EFFECTS OF LINGUISTIC STRUCTURE ON THE PERCEPTION OF VISUAL-MANUAL COMMUNICATION

An fMRI Study of American Sign Language (ASL) and Communicative Non-Linguistic Gesture

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Introduction

What drives the neural organization for language? Traditional hypotheses about cortical organization for language hold that perisylvian language areas have become specialized for language either because of a bias for processing rapidly changing sequences of sounds, as needed for speech perception, or because of superior analytical processing abilities, as needed for the computation of linguistic structure.

Here we investigate the possibility that some perisylvian language areas may be recruited for comprehension of symbolic communication, independently of linguistic structure, whereas others may become selectively activated by linguistic knowledge. To distinguish these two possibilities, we developed materials that communicate symbolic information in the same modality , either through non-linguistic gestures or through language (American Sign Language - ASL). Importantly, participants had either native knowledge of a gestural language (ASL) or no such knowledge.

While many studies have investigated the brain systems for language as compared to nonlinguistic control stimuli, this may be the first that has examined differences in brain activation evoked by communication of the same information, in the same (visual-manual) modality, varying only the presence or absence of linguistic structure.

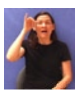
Methods

Participants

- 13 hearing non-signers
- 13 Deaf native signers

Stimuli

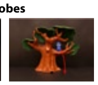
ASL



Gesture

- Gestured & ASL descriptions elicited using short videos of objects moving (Supalla, 1982) and clipart pictures of people and objects
- **Gestures** - Elicited from 3 hearing non-signers
- **ASL** - Elicited from a Deaf native ASL signer
- **Control Stimuli** - 3 movies overlaid, played backwards
- Participants in the fMRI study viewed these elicited movies of gesturing and ASL

Probes



Procedure

- Event-related fMRI
- Each trial: see movie (Gesture or ASL), then 2 probe pictures (1 from stimulus used to elicit gesture/ASL, 1 foil) - choose which had been described
- Control trials: see backwards-overlaid movie, detect instances of 3 identical hand shapes

MR Scanning

- EPI-BOLD @ 3T; TR = 2 s; TE = 40 ms; 4x4x4 mm voxels

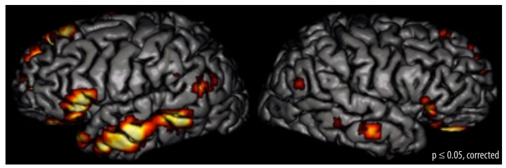
Data Analysis

- Slice timing corr. & realignment with AFNI; skull stripping & spatial normalization to MNI template with FLIRT (FSL); 8 mm FWHM smoothing
- Individual stats: multiple regression with 3dDeconvolve (AFNI). Only trials responded to correctly were included (incorrect trials as covariate of no interest)
- Group stats: 3-way mixed effects ANOVA (3dANOVA3), 2 (Signers/Non-Signers) x 2 (Gesture/ASL); Ss as random effect

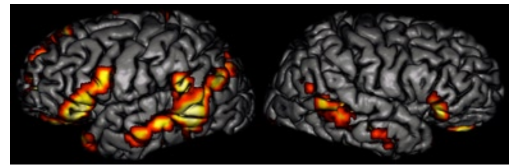
Results

I. Common Regions of Activation Across Gesture & ASL

Signers

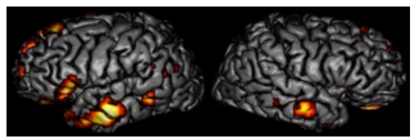


Non-Signers

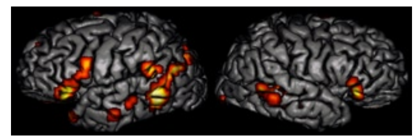


Each Condition separately vs. control stimuli:

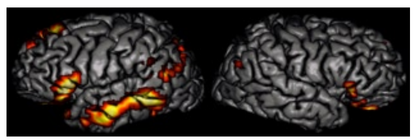
Gesture (Signers)



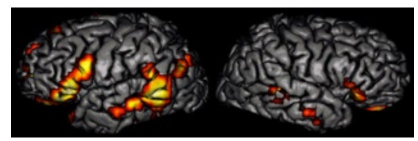
Gesture (Non-Signers)



ASL (Signers)



ASL (Non-Signers)



Conclusions - Section I

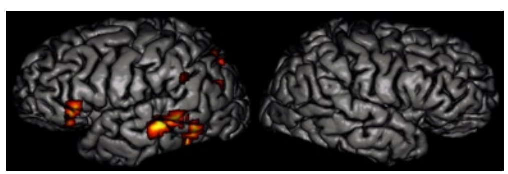
A network of areas was activated in both signers and nonsigners as they viewed symbolic communication, whether sign or gesture. These included IFG, middle and posterior extent of the STS, dorso-medial prefrontal cortex and gyrus rectus. Activations were generally left-lateralized (LH vs. RH in ROIs, $p > 0.0005$).

II. Effects of Linguistic Structure

Signers

ASL > Gesture

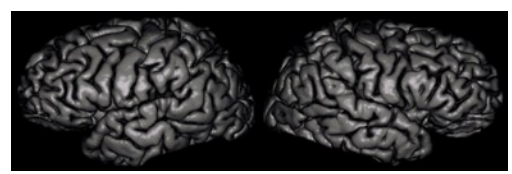
Effect of visual-manual linguistic structure



Non-Signers

Gesture vs. ASL

No low-level stimulus effects



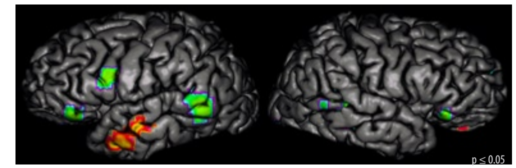
Conclusions - Section II

Comparison of ASL versus gesture materials in each population revealed areas that were selectively more activated by ASL in signers. Importantly, non-signers did not differentiate between ASL and gesture, revealing, as expected, an inability to appreciate linguistic structure in ASL. Signers exhibited greater left IFG and left posterior STS for ASL than gesture. This difference cannot be attributed to an overall difficulty effect, as signers were faster and more accurate with ASL (see Section IV). These areas have been associated with lexical access and phonological processing, and may reflect the phonological structure and established lexical-semantic knowledge in ASL.

III. Effects of Linguistic Knowledge

Signers vs. Non-Signers

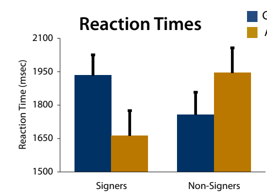
Gesture + ASL

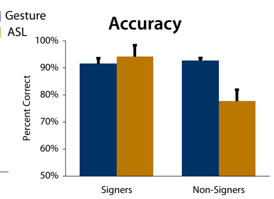


Signers > Non-Signers   Non- Signers > Signers

Across both ASL and gesture, signers showed greater recruitment than non-signers of LH anterior STS (implicated in syntactic processing and in syntactic-semantic integration) and RH gyrus rectus. These areas thus appear to reflect processing involving knowledge of linguistic structure, even when signers watch non-linguistic gesture. Non-signers showed greater reliance on bilateral posterior STS and pars orbitalis, as well as LH premotor cortex. These areas appear to be recruited during interpretation of symbolic gesture even when it is not grounded in linguistic analyses.

IV. Behavioural Data





Signers showed faster and more accurate comprehension of ASL than of non-linguistic gestures. Non-signers showed the opposite pattern, with faster and more accurate processing of non-linguistic gesture (though slower than for signers viewing ASL). Significant Group x Condition interactions for both RT & accuracy, $p < 0.005$.

Conclusions

Overall, our results suggest that the traditional "language network" may comprise at least 3 functionally distinct neurocognitive networks, whose operation can be separated by our contrasting materials and subject populations:

1. A system activated equally by both linguistic and non-linguistic gesture, in both signers and non-signers, may be involved in the *processing of symbolic communicative behaviour*: IFG (bilateral), LH posterior STS, LH gyrus rectus, & LH dorsomedial prefrontal cortex
2. Brain areas selectively more activated by linguistic materials in signers, which therefore appear to reflect the *processing of linguistic structure (particularly phonological and lexical-semantic) in sign language*: LH IFG & LH posterior STS
3. Regions activated more in signers than in non-signers during the processing of both ASL and gesture may underlie the *use of linguistic knowledge*, particularly syntactic and semantic, in processing symbolic communication, even when the communication is through nonlinguistic gesture: LH anterior STS, as well as RH gyrus rectus. The fact that these areas are not as active in hearing non-signers when watching gesture suggests that knowledge of a sign language may change the way participants process nonlinguistic gesture, perhaps viewing gesture sequences as more highly structured in morphology, syntax and semantics.

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