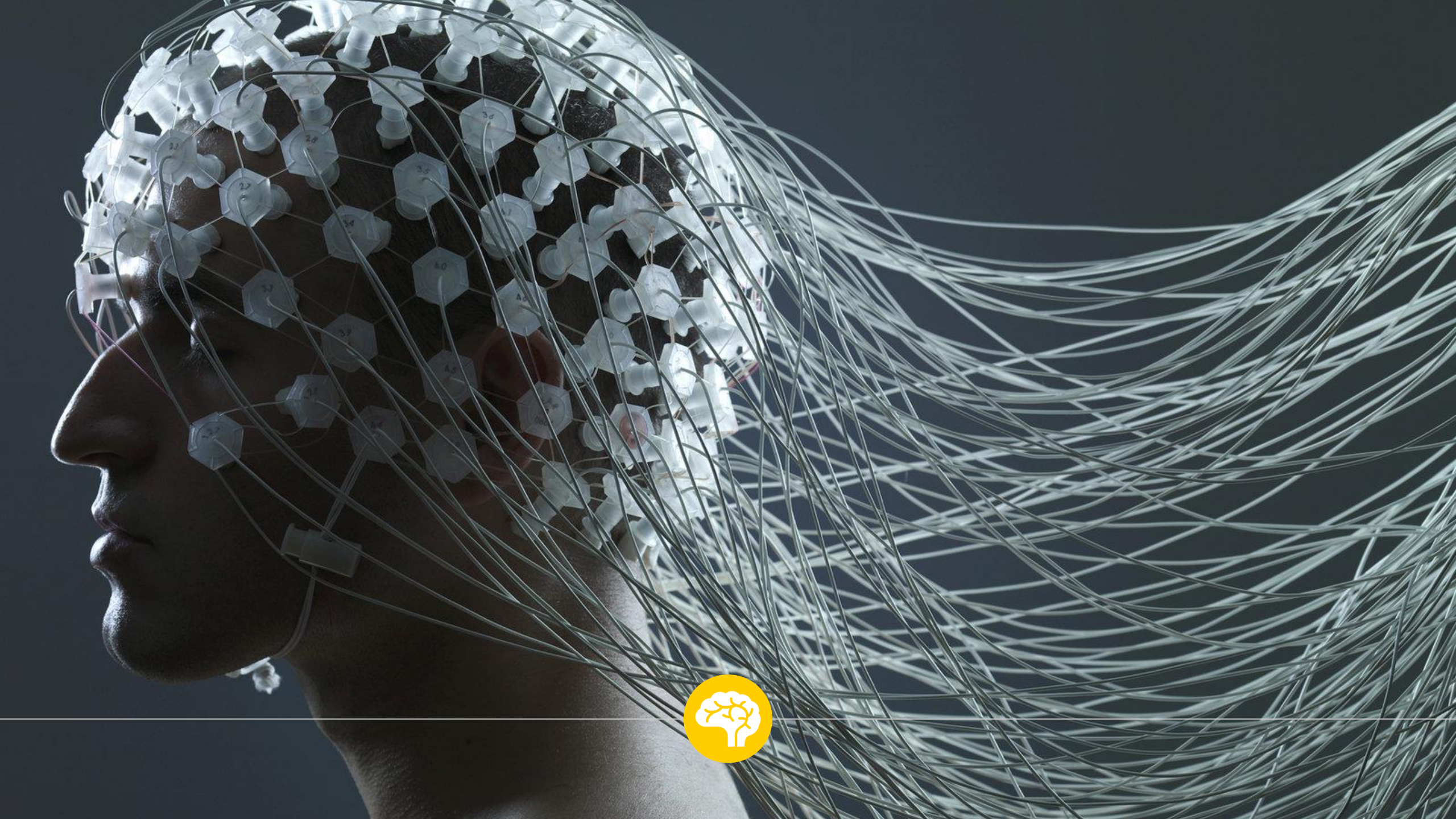
Neural Commitment

- Language exposure produces neural commitment.
  - Causes physical change in neural tissue
  - Affects future processing and learning

Kuhl et al. (2008)

Neural Commitment

- Will neural commitment be detectable after very brief exposure in a laboratory setting?



Phonotactic Pattern Learning

ʃeʃo sasi sosu

ʃuʃa siʃe

The pattern

- Sibilant harmony
  - Attested in Chumash and Navajo

- Non-local pattern
  - The agreeing segments can be non-adjacent

shtoyonowonowash – ‘it stood upright’

Applegate (1972), Sapir and Hoijer 1967

Our Study

- Artificial Grammar Learning Paradigm
- Between subject design
  - Two groups: one group gets implicit training, the other group gets explicit training
  - Both get the exact same test
- Categorization task
- Measure brain responses

Experimental Design

Implicit Group (N=24)	Explicit Group (N=21)
	Explicit Rule Telling and Familiarization with Feedback
Training Phase- exposure to the artificial pattern (Listen and Repeat)	Training Phase- exposure to the artificial pattern (Listen and Repeat)
Testing Phase- Oddball Paradigm (EEG) (300 Trials*1Block)	Testing Phase- Oddball Paradigm (EEG) (300 Trials*4Blocks)

Test Phase

- Oddball paradigm
  - **Ungrammatical** words appear infrequently among frequently appearing **grammatical** words.
- Categorization task
  - Categorize each word as part of the language or not by button press

sisa ʃaʃa sisu seʃo

Stimuli

- CV.CV, with sibilants ([s, ʃ]), [a, ɛ, ɔ, i, u].

- 100 words:
  - half agreeing - [saso], [ʃeʃi]
  - half disagreeing - [saʃi], [ʃeso]
- Naturally recorded
- Strictly controlled duration, each word 400 ms (and violation and 200 ms)

Results

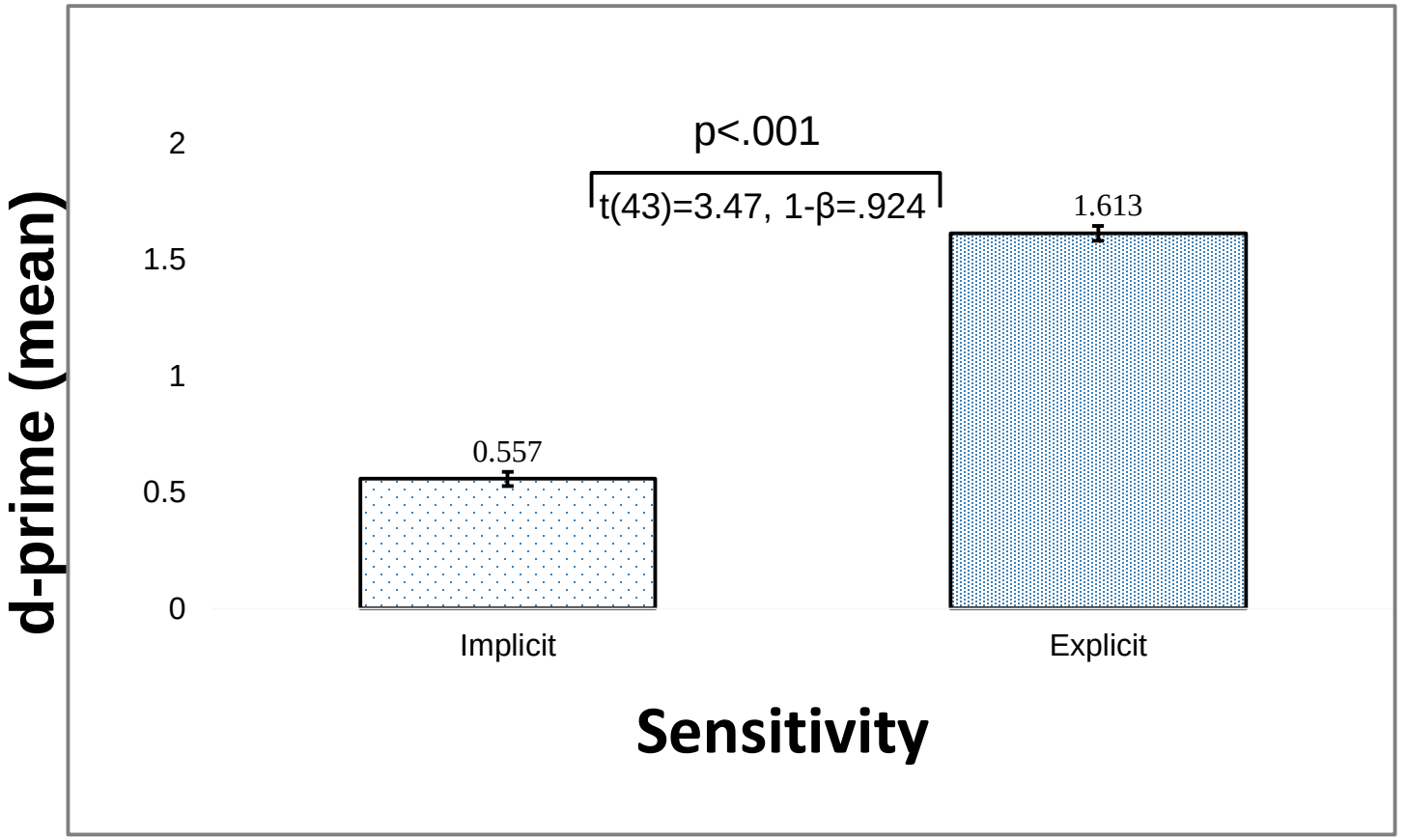
Do implicit and explicit learning lead to different neural commitments?

- Two measures – behavior and brain response

Behavioral Results

Sensitivity index (d-prime)

Behavioral Results



- Both groups learned the pattern, but explicit group performed better.

EEG Results

P3 and LPC

EEG predictions

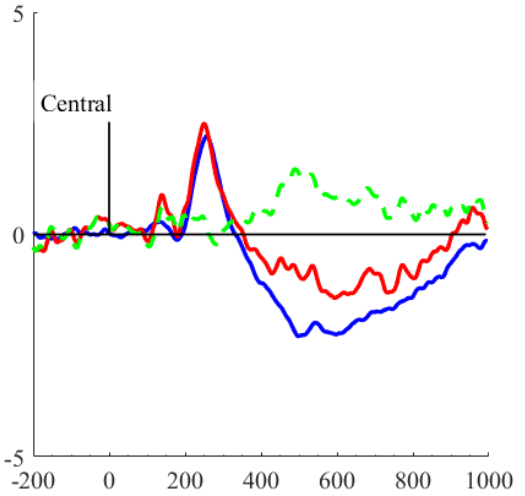
- Categorization task – oddball design

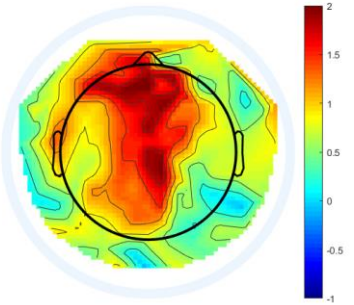
- P3 – index of categorization
  - Peaks 300ms after stimulus onset before the button press
  - P3 difference wave reflect processing difference grammatical and ungrammatical

Luck et al. (2009)

EEG results - P3

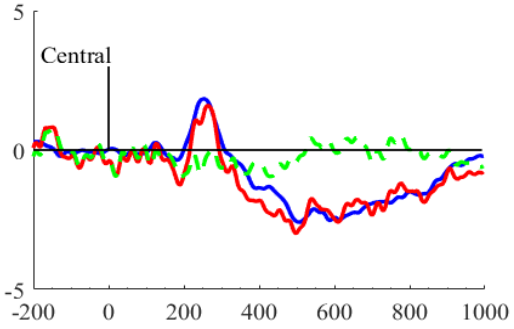
- Implicit group – P3
  - Peaks 300ms after violation point
  - F(1,23)=11.43, p<.003, 1-β=0.875



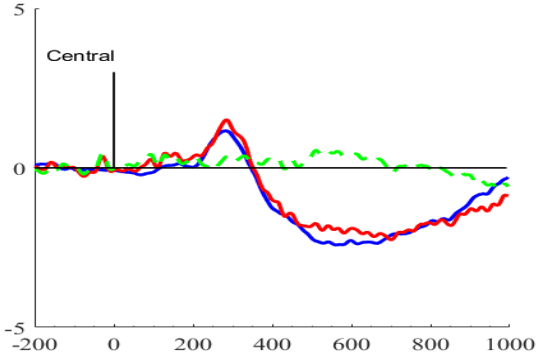


500ms

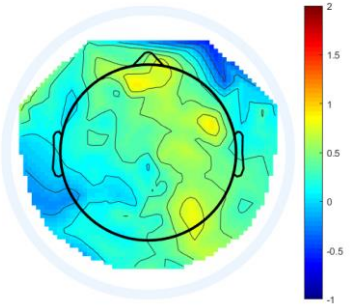
- Explicit group – **no** P3
  - F(1,20)=3.48, p=.077



300 Trials



1200 Trials



500ms

EEG predictions

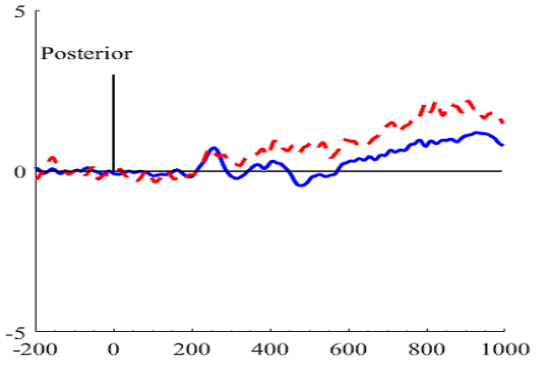
- LPC – anomaly detection in rule-governed sequences
  - Peaks 600ms after stimulus onset
  - Ungrammatical words elicit higher positivity

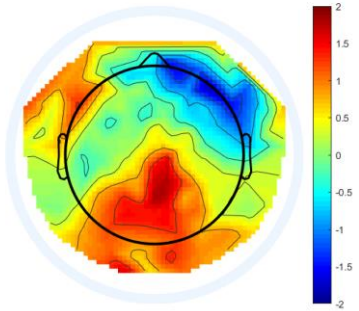
- Native speakers', L2 learners' and lab learners' processing of phonological violations elicit LPC.

McLaughlin et al. (2010), Domahs et al. (2009), Moore-Cantwell et al. (forthcoming).

EEG results - LPC

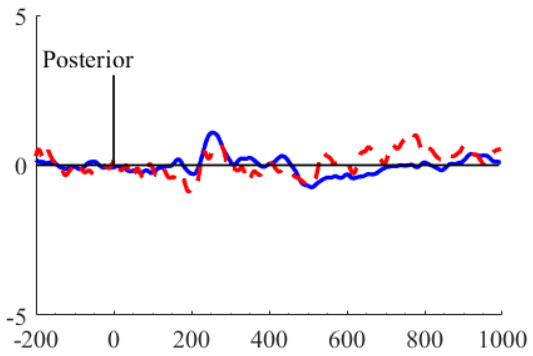
- Implicit group – LPC
  - Peaks 600ms after violation point.
  - t(23)=2.281, p=.032, 1-β=0.715



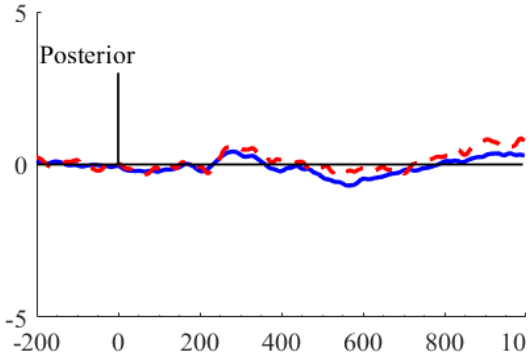


800ms

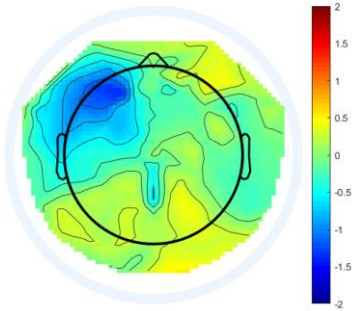
- Explicit group – **no** LPC
  - t(20)=1.263, p=.221



300 Trials



1200 Trials



800ms

Summary of the results

- Implicit group
  - Learned the pattern
    - Moderate behavioral sensitivity
  - Brain response to violation: P3 and LPC
- Explicit group
  - Learned the pattern
    - High behavioral sensitivity
  - No brain response to violation, despite the presence of a robust AEP and Readiness Potential.

Discussion

- The P3 difference wave reflects stimulus evaluation prior to motor response selection.
- P3 shows how your brain quickly computes the phonotactic difference between grammatical and ungrammatical words.

- The LPC shows that violations of non-adjacent phonotactic constraints influence later stages of cognitive processing.

Discussion

- These results support the distinction between implicit and explicit models.

- Implicit and explicit learning lead to different types of neural commitments.
  - Implicit learning leads to a measurable neural learning response typical of the categorization systems.
  - Explicit learning leaves the brain silent.

Moreton et al. (2017), Ashby and Maddox (2005)

Conclusion

- Implicit and explicit learning converge on similar knowledge states, but with different underlying neural mechanisms.

epl experimental psycholinguistics lab

Collaborators

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