VANDERBILT UNIVERSITY MEDICAL CENTER

The Impact of Emotional Processes on Cognitive Control in Young Children who Stutter

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Introduction

Cognitive control, which aids in inhibition and execution has been linked to speech fluency in other populations (i.e., ADHD; Engelhardt, Corley, Nigg, & Ferreira, 2010). Evidence shows that young children who stutter (CWS) exhibit differences in emotional processes (e.g., heightened emotional reactivity; Eggers et al., 2010; Zengin-Bolatkale, Conture, Key, et al., 2018) as well as cognitive control processes such as inhibition and execution (e.g., Eggers, De Nil, & Van den Bergh, 2013; Piispala et al., 2016). Further, there is evidence that cognitive control is susceptible to interference from concurrent emotional processes in children (Lamm et al., 2012), but these processes have not been studied in young children who stutter.

To investigate this, we measured P2, N2 and P3 event-related potentials (ERPs) and assessed behavioral accuracy and reaction time in a child friendly Go-NoGo task. We hypothesized that CWS, when compared to CWNS, would exhibit differences in cognitive control performance as indexed by cortical and behavioral responses.

Methods

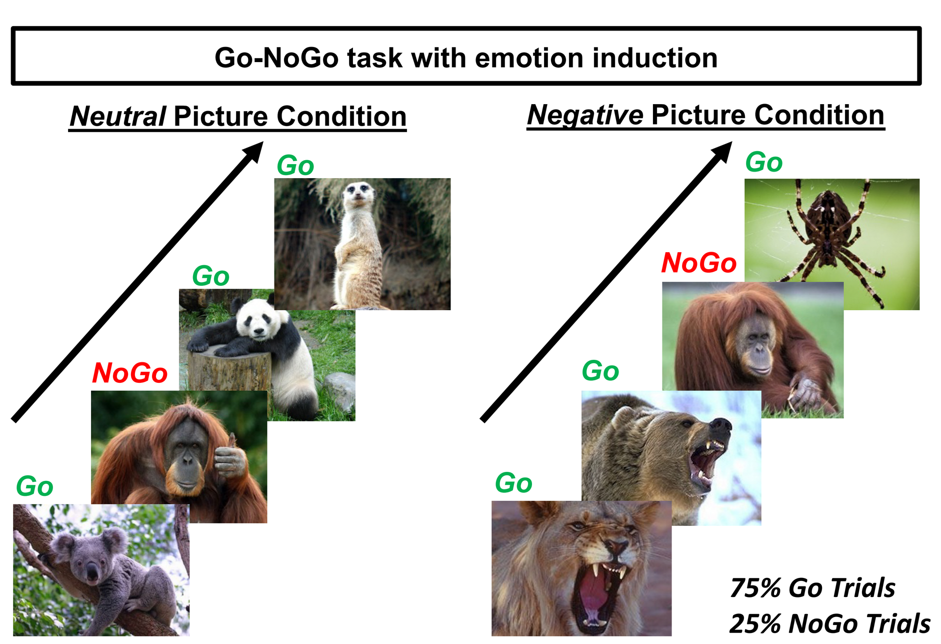
Participants:

- 37 CWS (22 M, 15 F) and 42 CWNS (23 M, 19 F).
- Children were between 3 years 1 month to 6 years 9 months of age.
- CWS' chronological age (M=58.4, SD=13.12) did not significantly differ from that of CWNS (M=57.5, SD=12.6): t(75)= -0.31, p=.757.

Procedure and stimuli:

Children performed a child-friendly Go/No-go task ("Zoo Game") with emotion induction based on the task by Grammer et al. (2014):

- The goal was to help a zookeeper to catch the animals that escaped from the zoo by pressing a button (Go) as they saw animal pictures on the computer screen.
- The exception was two orangutans, who were "helpers," for which the participants had to **inhibit** their response to push the button (NoGo).
- 75% Go trials and 25% NoGo trials ensured a prepotent desire to respond.
- Two blocks: Affective (e.g., large dog aggressively showing teeth, spider, snake, etc.) and Neutral (e.g., cute panda bear, kangaroo, etc.) pictures in the Go trials: (160 trials: 120 Go, 40 NoGo in each block).



ERP recording and Data analysis:

- Recording of event-related potentials (ERPs) using a high-density array of 128 Ag/AgCl electrodes embedded in soft sponges (Geodesic Sensor Net, EGI, Inc.).
- Cleaning & analysis of ERP data using Net Station 5.3 and R statistical Software .

N2P2 amplitude:

- **P2 and N2 amplitudes** were scored by computing the mean amplitudes for each participant in the time window [180-280ms for P2, 320-520ms for N2] from 8 mediofrontal electrodes in the FCz (frontocentral) location.
- Following Lamm et al. (2012) N2 amplitude was indexed by subtracting P2 amplitude from N2 amplitude (**N2-P2**) since the waveforms were not morphologically independent (both had negative amplitudes).

P3 amplitude:

- **P3 amplitudes** were scored by computing the mean amplitudes for each participant in the time window [400-750ms] from 8 mediopartietal electrodes in the Pz (midline parietal) location.

Behavioral responses:

- Participants' proportion correct (accuracy), premature responses (<200ms) and mean reaction times (RTs) were computed separately for Go and NoGo trials.
- In the case of premature responses and reaction times NoGo values represent incorrect responses.

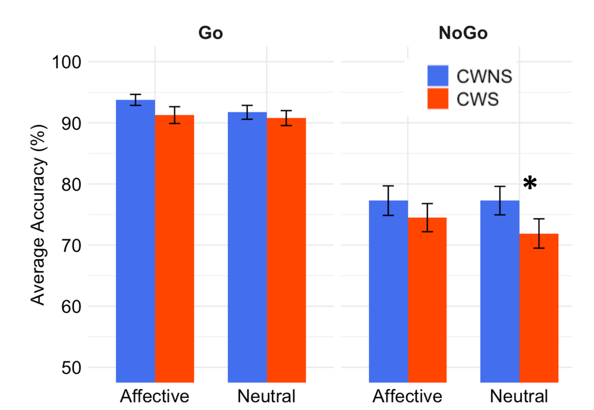
Results

Behavioral Results

Accuracy Percentage:

Talker Group (CWS, CWNS) x Condition (Go, NoGo) x Emotion (Affective, Neutral) mixed-effects model with age and gender:

- NoGo accuracy (M= 75%) < Go accuracy (M = 92%), F(1,231)= 186.6, *p<.0001*
- Accuracy increased with age F(1,75)= 6.37, *p=0.01*
- CWS were less accurate than CWNS during **NoGo**, t(137)= 1.99, *p*=0.04, particularly **Neutral NoGo** t(242)= 2.01, *p*=0.03 (CWS= 72%, CWNS = 77.4%)



Premature responses (<200ms):

Talker Group (CWS, CWNS) x Emotion (Affective, Neutral) models with age & gender:

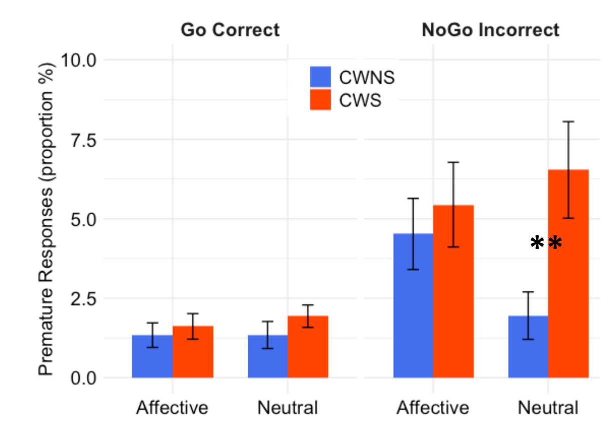
- Premature responses decreased with age:

Go: F(1,74)=4.06, *p*=.047,

NoGo: F(1,74)=12.05, *p*=.0008

NoGo Incorrect:

- CWS (M = 6%) had more premature pushes than CWNS (M= 3.1%), F(1,74)=5.31, p = .02, particularly during Neutral, t(145)=-2.89, *p*=.004



Reaction Time (>200ms):

Talker Group (CWS, CWNS) x Emotion (Affective, Neutral) models with age & gender:

- Reaction Time decreased with age:

Go: F(1,74)=52.61 *p*< .0001,

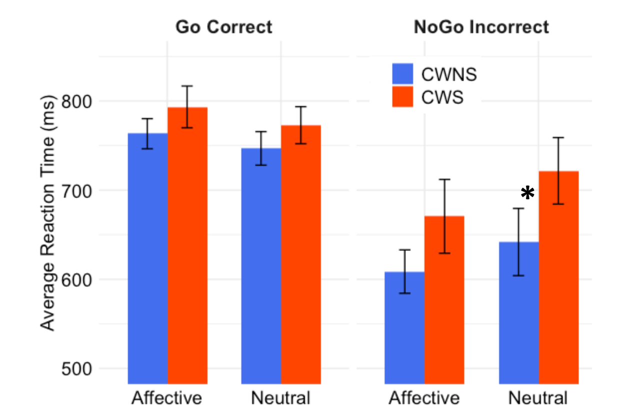
NoGo: F(1,74)=38.7 *p*< .0001

Go Correct:

- CWS (M = 788 ms) tended to be slower than CWNS (M= 753 ms), F(1, 74) = 2.87, *p* = .09)

NoGo Incorrect:

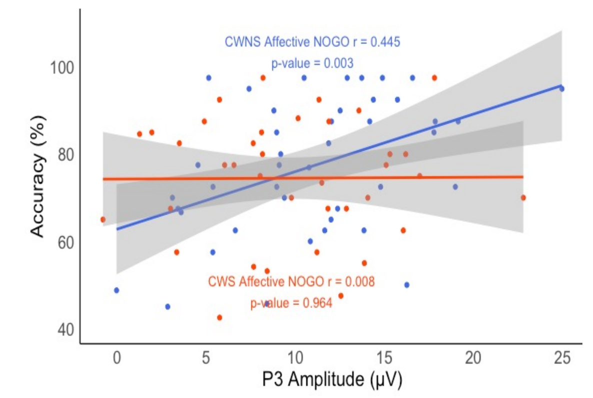
- CWS (M = 703 ms) were slower than CWNS (M= 623 ms), F(1, 74) = 4.89, *p* = .03



Cortical Predictors of Behavioral Accuracy:

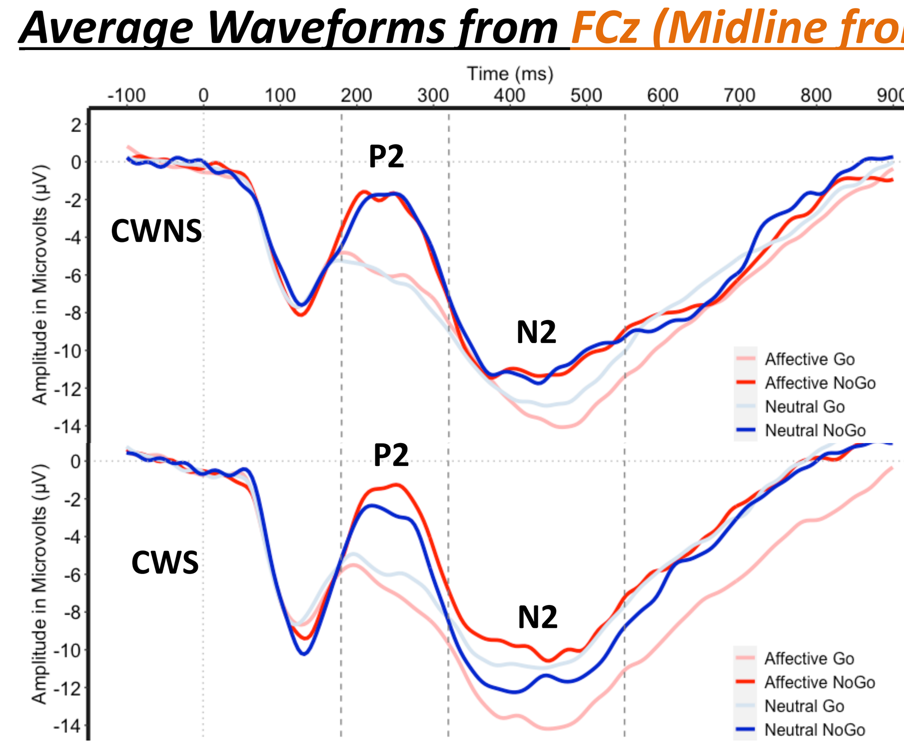
Linear regression model on overall **accuracy** using individual cortical markers as predictors:

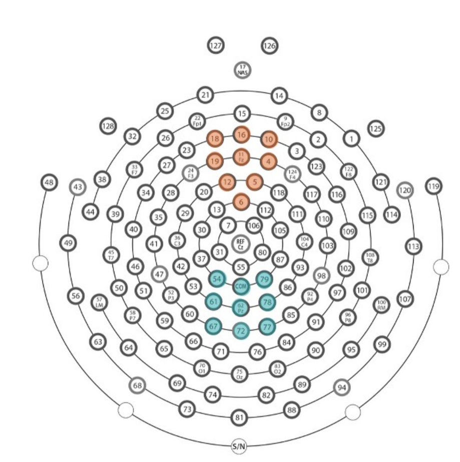
- **Mean P3** was a significant predictor for accuracy, F(1,69)= 6.23, *p* = .01.
- Only **CWNS (vs. CWS) during affective NOGO** had a significant correlation between P3 and accuracy, r = .45, *p* = .003.



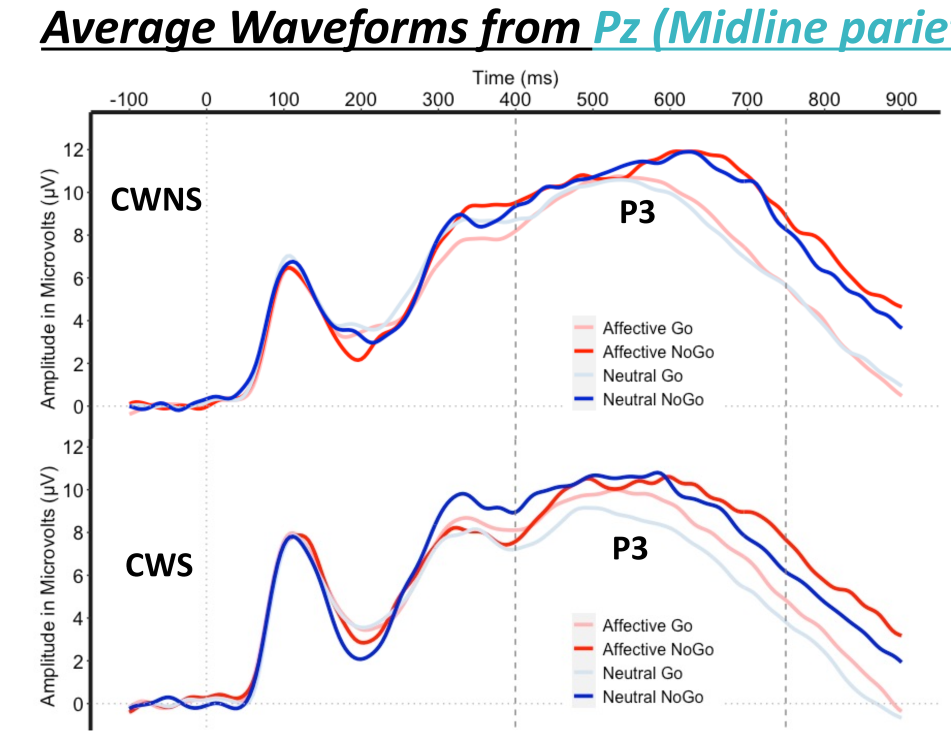
Cortical Results

Average Waveforms from FCz (Midline frontocentral):





Average Waveforms from Pz (Midline parietal):



N2-P2 Mean Amplitude:

Talker Group (CWS, CWNS) x Condition (Go, NoGo) x Emotion (Affective, Neutral) linear mixed-effects model with age as covariate showed:

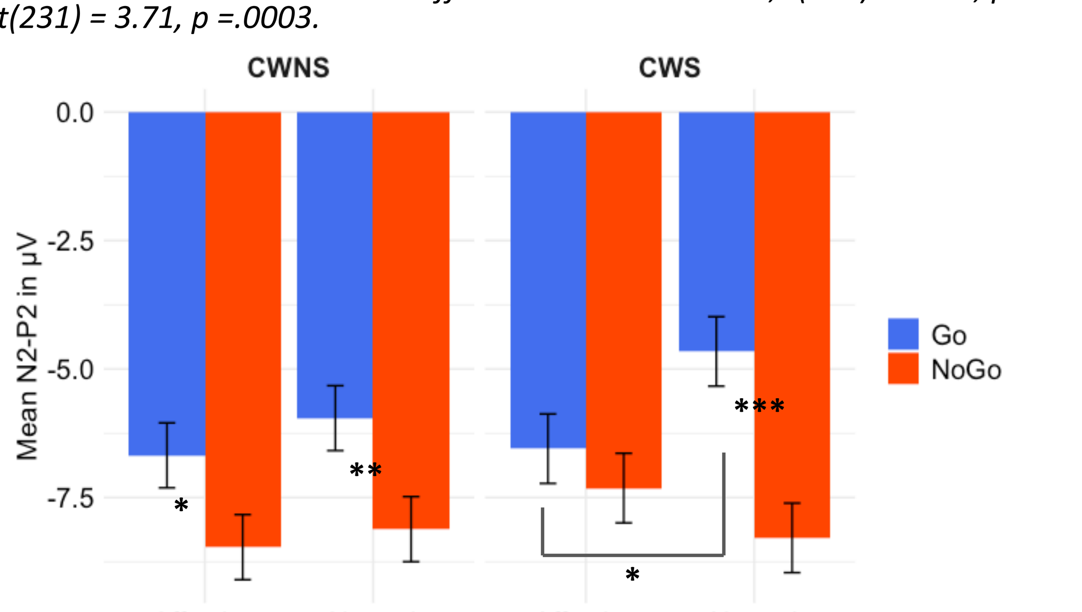
- Main effect of Condition: NoGo (more negative) > Go F(1,231)= 22.98, *p<.0001*
- Three-way Group x Condition x Emotion interaction: F(1,231)= 4.28, *p= .03*

CWNS:

- *NoGo > Go in Affective, t(231) = 3.06, p=.0024.*
- *NoGo > Go in Neutral, t(231) = 3.71, p =.0003.*

CWS:

- *NoGo > Go in Neutral t(231) = 5.85, p < .0001*
- *NoGo **NOT** > Go in **Affective** t(231) = 1.23, p= .21.*
- *Affective Go > Neutral Go, t(231) = -3.05, p= .0025.*



P3 Mean Amplitude:

Talker Group (CWS, CWNS) x Condition (Go, NoGo) x Emotion (Affective, Neutral) linear mixed-effects model with age as covariate showed :

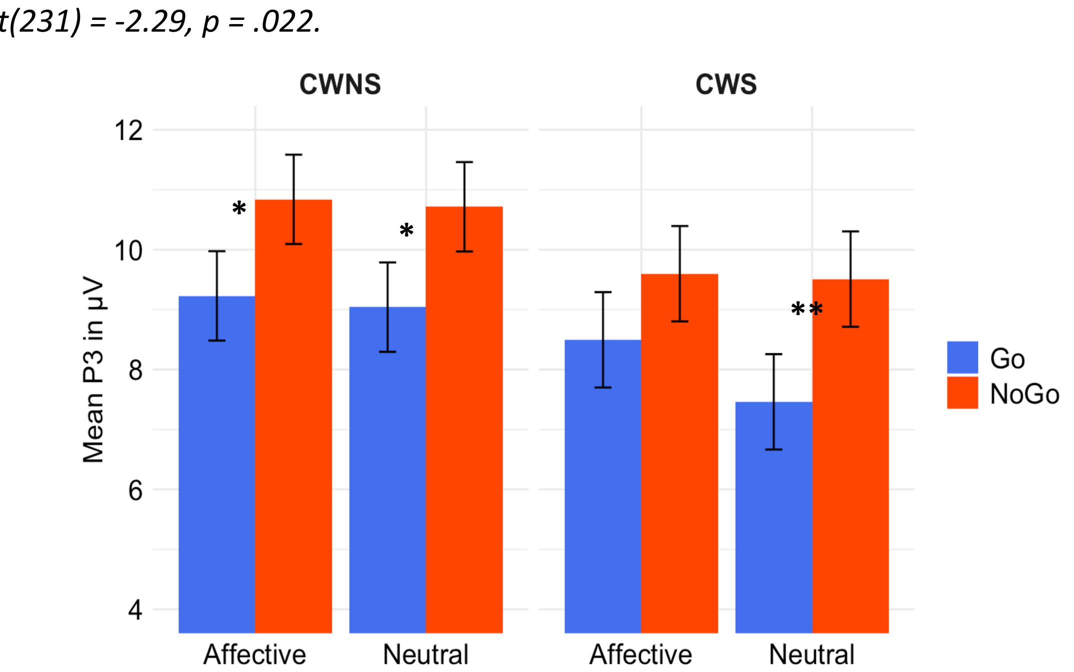
- Main effect of Condition: NoGo > Go: F(1,231)= 8.79, *p = .0032.*

CWNS:

- NoGo > Go in Affective, *t(231) = -2.3, p = .028*
- NoGo > Go in Neutral *t(231) = -2.29, p = .022.*

CWS:

- *NoGo **NOT** > Go in **Affective**, t(231) = -1.41, p = .15)*
- *NoGo > Go for in Neutral, t(231) = -2.63, p = .009.*



Preliminary Conclusions

Behavioral findings:

- Behavioral results indicate that children in this young age range are able to successfully complete the present Go/NoGo task.
- CWS might have a less mature or efficient behavioral response system in support of both execution (Go) and inhibition (NoGo) as evidenced by lower accuracy during the neutral NoGo condition, as well as higher proportion of premature responses (for <200ms)and slower mean reaction times (for >200ms) during incorrect NoGo responses.

N2-P2 findings:

- Participants displayed significantly more negative N2-P2 mean amplitude during NoGo trials compared to Go trials, which is consistent with previous studies of children using this task (Lamm et al., 2012).
- In the affective condition, CWS exhibited significantly diminished differentiation in neural responses between Go and NoGo trials, which may reflect a less distinct neural signature for response inhibition and potential difficulties in conflict detection and inhibition processes.
- CWS exhibited reduced N2-P2 in response to Go in the neutral compared to the affective condition, which may reflect decreased neural resources in support of response preparation and activation in the neutral condition.

P3 findings:

- The participants overall exhibited more positive (greater) P3 responses during NoGo trials in comparison to Go trials. This may reflect greater neural resources in support of cognitive control, specifically attentional processes, allocated for target detection of the NoGo stimuli.
- CWS had a diminished differentiation of Go and NoGo trials during the affective condition, which might be reflective of a reduced differentiation of cognitive and attentional resources across Go and NoGo, and more difficulty detecting the target stimuli required by the inhibition task.

P3 and behavioral accuracy relationship:

- P3 amplitude may be a key neural marker of the cognitive control processes that facilitate accurate response inhibition and execution performance during early childhood. Notably, this association was most pronounced for CWNS during the affective condition, which may indicate that their neural responses are more closely linked to their behavioral response processes.

The results of the present study demonstrate that CWS, compared to CWNS, exhibit differences in cortical and behavioral responses during an inhibitory control task with emotion induction. Future studies should examine whether these processes relate to processes of speech production and stuttering.

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