Spatiotemporal Patterns Underlying Morphological Processing in a Minimally Inflected Language

Yun-Hsuan Huang[1,2], Elisabeth Fonteneau[1,2], Caroline M. Whiting[1,2], Li Su[1], Qing Cai[3] & William D. Marslen-Wilson[1,2]

[1]University of Cambridge, UK; [2] MRC Cognition and Brain Sciences Unit, Cambridge, UK
[3]East China Normal University, China

Introduction

Linguistic combinatorial processing, for example, syntactic structure building and morphological inflection, is widely taken as a distinctive feature of human language.

It has been hypothesised that a left fronto-temporal network involving the left inferior frontal (BA 44, 45) and anterior temporal areas is crucially implicated in combinatorial processing. By contrast, a bilateral network, which includes left and right temporal areas, is involved in lexico-semantic processing [1].

Evidence from studies on typologically different languages (English, Arabic [2], and Polish [3]) supports this hypothesis.

However, these languages are either moderately or richly inflected languages.

If the involvement of the left fronto-temporal network can also be identified in a minimally inflected language like Mandarin, it will strengthen the potential universal role for the left fronto-temporal network in inflection processing.

To test this hypothesis, we looked at bimorphemic words of three types in Mandarin: aspectually inflected verbs and two types of non-inflected words: compound and derived words. We predicted that only the inflected words would elicit patterns in the left fronto-temporal areas whereas the other two word types would not.

Methods

Stimuli - Three main types of disyllabic words, differing in the identity of the second morpheme were contrasted. 58 items per word type; 1 presentation for each block (4 presentations in total).

Participants -18 adult native speakers of Mandarin Chinese

Task - Passive listening with 10% one-back semantic task

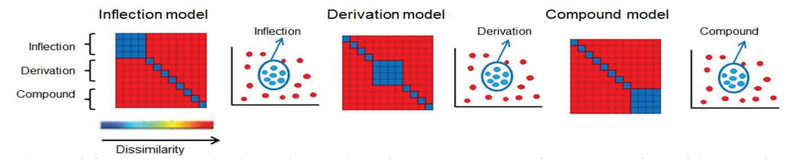
Acquisition - Simultaneous EEG-MEG data (306-channel Vectorview system and a 70-channel EEG cap).
Alignment point: second morpheme onset
Epoching: 0 - 700 msec after second morpheme onset
Baseline: 100 msec before word onset

Word Type	Category	2ND Morpheme	Example	Gloss
Inflected	Perfective	perfective marker *le*	*chang* 'sing' *le*	have sung
	Continuous	continuous marker *zhe*	*mo* 'touch' *Zhe*	touching
Derived	Verb	verbalizing morpheme *hua*	*jing* 'pure' *hua*	to purify
	Noun	nominalizing morpheme *du*	*shi* 'wet' *du*	wetness
Compound	Verb	root morpheme	*hu* 'to exhale' *xi* 'to suck in'	to breathe
	Noun	root morpheme	*gu* 'old' *shi* 'event'	story

Source Reconstruction - Three-layer boundary element model (Freesurfer)using participants' MRI scans. L2 Minimum Norm Estimate [4] was used to compute the source.

Multivariate Pattern Analyses – Spatiotemporal Searchlight Representational Similarity Analysis [5]. Masks - lateral masks; searchlight radius - 20mm; window width: 50msec; time step - 20 msec. Source data of items of each word type for each participant were averaged and treated as one condition: 3 word types x 4 presentations = 12 conditions in total

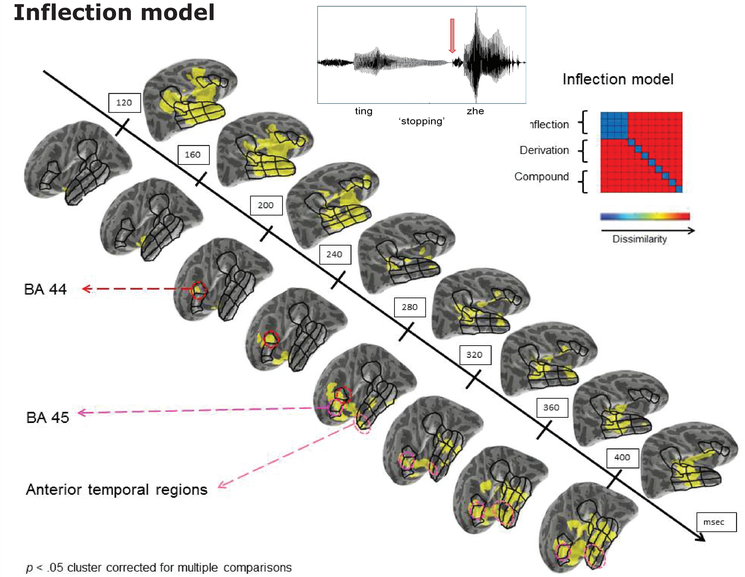
Representational Similarity Analysis (RSA) Models -



Each model represents the hypothesis that the spatiotemporal patterns elicited by words of a specific word type are similar to each other but are dissimilar to words of the other two word types; moreover, the patterns elicited by each of the other two word types are also heterogeneous.

Results

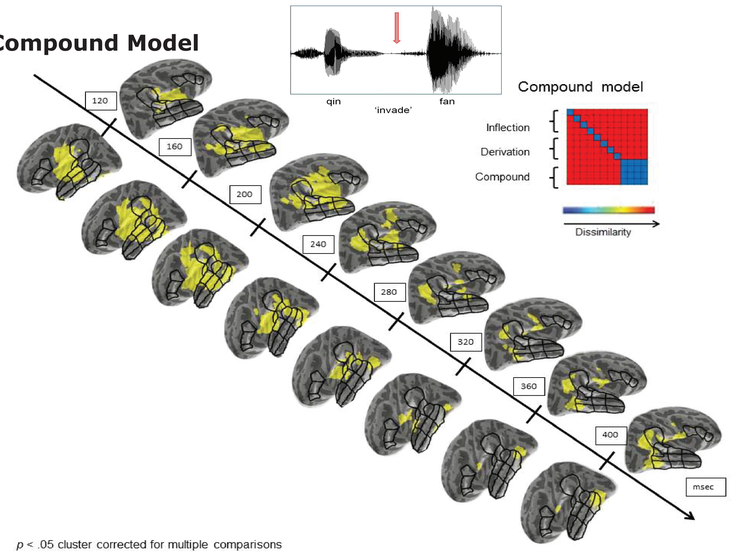
Inflection model



$p < .05$ cluster corrected for multiple comparisons

The inflection model correlated with spatiotemporal patterns in both hemispheres. For detailed evaluation of specific results, see plots of average t values in selected ROIs.

Compound Model



$p < .05$ cluster corrected for multiple comparisons

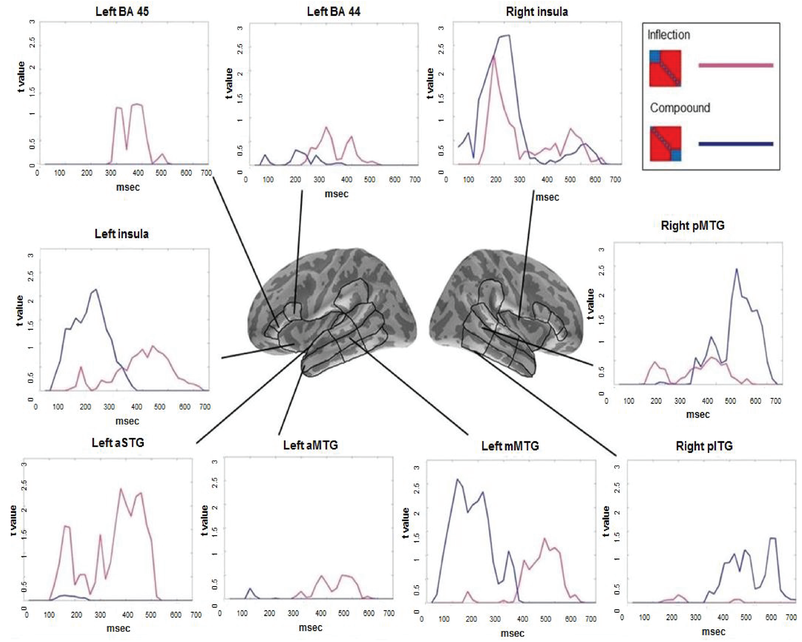
The compound model also elicited spatiotemporal patterns bilaterally. For detailed evaluation of specific results, see plots of average t values in selected ROIs.

Derivation Model

The spatiotemporal searchlight did not return any significant or marginally significant clusters for the derivation model.

Results

Average t values in Selected Regions of Interest



The time series of average t values in the spatiotemporal clusters identified by searchlight in nine ROIs are plotted here. The ROIs include pars opercularis (BA 44), pars triangularis (BA 45), insula, anterior superior temporal gyrus (aSTG), and anterior middle temporal gyrus (aMTG) in the left hemisphere; insula, posterior middle temporal gyrus (pMTG) and posterior inferior temporal gyrus (pITG) in the right hemisphere. The inflection model (red line) has higher overall average t values in left BA 44, 45 and anterior temporal and middle temporal gyri. The compound model (blue line) dominates in the left and right insular regions and left middle superior temporal gyrus as well as posterior middle and inferior temporal gyri on the right.

Conclusions

Only inflected words were found to correlate with patterns in left BA 44, 45 and left anterior temporal areas. The early right frontal and temporal cluster also observed for inflected words may reflect, consistent with previous studies, the language-specific demands for contextual integration for aspect markers in Mandarin.

Compound words elicited no left inferior frontal gyrus or anterior temporal involvement, correlating instead with bilateral and insular areas. These may correspond to regions for lexico-semantic processing. Derived words generally elicit bilateral temporal activations in other cross-linguistic studies, but here we found no consistent patterns. Further research is needed to determine why responses for (notionally) derived words in Mandarin are more heterogeneous than those for the other two word types.

Overall, similar to more richly inflected languages, a similar functional partition was observed in Mandarin, with only inflectional morphemes engaging a LH fronto-temporal network. These cross-linguistic parallels suggest that this LH network may serve a universal functional role for linguistic processing linked to inflection.

References

1. Bozic, M., Tyler, L. K., Ives, D. T., Randall, B., & Marslen-Wilson, W. D. (2010). Bihemispheric foundations for human speech comprehension. *Proceedings of the National Academy of Sciences, 107(40),* 17439-17444.
2. Boudelaa, S., Pulvermüller, F., Hauk, O., Shtyrov, Y., & Marslen-Wilson, W. (2010). Arabic morphology in the neural language system. *Journal of Cognitive Neuroscience, 22(5),* 998-1010.
3. Szlachta, Z., Bozic, M., Jelowicka, A., & Marslen-Wilson, W. D. (2012). Neurocognitive dimensions of lexical complexity in Polish. *Brain and Language, 121(3),* 219-225.
4. Hämäläinen, M. S. & Ilmoniemi, R. J. (1994). Interpreting magnetic fields of the brain: minimum norm estimates. *Medical and Biomedical Engineering and Computing, 32,* 35 – 42.
5. Su, L., Fonteneau, E., Marslen-Wilson, W., & Kriegeskorte, N. (2012). Spatiotemporal Searchlinght Representational Similarity Analysis in EMEG Source Space. *2nd International Workshop on Pattern Recognitoin in Neuroimaging* (PRNI 2012).

yhh25@cam.ac.uk