SNL2020 Sandbox Abstract

Representing roots: A neural decoding study of the representation of Arabic root morphemes

Enes Avcu[1], Olivia Newman[1], Seppo Ahlfors[1,2], David Gow[1,2,3]

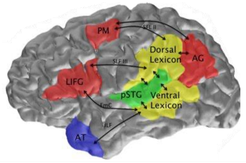
Massachusetts General Hospital/Harvard Medical School[1], Athinoula A. Martinos Center for Biomedical Imaging[2], Salem State University[3]

The Big Questions

- Do different brain regions store morphological versus non-morphological representations of wordform?
- Do Arabic roots have privileged neural representation?
- Do morphological and non-morphological of wordform interact in auditory lexical access?

Morphology and Lexical Access

- Linguistic theories recognize parallels and interacting phonological and morphological lexical representations.
- Data from a variety of behavioral and neural paradigms have provided mixed support for the role of morphological decomposition in auditory word recognition (Ettinger, Linzen and Marantz (2014)).
- Gow's (2012) dual lexicon model posits dissociable morphological/syntactic and articulatory/phonological stores of word form in the ventral and dorsal speech processing streams in posterior middle temporal gyrus (pMTG) and supramarginal gyrus (SMG) respectively.



Arabic Word Formation Processes

- Arabic is a non-concatenative language in which wordforms (e.g. *tamra* [date fruit, singular]) are created by infixation of word form patterns (e.g., $C_1VC_2C_3V$) into triconsonantal roots (e.g. [t.m.r]).

ROOT	t		m	r	
	|		|	|	
	t	**a**	**m**	**r**	**a**
	|			|	
WORD PATTERN	C_1	V	C_2	C_3	V

- Morphological decomposition processes in Arabic therefore should require the independent representation of infixation word patterns and triconsonantal routes.
- Evidence from concatenative languages suggests that spoken word recognition may entail parallel non-morphological representations of wordform that mediate the mapping between sound and articulation.

Strategy

• Our group has demonstrated that MRI-constrained simultaneous MEG/EEG support ROI-based neural decoding of abstract phonological properties in SMG and pMTG, but not in most activated language regions (Gow et al., in prep).

•We will apply the same analyses to compare decoding of distributed Arabic root forms and matched non-root sequences formed through prefixation.

•We will apply effective connectivity analyses to characterize patterns of interaction between areas supporting morphologically- and non-morphologically based wordform representation in word recognition.

Stimuli

Triconsonantal Roots	Prefixed Roots
[m.w.l]	m + [w.l.d]
[t.b.l]	t + [b.l.d]
[t.m.r]	t + [m.r.n]

Comparison

'**ma**w**wa**l**a**' vs. 'ma**wa**l**id**'
'**ta**b**a**l**a**' vs. 'ta**b**all**a**d**a**'
'**ta**m**a**ra' vs. 'ta**m**ar**i**n'

•Stimuli were recorded in a sound-proof room by a native speaker of Modern Standard Arabic (MSA). PRAAT was used to normalize the intensity of each word to be 70 dB, and an overlapping method was used to make the word length equal across all the words (735 ms).

•An auditory lexical decision task is used with 960 trials. In each trial, native speakers of MSA are played a word or nonword and asked to press one of two buttons to signify if they think the item was a word or nonword.

•Reaction time and accuracy data are both collected in the experiment

Behavioral Pilot Testing

•Using Prolific online crowd sourcing platform, pilot subjects can be tested online to validate our materials.

•We will use Prolific to recruit and test 50 native Arabic speakers who are righthanded, and do not possess any significant auditory, visual, or motor deficits.

Prolific

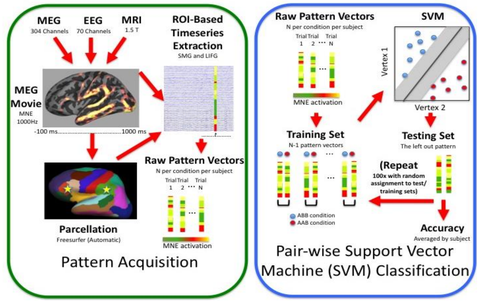
Imaging

- Simultaneous MEG (306 channel) and EEG (70 channel) are acquired during task performance.
- 3T MRI anatomical data are collected after MEG testing.
- High spatiotemporal resolution MR constrained MNE MEG/EEG minimum-norm estimates of source space activity over all cortical surfaces are created.

Effective Connectivity

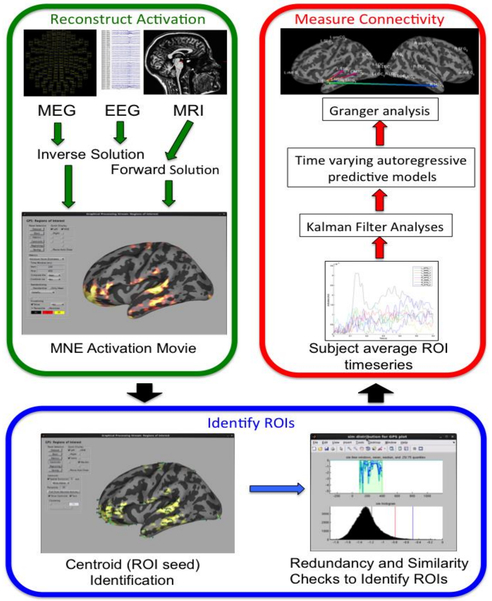
- Effective connectivity analyses are conducted using the GPS software package developed by our group (https://www.martinos.org/software/gps).
- Kalman filter-based Granger causality analysis of ROI data to identify patterns of directed connectivity over large networks with millisecond resolution, and without the requirement of stationarity.
- Separate analyses are run for each response type using a common set of data-defined ROIs.

ROI-Based Neural Decoding of MEG/EEG/MRI Data



Prediction: Activity in the SMG will effectively decode phonological patterns but will not show differential encoding of familiar root morphemes. In contrast, the pMTG will decode distinctions between roots and phonologically matched multimorphemic sequences.

Effective Connectivity Analysis of MEG/EEG/MRI Data



Prediction:

- Early activation of non-morphological articulatory phonological wordform will influence morphological wordform representation activation in pMTG.
- ..also that both pMTG and SMG will influence acoustic phonetic processes associated with the posterior superior temporal gyrus (pSTG).
- We further hypothesize mixed evidence for morphological decomposition is related to variability in the strength of top-down influences by pMTG on pSTG.

Athinoula A. Martinos Center For Biomedical Imaging

NIDCD

Acknowledgements: This work was supported by NIDCD grant R01DC015455 and benefited from funding from CFNT grant P41EB015896 and S10RR014978. We would like to thank Sami Boudelaa for their invaluable advice and Aly Hassan and Mousa Elsayed for their native speaker judgments.