

Age of acquisition effects on the functional organization of language in the adult brain

Mayberry et al., 2011



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Why?

- Do the unique and life-long psycholinguistic effects associated with a lack of language in early life reflect differential neural language processing by the adult brain?
- Earlier neuroimaging studies of non-native signers produced inconsistent results; therefore, **the effect of AoA on adult neural sign language processing remains unknown.**

Hypotheses

- Deaf native signers whose age-onset of language acquisition was from birth would show activation in the brain's classic LH language regions.
- Deaf non-native signers whose age-onset of language acquisition was beyond infancy would show neural activation pattern that deviate from the classic one in some systematic fashion.
- AoA effects should be observed independent of task performance levels.

Participants

- 22 adults (11 females) were profoundly deaf ($> 90\text{dB}$)
 - 6 participants were native signers whose parents signed to them from birth
 - 13 participants were non-native signers who acquired ASL outside home
 - 1 participant had hearing parents who signed with him/her from 3 years old
- Years of using American Sign Language: at least 19 years
- AoA: 3 different development epochs
 - Infancy: birth – 3 years
 - Early childhood: 4 – 7 years
 - Late childhood: 8 – 14 years

Stimuli

- Linguistic tasks

- Grammatical judgment task

45 grammatical and 45 ungrammatical ASL sentences of 4 types (simple, negative, inflecting verb, and WH-questions)

- Phonemic-hand judgment task

The same 90 stimuli are used for phonemic-hand judgment. Participants decide whether the final sign of the ASL sentence was made with one hand

- Baseline task

- Still image watching

Participants watch a still image of the signer whose facial expression was neutral and whose body posture had arms at rest

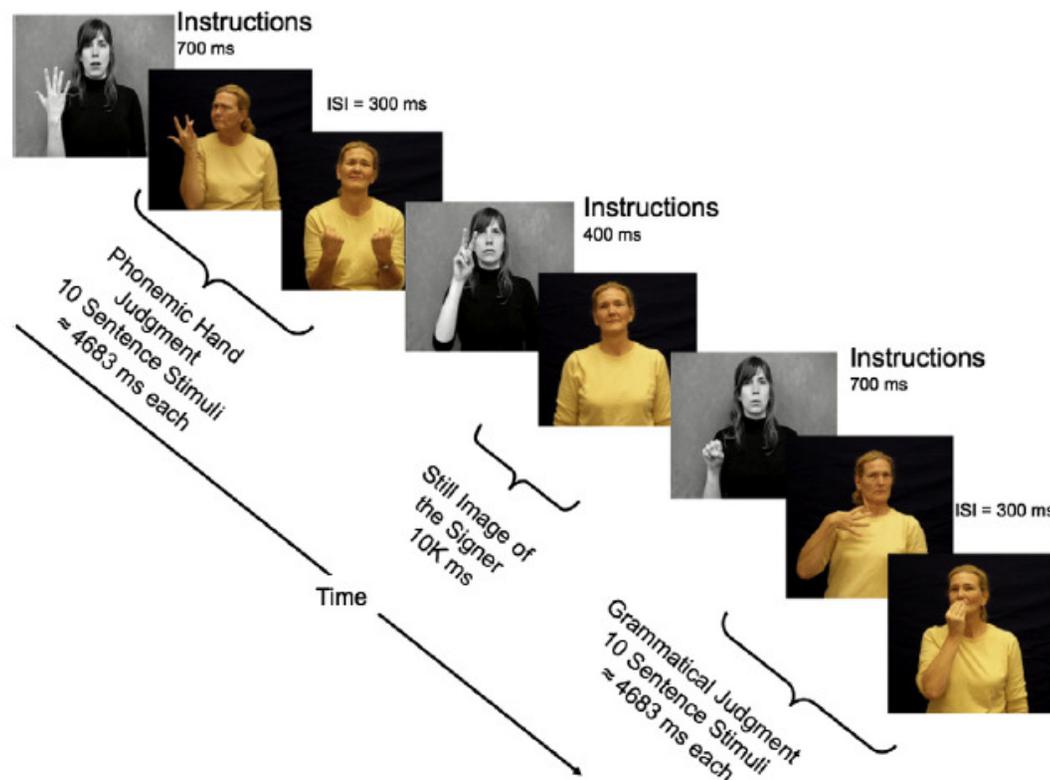


Fig. 1. Study experimental design. Schematic timeline showing the sequence of instructions and blocks for the phonemic-hand judgment task, the baseline condition, and the grammatical judgment task. Each photo is one video frame taken from the three ASL conditions. As shown here, instructions were given in black and white to contrast with the stimuli which were shown in color. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Behavioral results

- AoA affected sensitivity to grammatical judgment task but not to phonemic-hand judgment.
- Grammatical judgment performance was negatively related to AoA.
- Phonemic-hand judgment performance was not significantly related to AoA.

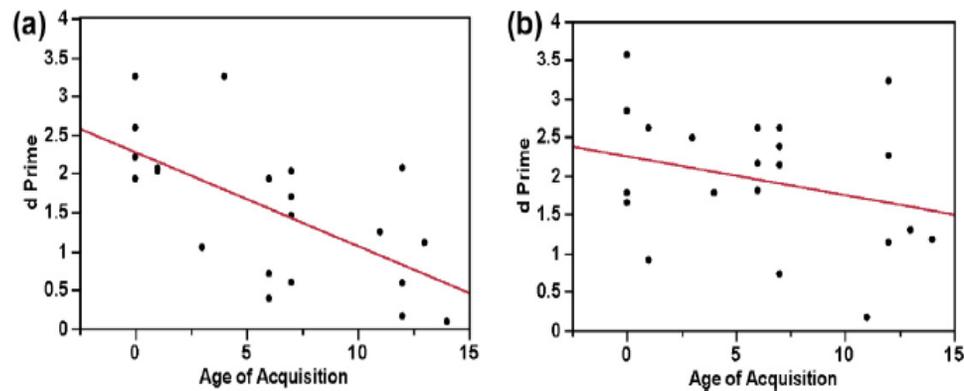


Fig. 2. Linguistic task performance. (a) Scatterplot and regression line for grammatical judgment performance measured in d-prime as a function of AoA. (b) Scatterplot and regression line for phonemic-hand judgment performance measured in d-prime as a function of AoA (see Table 3).

fMRI neuroimaging activation results

- There was an anterior-posterior difference in activation patterns between the two judgment tasks, with predominant frontal-lobe activity for grammatical judgment and posterior cortex activity for phonemic-hand judgment
- Grammatical judgment is lateralized to the LH.

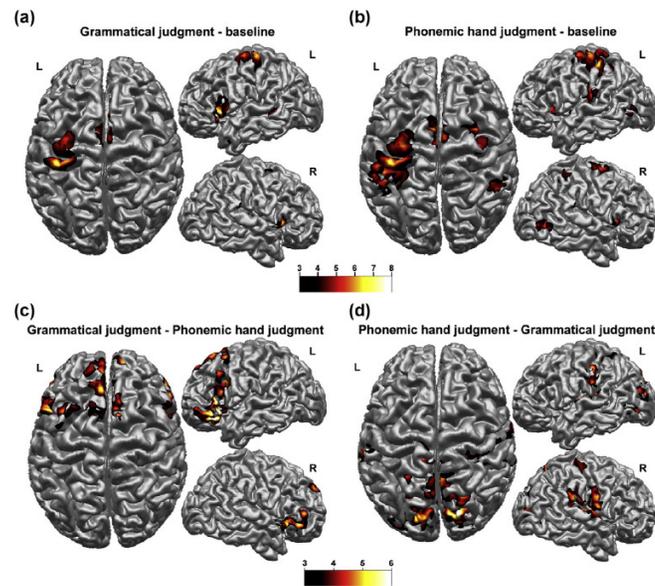


Fig. 3. Activations unique to the linguistic conditions. (a) 3-D rendered image showing BOLD activation patterns for grammatical judgment with baseline subtracted. (b) 3-D rendered image showing BOLD activation patterns for phonemic-hand judgment with baseline subtracted. (c) 3-D rendered image showing BOLD activation patterns for grammatical judgment with phonemic-hand judgment subtracted. (d) 3-D rendered image showing BOLD activation patterns for phonemic-hand judgment with grammatical judgment subtracted. The color bar encodes t -statistics indicating the significance level with a threshold at $t > 4.14$ for the peak and $t > 3.10$ for activation clusters greater than 222 mm³. L = left hemisphere; R = right hemisphere.

AoA effects on neural activation results

- Early AoA associated with increased activation in anterior VOIs (voxel of the regions of interest) in the classic language areas and decreased activation in posterior VOIs
- Late AoA showed decreased activation in anterior VOIs in the classic language areas and increased activation in posterior VOIs
- There was no AoA effects observed for the baseline task of watching a still image of a signer.

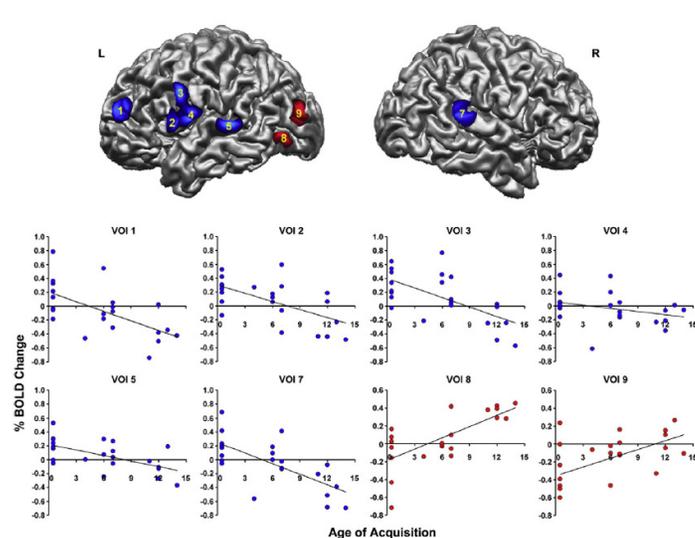


Fig. 4. AoA effects on grammatical judgment activation. 3-D rendered image showing brain areas sensitive to AoA for grammatical judgment; L = left hemisphere; VOI's 1-9; R = right hemisphere; Blue = negative linear relation to AoA; Red = positive linear relation to AoA; Regression scatterplots show brain activity in all the VOI's for the grammatical judgment task as a function of AoA; % BOLD change (y-axis) in relation to AoA (x-axis). Of particular note is VOI 2 (left frontal operculum) and VOI 9 (left occipital cortex, BA 18).

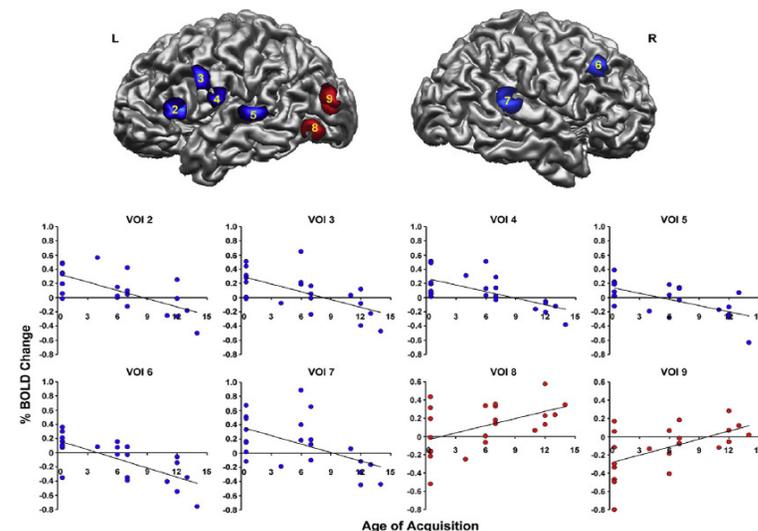


Fig. 5. AoA effects on phonemic-hand judgment activation. 3-D rendered image showing brain areas sensitive to AoA for phonemic-hand judgment; VOI's 2-9; L = left hemisphere; R = right hemisphere; Blue = negative linear relation to AoA; Red = positive linear relation to AoA; Regression scatterplots showing brain activity in all the VOI's for the phonemic-hand judgment task as a function of AoA; % BOLD change (y-axis) in relation to AoA (x-axis). Of particular note is VOI 2 (left frontal operculum) and VOI 9 (left occipital cortex, BA 18).

Relevance

- Be consistent with previous neurolinguistic research in sign language which showed neural activation in brain.
- Provide new insights into the nature of the critical period for language (by comparing AoA effects on the activation patterns for 2 different linguistic tasks)
- Find out that overlap in functional anatomy for spoken and signed language processing is only observed when language acquisition begins in early life.

Limitations

- The 3rd hypothesis was challenged as the performance of phonemic-hand judgment task was insignificantly related to AoA.
 - In grammatical judgment task, there was a correlation between performance and activation observed in VOI 1 (left dorsolateral prefrontal cortex) and VOI 4 (left ventral premotor region). So, **performance had effects on activation?**
 - *"VOIs in the left occipital cortex show a trend for AoA effects in phonemic-hand judgment, but are only significant for AoA effects in the grammaticality judgment condition."* (p.23)
 - *"Another counter-argument comes from the results of the present phonemic-hand judgment task where performance was unrelated to AoA"* (p.27)

Limitations (cont.)

- There is a lack of activation in LIFG in even early AoA participants when performing phonemic-hand judgment task. This is explained in the article that the task require shallower linguistic analysis. So **activation depends on task levels**, not AoA?
- The same stimuli (90 ASL sentences) were used for both grammatical and phonemic-hand judgment tasks. This might cause interference during neural processing.
- The grammatical judgment task has widely been used to measure L2 proficiency in fMRI research, but this case sounds like a investigation of L1.

Suggestion for further research

More fMRI research can be carried out to:

- compare AoA effects on the activation patterns for 2 other different linguistic tasks
- find out the ways in which neuronal and linguistic development interact