FLUENCY AND SPEECH RATE IN EPILEPSY: CORRELATIONS WITH FMRI PROFILES

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ABSTRACT

Fluency and speech rate were examined in children with epilepsy, a group known to demonstrate depressed language skills. We also sought possible functional markers of increased disfluency during speech production tasks regardless of group. Children with epilepsy (CWE) had significantly more disfluencies in their narratives than their typically-developing peers (TD), while speech rate did not differ between groups. fMRI activation in working memory regions during a covert language processing task was significantly correlated with increased disfluency in another task involving narrative speech production. Additionally, there was a significant positive correlation between disfluency frequency and laterality of activation in the cerebellum. These results support the hypothesis that children with weaker language skills demonstrate increased levels of disfluencies in their narrative speech. Findings also suggest that children with higher rates of conversational speech disfluency may activate additional language and working memory regions when processing language, possibly reflecting the need for more mid-utterance incremental processing.

BACKGROUND

- Children with epilepsy (CWE) demonstrate depressed language skills, although deficits are often subtle and underdiagnosed
- Individuals with weaker language skills may demonstrate increased levels of disfluency and slower rates in their spontaneous narrative speech
- fMRI studies support behavior data demonstrating that CWE perform differently than TD peers on various language tasks, as indicated by differences in localization and lateralization of brain activity

GOALS OF THIS STUDY

1. Characterize the nature of speech disfluencies and speech rate in spontaneous narrative speech from CWE
2. Further explore the relationship between fluency, speech rate and language skills in children with and without compromised language abilities
3. Describe possible differences in brain activation during language tasks between CWE and TD peers
4. Identify possible functional markers of increased disfluency during speech production regardless of group

METHODS

Participants

- 52 participants consisting of 26 children with epilepsy and 26 typically-developing peers, ages 4-12 years
  - CWE-R = children with recent-onset (< 1 year following second seizure) epilepsy
  - TD-R = typically-developing peers age- and gender-matched to CWE-R
  - CWE-C = children with chronic (> 3 years) epilepsy
  - TD-C = typically-developing peers age- and gender-matched to CWE-C
- All fMRI analyses were conducted with 44 children, as imaging data was not available for all participants
- Participants received comprehensive speech, language, developmental, and psychoeducational testing prior to experimental fMRI studies.

Narrative Analysis

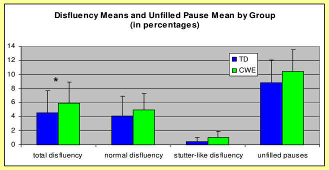
Each child provided a narrative elicited by *Frog, Where Are You?* by Mercer Mayer (1969) which was transcribed into CHAT using the CHILDES conventions (MacWhinney, 2000). Narratives were coded for disfluencies and unfilled pauses. Speech rate was also computed from ten successive utterances using the Praat software program (Boersma, 2001). Mann-Whitney U tests were used to compare disfluency/pause frequencies and speech rate between groups. Correlations were performed to compare disfluency and speech rate measures as well as to compare these measures with other demographic variables (e.g., age, standardized language measures).

Functional Imaging Analysis

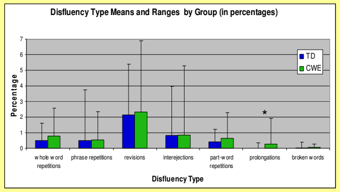
Participants performed an auditory description decision task (ADDT) in which they were asked to listen to sentences that described common, concrete nouns and press a button if the description was accurate (e.g., something you sit on is a *chair).* Participants' task performance (i.e., accuracy, reaction time) was collected during the scan. Functional data were acquired using a 3.0 Tesla Siemens Magnetom Trio equipped with a standard CP head coil. Statistical Parametric Mapping software (University College London, London) and the Statistical Analysis Toolbox through Matlab (The MathWorks, Inc; Natick, MA) was used to preprocess the imaging data, as well as to perform group analyses used to examine group differences in activation and to perform regression analyses to correlate language variables with brain activation. Laterality index (LI) was also computed for three regions of interest (inferior frontal gyrus, Wernicke's area, cerebellum) to compare the frequency of typical and atypical language dominance in CWE and TD peers.

RESULTS

DISFLUENCY FREQUENCY AND TYPES

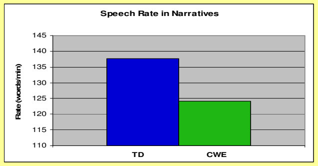


- CWE (CWE-R and CWE-C combined) had a significantly higher frequency of total disfluencies than their TD peers.
- CWE did not have a higher frequency of either normal disfluencies or stutter-like disfluencies or unfilled pauses than their TD peers. Differences in SLD frequency approached significance level with a *p*-value of 0.052.
- No significant differences in disfluency or pause frequencies for CWE-R versus TD-R or CWE-C versus TD-C.



- The distribution of disfluencies was similar between groups, with the exception of prolongations. CWE had significantly more prolongations as compared to the TD group ($p < 0.001$).

SPEECH RATE

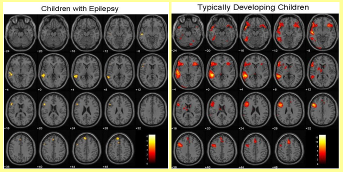


- CWE did not have a significantly slower rate than their TD peers.
- Speech rate was not significantly different between CWE-R compared to TD-R and CWE-C compared to TD-C.

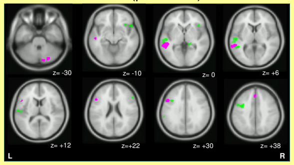
DISFLUENCY AND SPEECH RATE CORRELATIONS

- Age and disfluency frequency were positively correlated which supports the prediction that older children, who are assumed to be more proficient in using more complex language, have lower frequencies of disfluencies.
- Total disfluency frequency was not correlated with any standardized measure of IQ or language. However, without the correction for multiple correlations, *WASI* Verbal IQ and *EOWVT* standard scores would correlate with total disfluency at the $p < 0.05$ level.
- Speech rate and disfluency frequency had an inverse relationship, such that as speech rate increased, total disfluency mean decreased, indicating that children with more disfluency were less efficient communicators.

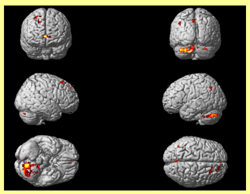
FUNCTIONAL IMAGING



- CWE and TD groups showed similar activation on group maps; however, there was significantly less activation overall for the CWE group. For both groups, an area of left-lateralized activation in classical language areas within frontal and temporal lobes was revealed (p < 0.001).



- TD group had greater activation than the CWE group in the left middle frontal gyrus, left precentral gyrus, left superior temporal gyrus, left and right inferior parietal lobes, and right superior temporal gyrus (green areas).
- Activation in the left superior temporal gyrus, left middle temporal gyrus, left inferior frontal gyrus, left superior frontal gyrus, left middle frontal gyrus and right cerebellum was common between all participants (magenta areas).
- CWE did not have any areas of greater activation as compared to the TD group.



- Activation in the left cerebellum, left occipital lobe, right cerebellum, left middle frontal gyrus, left inferior parietal lobe, left posterior cingulate gyrus, right middle frontal gyrus and right superior frontal gyrus increased as total disfluency frequency increased. As total disfluency frequencies decreased, activation in the right posterior cingulate gyrus and left parahippocampal gyrus increased.

Measure		LI ROI IFG	WA	Cerebellum
Child's Total	r	-.23	-.13	.32*
Disfluency Mean	p	.13	.42	.04
Child's Normal	r	-.22	-.13	.25
Disfluency Mean	p	.16	.42	.11
Child's Stutter-like	r	-.16	-.10	.32*
Disfluency Mean	p	.29	.52	.04

* Significant at $p < .05$

Measure	Typically-Developing Children N=22	Children with Epilepsy N=22	Z	p
IFG LI	0.59 (.40)	0.31 (.67)	1.09	0.275
WA LI	0.82 (.14)	0.47 (.62)	1.97*	0.048
Cerebellum LI	-0.74 (0.26)	-0.55 (0.41)	-1.37	0.170

*Significant at p <0.05
Note: n=21 for cerebellum LI for both TD and CWE, as LI could not be calculated for this ROI for one child in each group because there were not enough voxels in the left hemisphere

- Left language lateralization was found in the majority of TD and CWE groups for IFG and WA, with right lateralization in the cerebellum; however, the incidence of atypical language representation for at least one ROI was higher in CWE when compared to TD children.
- Greater atypical (left) activation in the cerebellum was associated with a higher total disfluency frequency.

CONCLUSIONS

1. Narratives from CWE have *more disfluencies*, with *similar speech rates* as compared to narratives from TD peers
2. CWE had significantly *less activation overall* during the auditory decision task, with *greater amounts of atypical language representation* in at least one region of interest
3. fMRI activation in the *working memory network* (cerebellum, posterior cingulate gyrus, middle frontal gyrus, inferior parietal lobe, and superior frontal lobe) was significantly correlated with *increased disfluency* in narrative speech regardless of group
4. ***Lateralization of activation to the left cerebellum was positively correlated with total disfluency frequency and stutter-like disfluency frequency***

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