Towards a functional ontology for working memory for sign and speech

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Background

The functional ontology provides a new framework for connecting abstract cognitive function and specific neural structure using two types of inference: a) function-to-structure deduction and b) structure-to-function-induction. With a), different patterns of cerebral activity under two experimental conditions imply at least one different function between the two conditions. With b), activity in the same brain region under two conditions implies a common function.

The neural signature of verbal and non-verbal working memory (WM) has been extensively investigated and work has commenced on investigating the neural correlates of WM for sign language. The sign languages of the Deaf are natural languages where information is transferred in the visuospatial mode, and thus provide a challenge to models that postulate different components for verbal and visuospatial processing. WM for sign language has been shown to share extensive neural networks, including the left inferior prefrontal lobe, with WM for speech. However, WM for sign language also engages superior parietal and occipito-temporal regions bilaterally, probably relating to sign storage in WM, with ventral regions related to storage of individually identified signs and the dorsal regions related to the ordering of those sign in a virtual visuospatial array. Furthermore, using a speech-sign integration task we have shown that the episodic buffer of WM engages a network of posterior regions centered on the temporal lobes bilaterally.

Main Contribution

These results can be interpreted within the framework of a functional ontology of WM for sign and speech. With a) modality-specific neural activation for WM for sign language indicates two different functions for the two different language modalities. This can be accommodated within a component model if the function of the visuospatial sketchpad is extended to include sign language processing. Again, with a), cross-modal activation specific to integration of sign- and speech-based information in WM indicates a separate integration function. This can be accommodated within the component model if the function of the episodic buffer is extended to include speech-sign integration. Finally, with b) common activation for sign and speech in the left inferior frontal lobe suggests that rehearsal mechanisms associated with this region are not specific to the speech modality and that the rehearsal mechanism of the phonological loop seems to process both sign and speech.

Implications

The resulting functional ontology suggests that although there seem to be separate components of WM for sign, speech and integration of the two modalities, adjustments may need to be made to the component model if it is to accommodate sign language processing. These adjustments include fractionation of functions previously thought to be unitary but which do not share a neural substrate (eg WM storage in sign and speech) and integration of functions previously thought to be distinct but which turn out to share a neural substrate (verbal and visuospatial rehearsal in WM). This suggests directions for future work.

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