Modulation of speech processing following item repetition

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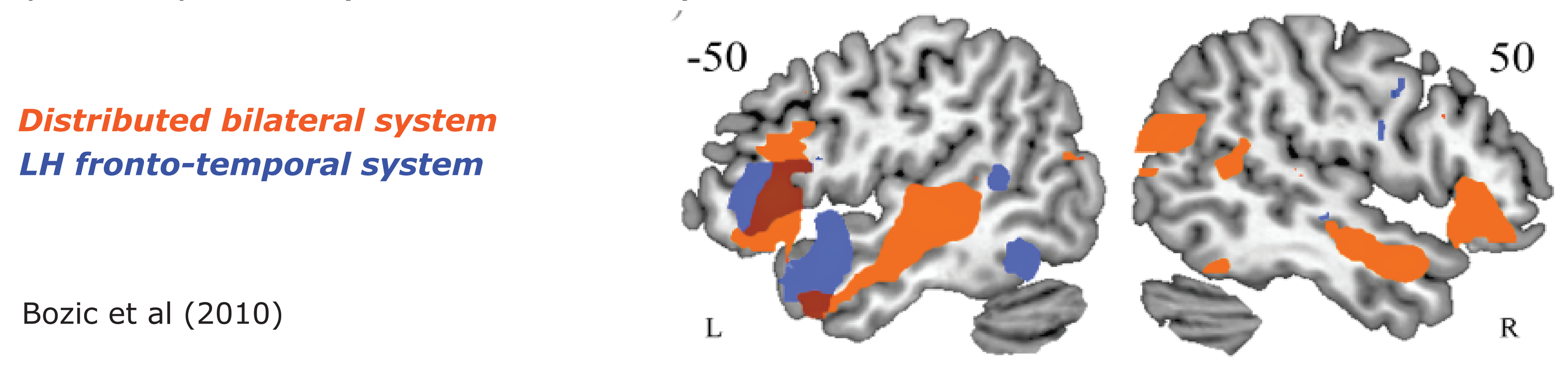
Neurobiology of speech comprehension

Abundant neuroimaging and neuropsychological evidence shows that spoken language comprehension engages a network of bilateral fronto-temporal brain regions (*Marslen-Wilson & Tyler, 2007*).

This bilateral fronto-temporal language network consists of two joint but functionally distinct systems: a distributed bilateral system, which supports semantic and pragmatic interpretation of auditory inputs, and a left hemisphere fronto-temporal system, selectively tuned to the processing of grammatically complex sequences (*Bozic et al, 2010*).



Bozic et al (2010)

A commonly used approach to testing the processes within the language network (particularly in the MVPA literature) is to present relevant test items multiple times and then collapse over these multiple repetitions. However, on-line speech comprehension is a dynamic process, driven by a continuously varying spoken input. This raises the question of the ways item repetition affects the activation patterns in the language processing network. We employed standard univariate and novel multivariate techniques to assess changes in the amount and the type of processing within the fronto-temporal language network following item repetition.

The current experiment focused on two questions:

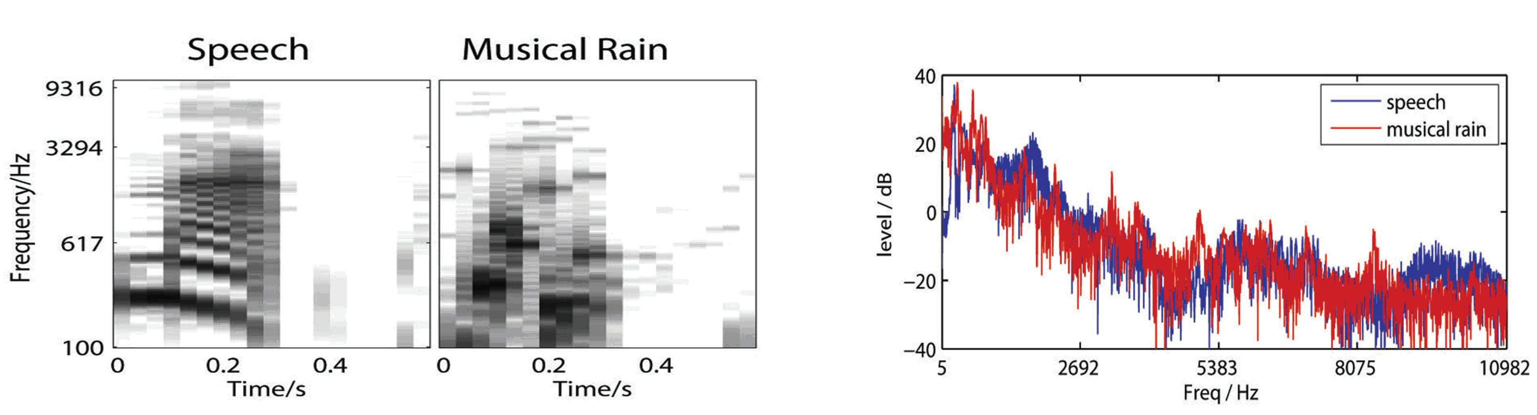
1) ***what are the effects of item repetition on lexical recognition (dissociating speech from non-speech), a process which primarily engages the bilateral system?***
2) ***how does item repetition affect grammatical processing?***

Design and methods

Twenty verbs (10 regular and 10 irregular) were matched on a range of psycholinguistic variables and embedded within short phrases. To manipulate the grammatical processing demands, verbs were presented in three contexts: uninflected, combined with the *-s* inflection, and combined with the past tense *-ed* inflection. A well-matched acoustic baseline token (envelope-shaped Musical Rain, MR) was created for each phrase. This gave a total of 120 test items.

Regular verb	Irregular verb	Regular MR	Irregular MR
I walk	I fall	I walk MR	I fall MR
He walks	He falls	He walks MR	He falls MR
He walked	He fell	He walked MR	He fell MR

Envelope-shaped MR baseline shares the complex auditory properties of speech without triggering a speech percept. The spectrograms and Fourier transforms of a speech token and the corresponding MR show that they are well matched.



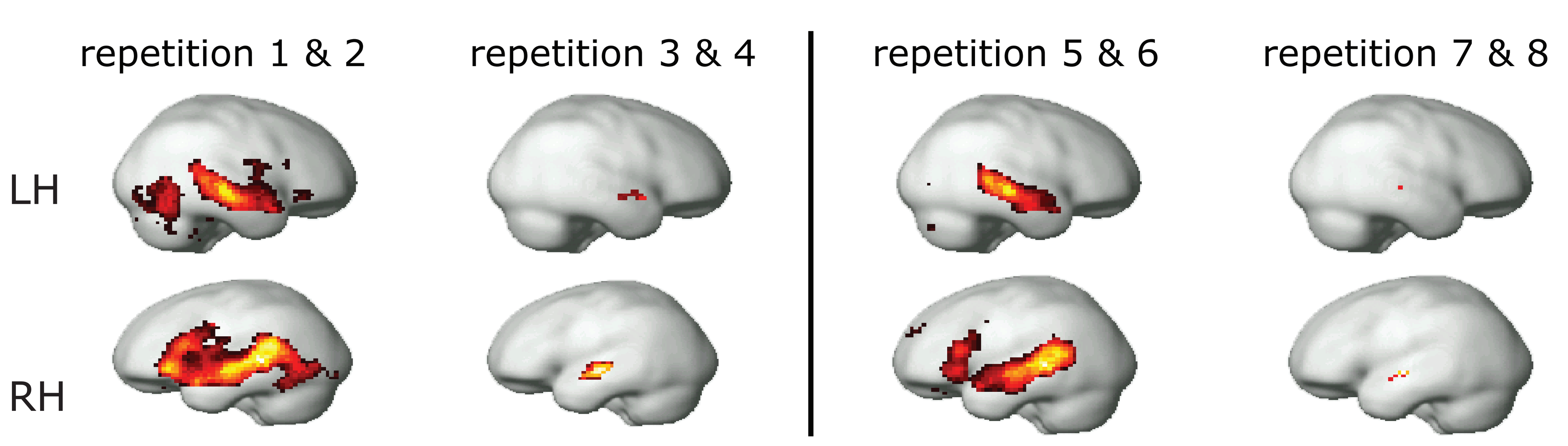
Each item was repeated 8 times over the course of experiment. The experiment was structured into 2 runs of 4 blocks, with a break between the two runs. Each block contained all experimental items presented in random order. Participants listened passively and occasionally performed a one-back semantic completion task.

Imaging procedure: 20 participants were scanned on a 3T Siemens system, using a quiet continuous EPI sequence (TR = 2s). Data were analysed in SPM5, using univariate approaches and multivariate Representational Similarity Analyses (RSA).

Univariate results

Words minus MR baseline across repetitions

p<.005 uncorrected



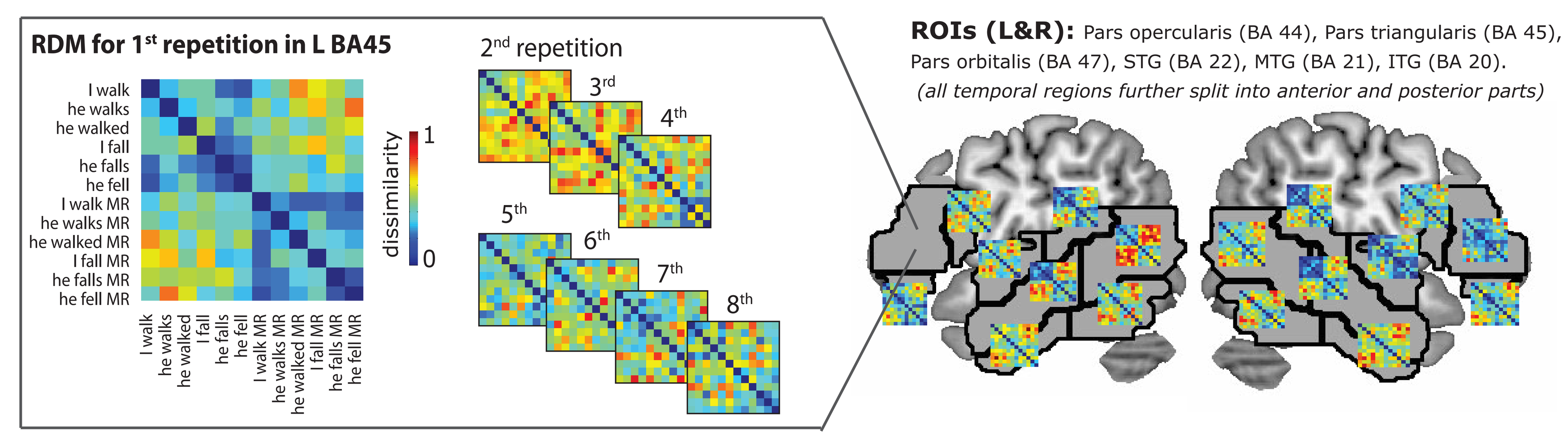
The amount of activation is modulated by item repetition and data acquisition protocol.

Multivariate RSA results

RSA is a multivariate pattern analysis method that reveals the information carried by a pattern of activation across multiple voxels (*Kriegeskorte et al, 2008; Su et al, 2010*).

In RSA, patterns of activation are expressed as Representational Dissimilarity Matrices (RDMs), which show correlation distances between activation patterns for each pair of conditions. Inference is drawn from a second level analysis that compares activation RDMs to theoretical models, also expressed as RDMs. A range of theoretical models can be created, allowing us to investigate very specific language processing dimensions.

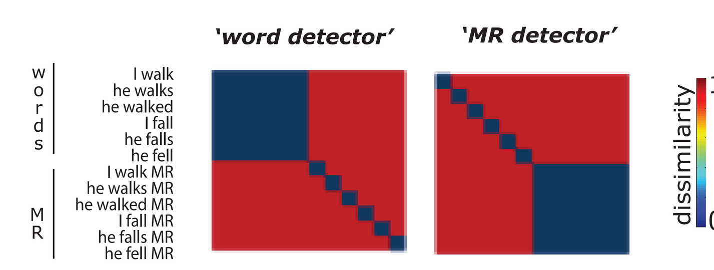
1) RDMs were extracted in anatomically defined ROIs for each repetition



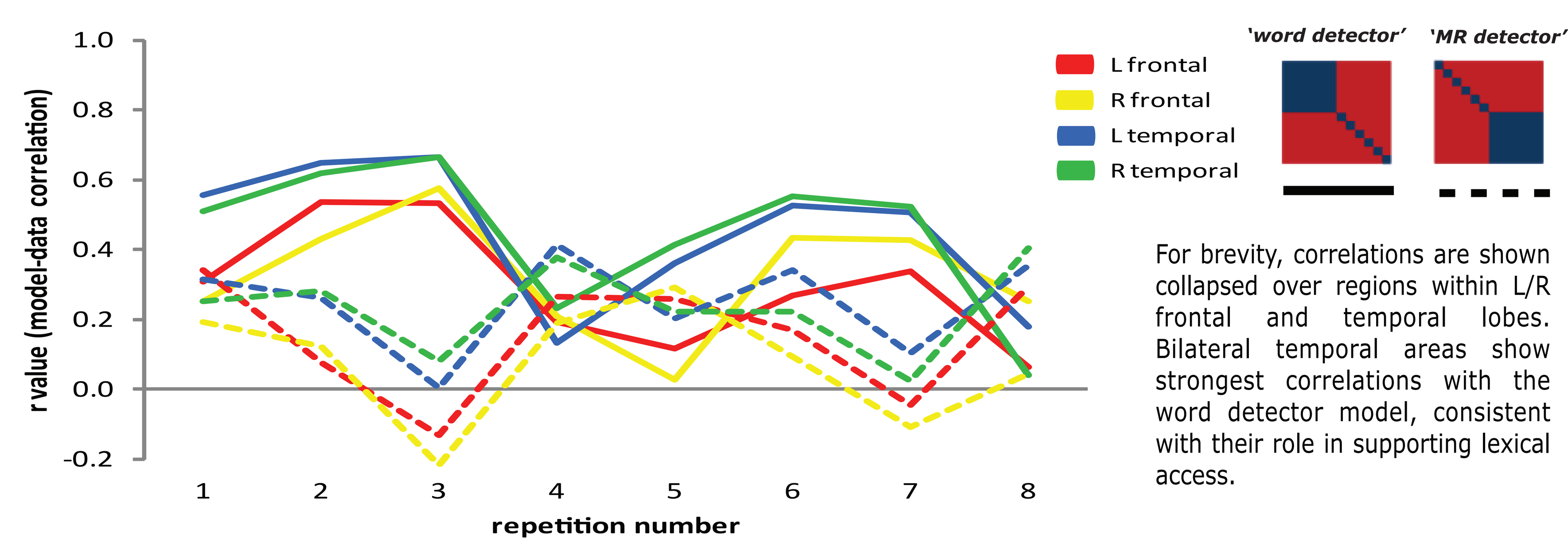
2) RDMs for each repetition were correlated to theoretical RDMs

a) ***Lexical recognition over repetitions*** (the process of dissociating speech from non-speech) was tested by correlating data RDMs for each repetition to 'word detector' and 'MR detector' models.

The two 'detector' models code for the processing of words and MRs separately, asking which regions show activation patterns specific for speech or non-speech sounds. Blue indicates high correlation between the activation patterns, red indicates the absence of correlation.

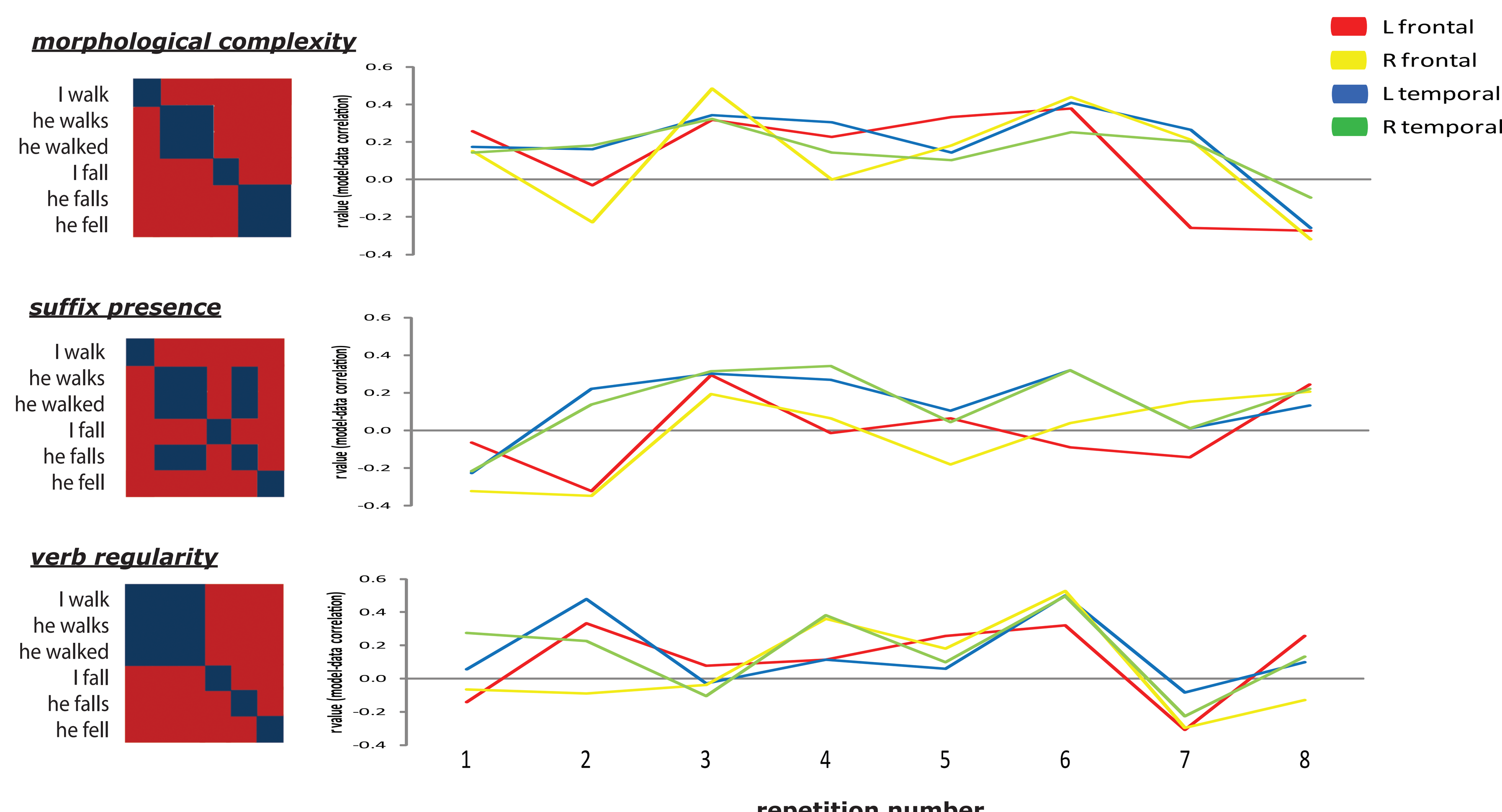


The graph below illustrates correlations between the models and the data at each repetition. It shows that most regions correlate to both models at first presentation, suggesting that the activations are driven by dissociating speech from non-speech. For repeated items the correlations are generally stronger with the word detector model, suggesting that activation patterns become specific to word identification over time**.** The structure of the experimental runs also appears to modulate the corrrelations.



For brevity, correlations are shown collapsed over regions within L/R frontal and temporal lobes. Bilateral temporal areas show strongest correlations with the word detector model, consistent with their role in supporting lexical access.

b) ***Grammatical processing over repetitions*** was tested by correlating data RDMs for words to a range of models that specify different grammatical properties. Correlations show substantial variation over repetitions and brain regions, suggesting significant distinctions in the type of grammatical information processed.



Summary and conclusions

Item repetition affects both the amount and the type of processing within the fronto-temporal language network.

Lexical recognition and grammatical computation vary over time and across regions. Data acquisition protocol also seems to have an effect on the activation patterns.

Simple averaging across repetitions may result in a loss of relevant information about the network's behaviour, and should be used with caution.

References

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