



The Role of the Left Temporal Pole in Language Processing: A MEG Investigation into the Interaction between Combination and Concept Specificity Effects

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Introduction

❖ Background – two effects in the left anterior temporal lobe (LATL) related to language processing:

❖ **Concept specificity effect:** (i) **Semantic dementia patients** suffer from the loss of semantic memory and have difficulty in processing concepts of a specific meaning (e.g., Snowden et al., 1989; Hodges et al., 1992; Mummery et al., 2000, etc.). (ii) **Healthy subjects:** increased brain activity in LATL associated with the processing of more specific concepts (e.g., Rogers & Patterson, 2007) (iii) **Left temporal pole:** the most affected region in processing proper names (e.g., Grabowski et al., 2001).

❖ **Combination effect:** Increased brain activity in the LATL associated with the processing of well-formed meaningful combinatorial structures both on the sentence level and for small phrases. (**Hemodynamic evidence:** Mazoyer et al. 1993; Vandenberghe et al. 2002; Humphries et al. 2005; **MEG evidence:** Bemis & Pykkänen, 2011, 2013a, 2013b; Westerlund & Pykkänen, 2014; Westerlund et al, subm.)

❖ What is the relationship between these two effects? Could the combination effect be explained as an instance of the specificity effect (i.e., adding words increases specificity)?

❖ Westerlund & Pykkänen (2014, *Neuropsychologia*):

The LATL effect of adjectival modification is larger for less specific nouns.

❖ Current questions:

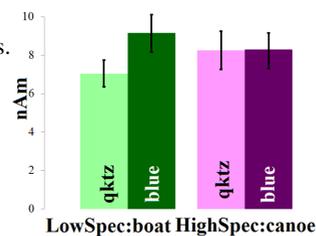
❖ What are the word by word dynamics of the effects of single-word specificity and composition on LATL activity?

Do they localize similarly in time and space?

❖ Are specificity effects modulated by structural positions?

❖ **Goal and design:** We aimed at a design that would (i) keep the syntactic structures the same through all the conditions (ii) keep the word categories the same through all the positions (iii) manipulate the single-word specificity of each word.

❖ To achieve this, we used noun-noun compounds of the shape **noun modifier + noun head word** and varied single-word specificity of both the modifier and the head word.



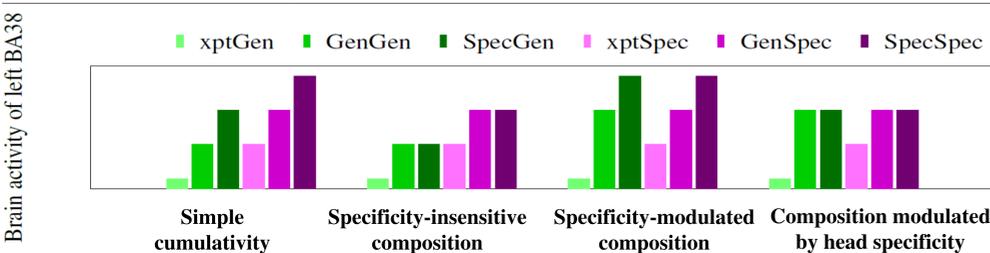
Design and Stimuli

Noun-noun compounds	Consonant string (xpt)	General modifier (GenMod)	Specific modifier (SpecMod)
General head word (GenHead)	xptGen: rkbl dish	GenGen: vegetable dish	SpecGen: tomato dish
Specific head word (SpecHead)	xptSpec: rkbl stew	GenSpec: vegetable stew	SpecSpec: tomato stew

❖ Hypotheses and predictions for LATL activity elicited by the head noun:

- ❖ **H1 – Simple cumulatvity:** LATL amplitudes reflect the cumulative specificity of all words that have so far contributed to the conceptual representation.
- ❖ **H2 – Single word specificity plus specificity-insensitive composition:** LATL amplitudes reflect the conceptual specificity of the current word (the head noun) plus an added composition effect when a modifier is present. But the size of the composition effect is not modulated by the specificity of either the head word or the modifier.
- ❖ **H3 – Single word specificity plus specificity-modulated composition:** More specific head words are less affected by composition (Westerlund & Pykkänen, 2014), but more specific modifiers elicit a larger composition effect (more features added).
- ❖ **H4 – Single word specificity plus composition modulated by head-noun specificity only:** More specific head words are less affected by composition (Westerlund & Pykkänen, 2014), but the specificity of the modifier does not matter.

Conditions	Examples	Prediction (1)	Prediction (2)	Prediction (3)	Prediction (4)
xptGen	<i>qptg dish</i>	+	+	+	+
GenGen	<i>vegetable dish</i>	++	++	+++	+++
SpecGen	<i>tomato dish</i>	+++	++	++++	+++
xptSpec	<i>qptg soup</i>	++	++	++	++
GenSpec	<i>vegetable soup</i>	+++	+++	+++	+++
SpecSpec	<i>tomato soup</i>	++++	+++	++++	+++

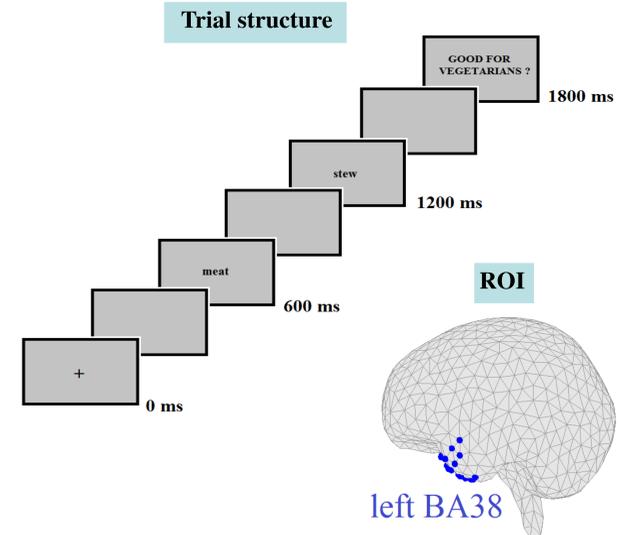


❖ Stimuli:

- ❖ 48 trials in each of the 6 conditions
- ❖ Words (general / specific modifiers, general / specific head words) were matched for length, number of syllables, number of morphemes, lexical decision reaction time, naming reaction time, frequency, log frequency (values from the English Lexicon Project and the Corpus of Contemporary American English).
- ❖ Phrases were matched for bigram frequency and transition probability (values from the Corpus of Contemporary American English).
- ❖ Tasks: a short question related to either the modifier or the head word or both.

MEG Methods and Analyses

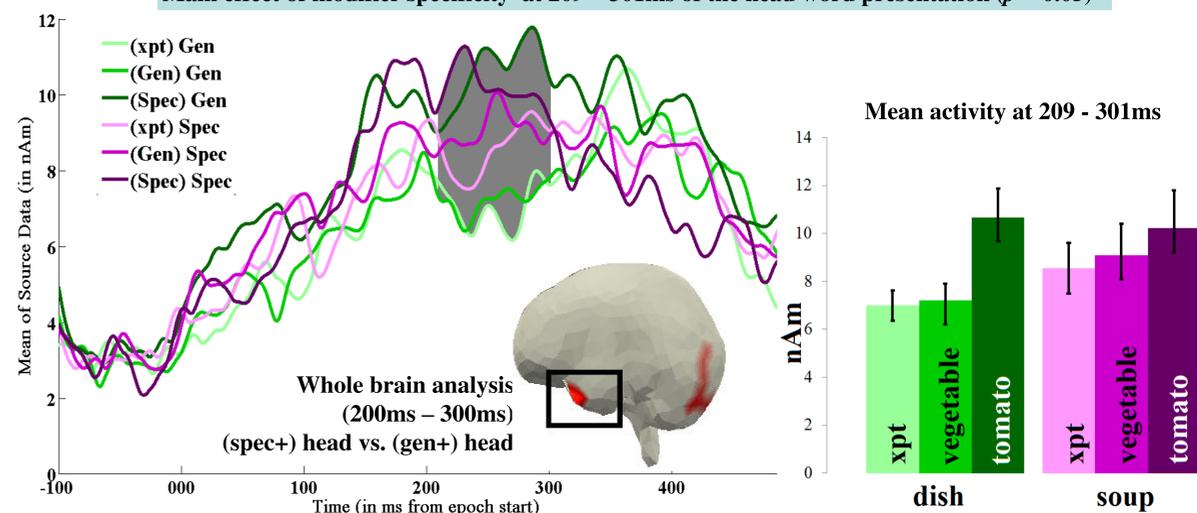
- ❖ 19 right-handed, native English speakers.
- ❖ 157-channel axial gradiometer array at NYU in NY.
- ❖ Kanazawa Institute of Technology, Japan.
- ❖ Recording band 0-200Hz, 60Hz notch filter, 1000Hz sampling rate.
- ❖ Trials that exceeded an amplitude threshold of 3000fT were rejected.
- ❖ BESA 5.1 package used for calculating distributed source solutions.
- ❖ We analyzed activity time-locked to the presentation of the modifier and the head word.
- ❖ **ROI analyses:**
 - ❖ ROI – left BA38 (i.e., the left temporal pole).
 - ❖ Time window: 150ms – 350ms after the onset of the modifier and the head word (i.e., the time window of combination effect in Bemis & Pykkänen, 2011, 2013a, 2013b; Westerlund & Pykkänen, 2014, etc.
 - ❖ **Three ROI analyses**, corrected for multiple comparisons with cluster based permutation tests (Maris & Oostenveld, 2007):
 - ❖ Cluster-based permutation ANOVA across the 6 conditions
 - ❖ 2 cluster-based permutation t-tests: (i) modifier position: spec vs. gen; (ii) head word position: xptSpec vs. xptGen.



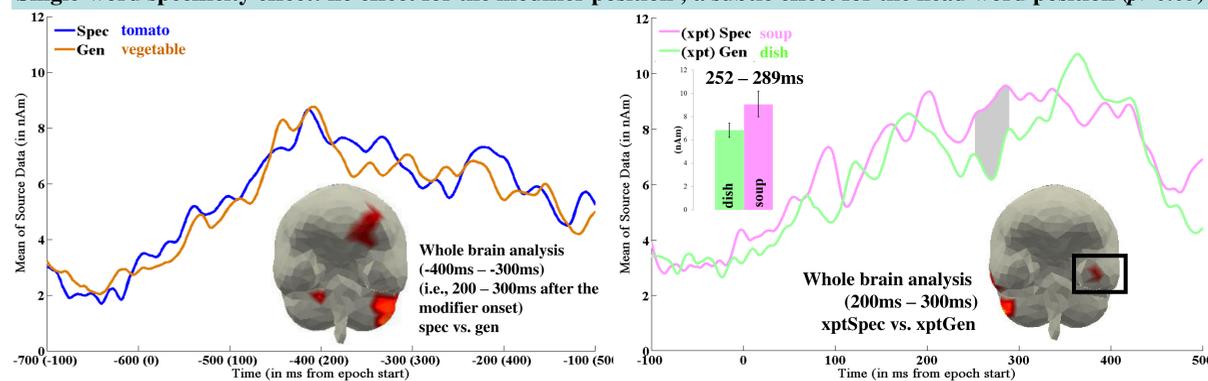
- ❖ These ROI analyses were followed by uncorrected whole-brain analyses to affirm whether the effects shown in ROI analyses reflected activity in the left temporal pole in fact.
- ❖ **Three whole brain analyses:**
 - (i) at the head word presentation: specific modifiers vs. general modifiers;
 - (ii) spec modifiers vs. Gen modifiers;
 - (iii) xptSpec vs. xptGen.

Results

Main effect of modifier specificity at 209 – 301ms of the head word presentation ($p = 0.05$)



Single-word specificity effect: no effect for the modifier position ; a subtle effect for the head word position ($p > 0.05$)



Summary and Conclusion

- ❖ **Composition:** The LATL composition effect was heavily modulated by modifier specificity: a robust composition effect was only obtained when the modifier was specific. Also, as in Westerlund & Pykkänen (2014), the composition effect was larger when the head noun was less specific.
 - A modifier reliably adds to LATL amplitude only when it robustly increases the conceptual specificity of the noun.
- ❖ **Single word specificity:** A subtle effect of specificity was observed on unmodified single words (as in Westerlund & Pykkänen, 2014). However, nouns in the first position (i.e., modifiers) showed no such effect. These results suggest that single word specificity effects may only be observed in structural positions where the conceptual analysis has been “completed” (i.e., 2nd position only in the current design).
- ❖ Overall, our results suggest that the LATL reflects not the level of specificity of the currently processed lexical representation (e.g., no increase for +Spec in first position), but the dynamic changes in the currently constructed conceptual representation. A large boost in specificity, as elicited by adding a specific modifier to a less specific head noun, drives this activity the most.