Acquisition of a Signed Language from Birth Changes the Neural Organization for Spoken Language Processing in Hearing Bilinguals

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Introduction

Bimodal bilinguals acquire one language visually (American Sign Language, or ASL) and another auditorily (English), using the vocal tract to speak and the hands to sign. In contrast 'unimodal bilinguals' grow up using two spoken languages that share the same output channel (the vocal tract) and perceptual system (audition).

Unimodal bilinguals need not allocate neural resources differentially to perceive their two spoken languages. In contrast, for bimodal bilinguals, perception of ASL and English may require different distributions of neural resources. Thus, the neural system for spoken language perception may undergo functional reorganization.

Does lifelong experience with a visuospatial language influence the cortical system for spoken language comprehension? We answered this question using fMRI to compare the brain responses of bimodal bilinguals with those of monolinguals during audiovisual perception of English sentences.

Methods

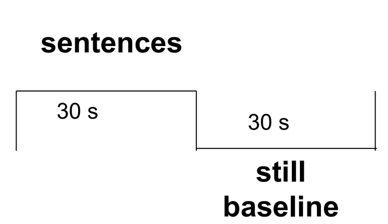
Participants:
13 hearing native ASL-English bilingual adults (6 males)
13 hearing non-signing native English monolingual adults (7 males)

Stimuli & Procedure:
- Audio-visual clips, duration = 2.3 - 5.7 sec (mean = 3.9s)
- Female actress facing the camera, neutral affect and expression

Experimental Task:
- Actress speaks short sentences, average length = 8 words
- Each sentence describes a simple scene
  - e.g. The deer slept next to the brook.
    The sports car went from Del Mar to La Jolla shores.
    The bum ziggzagged next to the river for many hours.
- Press button for semantically anomalous sentence (0-2 per block)

Baseline Task:
- Actress at at rest, simultaneously presented tone, black or white dot on chin
- Press button for change in tone or color of dot on actress's chin

Blocked Design:
- Each block = 30s (15 time points)
- 9 on/off cycles per run for 3 runs



Imaging methods:
Acquisition
– GE 3T, gradient echo echo planar imaging
– TR = 2; FOV = 220, 36 4mm slices, whole brain
Statistical Analysis
– General linear model, multiple regression using AFNI
– Within & between group mixed effects ANOVA on beta weights from individuals
– Conjunction maps of group level mixed effects FDR corrected statistical

Results

Conjunction: Stimulus Main Effect (each group $p < .01$, corrected)

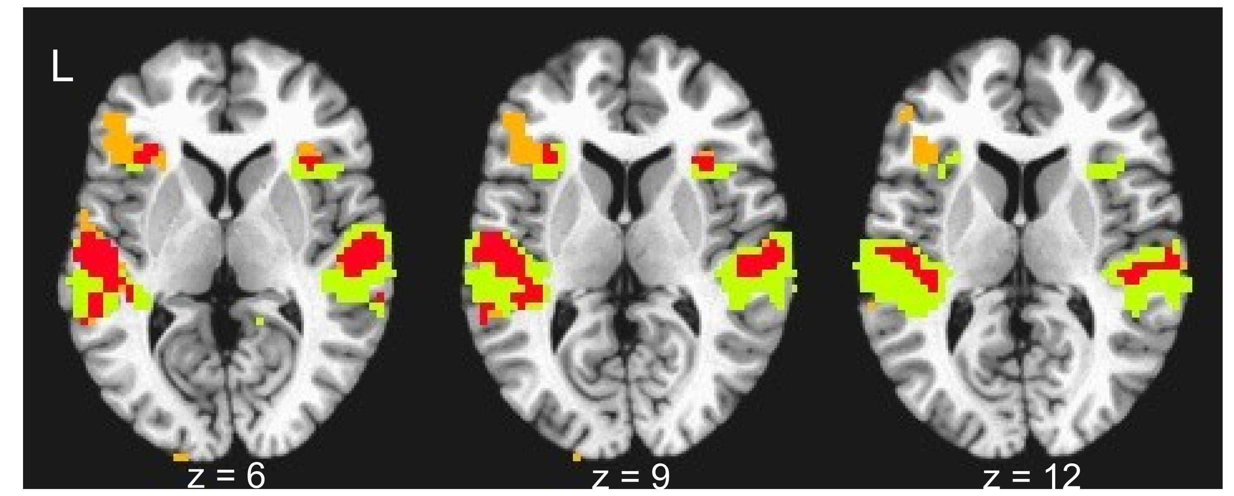
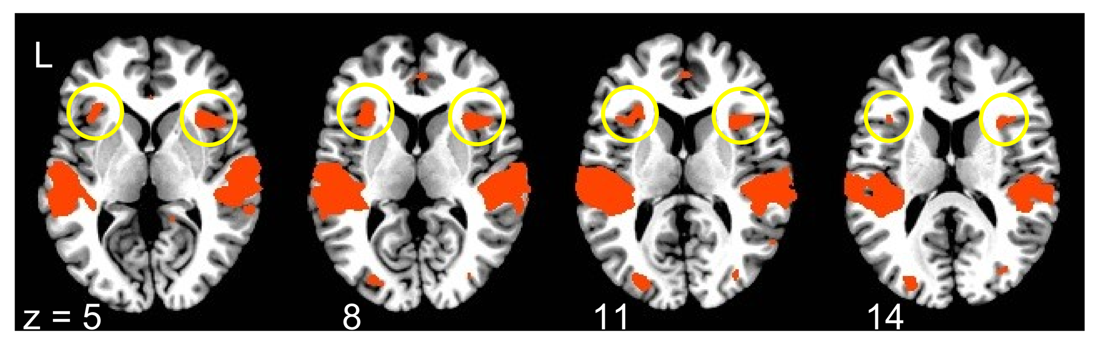


Fig 1: Conjunction map shows that spoken English perception elicits overlapping patterns of activation in bimodal bilingual and monolingual groups (red). However, ASL-English bilinguals rely more on bilateral STG/S (green) and monolingual English speakers rely more on the left inferior frontal gyrus(orange).

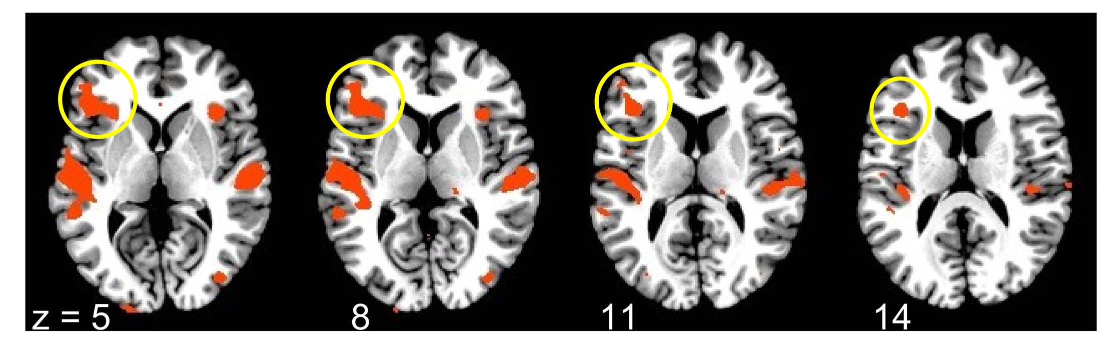
Although both groups activated IFG/insula bilaterally, monolinguals showed a strong left hemisphere bias, whereas activity was more evenly distributed between hemispheres in ASL-English bilinguals.

Sentences vs.Still Baseline, $p < .01$, corrected

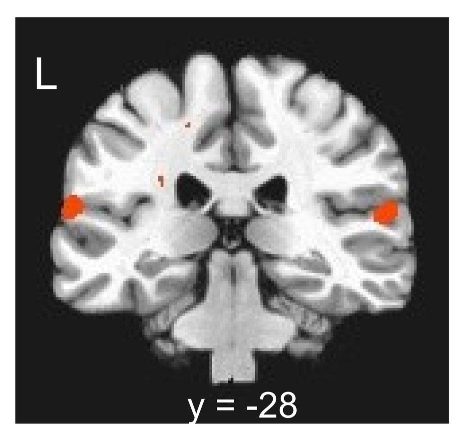
Bimodal Bilinguals,



Monolinguals

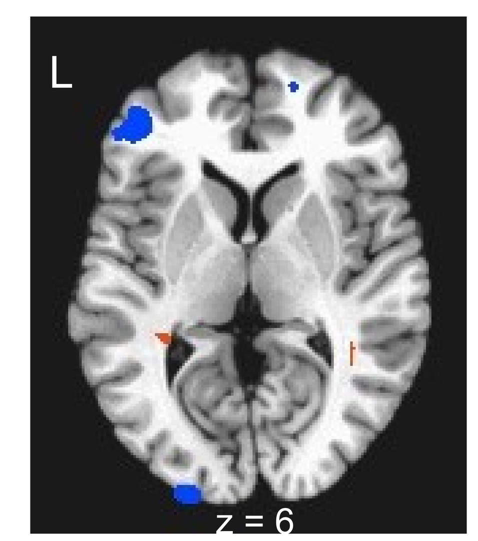


ANOVA: Group Main Effect ($p < .01$, uncorrected)



Bimodal Bilinguals > Monolinguals
Monolinguals > Bimodal Bilinguals

Fig 2: Direct comparison of groups shows regions more active in bimodal bilinguals (STG/S, red regions) vs. monolinguals (L IFG, blue regions) during English perception.



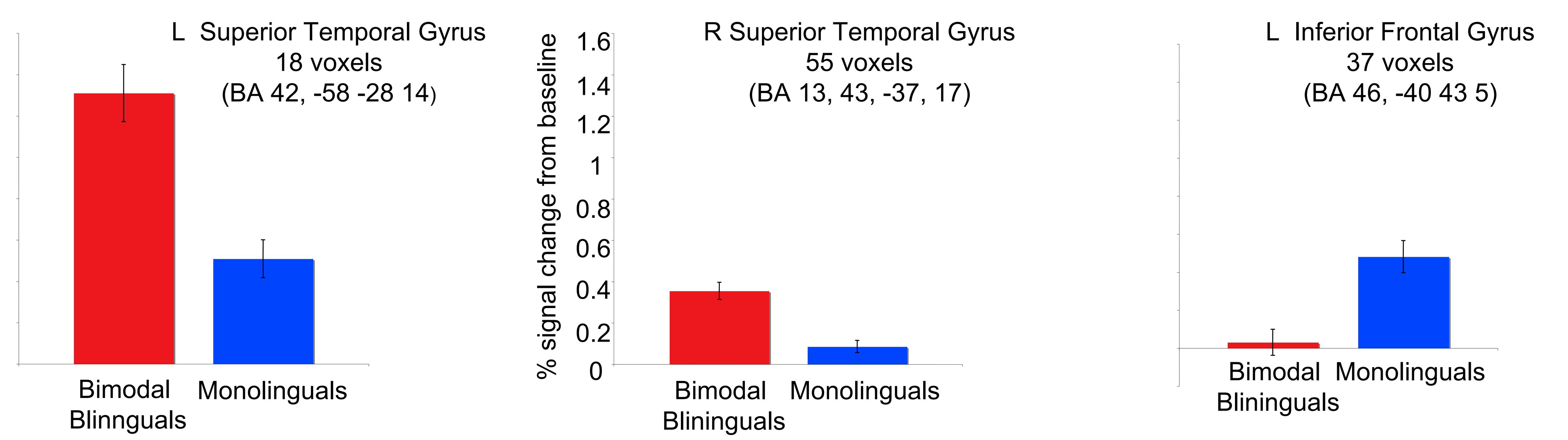


Fig 3. Group averaged response in each cluster (from ANOVA) with standard error of the mean and Talairach coordinates for local maxima.

In bimodal bilinguals, perception of spoken English elicited greater activity in a region of STG/S associated with mouth movements and speech reading[1-4] in comparison with monolinguals. In contrast, monolinguals activate the left inferior frontal gyrus more than bimodal bilinguals.

Summary & Conclusion

1. ASL-English bilinguals activate a neural system that overlaps with that of English monolinguals during perception of spoken English, yet functional reorganization is apparent in some perisylvian regions.

- Bimodal bilinguals show increased activation in bilateral superior temporal gyri compared to monolinguals.

  Bimodal bilinguals may attend more visual aspects of language, and to mouth movements in particular. Mouthing conveys both affective and linguistic (syntactic) information in ASL. Thus, mouth movements may be particularly salient for bimodal bilinguals, leading to increased processing demands in STG.

3. Bimodal bilinguals activated left inferior frontal gyrus to a lesser extent than monolinguals, and also showed a more bilateral distribution of activity in insula/IFG than monolinguals.
   - Bimodal bilingual and deaf native signing groups show increased white matter volume in the R insula compared to monolinguals, indicating that lifelong use of two different language modalities may lead to enhanced connectivity[5].
   - Bimodal bilinguals reduced dependence on L IFG and greater bilateral activation, coupled with changes in white matter volume in IFG/insula, may reflect an increased reliance on cross-modal sensory integration resulting from the use of multiple input/output channels for language in bimodal bilinguals.

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