The roles of the right hemisphere and the anterior midline field in semantic processing: MEG studies

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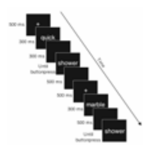
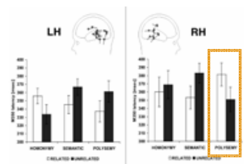
It is by now uncontroversial that language processing is not limited to the "classic" language areas, i.e., Broca's and Wernicke's. However, the contribution of other areas remains elusive at best. We have studied semantic processing in both the lexical and sentential domains, in order to investigate representational questions about morphology and the neural mechanisms of semantic composition. Our results indicate significant right hemisphere and prefrontal contributions to language processing.

Lexical semantic processing and the right hemisphere

How does the brain represent the flexibility of word meaning, i.e., polysemy? For example, *paper* can be used to refer to material made of pulp, to a newspaper publisher, to an electronically submitted essay, to an act of wallpapering, etc. We recently investigated the representation of polysemy with MEG (Pylkkänen, Llinás & Murphy, in press, *JCN*) . We predicted that different senses of the same word should involve access to the same morphological root, indexed by ***M350 priming in the left hemisphere***. This is exactly what we found. In addition, we found that ***sense-relatedness delays processing the right hemisphere (RH)*** roughly in the M350 time window. No RH delay was found for homonyms or semantic controls.

TABLE 1	RELATED PRIME	TARGET
Homonymous	river bank	savings bank
Polysemous	lined paper	liberal paper
Semantic	lined paper	monthly magazine





What Drives the Right Hemisphere Delay?

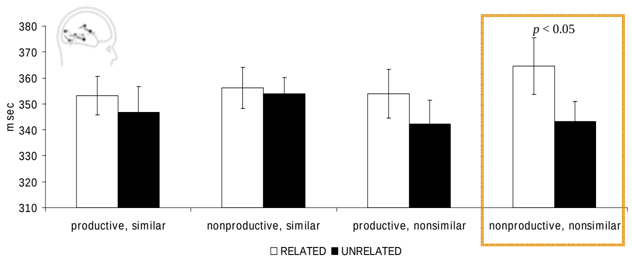
The materials of the above experiment involved many different types of polysemy. Some pairs followed productive patterns of sense extension, such as the animal - meat alternation (*raw chicken - loud chicken*), others did not (*polluted atmosphere - relaxed atmosphere*). Further, the pairs represented a wide range of semantic similarity. In a second experiment we tested whether the RH delay is modulated by productivity and/or semantic similarity. Specifically, we hypothesized that ***if the RH delay involves competition between stored senses, and if productive sense extensions are derived via rule and hence are not stored, the RH delay should be specific to non-productive polysemy.***

Subjects 19 native English speakers, 14 of whom had right hemisphere activity at 300-400ms. ***Materials*** Productivitiy and semantic similarity were manipulated in a paired design. Productive stimuli all exemplified robustly productive polysemy patterns (such as the animal-meat, building-institution and object-content alternations). Semantic similarity judgments came from a prior ratings study. Priming was assessed with respect to unrelated controls.

TABLE 2	RELATED PRIME	TARGET
productive, similar	*green book*	*insightful book*
non-productive, similar	*relaxed atmosphere*	*polluted atmosphere*
productive, non-similar	*loud chicken*	*raw chicken*
non-productive, non-similar	*fictional character*	*boldface character*

Task: Sensicality judgment. ***MEG recording:*** 148-channel neuromagnetometer (4-D Neuroimaging, Magnes WH 2500). ***Multidipole modeling:*** A multiple-source model, BESA (Brain Electric Source Analysis), was applied to all MEG activity elicited at 0-500 ms.

Right Hemisphere Results: Related targets elicited longer latency right hemisphere activity for all types of polysemy. However, this effect appeared to be mainly driven by nonproductive nonsimilar prime-target pairs. Thus our findings show that ***RH sense-competition effects are most robust for those cases where the sense-extension does not follow a rule (and hence must be memorized) and where the two senses are semantically quite distant.***



Semantic composition and the anterior midline field (AMF)

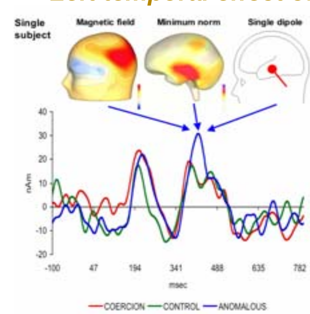
After word meanings have been accessed, how does the brain build complex sentence meanings? To investigate this, we manipulated the semantic processing effort of plausible grammatical sentences in MEG. Sentences involving ***complement coercion*** were contrasted with semantically simple sentences. In complement coercion, an event-selecting verb (e.g., *begin*) combines with an entity denoting an object (*begin the book*) in such a way that interpretation of the sentence requires creation of semantic structure that is not explicitly present in the input (*begin to read the book*). Extensive behavioral evidence suggests that complement coercions elicit a processing delay (e.g. McElree, et al., *Cognition*, 2001). Coercion was further contrasted with anomalous sentences. ***If coercion is costly because of low(er) cloze probablity, coercion should elicit an N400 effect. However, if processing compositionally complex sentences is qualitatively different from processing anomalous sentences, the generators of the coercion effect should be distinct from the generators of anomaly effects.***

Coerced:	***The professor began the book before his evening tea.***
Implausible:	***The professor disgusted the book before his evening tea.***
Control:	***The professor read the book before his evening tea.***

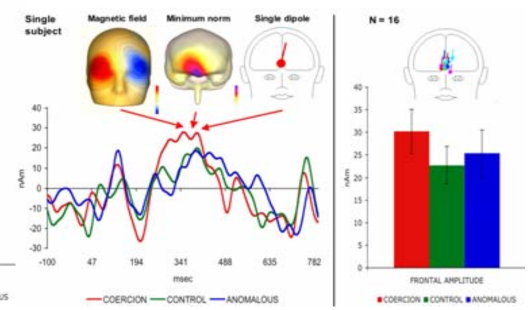
Subjects: 16 native English speakers. ***Stimulus presentation:*** Word by word, 300ms on, 300ms off. ***Task:*** Off-line sensicality judgment. ***MEG recording:*** 148-channel neuromagnetometer (4-D Neuroimaging, Magnes WH 2500). Sampling rate: 678 Hz. Recording band: .1- 200Hz. ***MEG analysis:*** A multiple-source model, BESA (Brain Electric Source Analysis), was applied to all MEG activity elicited at 0-600 ms.

Results: Distinct effects of coercion and anomaly

Left temporal effect of anomaly



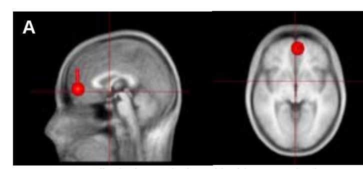
Anterior midline effect of coercion



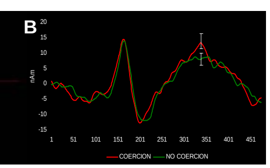
Conclusion

An increasing body of research suggests that the right hemisphere is important for many aspects of language processing. Our results suggest that one primarily right-lateralized process is selection among the memory representations of multiple competing senses of a single morpheme.

At the sentence level, when sentence meanings are not straightforwardly predictable from the meanings of their syntactic parts, an area in ventromedial prefrontal cortex is activated. This are is uncontroversially involved in higher cognition in general, including decision making and theory of mind. Thus this area may be an important "interface" between language and other cognitive skills.



A. Mean AMF dipole (n = 16) plotted inside a standard MRI. The AMF localizes in ventromedial prefrontal cortex. While this area is often activated by linguistic stimuli, it is also involved in higher cognition in general, including decision making and theory of mind.



B. Grandaverage AMF source waveform for all 16 subjects. The mean AMF dipole (see left) was fitted into all subjects' data. The coercion effect is replicated with this very simple single dipole model.