Neural underpinnings of rate of speech input on auditory sentence comprehension in aphasic and unimpaired adults: An fMRI investigation

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Introduction
Research has shown that rate of speech input can affect auditory sentence comprehension in multiple populations (Love, 2007b and in preparation).

Neurologically-intact adults are negatively affected by the slowing of the input to rates outside the normal range (4-6 syllables/second), as demonstrated by decreased accuracy on final interpretation tasks & abnormal activation patterns in real-time parsing tasks.

Neurologically impaired adults with aphasia have a language impairment resulting from acute neural trauma (stroke). One subset of individuals with aphasia are those who have sustained anterior (L IFG) damage. This group has been shown to yield slower-than-normal lexical access in priming studies (Prather et al, 1997).

This anterior-lesioned patients also demonstrate poor comprehension of non-canonical structures such as object relative constructions (OR; see below for examples) and a breakdown in automatic online parsing routines involved in the comprehension of these complex sentences.

A slower rate of speech (1/3 to 2/3 normal speed) is beneficial to anterior-lesioned patients:

- Improvement in offline comprehension
- Recovery of normal-like online activation patterns

Rate manipulations negatively affect unimpaired language processing, but substantially improve language processing following (left) anterior cortical lesions.

This Study
We investigated the neural bases of the effect that speech rate input has on auditory sentence processing.

Participants
Control group
Eight right-handed native speakers of English with no History of neurological damage (5 females; mean age: 24.75, SD: 6.54) participated for payment.

Individuals with aphasia
Eighteen* stroke survivors with aphasia participated in this study for payment.

Design and Materials
We examined the comprehension of two length-matched sentence constructions, standardized to offer in processing difficulty: The little boy in the blue shirt instructed the teacher.

Active constructions (ACT; easy)
The little boy in the blue shirt instructed the teacher.

Object-relative constructions (OR; hard)
The boy ate the fish, that the waves washed onto the shore.

Participants made motoric responses to indicate awareness of each of the sentences in two rate conditions:

Normal speed
5.6 syllables/second

Slowed speed
3.4 syllables/second

MRI
Scanning was performed on a Siemens 1.5T clinical MRI scanner fitted with a three-axis local head gradient coil.

Structural MPRA
45 contiguous slices at 4mm thick (4x4x4), FOV = 256, flip angle: 90º,TR=1.875, 98 reps.

Functional imaging
16 contiguous slices at 4mm thick (4x4x4), FOV = 256, flip angle: 90º,TR=1.875, 98 reps.

Design parameters
Within-subject, blocked design
3 cycles of 30 seconds off (silence)/30 seconds on (sentences) [total run time: 3:06 min per run]

Normal rate conditions: 8 sentences per cycle, resulting in 24 stimuli per run

Slow rate conditions: 4 sentences per cycle, resulting in 12 stimuli per run

Analysis
Using AFNI (Cox, 1996), data from each subject were first corrected for motion and other artifacts. A correlational analysis was done within a block-design input that was converted to Z scores which were then registered to Talairach space.

All eight control subjects were then combined for group analysis (35x3DVAHA).

Results
Controls
- Active constructions engaged left inferior frontal regions at normal speed but not at slow speed.
- Object relatives engaged bilateral IFG in both rate conditions and did so more intensely than ACT, reflecting heavier syntactic processing loads.
- Slowing of the rate of speech resulted in the disengagement of L IFG for ACT yet a more focussed increased intensity in bilateral STS and STG. Similarly, this increase in intensity in STS and STG was also demonstrated in the OR condition, however, additionally a more defined, intense L IFG pattern emerged.

Patient SH
- Peri-lesional areas were engaged in all conditions.
- R IFG was not engaged by the task condition more than baseline in normal ACT, was recruited in normal OR and intensely activated in slow ACT and OR.

Patient PY
- The task - baseline contrast did not return activation of peri-lesional areas in any condition. Right hemisphere IFG recruitment was observed as early as normal ACT.
- Increased activity bilaterally with increased syntactic load and slowed rate of input (Normal ACT is normal OR to slow ACT) until the hardest condition, (Slow OR).

Discussion
Across both populations, manipulating the rate of speech influenced activation patterns in the primary auditory cortices and language-related areas (more specifically, L IFG and its right homologue).

In unimpaired adults, right IFG seems to hold a supporting function in cases of high syntactic processing loads (e.g., OR construction) and/or temporal demands (rate of speech). Interestingly, L IFG does not seem to be more engaged during the task than the baseline condition when there are no high (syntactic or temporal) processing demands.

Patients SH and PY demonstrated differential use of right hemisphere support. SH engaged peri-lesional areas and incrementally activated right IFG following (syntactic and temporal) processing manipulations. In contrast, PY did not engage peri-lesional areas more in the task than in the baseline, and instead depended on right hemisphere support in easier conditions. PY’s recruitment of RH homologues increased with both the processing demands of complexity and rate. Interestingly, in the hardest task (slow OR) they do not see a pure additive effect, but a more focal intense pattern.

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References

Image 1:
- T-value: 3.580
- Z-value: 3.277
- Subject: SH

Image 2:
- T-value: 3.580
- Z-value: 3.277
- Subject: PY

Image 3:
- T-value: 3.580
- Z-value: 3.277
- Subject: Patient SH

Image 4:
- T-value: 3.580
- Z-value: 3.277
- Subject: Patient PY

Image 5:
- T-value: 3.580
- Z-value: 3.277
- Subject: Control Group