

Research Paper: The Effects of Emotional Content on Phonological Processing in Children Who Stutter



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ABSTRACT

Objectives: Stuttering and phonological processing are mutually related. Emotion is an effective factor in fluency and language processing; however, its underlying neural mechanism remains unclear. Event-Related Potential (ERP) is a non-invasive highly-beneficial method with high time resolution for language processing. The present study aimed to explore phonological processing in emotional words in Children Who Stutter (CWS), compared to Typically-Developing Children (TDC).

Methods: Ten Persian-speaking CWS (3 girls, 7 boys), aged 7-10 years (Mean±SD = 8.9±0.11) and 10 TDC who are matched in age (Mean±SD = 8.7±0.12) and gender were given 120 emotional words (high-valence low-valence) and neutral words to read. Phonological processing was measured by the aloud reading task, while ERP was simultaneously recorded. The collected results were analyzed as behavioral (reaction time and reading accuracy) and electrophysiological (amplitude and topography). Repeated-measures Analysis of Variance (ANOVA) and Independent Samples t-test were used for between-group comparisons.

Results: The obtained behavioral data included Reaction Time (RT) and accuracy. There were no significant differences between the explored CWS and TDC in RT and accuracy ($P > 0.05$). The mean value of amplitudes presented significant differences between CWS and TDC in language processing areas ($P < 0.05$). The collected results indicated higher mean values of amplitude for neutral words. The distribution highly differed between the investigated CWS and TDC in neutral and negative words. However, there were similarities in positive words in distribution between the study groups.

Discussion: The studied CWS and TDC were similar concerning behavioral results. High-valence words in the CWS group presented a higher similar distribution, compared to the TDC groups; however, low-valence words in the explored CWS had a more similar amplitude to the TDC group for neutral words. Then, emotional content facilitated phonological processing in the investigated CWS in the given time range.

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Highlights

- Emotion affects language processing and disfluency rate in stuttering; however, the underlying mechanism of emotional content word processing in CWS remains unclear.
- The aloud reading task and ERP were used to investigate this mechanism and the differences between CWS and TDC in phonological processing time range; 100-400 ms before overt articulation.
- Our results suggested that CWS experience a longer reaction time and less accuracy; however, this difference was not statistically significant. The amplitude of recorded ERP was different between the studied CWS and TDC in language processing areas in emotional and neutral words. Topography data indicated similarities in positive (high-valence) words between the explored CWS and TDC.
- Generally, emotional content approximates recorded ERP for CWS, compared to TDC.

Plain Language Summary

Stuttering is of an unknown phenomenon, as the main cause of stuttering remains unclear. Some theories suggest that brain function is different between CWS and TDC. However, the difference can be interpreted in numerous aspects and careful investigations are needed. Additionally, emotion affects stuttering and language processing. The present study measured the brain function with emotional content. The collected results suggested that CWS are more similar to their healthy peers concerning emotional content stimulus, specifically the positive ones.

1. Introduction

Phonological processing and stuttering are mutually related in Children Who Stutter (CWS). Behavioral studies declared that children with persistent stuttering experience a longer delay in phonological development than recovered children [1]. Furthermore, phonological disorders are more prevalent in CWS, compared to the healthy population [2]. Electrophysiological investigations also found that the neural basis of phonological tasks in CWS differs from that of their fluent peers [3]. Using the same tasks in adults who stutter presented significant differences between adults who stutter and their healthy counterparts in electrophysiological assessments; however, they had similar functions in behavioral tasks [4]. Adults who stutter were reported to have a longer reaction time than their nonstutterer peers [5], which may be because they had slower language processing [6]. However, such evidence in children is scarce. The electrophysiological assessment of stuttering in children is very helpful; such data could provide an insight to the neural basis of stuttering in CWS before it changes by compensatory strategies and emerging secondary behaviors [7].

Stuttering is a speech disorder which can be affected by emotions [8-10]. It is suggested that stuttering behaviors change during an emotional situation, especially in CWS

[9]. Furthermore, negative emotions could slow articulation rates in children with persisting stuttering; however, it is not an influential factor in recovered and Typically-Developing Children (TDC) [10]. It remains unclear how emotional content can change fluency, as there is no concise electrophysiological evidence in this respect.

Additionally, emotion is not a well-defined concept [11]; it could be any mental experience, i.e. intense and hedonistic, and being pleasant is a key component in emotion [12]. Generally, the emotions based on affective actions might be best defined in two main aspects, including valence and arousal. Valence reflects how a pleasurable and arousal object refers to high physiological activity of the event or word which produce agitation [13]. Emotion in communication is a complicated phenomenon, i.e. expressed through two channels; verbal or emotional content and non-verbal or emotional prosody [14]. Emotional content, specifically valence impacts language processing [15, 16]. Besides, dipolar fronto-occipital activity in topography was detected in emotional word processing [17]. Although a large body of studies exists on emotional perception, this concept is conspicuously limited in emotion literature [18]. Emotional content words required further neural activity for reading aloud tasks, compared to neutral words. Besides, positive words with a high valence had an easier processing than negative words with a low valence [19].

According to Levelt's model of speech production, phonological processing is one part of language processing, i.e. supposed to be followed by articulation [20]. Then, it can be a main part of every verbal task, like loud reading [21]. Therefore, loud reading was used to assess phonological processing in this study and the time (100 to 400 msec) before the onset of articulation was considered as the phonological processing level [22].

Event-Related Potentials (ETPs) recording is a non-invasive neuroimaging method with high temporal resolution. Accordingly, there is an extensive interest to explore the neural basis of language processing by this method [23]. ERP is widely used in emotional language processing and various relevant data have been reported [24, 25]. Kissler and Herbert suggested that cortical activation in emotional word processing differs from that of the neutral words. Their results indicated that N1 (110-140 ms), Early Posterior Negativity (EPN, 216-320 ms), and Late Positive Potentials (LPP, 432-500 ms) are observed in time window in emotional content words in silent reading task [26]. Kissler et al. illustrated that EPN is increased in high-arousal words in silent reading tasks [25]. Generally, there exist two main approaches to analyze ERPs recording, including response-locked and stimulus-locked time window. Laganaro proposed a different method for ERP analysis, which integrates response-locked and stimulus-locked time windows. Then, analysis is conducted from stimulus to response. This process can lead to different results in ERP analysis in language production tasks [27].

ERP studies to avoid possible artifact resulting from overt articulation, have used silent tasks, where respondents were requested to say the words in their mind. Interestingly, they presented the same planning processes [27]. We analyzed ERP/EEG before overt articulation level according to Levelt's model to avoid noisy EEG results from articulation.

This study aimed to probe emotional content and neutral words in phonological processing (100-400 ms before articulation). The same was measured through a reading aloud task in CWS using ERP recording and comparing the data with their TD peers.

2. Methods

Ten CWS (3 females and 7 males; age range: 7-10 years (Mean \pm SD = 8.9 \pm 0.11 years) and 10 TDC who were matched in age (Mean \pm SD = 8.7 \pm 0.12 years) and gender participated in this study (Table 1).

The study subjects were monolingual native Persian-speaking children recruited by parents' report. All study participants needed to have a healthy or corrected-to-normal vision and normal hearing. According to the speech therapist's opinion, the research participants had no history of speech or language disorders, except stuttering in the experimental group. Speech and language development was also reported as normal by the study subjects' parents. Additionally, an expert pediatric neurologist confirmed the lack of neurological or psychological disorders. Besides, their psychomotor development was normal. Edinburgh Handedness Inventory [28] was completed for each child; the left-handed children were excluded from this investigation. CWS who met these inclusion criteria were referred to us from private speech therapy clinics in Tehran City, Iran, or from pediatric neurology clinics in Children's Medical Center of Tehran University of Medical Sciences. The control group members were selected based on the age and gender of the experimental group from the speech therapy student's families, public schools, and private language classes in Tehran City, Iran. The Ethics Committee of Tehran University of Medical Sciences (TUMS) approved the present study. All parents provided written informed consent forms for their children's participation in this research.

This study was conducted in the ERP lab in the Rehabilitation Faculty of Tehran University of Medical Sciences from June to November 2017.

The emotional Persian words list has been prepared by Nazari et al., which included 180 words with their scores in arousal and valence [29]. These words were divided into positive (high-valence), negative (low-valence), and neutral ones based on their valence score. Each category included 40 words. Then, this 120-word list was assessed in children respecting being understandable. Finally, the emotional words list for children was prepared by Salehi et al. [16]. Ultimately, the words in the final list were matched concerning the length of word (syllable) and frequency ($P > 0.05$) and were prepared for the electrophysiological test (Table 2).

EEG recording was explained simply for children and their parents, then they visited the laboratory to acclimated to it. Later, the children's parents completed the demographic information forms. Concurrently, Stuttering Severity Index-3 [30] was performed by an expert speech therapist. Then, the training phase was conducted by 10 words to prepare the explored children. It was instructed that the child should read the presented word at the soonest possible.

Next, the main trial with 120 words 40 words per category (positive, negative, neutral) was presented to them in a pseudorandom sequence. Notably, a plus sign (+) was illustrated between words as a fixation for 1000 milliseconds. The stimulus, i.e. words, were presented in the center of the monitor in Bttr black font with size 64 on a grey background for 2000 milliseconds.

The recording was conducted in an acoustic room, while children were seated 40 cm from the PC monitor. Simultaneously, the research participants were requested to wear an ERP cap with 64 electrodes, i.e. personally selected per child based on their head circumference from 3 cap sizes. The Fpz was at 1/10 Nasion to Inion. Since the response was reading aloud, a microphone was placed 10 cm from the mouth for recording verbal response and reaction time.

Recording EEG was performed by EB-Neuro system and Galileo Net software (Italy) with a sample rate of 256 Hz. It was 64 channels recording by 10-10 international system of electrode placement. All electrodes were referenced to left and right mastoids. The data bandwidth was equal to 0.1 Hz to 40 Hz. Verbal responses, i.e. recorded between 200-2000 ms after stimuli presentation, were analyzed.

The EEGLAB software was employed for ERP visualization and analysis. The obtained data were prepro-

cessed with Artifact Subspace Reconstruction (ASR) and PREP pipeline [31, 32]. Time windows for ERP and the region of interest characterized by repeated measure were conducted by EEGLAB.

We performed the data analysis in SPSS. In this study, continuous variables were expressed as Mean±Standard Deviation (SD). Repeated-measures Analysis of Variance (ANOVA) and Independent Samples t-test were used for between-group comparisons. All statistical tests were two-tailed and $P < 0.05$ was considered statistically significant.

3. Results

Reading accuracy and Reaction Time (RT) were obtained from accurate recorded signal and analyzed as behavioral results.

The obtained data indicated no significant interaction between CWS and TDC in the number of accurate words ($F_{2,36} = 0.69$; $P = 0.506$). Our analysis suggested a significant relationship between accuracy and the emotional category of words ($F_{2,36} = 9.68$; $P < 0.001$). As per Figure 1, in both research groups, the accuracy of positive emotional content words was significantly more than the accuracy of negative emotional content words ($P = 0.007$) and neutral words ($P = 0.002$).

Table 1. Demographic features of the study participants

ID	CWS			TDC	
	Age (Month)	Gender	SSI	Age (Month)	Gender
1	91	F	Moderate	122	M
2	105	F	Very mild	106	F
3	129	M	Moderate	103	M
4	98	M	Mild	107	M
5	97	M	Severe	98	M
6	120	M	Mild	92	F
7	105	M	Moderate	132	M
8	95	F	Mild	108	M
9	111	M	Severe	101	F
10	105	M	Moderate	89	M
Mean±SD	105.6±11.74			105.8± 12.99	

SSI: Stuttering Severity Index; SD: Standard Deviation; M: Male; F: Female.

Table 2. Characteristics of word stimuli

Emotional Words	Mean±SD			P
	Positive	Negative	Neutral	
Valence	5.83±0.37	2.20±0.51	4.25±0.31	0.07
Arousal	4.35±0.57	4.64±0.9	3.72±0.21	0.11
Word length (syllable)	2.10±0.77	1.80±0.75	1.92±0.57	0.83
Frequency	1.89±0.28	1.74±0.25	1.78±0.27	-

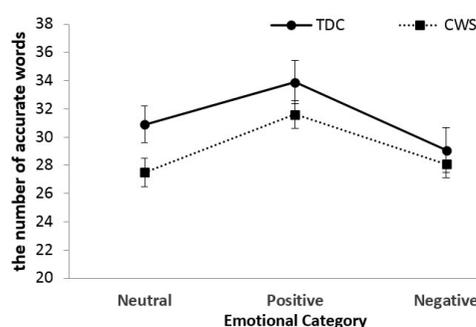
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Although the mean value of reaction time in the CWS group was more than the TDC, this difference was not statistically significant ($F_{1,18}=2.68$; $P=0.119$). As shown in Figure 2, ANOVA data revealed significant differences in reaction time concerning negative, positive, and neutral words between the explored CWS and TDC ($F_{2,36}=6.20$; $P=0.005$).

The amplitude data analysis in 11 regions of the brain, for neutral, positive, and negative words were performed for the studied CWS and TDC by t-test, and the relevant results are explained as follows. As per Table 3, the mean minimum and maximum values of amplitude were compared between the explored CWS and TDC. The minimum score of amplitude (negative) of the CWS in parietal ($P=0.003$), left posterior ($P=0.002$), left temporal ($P=0.001$), and occipital ($P=0.001$) aspects were significantly smaller than those of the TDC ($P<0.005$). The maximum score of amplitude of CWS in prefrontal, right frontal, and left frontal dimensions were significantly more negative than those of the TDC ($P=0.008$, $P=0.009$, and $P=0.01$, respectively). There were no significant differences in other regions ($P>0.05$).

According to Table 3, the mean maximum amplitude in the prefrontal ($P=0.02$) and left frontal ($P=0.018$) aspects of the studied CWS was significantly higher than that of the TDC. There were significant differences between the explored CWS and TDC groups concerning the right posterior in the mean minimum score of amplitude ($P=0.031$). The mean value of the minimum amplitude was also smaller in the left frontal, left temporal, parietal, and left posterior of the CWS group; however, these scores were not statistically significant ($P=0.067$, $P=0.070$, $P=0.052$, $P=0.63$ respectively). There were also no significant differences in other regions ($P>0.05$).

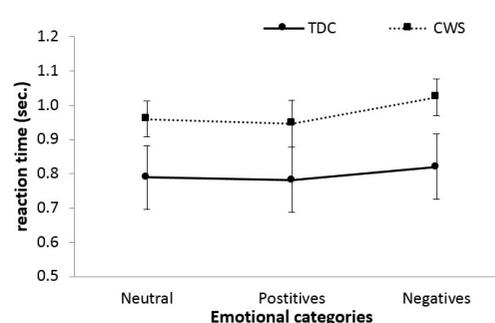
The mean maximum value of amplitude in the CWS group was significantly higher than those of the TDC in the prefrontal and left frontal regions ($P=0.020$, $P=0.018$, respectively). The mean maximum score of amplitude in the CWS group concerning the central, right temporal, parietal, and left posterior regions was higher than those of the TDC group; however, these values were not statistically significant ($P=0.080$, $P=0.086$, $P=0.057$, $P=0.068$, respectively). Besides, there were no significant differences in other regions ($P>0.05$).



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Figure 1. The number of accurate words in emotional categories

TDC: Typically Developed Children; CWS: Children Who Stutter; Values are presented as Mean±SD.



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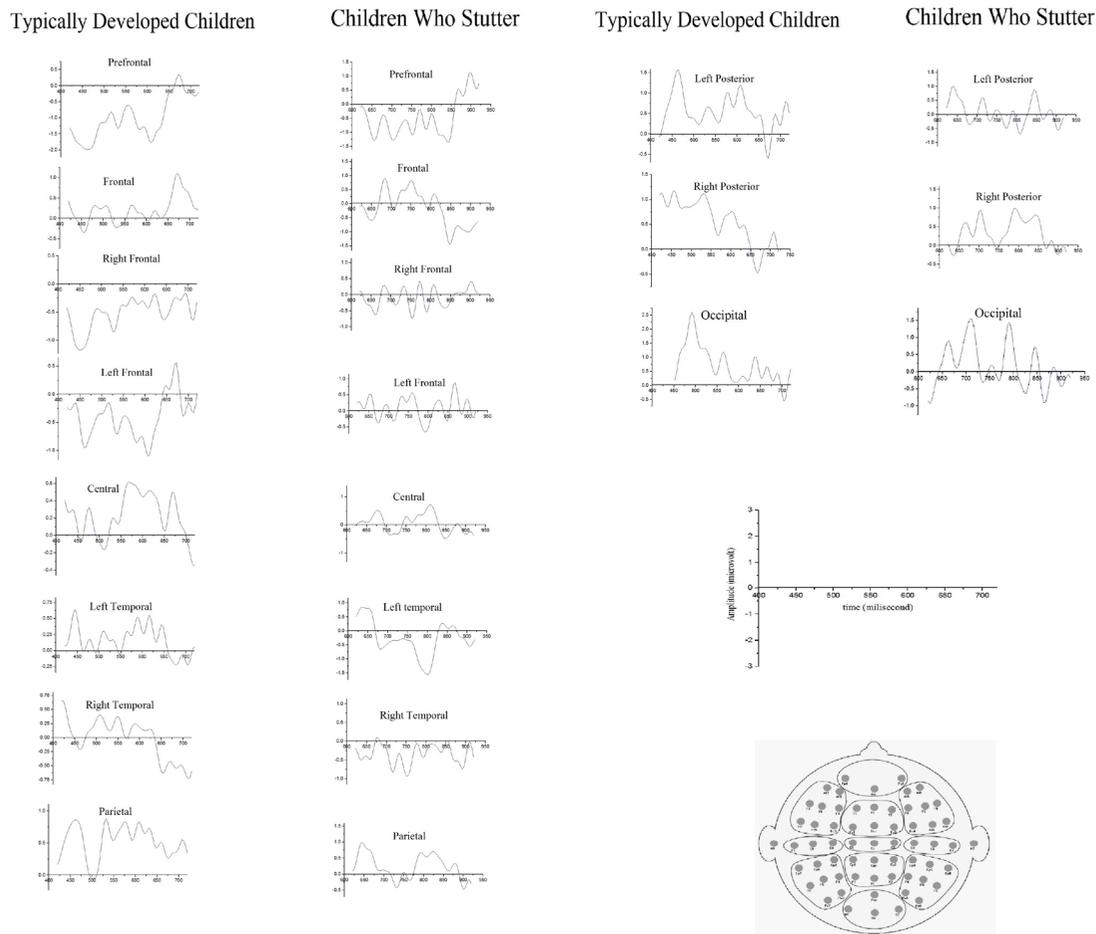
Figure 2. The mean values of reaction time in emotional categories

TDC: Typically Developed Children; CWS: Children Who Stutter; Values are presented as Mean±SD.

Table 3. Comparing the maximum and minimum values of amplitude in the TDC and CWS groups for negative, positive, and neutral words

Words	Brain Areas	Max			Min		
		Mean±SD		P [†]	Mean±SD		P [†]
		TDC	CWS		TDC	CWS	
Neutral	Prefrontal	1.06±1.64	3.82±2.42	0.008	-4.23±2.78	-3.88±1.37	0.725
	Frontal	1.91±0.37	2.46±1.4	0.256	-1.9±0.83	-2.49±0.79	0.117
	Right Frontal	1.3±0.63	2.39±0.96	0.009	-2.00±0.97	-2.60±1.09	0.213
	Left Frontal	1.42±0.71	3.13±1.73	0.01	-2.77±0.8	-3.86±1.47	0.058
	Central	1.82±1.18	2.75±1.75	0.178	-1.59±0.71	-2.26±0.93	0.086
	Left Temporal	1.91±0.84	2.84±1.72	0.149	-1.4±0.76	-2.98±0.96	0.001
	Right Temporal	2.2±1.07	2.9±0.64	0.11	-1.84±0.77	-2.27±1.5	0.106
	Parietal	2.44±1.24	3.04±1.18	0.283	-1.24±0.63	-2.25±0.7	0.003
	Left Posterior	2.7±1.02	3.26±1.38	0.315	-1.29±1.33	-3.41±1.28	0.002
	Right Posterior	2.88±1.35	3.74±1.34	0.168	-1.57±1.35	-2.37±1.16	0.172
Positive	Occipital	3.39±1.41	4.41±1.76	0.168	-2.05±0.88	-4.14±1.46	0.001
	Prefrontal	1.31±1.45	3.55±2.3	0.02	-3.15±1.89	-4.01±1.35	0.257
	Frontal	1.77±0.85	2.49±1.43	0.187	-1.6±0.78	-2.26±1.58	0.253
	Right Frontal	1.54±0.96	2.36±1.71	0.203	-2.29±1.03	-2.83±0.76	0.204
	Left Frontal	1.5±0.59	2.3±0.78	0.018	-2.17±0.8	-3.03±1.15	0.067
	Central	1.41±1.24	2.58±1.56	0.08	-1.4±0.96	-1.74±0.93	0.431
	Left Temporal	1.56±0.7	2.24±1.06	0.109	-1.57±0.41	-2.33±1.12	0.07
	Right Temporal	1.87±0.67	2.47±0.82	0.086	-1.59±0.6	-2.41±1.64	0.154
	Parietal	1.91±1.21	3.13±1.46	0.057	-1.36±0.77	-2.33±1.25	0.052
	Left Posterior	2.57±1.06	3.54±1.16	0.068	-1.66±1.04	-3.1±2.05	0.063
Negative	Right Posterior	2.28±1.16	3.01±0.87	0.133	-1.18±0.84	-2.45±1.51	0.031
	Occipital	3.38±2.2	4.28±1.01	0.571	-2.68±1.58	-3.47±1.82	0.313
	Prefrontal	1.71±1.28	3.56±2.24	0.036	-3.78±2.57	-4.05±1.53	0.782
	Frontal	1.89±0.87	2.33±1.13	0.342	-1.74±1.22	-2.78±1.25	0.074
	Right Frontal	1.16±0.76	2.53±1.44	0.016	-2.26±0.94	-2.22±1.29	0.946
	Left Frontal	1.5±0.96	2.61±1.83	0.105	-2.35±0.99	-2.38±1.05	0.949
	Central	1.88±0.89	2.33±1.16	0.344	-1.6±0.75	-2.36±1.3	0.131
	Left Temporal	1.91±1.33	2.18±0.98	0.609	-1.56±0.77	-3.04±2.08	0.05
	Right Temporal	1.7±0.68	1.76±0.62	0.828	-2.07±0.84	-2.73±1.55	0.249
	Parietal	2.23±1.16	2.92±1.78	0.383	-1.38±0.76	-2.4±1.56	0.07
Left Posterior	2.78±1.64	2.71±1.59	0.924	-1.67±1.48	-2.46±0.94	0.171	
Right Posterior	3.12±1.07	3.05±0.85	0.877	-1.77±1.23	-2.5±1.47	0.239	
Occipital	3.83±1.69	3.68±1.16	0.811	-2.24±1.61	-3.63±1.49	0.06	

TDC: Typically Developed Children; CWS: Children Who Stutter; †t-test.



Plots for negative words

Figure 3. ERP averages elicited by negative words in the aloud reading task among the explored CWS and TDC

As per Table 3, the mean minimum value of amplitude in the frontal, left temporal, parietal and occipital regions of the CWS group was lower (negative) than that of the TDC; however, these values were not statistically significant ($P=0.074$, $P=0.050$, $P=0.070$, $P=0.060$, respectively). There were also no significant differences in other regions ($P>0.05$).

The mean maximum value of amplitude in the prefrontal and right frontal of the explored CWS was significantly greater than that of the TDC group ($P=0.036$, $P=0.016$, respectively). There were no significant differences in other regions ($P>0.05$).

As per Figure 3, Figure 4, and Figure 5 (Appendix 1), comparing CWS and TDC by global field method [27] suggested that the peak to peak distance in CWS were greater than those of the TDC in neutral words in all brain areas. The peak to peak distance in the CWS group

was significantly more than those of the TDC, except in occipital lobe for positive words. For negative words, the peak to peak distances were greater in the CWS than the TDC group in the left temporal, right frontal, prefrontal, and parietal areas.

As shown in Figure 6, there existed a very different pattern of energy distribution in the explored CWS and TDC. Accordingly, more activity for neutral word reading task in the studied CWS was a limited area in occipital; however, in TDC, there was a very wide area in occipital lobe. A diffusive pattern was observed in the studied CWS, compared to the TDC group.

As per Figure 7, the most similar pattern was detected in positive words. More activity in the occipital lobe was detected in both study groups for the positive word reading task. However, there was an irregular pattern of energy for positive words in the investigated CWS,

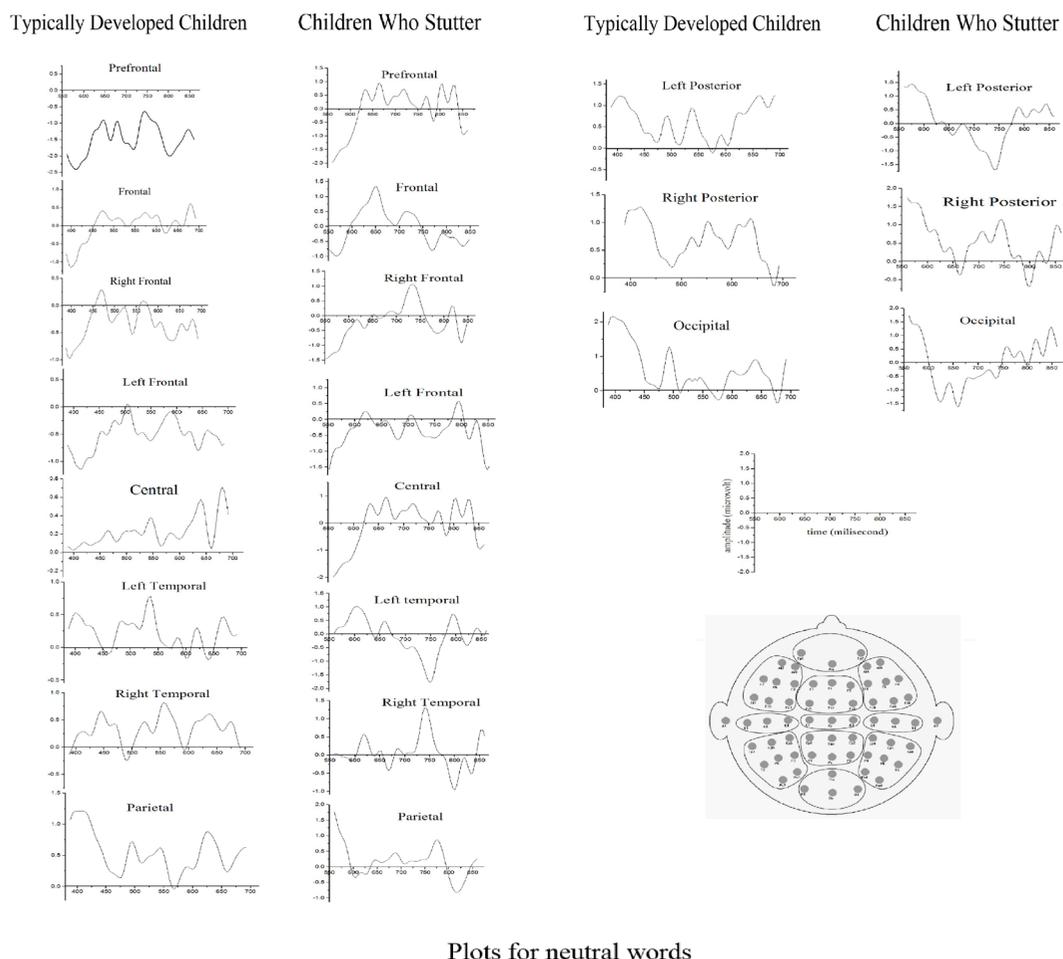


Figure 4. ERP averages elicited by neutral words in the aloud reading task in the studied CWS and TDC

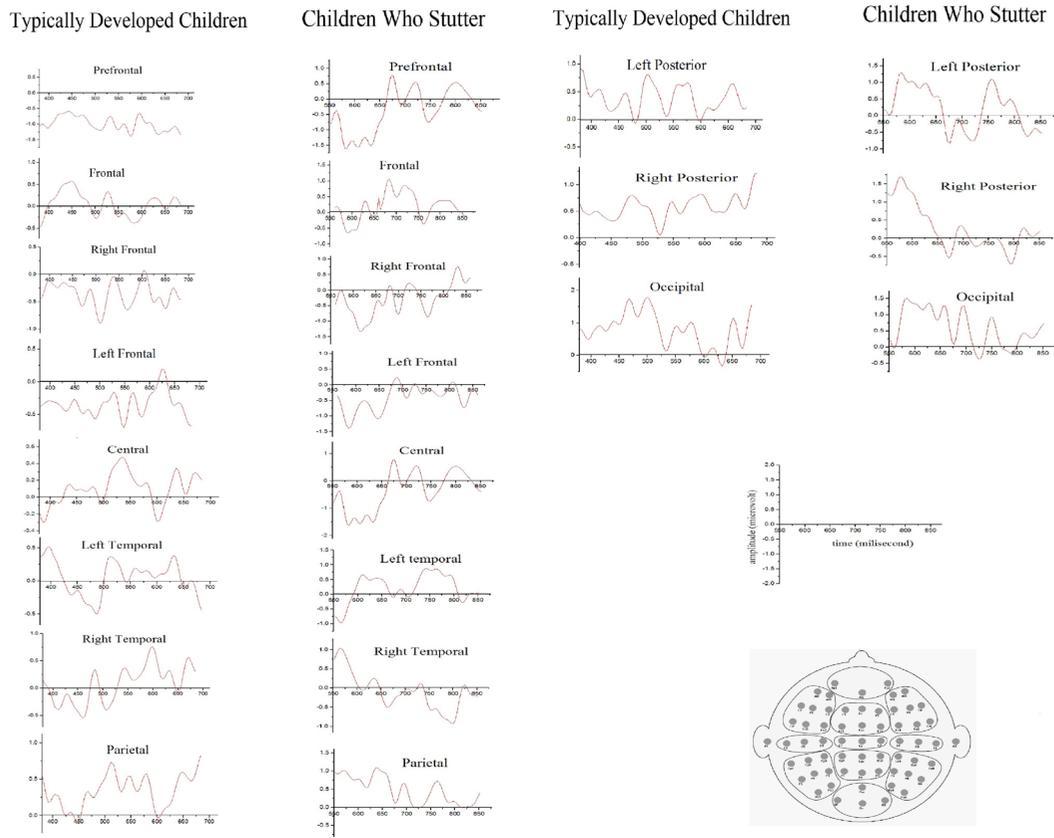
compared to the TDC group. Besides, more activity was observed in the central areas of the CWS group. Similarly, there exists a diffuse and irregular pattern for negative words in CWS. A higher activity level was recorded in the central areas for the explored CWS, compared to the TDC group. However, the highest activity level was detected in the occipital lobe for both study groups (Figure 8).

4. Discussion

The main purpose of this study was to compare emotional word processing between CWS and TDC. Our results are discussed in two main parts, including behavioral and electrophysiological results.

The behavioral analysis results suggested no significant differences between the studied TDC and CWS in response accuracy; however, the CWS group provided less accurate responses, compared to the TDC group. This difference cannot be attributed to reading disability, because both research groups had no history of reading disability.

There was limited time for each word to be read; accordingly, the CWS group seemed to require further time for the emotional words reading aloud task. Apparently, temporal constraint made reading task different from routine reading. However, achieving less scores in accuracy for the aloud reading task in the explored CWS can be explained by a subtle and subclinical deficit in the phonological processing system [33]. However, the observed difference was not significant. Reaction times in the CWS group was longer than those of the TDC; however, the differences were not significant. It was predictable that stuttering would cause longer reaction time [5], because of slower language processing [6]. Despite this deficit in language processing system in CWS, the difference was not significant in the aloud reading task of single emotional words. Perhaps this simple task failed to challenge the phonological processing system. Thus, all investigated CWS were fluent in the aloud reading of single emotional words. It might reduce phonological processing load.



Plots for positive words

Figure 5. ERP averages elicited by positive words in the aloud reading task among the investigated CWS and TDC

Additionally, there were no significant differences between the CWS and TDC groups in behavioral results for phonological processing in emotional content words. This finding was in line with a previous study reporting that CWS and TDC were similar in behavioral analysis for phonological processing without considering emotional content [3, 4].

The collected electrophysiological data were analyzed by global field approach in 100 to 400 millisecond before

articulation [27]. The relevant results illustrated significant differences concerning amplitude between the explored CWS and TDC in the prefrontal, right frontal, left frontal, left frontal, parietal, left posterior, and occipital regions in neutral words reading. Reportedly, there were greater amplitude for CWS than TDC. It is suggested that CWS requires greater neural activity than TDC in the motor and visual areas [34] for neutral words. There were significant differences between the explored CWS and TDC in the prefrontal, left frontal, and right poste-

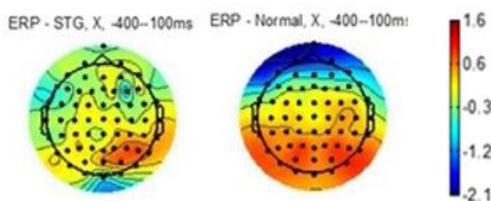


Figure 6. The topography of neutral words in CWS (left) and TDC (right)

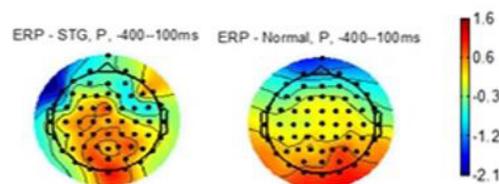


Figure 7. The topography of positive words in the explored CWS (left) and TDC (right)

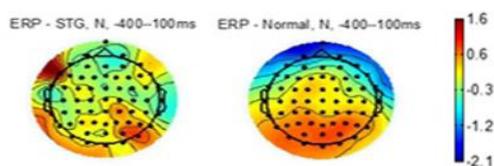


Figure 8. The topography of negative words in the studied CWS (left) and TDC (right)

rior regions for positive word processing; the same was only true for the prefrontal and right frontal respecting negative word processing. These findings suggested that motor and visual regions and the areas related to emotional processing in the brain had higher neural activity in the CWS group than the TDC group for emotional and neutral words reading. In other words, different neural activity was recorded in CWS, in spite of fluent production and similar behavioral responses.

The greatest difference between the explored CWS and TDC regarded neutral words; the highest similarity concerned negative words. Emotional content words were more similarly processed by the studied CWS and TDC, compared to neutral words. Therefore, emotional content facilitates processing in CWS [18].

Replicating a previous study, we have detected dipolar fronto-occipital activity in topography for emotional words in TDC [17]. On the other hand, the topographical patterns of ERPs were different between the CWS and TDC groups. Accordingly, the recorded topography for the CWS group was not similar to a normal processing. Additionally, the most similar pattern in topography was recorded for high-valence words; subsequently, we concluded that valence has facilitated processing in the studied CWS and made it similar to a normal processing. These findings were consistent with those of previous studies [16, 19].

The severity of stuttering was considered as a contextual variable in the present study, which can be a dependent variable. Additionally, various tasks can be an appropriate representative for phonological processing. The reported results are comparable to the present study findings.

5. Conclusion

The current research data suggested that high-valence emotion presented a normalizing effect on distribution; low-valence emotion provided facilitating effect on amplitude. Accordingly, the phonological processing of emotional content words was more similar to normal phonological processing, compared to neutral words in the studied CWS considering the electrophysiological results;

however, behavioral results indicated no differences between the CWS and TDC groups. The same was reported for adults who stutter [4]. Adults and children who stutter seem to be vulnerable in phonological processing [3, 4].

Thus, differences between the explored CWS and TDC in electrophysiological data and similarities in behavioral data can be attributed to subtle deficits as the neural basis of phonological processing level in speech production for the aloud reading of emotional and neutral words.

These results can be helpful for clinical practice considering emotional words as a level of language processing in language hierarchy.

Ethical Considerations

Compliance with ethical guidelines

This study was registered and approved by the Research Council, School of Rehabilitation, Tehran University of Medical Sciences (TUMS) on 2/28/2018. All study participant's parents provided a written signed informed consent form.

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Authors' contributions

Manuscript preparation and edition, supervision, concept, design and literature review: All authors; Data gathering: Sousan Salehi, Ahmadreza Khatoonabadi; Statistical analysis: Sousan Salehi and Saman Maroufizadeh.

Conflict of interest

The authors declared no conflicts of interest.

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Appendix 1. Brain areas

Prefrontal	Fp1, Afz, Fp2
Frontal	F1, Fz, F2, Fc1, Fcz, Fc2
Right frontal	Af4, Af8, F4, F6, F8, Fc4, Fc6, Ft8
Left frontal	Af7, Af3, F7, F5, F3, Ft7, Fc5, Fc3
Central	C1, Cz, C2
Left temporal	T3, C5, C3
Right temporal	T4, C4, C6
Parietal	Cp1, Cpz, Cp2, P1, Pz, P2
Left posterior	Tp7, Cp5, Cp3, T5, P5, P3, Po7, Po3
Right posterior	Cp4, Cp6, Tp8, P4, P6, T6, Po4, Po8
Occipital: Poz	O1, Oz, O2

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