Electrocortical activity during semantic retrieval is modulated by feature modality

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Introduction

There is ongoing debate about the organization of semantic representations within the temporal lobe. Some propose they are segregated in an amodal symbolic system,[1] while others posit they are stored in a distributed hierarchical network consisting of layers of grounded abstractions.[2] In the first framework, representations are isolated from perceptual cortices, whereas in the latter they are closely associated to sensory-motor cortical areas.

We investigated the temporal-spatial properties of semantic retrieval in posterior temporal cortex by measuring high gamma power (HGP) with electrocorticography (ECoG) while a subject was presented with identical images and sounds during semantic retrieval of modal features. We hypothesized that retrieval of modal features would engage association cortex within or near each corresponding perceptual system, and that the temporal sequence of these feature-specific semantic retrieval responses would relate to their position on the semantic hierarchy.

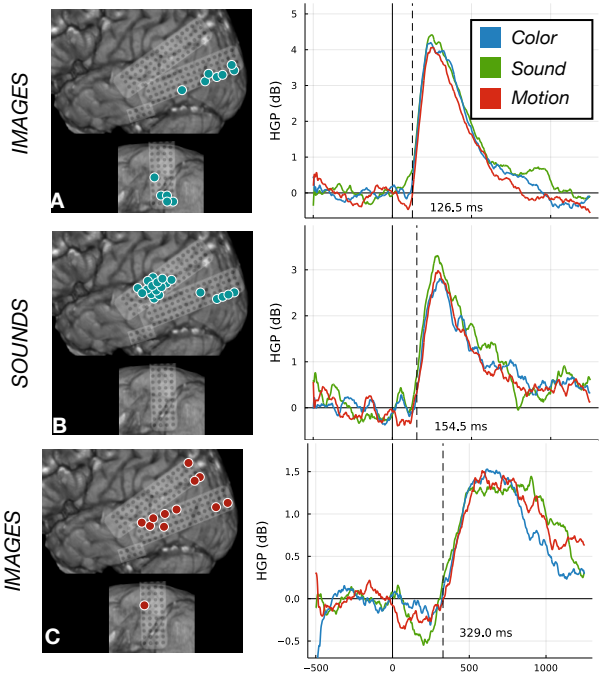

Figure 1. Electrode locations and average HGP of typical early response to (A) images and (B) sounds, along with (C) late responses to image stimuli. Electrode locations are colored as early (cyan), mid (yellow), or late (red) levels of processing. HGP response is colored based on task demands: color (blue), sound (green) or motion (red) discrimination.

Methods

Data were collected from a 70 year-old woman, who underwent awake temporal craniotomy for a low-grade left hippocampal lesion. Three ECoG grids were placed across the superior temporal gyrus (STG) and inferior parietal lobe, middle temporal gyrus (MTG) and lateral occipital cortex, and inferior temporal lobe. Grids contained 4x16 2mm contacts, with 4mm spacing (192 leads total). Grids were placed based on hypothesized locations of unimodal and multimodal semantic areas. The subject viewed either grayscale photographs of animals or artifacts ("IMAGES") or heard characteristic sounds of animals or artifacts ("SOUNDS") and made yes/no decisions on sensory-motor features (e.g., "Can you throw this?"). Each question covered one of 4 domains (sound, color, motion, or manipulation), with 2 questions per domain (8 semantic judgments x 8 images = 64 trials total). For simplicity of presentation, manipulation results are omitted here. ECoG data was acquired at 2000Hz and HGP was calculated using the Hilbert transform of a 70-200Hz band-pass filter, Z-transformed using the 250ms preceding stimulus presentation. For visualization a 50ms moving average (MA) was applied.

Results

Early activity (<150ms) to image stimuli showed a consistent pattern of activation (Figure 1A) starting from the lateral occipital lobe and extending along the posterior inferior temporal cortex, including the parahippocampal gyrus (PHG), consistent with previous studies,[3] unaffected by feature domain of the task. Early activity to sound stimuli showed a similar pattern in the superior temporal gyrus (Figure 1B), with no early activity in the PHG. Electrodes located in high-level semantic areas (Figure 1C) activated consistently later (>350ms) to both image and sound stimuli, and also lacked differentiation by task.

Several other locations, however, showed distinct modulation by task demands. For example, a group of electrodes on the inferior temporal lobe differentially activated during color feature judgments, both for image and sound stimuli (Figure 2). Another group of electrodes in the posterior MTG was differentially activated during sound judgments, both for image and sound stimuli. The majority of areas with differential activation activated earlier than multimodal activity for the same stimuli. In addition, activation for semantic features related to the presentation modality occurred earlier (e.g., color-feature areas in Figure 2 activate earlier to images while sound-feature areas in Figure 3 activate earlier to sound stimuli).

Conclusions

Early neural activity was dominated by stimulus processing, similar across feature modalities, relating to the presentation modality. Around ~200-400ms, activation in several temporal lobe regions was modulated by the feature modality of the task. This effect cannot be attributed to stimulus differences, as the same stimuli were used for all conditions. Tasks requiring modal semantic knowledge activated specific cortical areas in a spatial and temporal functional layout consistent with previous findings.[2] These findings support a distributed architecture of multimodal integration for concept representation, including the involvement a hierarchy of unimodal and heteromodal cortical areas, activated based on task demands.

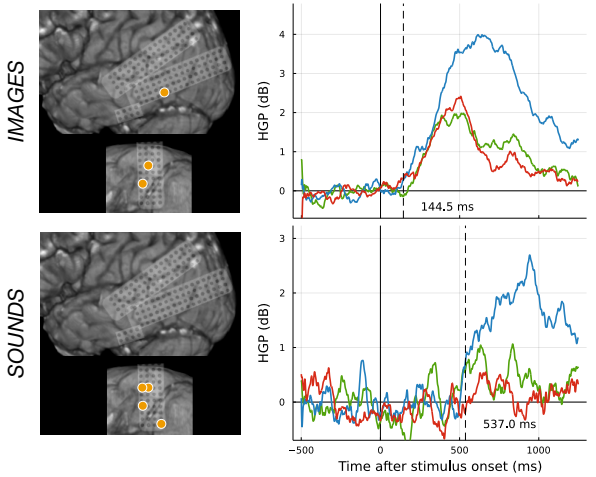

Figure 2. Electrode locations that showed differential activity when making color decisions, both when presented with images (top panel) and sounds (bottom panel). Notably, activity occurred earlier when presented with images.

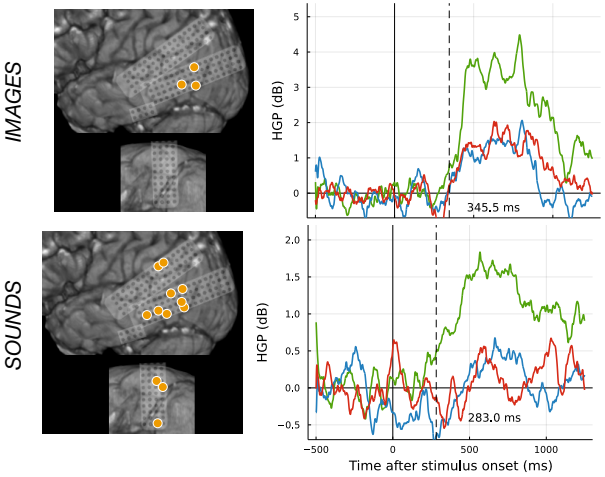

Figure 3. Electrode locations that showed differential activity when making sound decisions, bot when presented with images (top panel) and sounds (bottom panel). Notably, activity occurred earlier hone presented with sounds.

References

1. Lambon Ralph MA, Jefferies E, Patterson K, Rogers TT. The neural and computational bases of semantic cognition. *Nat Rev Neurosci*. 2016;18(1):42-55. doi:10.1038/nrn.2016.150
2. Fernandino L, Binder JR, Desai RH, et al. Concept Representation Reflects Multimodal Abstraction: A Framework for Embodied Semantics. *Cerebral Cortex*. 2016;26(5):2018-2034. doi:10.1093/cercor/bhv020
3. Liu, H., Agam, Y., Madsen, J. R. & Kreiman, G. Timing, Timing, Timing: Fast Decoding of Object Information from Intracranial Field Potentials in Human Visual Cortex. Neuron 62, 281–290 (2009).