

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, supports speech-motor control and it 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

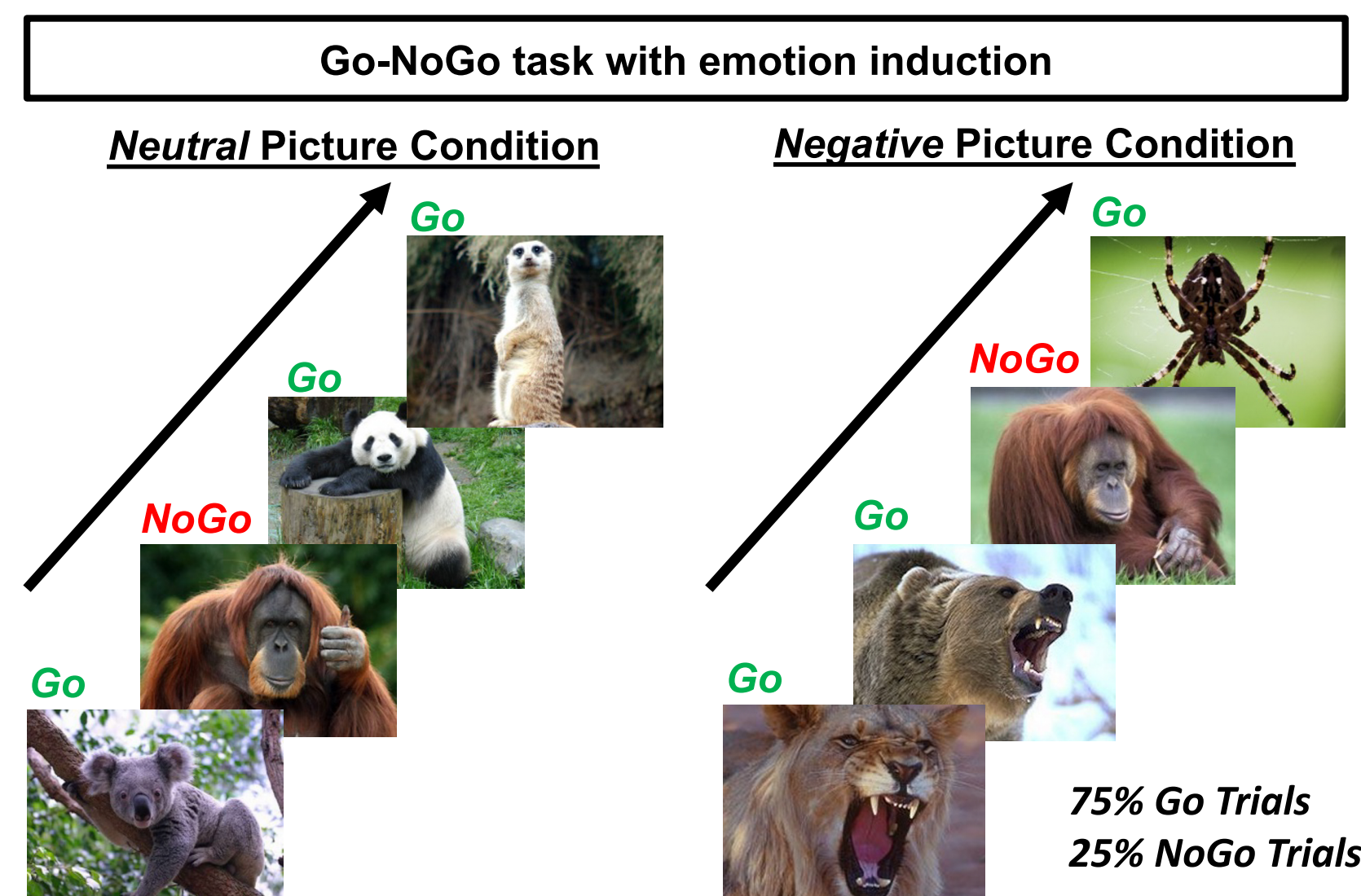
Participants:

- 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 (to ensure a prepotent desire to respond).
- Two blocks: Affective (e.g., large dog aggressively showing teeth, a large spider, snake, etc.) and Neutral (e.g., non-threatening looking 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:

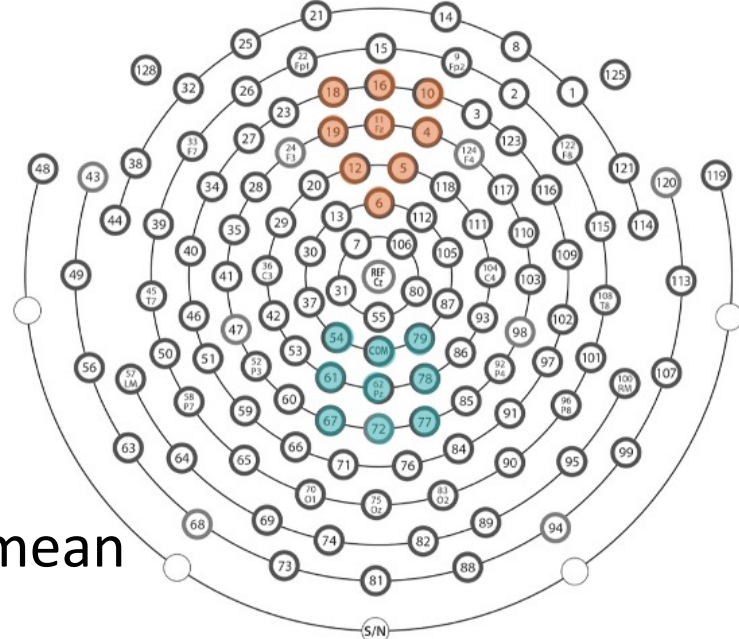
- P2 and N2 amplitudes** were scored by computing the mean amplitudes for each participant in the time window [180-280ms for P2, 320-520ms for N2] from 8 mediofrontal electrodes in the **FCz (frontocentral)** location.
- Following Lamm et al. (2012) N2 amplitude was indexed by subtracting P2 amplitude 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 medioparietal electrodes in the **Pz (midline parietal)** location.

Behavioral responses:

- Participants' proportion correct (accuracy) were computed separately for Go and NoGo trials, and mean response times (RTs) were computed for GO trials.



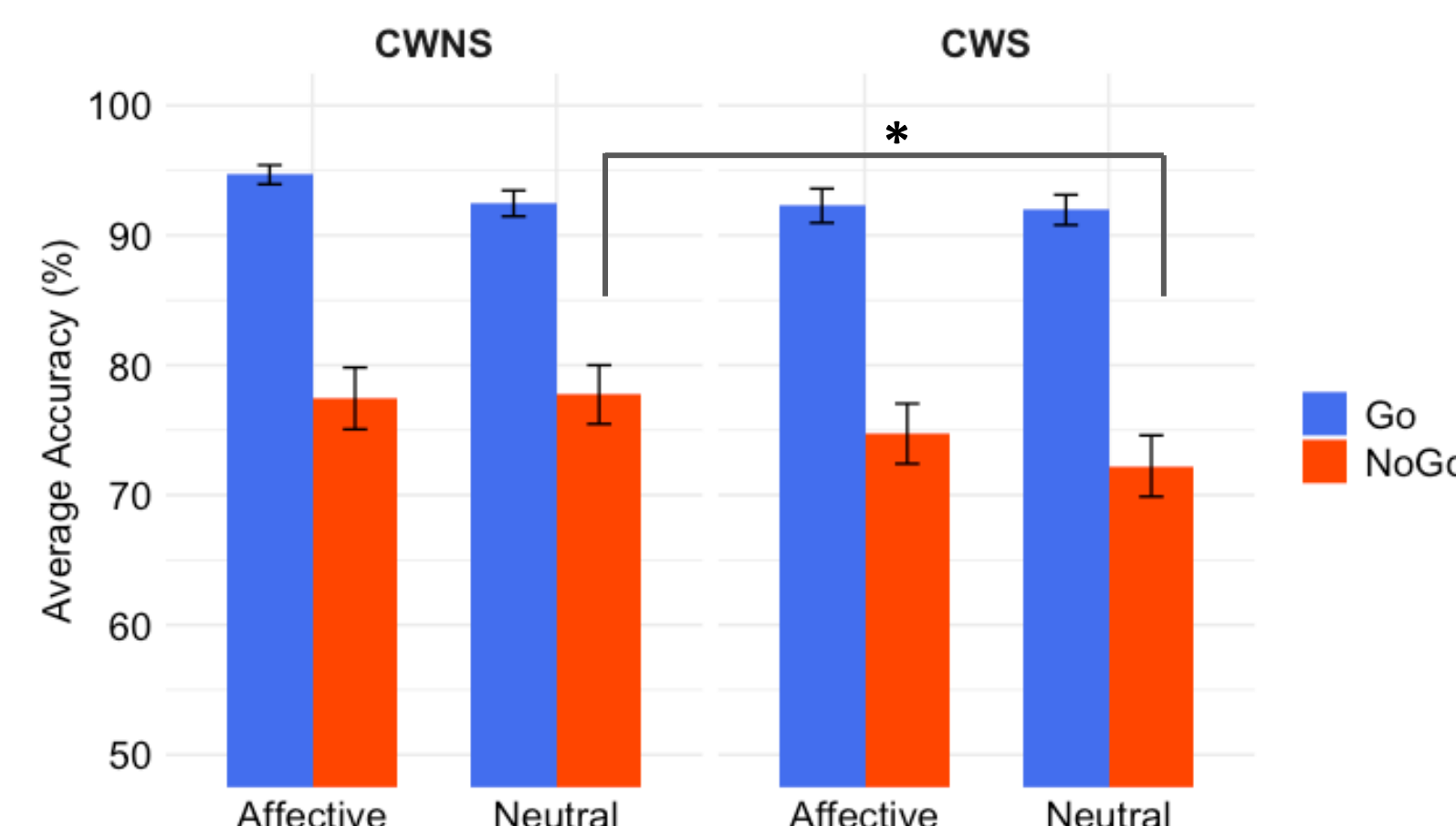
Results

Behavioral Results

Accuracy Percentage:

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

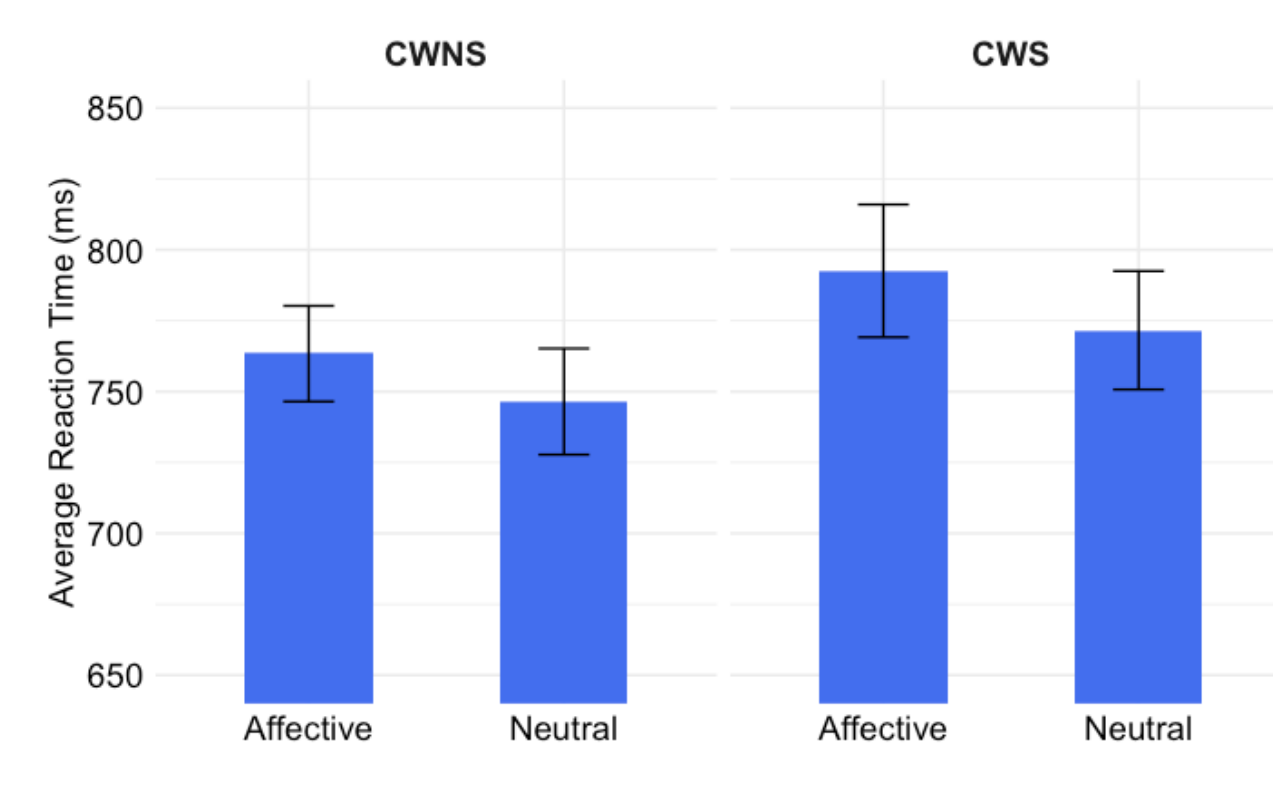
- Children were **less accurate** at NoGo (M= 75%) than Go (M = 92%), $F(1,231) = 186.6, p < .0001$
- Accuracy increased as age increased $F(1,75) = 10.97, p < .001$
- CWS (M=73.5%) were less accurate than CWNS (M= 77.7%) during NoGo, $t(149) = 2.11, p = 0.036$, in particular during **Neutral NoGo** $t(262) = 2.2, p = 0.028$



Reaction Time (GO trials only):

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

- Main effect of age: Reaction time decreased as age increased $F(1,74) = 90.68, p < .0001$
- CWS (M = 788 ms) showed a trend towards being slower than CWNS (M = 753 ms) – approaching significance, $t(74) = 2.94, p = .08$

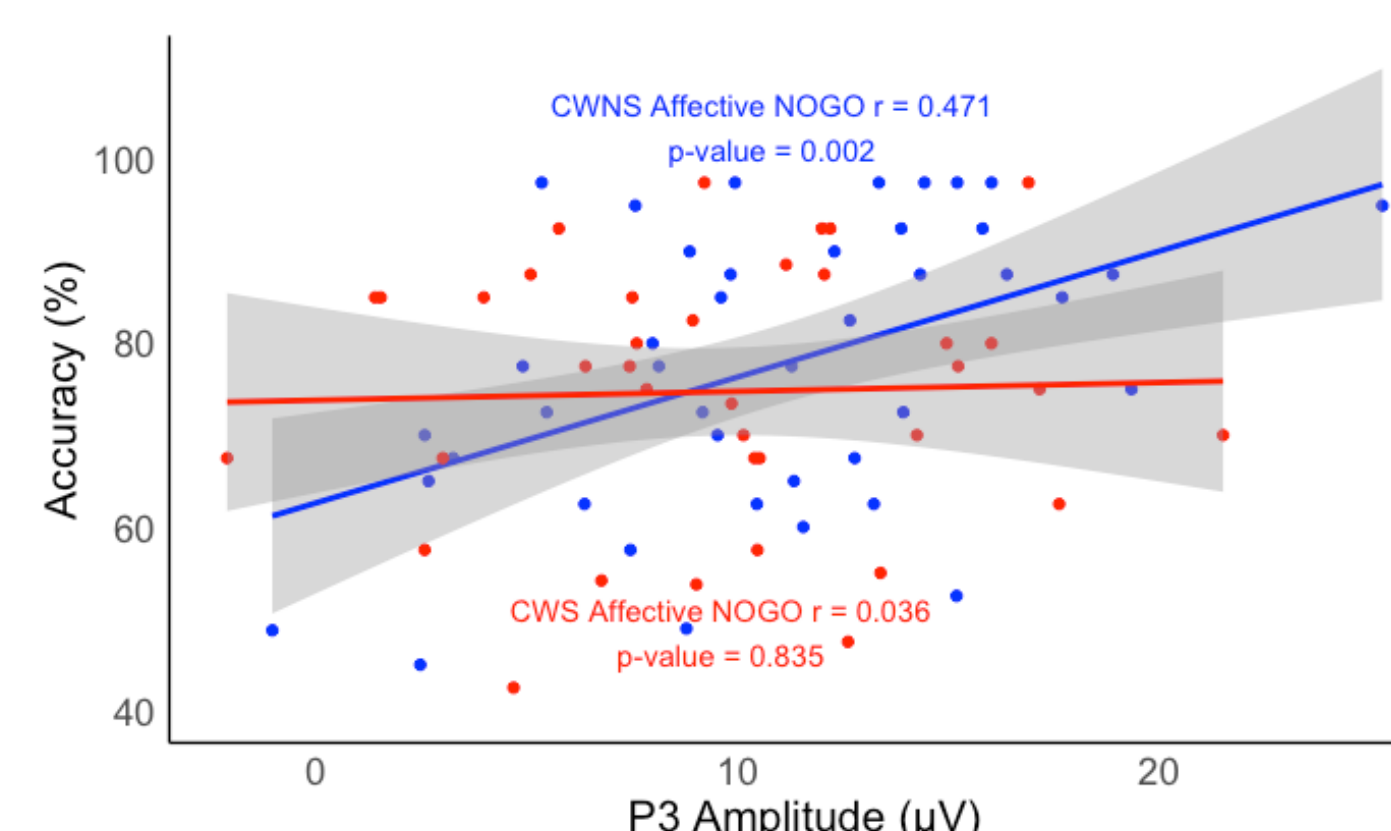


Cortical Predictors of Behavioral Accuracy:

Accuracy:

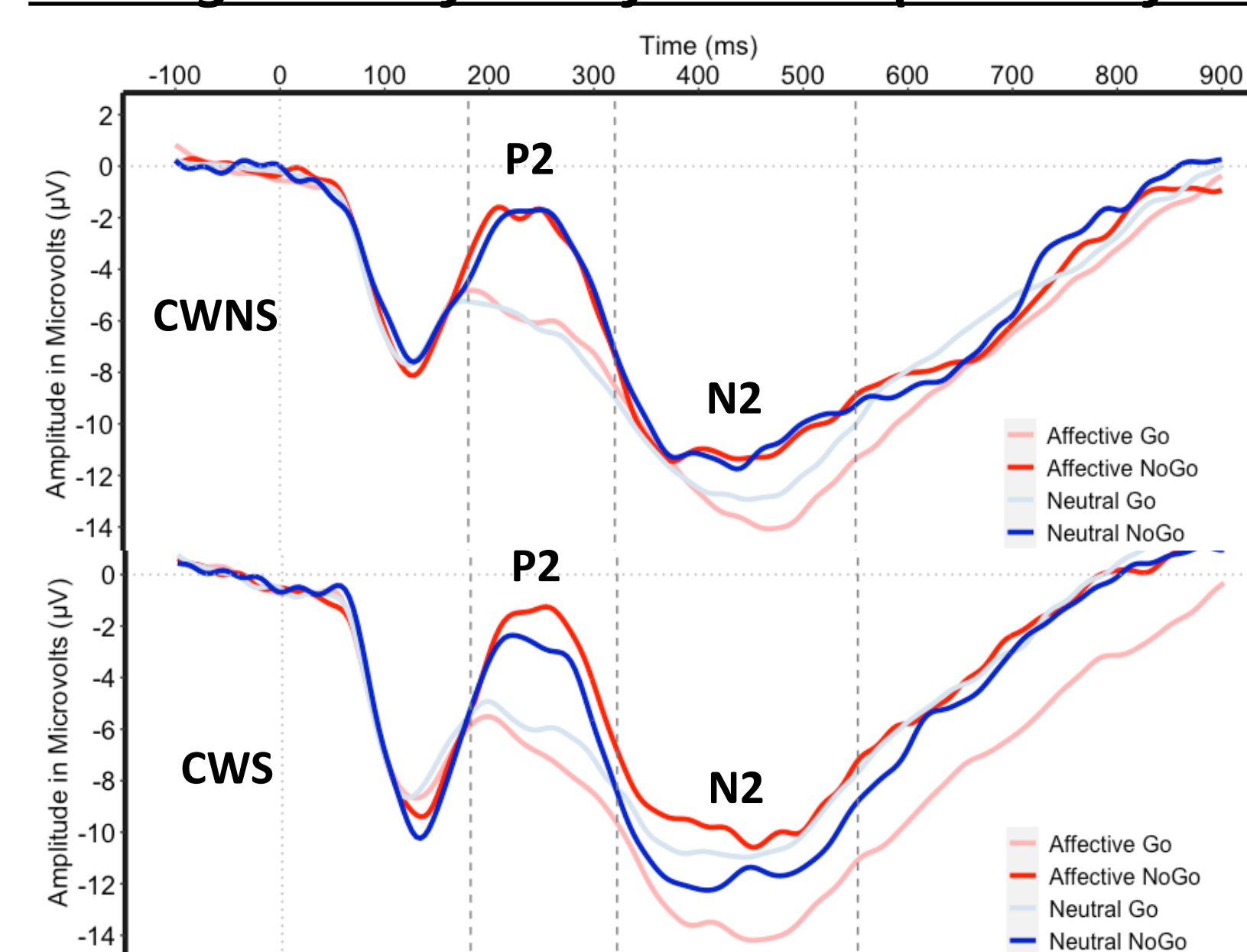
A linear regression model on **accuracy** using the individual cortical markers as predictors showed:

- Overall, only **Mean P3** was a significant cortical predictor for accuracy, $F(1,223) = 8.23, p = .004$.
- Only **CWNS (vs. CWS) during affective NOGO condition** had significant positive relationship between P3 and accuracy, $r = .47, p = .002$.



Cortical Results

Average Waveforms from FCz (Midline frontocentral):



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:

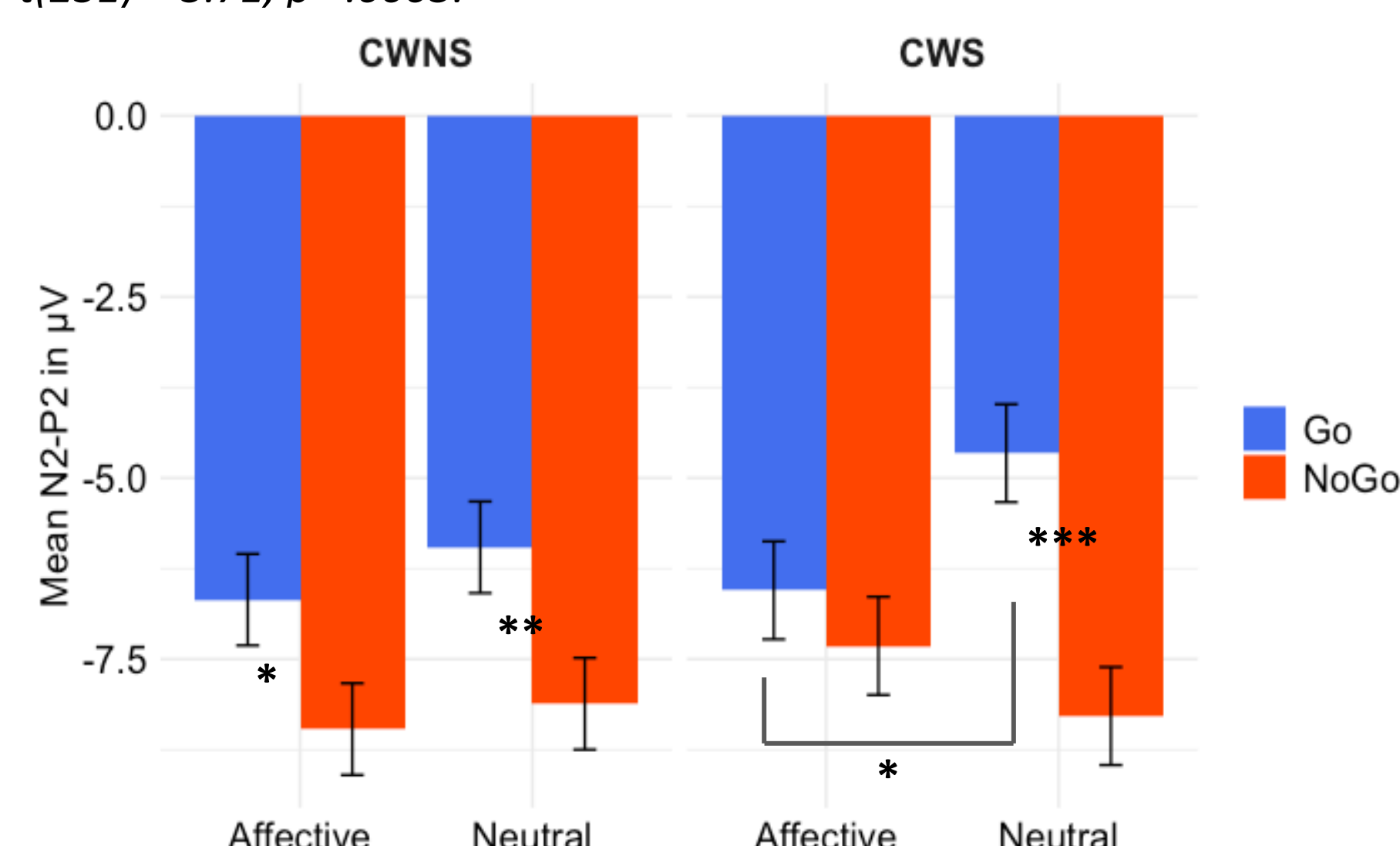
- Main effect of Condition: NoGo (more negative) > Go $F(1,231) = 22.98, p < .0001$
- Three-way Group x Condition x Emotion interaction: $F(1,231) = 4.28, p = .03$

CWNS:

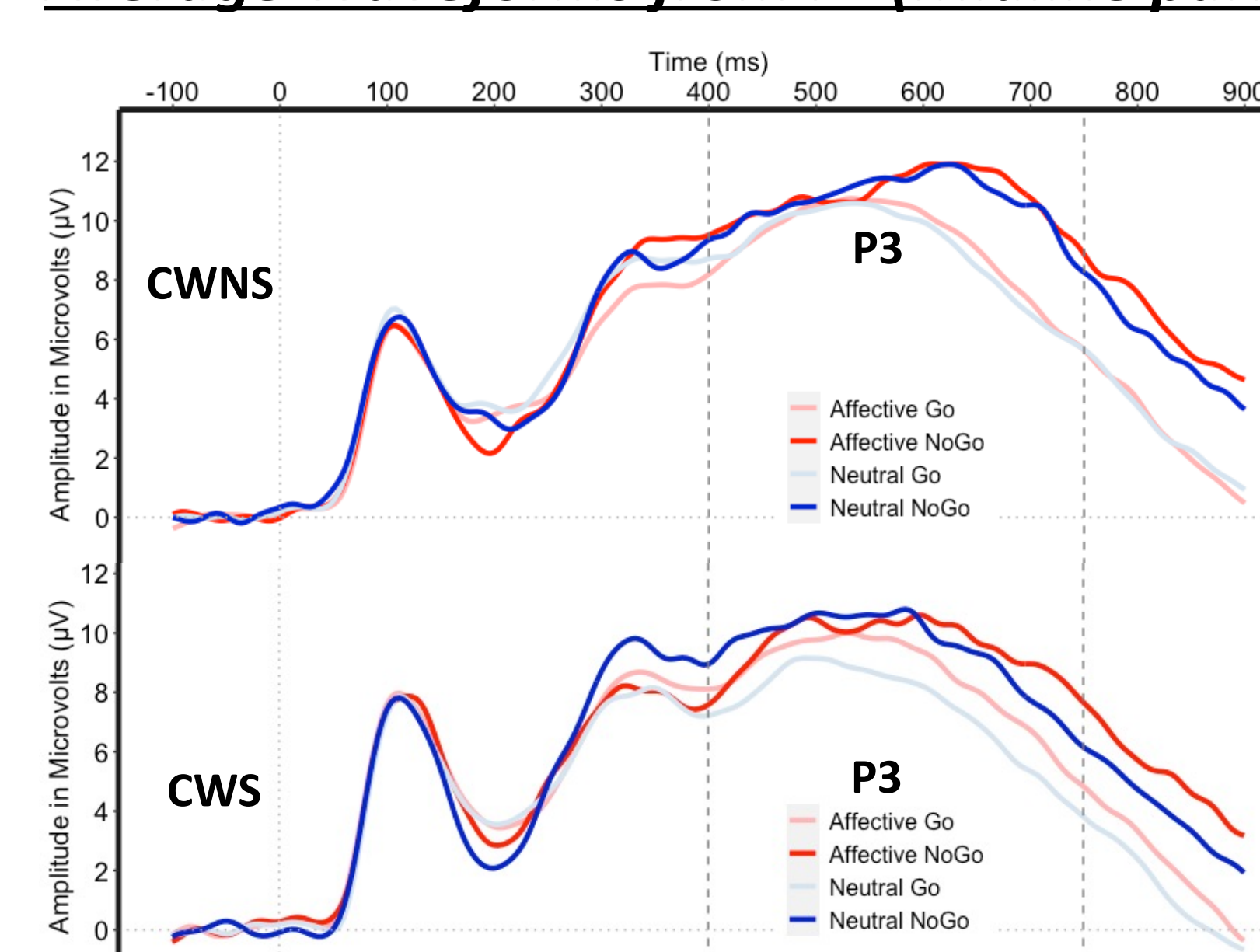
- NoGo > Go in Affective, $t(231) = 3.06, p = .0024$.
- NoGo > Go in Neutral, $t(231) = 3.71, p = .0003$.

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, $t(231) = -3.05, p = .0025$.



Average Waveforms from Pz (Midline parietal):



P3 Mean Amplitude:

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

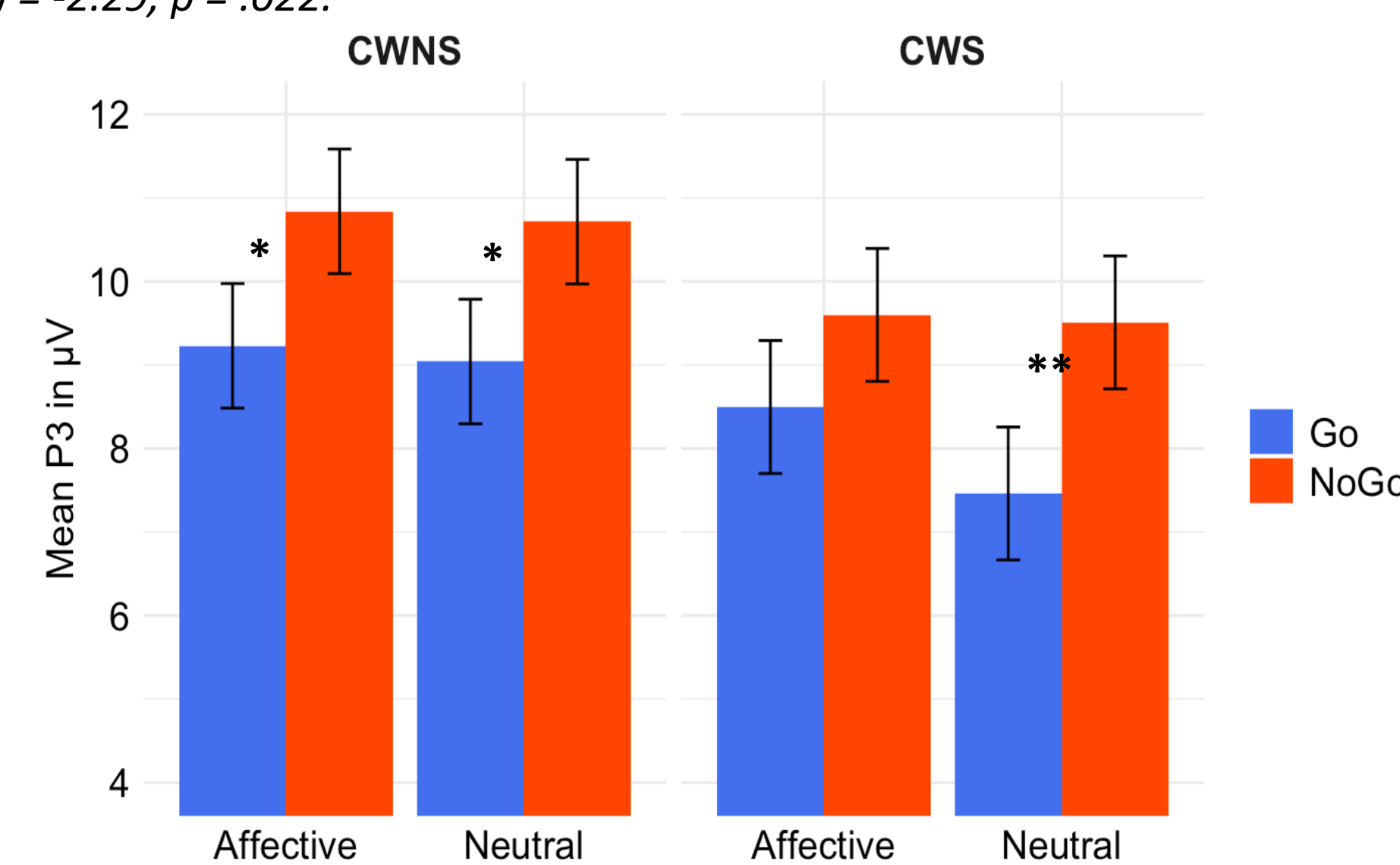
- Main effect of Condition: NoGo > Go: $F(1,231) = 8.79, p = .0032$.

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 (e.g., accuracy) 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 overall lower accuracy, particularly during the neutral NoGo condition, and a trend toward slower reaction times.

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.
- During the neutral condition, CWS exhibited reduced N2-P2 in response to the Go stimuli, which may reflect decreased neural resources in support of response preparation and activation.

P3 findings:

- The participants exhibited more positive 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 and may align with the finding of overall higher accuracy for CWNS.

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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