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# Metaphors and Mind: An ERP Study of How the Brain Processes Metaphors

Crystal Poole  
cpoole@pugetsound.edu

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# Metaphors and Mind: An ERP Study of How the Brain Processes Metaphors

Crystal Poole, Tim Beyer, and David Andresen  
University of Puget Sound

## Background:

The brain is sensitive to the content and structure of language. For example, literal phrases (LP, e.g., *revolution is war*) are processed differently than metaphors. Moreover, there are two types of metaphors: conventional metaphors (CM; e.g., *argument is war*) and novel metaphors (NM, e.g., *editing is war*). CM are common metaphors that are likely familiar, while NM are uncommon or entirely new metaphors. Although CM and NM are *not* structurally different, the brain does respond differently to these metaphors.

Event related potentials (ERPs) are one measure of how the brain processes LP, CM, and NM. In particular, the N400 is an ERP brain wave pattern which is sensitive to the meaning of linguistic stimuli. For example, LP evoke a smaller amplitude than metaphors, and NM evoke a greater amplitude than CM (Goldstein, Arzouan, & Faust, 2012). These processing differences have been proposed to be linked to verbal cognitive abilities (Beaty & Silvia, 2013) as well as familiarity (the more familiar, the more conventional a NM becomes; see e.g., Goldstein, Arzouan, & Faust, 2012). However, to date no study has linked processing differences between phrase types and verbal cognitive abilities using ERP data.

## Experimental Questions:

- 1) Are the LP, CM, and NM processing differences robust, and do they change as we think metaphorically?
- 2) How does familiarity influence how metaphors are processed?
- 3) Do individual differences in verbal cognitive abilities impact the N400?

## Method:

**Participants:** 20 fluent English speakers (4 male, 14 female, 2 non-binary; mean age = 21) with college-level education. Four were excluded for either technological issues, or excessively noisy data.

### Online Method (ERP):

ERP data was collected using a 32 channel Biosemi System on the scalp and referenced to left and right mastoid electrodes. Participants were asked to read phrases and decide whether each phrase 'makes sense'. Statistical analyses were run using the data from the Cz electrode, which showed the greatest N400 effect (see Fig. 1).

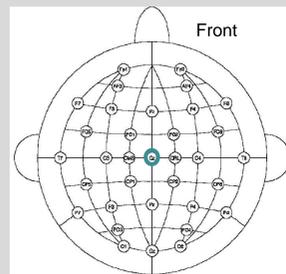


Fig. 1. Electrode placement on scalp. Cz electrode is marked in teal.

### Testing Session 1

Participants responded to:

- 40 literal phrases (LP)
- 40 novel metaphors (NM)
- 40 conventional metaphors (CM)

### Testing Session 3

Participants responded to:

- 40 literal phrases (LP)
- 40 novel metaphors (NM)
- 40 conventional metaphors (CM)
- **40 participant generated metaphors (PG)**

### Testing Session 2: Offline Method

- Participants generated 40 unique metaphors that "made sense" to them by completing a stem (e.g., \_\_\_\_\_ is war). The researcher ensured that these metaphors met study parameters. These 40 participant generated (PG) metaphors were presented during testing session 3.
- Participants completed measures of verbal cognitive abilities, including retrieval ability, intelligence (crystallized, fluid), and creativity

## Results:

### 1) Are the LP, CM, and NM processing differences robust, and do they change as we think metaphorically?

#### N400 Amplitude

- Metaphors show similar processing patterns (see Fig 2.):
  - CM and NM peak amplitude does not differ significantly ( $t_{(15)} = -0.74, p = .473$ )
  - LP peak amplitude significantly less negative than CM ( $t_{(15)} = 3.09, p = .007$ ) and NM ( $t_{(15)} = 3.76, p = .002$ ) (see arrow A)

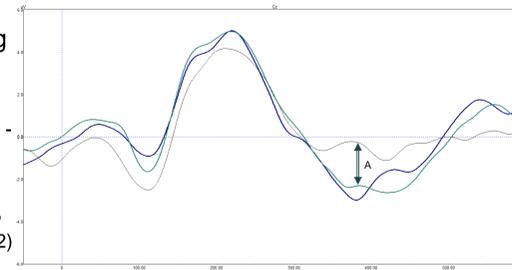


Fig. 2. N400 for LP (black), CM (teal), and NM (dark blue), averaged across testing sessions.

- Peak amplitude changes across testing sessions by phrase type (see Fig 3.):

- CM significantly more negative (greater amplitude) at testing session 3 ( $t_{(15)} = 2.15, p = .048$ )
- NM not significantly different from testing 1 to testing session 3 ( $t_{(15)} = -1.16, p = .265$ )
- LP not significantly different from testing 1 to testing 3 ( $t_{(15)} = 0.31, p = .764$ )

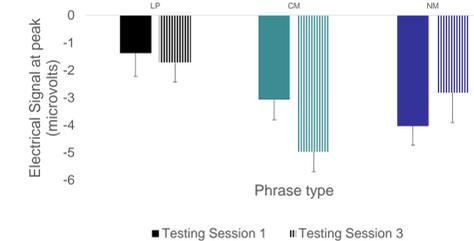


Fig. 3. Peak amplitude of N400 by phrase type and testing session.

#### N400 Duration

- Metaphors show similar duration (see Fig 4):
  - CM and NM do not differ significantly ( $t_{(15)} = 0.52, p = .608$ )
  - LP significantly shorter than CM ( $t_{(15)} = 3.03, p = .008$ ) and NM ( $t_{(15)} = 3.58, p = .003$ )
- Duration does not change across testing sessions by phrase type

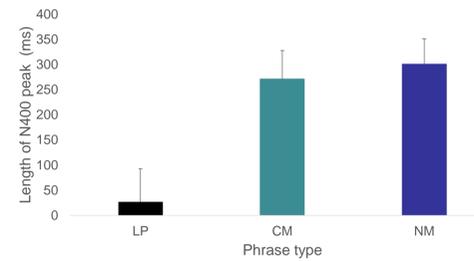


Fig. 4. Duration of N400 component by phrase type averaged across testing sessions.

### 2) How does familiarity influence how metaphors are processed?

#### N400 Amplitude

- PG show similar processing patterns to other metaphor types (see Fig 5.):
  - PG peak amplitude does not differ from CM ( $t_{(15)} = -1.15, p = .270$ ) and NM ( $t_{(15)} = -0.13, p = .897$ )
  - PG peak amplitude significantly more negative than LP ( $t_{(15)} = -2.73, p = .015$ )

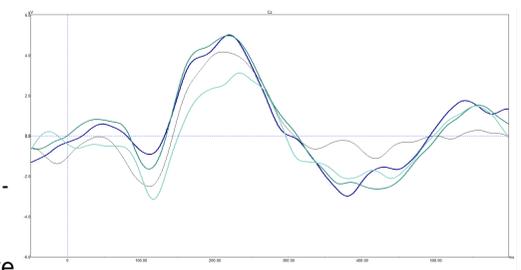


Fig. 5. N400 for LP (black), CM (teal), and NM (dark blue), averaged across testing sessions and PG (light teal).

#### N400 Duration

- PG show similar duration to other metaphor types (See Fig 6.):
  - PG does not differ significantly from CM ( $t_{(15)} = 0.90, p = .382$ ) and NM ( $t_{(15)} = 0.08, p = .935$ )
  - LP significantly shorter than PG ( $t_{(15)} = 3.88, p = .001$ )

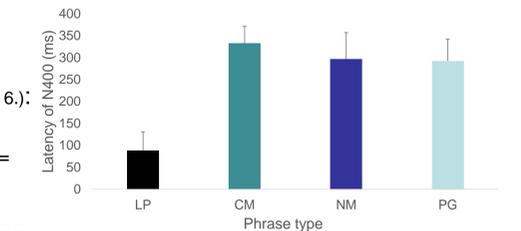


Fig. 6. Duration of N400 component by phrase type averaged across testing sessions including PG.

### 3) Do individual differences in verbal cognitive abilities impact the N400?

- No significant correlations between verbal cognitive abilities and processing except
  - Crystallized intelligence and CM duration ( $r_{(16)} = -0.569, p = .021$ )

Table 1. Verbal cognitive abilities correlated with peak amplitude and duration by phrase type

	LP Amp	CM Amp	NM Amp	PG Amp	LP Dur	CM Dur	NM Dur	PG Dur
Retrieval ability	0.434	-0.095	0.221	-0.044	0.095	-0.233	0.031	-0.008
Crystallized intelligence	-0.422	-0.276	-0.085	0.164	-0.443	<b>-0.569</b>	-0.159	-0.165
Fluid intelligence	-0.270	0.008	-0.063	-0.062	-0.055	-0.144	0.077	-0.033
Creativity	-0.312	0.197	-0.185	0.003	-0.189	0.006	-0.197	-0.092

Note: Amp stands for peak amplitude. Dur stands for duration. Bolded font shows significant correlation.

## Conclusions and Implications:

- Metaphors, regardless of type, are similar in terms of amplitude and duration, but differ from LP
  - This suggests that the relationships that make metaphors metaphors recruit similar language processing mechanisms
  - This is true for CM, which could be processed like LP due to familiarity
- Visual inspection shows that while metaphors are similar, they are not identical: NM had the greatest peak amplitude, LP have the smallest peak amplitude, and CM are in between; however, these differences in N400 peak amplitude are not significant
  - CM are processed differently from testing session 1 to testing session 3, possibly the metaphor creation task
  - People may think more or less "metaphorically" when processing conventional metaphors, which may depend on practice thinking about metaphors
- Participants process their own metaphors (PG) like other metaphors, so while familiarity with the metaphors led to a lower N400, it did not lead to 'conventionalization'
- Surprisingly, almost no individual differences in verbal cognitive abilities were found
  - Crystallized intelligence is related to the N400 duration during CM processing
  - Does this suggest metaphor processing is in itself a unique ability that is distinct from LP processing?

## References:

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