Investigating the neural mechanisms of syntactic expectations

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Introduction

- Languages have dominant word orders[1] that allow listeners to build expectations about the structure of an upcoming sentence[2], making language processing more efficient
- Expectancy is therefore a potential confound in studies relating to syntactic complexity, because complex sentences are typically less frequent (i.e. unexpected) and vise versa
- We implemented a paradigm in which the expectation for a word order was coupled to speaker identity by manipulating the speaker-specific probability of a particular word order
- This paradigm allows to distinguish between the processing of syntactic complexity and the processing of syntactic expectations
- Ambiguous probe trials were used to measure top-down expectations both on a behavioral and on a neural level

Research questions

Is there a functional differentiation between syntax and expectancy?

How are top-down expectations for syntax implemented in the brain?

Methods

- Twenty-eight right-handed, native German participants completed a training session and a testing session on two consecutive days
- In regular trials, sentences had either an easy *Subject-Object-Verb* (**SOV**) or a complex *Object-Subject-Verb* (**OSV**) structure. In probe trials, sentences were syntactically ambiguous (determiners replaced with noise)
- Two speakers (male/female) were operationalized as **SOV-Speaker** (high-frequent SOV vs. low-frequent OSV) or **OSV-Speaker** (high-frequent OSV vs. low-frequent SOV). Speaker gender was balanced across participants
- Speaker-syntax coupling was established in the regular trials during the exposure phase. Speaker-specific expectations were monitored via probe trials
- In these probe trials, participants had to select the subject/object in a comprehension task. This allowed to infer whether a sentence was interpeted as SOV or OSV
- The Test Session was conducted inside the MRI-scanner (3-Tesla, Preprocessing and Analysis in SPM12, Clusters are FWE-corrected $p < .05$, cluster-forming-threshold $p < .001$)

Paradigm

SOV

Heute hat der Mann den Freund gesehen.

Today has the [Nom.] man the [Acc.] friend seen.

Ambiguous Probe

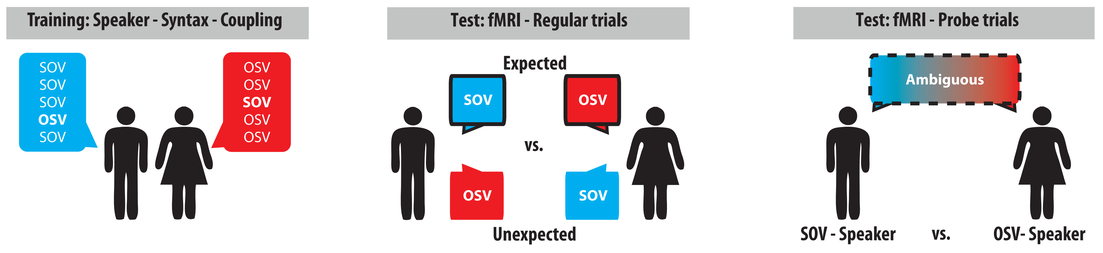
Heute hat **XXX** Mann **XXX** Freund gesehen.

*Today has **XXX** man **XXX** friend seen.*

OSV

Heute hat den Freund der Mann gesehen.

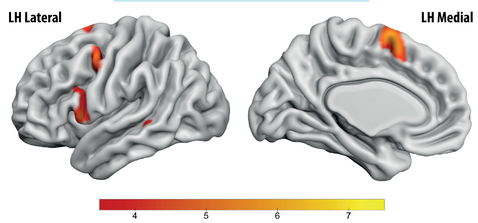
Today has the [Acc.] friend the [Nom.] man seen.



Results

Regular Trials

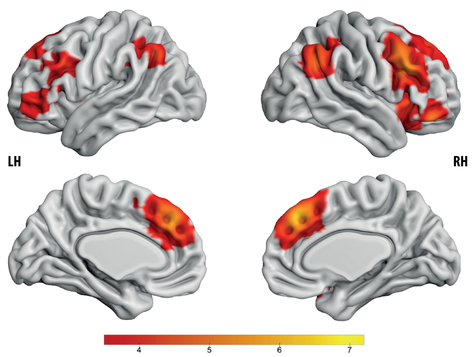
Syntactic Complexity



OSV (*SOV- Speaker*) + **OSV** (*OSV-Speaker*) > **SOV** (*SOV-Speaker*) + **SOV** (*OSV-Speaker*)

Increased activation for complex OSV structures compared to SOV structures - independent of expectancy due to speaker

Expectancy

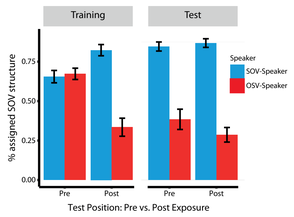


OSV (*SOV- Speaker*) + **SOV** (*OSV-Speaker*) > **SOV** (*SOV-Speaker*) + **OSV** (*OSV-Speaker*)

Increased activation for unexpected structures vs. expected structures - independent of syntax

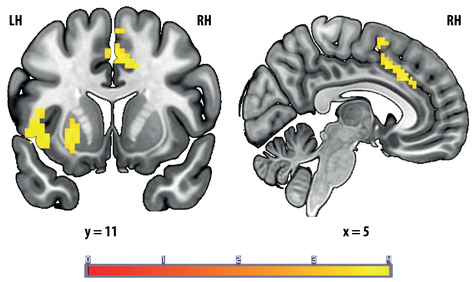
Probe Trials

Adaptation of Expectations



After exposure to the speaker-syntax coupling, participants build-up specific syntactic expectations based on speaker identity. (Speaker x Session x Position: $F(1,27) = 11.89$, $p = .002$)

Top-down speaker effect



OSV-Speaker > SOV-Speaker

Increased activation for the OSV-Speaker compared to the SOV-Speaker in the ambiguous probe trials (no syntax information in the sentences available).

Discussion

- Listeners adapted their synatctic expectations to the individual language use of a particular speaker
- We observed separate networks for syntactic complexity processing and the processing of expectancy based on speaker identity.
- Syntactic complexity effect was located in left-lateralized fronto-temporal regions (IFG pars opercularis, pMTG, premotor cortex, preSMA). Especially the left IFG and pMTG have been related to core linguistic computations of syntactic structure processing[3]
- Unexpected structures showed increased activation in a bilateral fronto-parietal network compared to expected structures (IFG pars orbitalis, MFG, Angular gyrus, preSMA, right IFG pars triangularis). This network might be related to pragmatic integration of speaker and syntax[4]
- Top-down effects in the absence of syntactic structure information (probe trials) were observed in cortical and sub-cortical areas including left Insula, left Putamen and ACC/preSMA. This regions possibly support controlled syntactic processing by means of re-sequencing[4,5]

Conclusion

Separate networks for linguistic syntax processing and para-linguistic expectations based on speaker identity

Syntactic complexity processing in a left-lateralized fronto-temporal network

Higher-order integration of speaker-identity and syntactic information in a bilateral, right-dominant fronto-parietal network

Top-down effects of syntactic expectations are supported by cortical and subcortical brain regions underlying controlled syntactic processing

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