Feedback Processing in Paired Associate Declarative Learning of Linguistic and Nonlinguistic Paradigms

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Introduction

Though it is recognized that feedback processing is essential for language learning, research has yet to examine the effect of the **linguistic system** on **feedback processing**. We hypothesize that the linguistic system plays an integral role in **declarative learning** and one's ability to utilize feedback effectively. To this end, we ask:

- How do learning outcomes differ between linguistic and nonlinguistic feedback-based two-choice paired associate tasks?
- Are neurophysiological differences in feedback processing, measured by feedback related event-related potentials (ERP) components, evident between tasks?

Background

Language skills and the ability to process feedback have both been recognized as essential for learning. **Feedback** plays an integral role in learning by providing evaluative information that **guides the learner**. The linguistic system provides the ability to **mediate the learning process verbally**, which in turn facilitates associative learning. For example, Fifer, Barutchu, Shivadasani, and Crewther (2014) examined associative learning of shapes, sounds, and pseudo words and found a learning advantage for linguistically salient stimuli.

Although language and feedback processing have been linked to learning, the relationship between the two has yet to be elucidated. More specifically, it remains to be evaluated how language skills are affecting the ability to process feedback effectively.

In this study, we hypothesized that the reduced ability to mediate the learning process verbally will not only affect learning outcomes but also the ability to utilize feedback effectively. Feedback processing was measured by examining two feedback related ERP components in linguistic and nonlinguistic paradigms.

Event-Related Potentials

Feedback Related Negativity (FRN)

- Elicited when the information about the accuracy of one's performance is unknown until it is communicated by an external feedback
- Elicited in numerous learning tasks
- A fronto-central negativity with a latency of 200-300 ms elicited by the presentation of negative feedback
- Localized to the dorsal anterior cingulate cortex

Fronto-Central Positivity (FCP)

- Positive signal that follows the FRN
- Latency of 300-400 ms following presentation of feedback
- Although this component is associated with the processing of feedback, its functional significance is yet to be determined

Methods

Participants

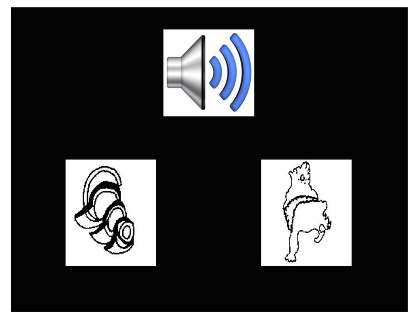
Sample Size	Descriptive Statistics	Exclusion Criteria
28 healthy participants	16 females, 12 males M = 25.19, ± 4.21	No history of head injury, neurological deficits, learning disabilities, ADHD/ADD, and psychological disorders

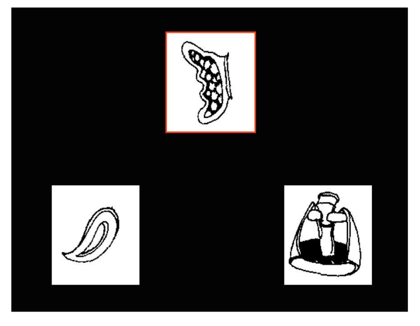
Stimuli

Paradigm	Stimuli
Linguistic	Auditory non-words lacking semantic content (e.g. *jelb, wosc*)
Nonlinguistic	Visually presented non-objects

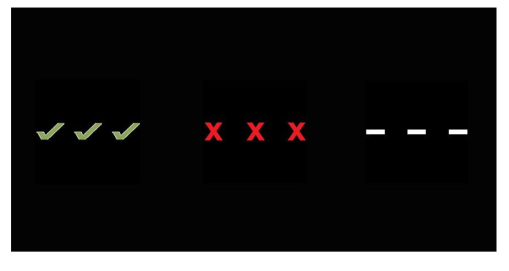
Procedure

Across All Rounds (blocks)	Round 1 (first block)	Rounds 1 - 5	Round 6 (test)
Participants were asked to learn 6 items across 6 rounds (blocks) for a total of 12 unique items in both tasks.	50% response rate to ensure consistent baseline.	Feedback after every response and time-locked to the EEG.	Participants rated confidence in their response on a scale of 1 (not confident) to 4 (confident). Feedback was not provided.





Schematic representations of linguistic (left) and nonlinguistic (right) paradigms.

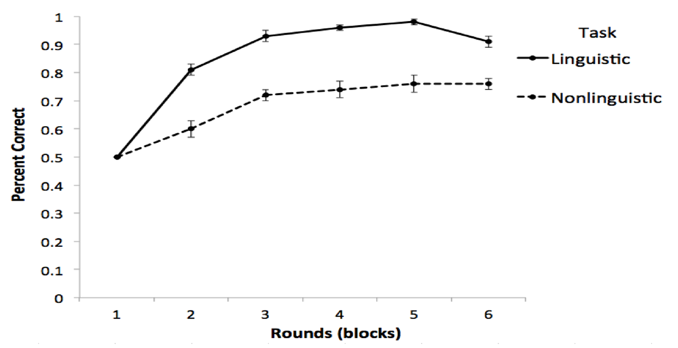


Images of positive and negative feedback, and no response.

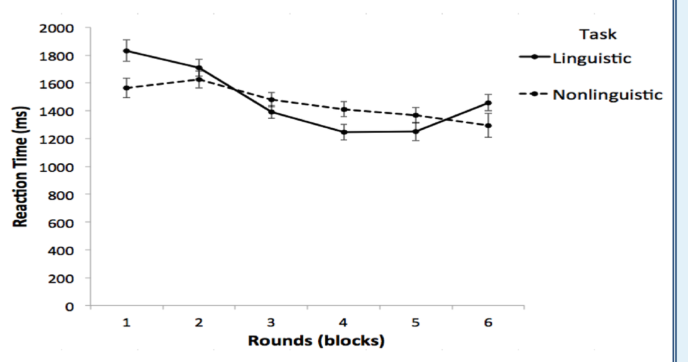
Data Analysis: The EGI 32-channel net and system was used to acquire and analyze EEG data. The EEG was continuously recorded at a 1000 Hz sampling rate and a 0.1 – 30 Hz bandpass. A temporal Principal Component Analysis was performed to analyze the EEG Data (Spencer, Dien, & Donchin, 2001). The PCA parses out the variance of waveforms and separates overlapping ERP components into temporal factors. Factor scores for each condition and electrode of interest were computed, resulting in a measurement of activity in the ERP. Two temporal factors relating to the FRN and Fronto-Central Positivity were identified in electrode *Fcz* (17). Rounds were collapsed into 3 groups.

Results

What differences in learning occurred between paradigms?

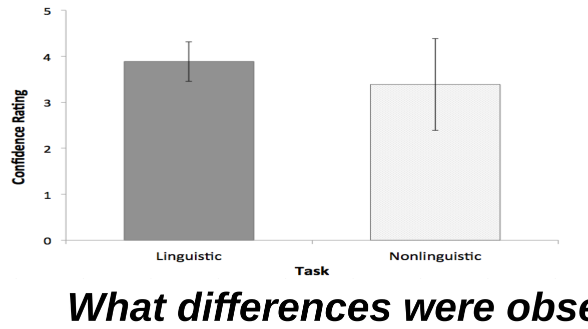


Overall, participants were **more accurate** in the **linguistic** paradigm, F(5, 23) = 39.50, p < .0001, η2 = .89, with significant differences noted in all rounds except round one.



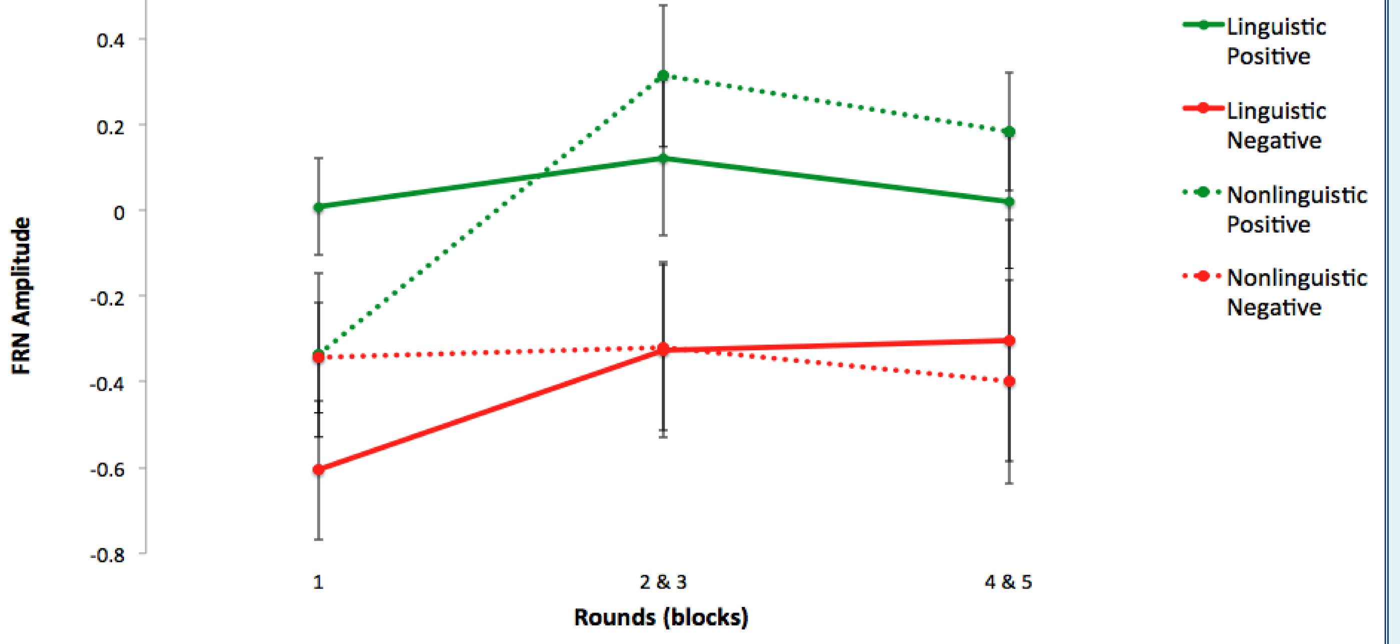
Overall, participants were **faster** in the **linguistic** paradigm in later rounds, F(5, 23) = 6.65, p < .001, η2 = .59, with significant differences noted in rounds one and four.

How confident were participants in their responses?



Participants were **more confident** in their responses in the **linguistic** paradigm, F(1, 670) = 73.53, p < .001.

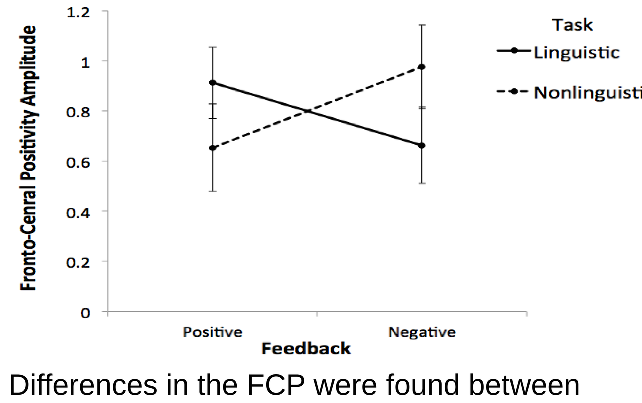
What differences were observed in the amplitude of the FRN?



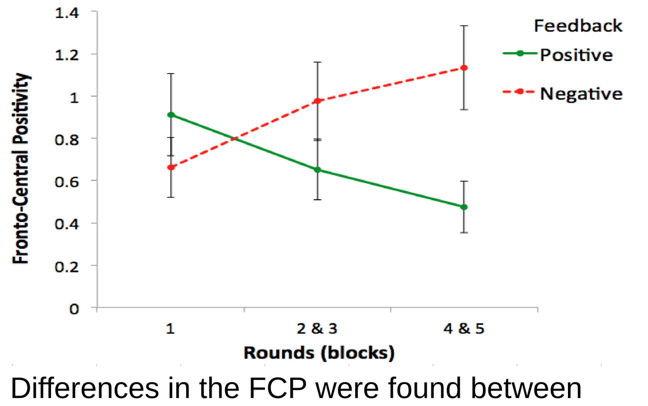
Overall, differences in the FRN were found between the linguistic and nonlinguistic task across rounds and feedback type, F(2, 26) = 5.22, p = .01, η2 = .28. Exploratory paired t-test analyses with Benjamini-Hochberg corrections were conducted.

- In round one (the initial phase of the learning process, when positive and negative feedback stimuli were equally probable), significant **differences** were noted between the processing of **positive and negative feedback in the linguistic paradigm**, but there were **no differences in the nonlinguistic paradigm**.
- In both linguistic and nonlinguistic paradigms, greater amplitudes of the FRN were found on negative feedback than positive feedback across all rounds, with the exception of round one.

What differences were observed in the amplitude of the FCP?



Differences in the FCP were found between linguistic and nonlinguistic paradigms on negative and positive feedback, F(1, 27) = 16.15, p < .001, η2 = .37. Specifically, **larger amplitudes** were noted on **negative feedback** in the **nonlinguistic** paradigm compared to the linguistic paradigm.



Differences in the FCP were found between positive and negative feedback across rounds, F(2, 26) = 11.49, p < .001, η2 = .47. Specifically, **larger amplitudes** were noted on **negative feedback** compared to positive feedback **in all rounds except round one**.

Discussion

Behavioral Data

- Results suggest a **learning advantage** in the **linguistic paradigm**, reaching near ceiling performance in rounds 4 and 5. This supports the hypothesis that the linguistic system plays an integral, facilitative role in declarative learning.
- Slower reaction times (RTs) were observed in the first round of the linguistic paradigm in comparison to the nonlinguistic task. However, a greater decrease in RT was observed in the linguistic paradigm in later rounds, suggesting faster processing of linguistic stimuli after repeated exposure to the stimuli.
- Our behavioral results are consistent with other studies examining learning in similar paradigms (e.g., Fifer et al. 2014).

Neurophysiological Data

- In round 1, a **larger FRN** was noted in the **linguistic paradigm** with **negative feedback**, whereas **no difference** was seen between positive and negative feedback in the **nonlinguistic paradigm**. These findings suggest an undifferentiated processing between positive and negative feedback in the nonlinguistic paradigm.
- As rounds progressed in the **nonlinguistic paradigm**, the amplitude of the **FRN decreased** on **positive** feedback with **no increase** on **negative** feedback, suggesting a lack of utilization of feedback over time in the nonlinguistic paradigm.
- Increased amplitudes of the fronto-central positivity were found associated with negative feedback, particularly in the nonlinguistic paradigm. These observations may suggest greater attentional resources involved in the processing of feedback in the nonlinguistic task.

Results illustrate that the reduced ability to mediate the learning process verbally in the nonlinguistic paradigm led to a reduction in the effective utilization and processing of feedback. This suggests both a **learning advantage** for **linguistic** paradigms and **distinct utilizations of feedback**.

Future Directions

- Future research is necessary to examine the relative contributions of the linguistic system and the modality of learning on feedback processing from both a behavioral and neurophysiological perspective.
- The utilization of feedback for learning by individuals with language disorders should be examined to strengthen the suggested role of language as a moderator factor in the relationship between feedback processing and learning.

Selected References

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