Valence effects on phonological processing in normal Persian speaking children: A study by ERP

Sousan Salehi1
Ahmad Reza Khatoonabadi1*
Mahmoud Reza Ashrafi2
Ghasem Mohammadkhani3
Saman Maroufizadeh4

1 Department of Speech Therapy, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran
2 Department of Child Neurology, Children's Medical Center, Tehran University of Medical Sciences, Tehran, Iran
3 Department of Audiology, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran
4 Department of Epidemiology and Reproductive Health, Reproductive Epidemiology Research Center, Royan Institute for Reproductive Biomedicine, ACECR, Tehran, Iran

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ABSTRACT
Objective: Emotional content and language processing has mutual relationship. But there is limited evidence in emotional production. Verbal emotion has two aspect including arousal and valence. The aim of the present study is investigation of effect of valence on phonological processing in Persian speaking children by ERP.

Material and methods: One hundred and twenty emotional words in three categories including positive (high valence or pleasant), negative (low valence or unpleasant) and neutral was given to 10 normal Persian speaking children to read aloud. Concurrently, Event Related Potentials were recorded by 64 electrodes. Phonological processing was supposed to be 100-400ms before articulation onset. Behavioral and electrophysiological results were analyzed in this time range.

Results: Positive words have more accuracy and smaller reaction time compare to negative words. These differences were statistically significant. Positive words extracted larger amplitude in frontal, temporal and posterior regions. Neutral word have larger amplitude in central regions. Topography illustrated diffuse activity in emotional words. There were significant differences between negative, positive and neutral words in prefrontal and right posterior regions.

Conclusion: Emotion increases brain activity in some regions. It lead in faster processing. Emotional content decreases amplitude and helps to phonological processing in limited regions.

1. Introduction

There is bilateral well-documented relationship between language processing and emotion. There is two main ways to produce emotion in language, verbal expression of emotion or emotional content and nonverbal or prosodic way [1]. It has been shown that emotional content has a key role in language processing even in single word processing[2]. Emotion in language has two dimensions, including: arousal and valence (pleasant). which are based on evaluative reactions[3]. Valence implies to pleasant or non-pleasant words and arousal implies to
agitation and calm of the word[4].

Decoding and encoding of emotional information are done quickly, then electrophysiological assessments can be very useful for the investigation [5]. Event Related Potentials (ERP) is an electrophysiological neuroimaging method which is recorded from scalp with millisecond time resolution, thereby help to unfold various levels of language processing[6]. ERP was utilized in emotional content word processing investigations, the most related results will be explained in the following.

Generally, it is shown that valence improve the function of word recognition[7]. It has been demonstrated that valence has effect on early response with dipolar fronto-occipital topography, high valence words generated higher amplitude than low valence words. The amplitude of the late positive complex (LPC) was different in neutral and emotional content words. Emotional word also have higher amplitude in left parietal region. Conversely in central region, neutral words have higher amplitude in reading task in Polish speaking adults[8]. Similarly in another investigation, the results showed positive (high valence) words were processed faster than negative (low valence) words as well as there was a decrease of N400 (300-410 ms) amplitude in positive words. Additionally, LPC amplitude (450-750 ms) was increased in positive words in lexical decision task [9].

Generally, it is illustrated that emotional words has enhancement in brain responses. There is electrophysiological responses for pleasant and unpleasant words generated from occipito – temporal regions in 200-300 ms after word onset in silent reading tasks. Besides, arousal is more effective than valence in other tasks. Emotional words also recalled faster than neutral words[10]. Then, ERP modulations are influenced by tasks too. Kissler and et al reported that EPN amplitude for emotional content words was increased in silent reading task in arousing words and it is influenced by word frequency. But LPC was depended on type of task, not emotional content[10]. Other ERP components which are reportedly related to emotional content are including P1-N1 and P2-N2, which are appeared in time window in 100-200 ms and 200-260 ms, respectively [11].

Previously, studies showed that emotional content effect on ERP recording in word comprehension, but little is known about emotional word production. Hinsonja and et al conducted a study for emotional words production investigation with emotional and neutral picture naming task, they suggested that neutral picture naming had shorter reaction time. There was increased amplitude in positive component in 400 millisecond for emotional content picture naming. They interpreted that it represented an interruption in phonological processing because of affective content[12].

Notably, there are two ERP analysis methods, stimulus-locked and response-locked[13]. All mentioned studies use stimulus locked method, whereas in the present study we will use response locked method and visual inspection[13].

On the other hand, phonological processing as a part of language processing will be considered a level before articulation, based on Levelt’s model of speech production[14]. Therefore, 100-400 millisecond before voice onset supposed to be phonological processing level of language processing in ERP analysis[15].

Additionally, there are a variety of tasks which are contained phonological processing such as aloud reading[16], as well as processing of emotional content words is questionable [17]. Then, phonological processing will be assessed by aloud reading task in the present study.

The present study is aimed to investigate influence of valence (pleasant and unpleasant) on phonological processing in normal Persian speaking children.

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2. Method

2.1. Participants

Ten normal children (7 boys), aged 7 – 10 years (Mean=8.7; S.D. = 0.12) had been taken part in this study. They were all monolingual native Persian speaking children with corrected to normal or normal vision. They have all normal speech – language – psycho – motor development, according to parent’s reporting and medical history. All were right handed according to Edinburg Handedness Inventory [18]. The study was approved by the ethics committee of Tehran University of Medical Sciences (TUMS). All parents signed written informed consent form.

2.2. Stimulus materials

There is an emotional Farsi words list that is evaluated based on arousal and valence (pleasant) score[19]. A first set of 180 emotional Persian words was selected from it according their scores in comprehensibility on children. Then these words were matched in frequency and length of words, finally 120 emotional words were prepared for the test. We categorized the words according their valence, then the list is including, 40 neutral words (their arousal and valence scores are 4±S.D.), 40 positive words (their valence score is more than 4±S.D. with any score in arousal) and 40 negative words (their valence score is less than 4±S.D. with any score in arousal), which are matched in frequency and word length (p-value >0/05).

2.3. Procedure

Children and their parents were familiarized with laboratory setting and the procedure of EEG recording. Then parents were asked to fill personal information forms. Children were seated on the chair in an acoustic room facing a PC monitor at the distance 40 cm and an ERP cap containing 64 electrodes was positioned on their head so that the Fpz was at 1/10 Nasion to Inion, it was metered by a measure tape for each participant. The size of cap was selected based on their head circumference. Microphone for verbal response recording was at the distance of 10 cm from the mouth. Then they were instructed to read the words aloud as soon as those appear on monitor. Before the main experiment, the training was administered by 10 words. When the subjects get ready, then the main trial would be begun with 120 emotional words. All words with any emotional content were presented in pseudorandom sequence. Each subject was given 120 words, 40 neutral, 40 positive and 40 negative words, between words a plus sign (+) was presented as fixation for 1000 ms. The stimuli were showed in black font (B Titr, size 64) on a grey background during 2000 ms in the center of the screen.

2.4. EEG recording

EEG was recorded from 64 channels attached to a cap based on 10-10 international system of electrode placement. All electrodes were re-referenced to the average of left and right mastoids. The recording data was conducted with a sample rate of 256 Hz using by EB-Neuro system and Galileo Net software (Italy). The data bandwidth was 0.1 Hz to 40 Hz. Responses between 200-2000 ms after stimuli presentation would be calculated as accurate response.

2.5. EEG analysis

The EEGLAB software was utilized for ERP visualization and analysis. Data was preprocessed with ASR and PREP pipeline[20, 21]. To determine time windows for ERP and region of interest repeated measure was conducted by EEGLAB.
3. Statistical analysis

In this study, continuous variables were expressed as mean (standard deviation). Repeated-measures ANOVA, followed by the Bonferroni test, was used to comparison between word categories. Statistical analysis was carried out with IBM SPSS Statistics for Windows, Version 22.0 (IBM Crop., Armonk, NY, USA). All statistical tests were two-sided and a \( P<0.05 \) was considered statistically significant.

4. Results

4.1. Behavioral results

Accuracy and Reaction Time (RT) was calculated. RT also was obtained from accurate responses.

Accuracy: there was significant differences between accurate responses in positive, negative and neutral words (\( F(2, 18) = 9.59; \ P=0.001 \)). Bonferroni test showed that accurate response in positive words was significantly more than negative words (\( P<0.001 \)). As seen in Figure 1, the mean of accurate responses in positive emotional content words was more than neutral words, but this difference was not statistically significant (\( P=0.143 \)). Also, the difference between neutral and negative words was not significant (\( P=0.504 \)).

![Figure 1: Accurate responses in word categories, the values are presented as Mean ± S.D.](image1)

Reaction time: results indicated that there were not significant differences between reaction time in positive, negative and neutral words by Greenhouse-Geisser test (\( F(1.23,11.03)=2.25; \ P=0.160 \)). But the mean of reaction time in negative words was more than positive and neutral words (figure 2).

![Figure 2: Reaction time in word categories, the values are presented as Mean ± S.D.](image2)
4.2. Electrophysiological results

This section including topographic and plots which analyzed by visual inspections. Statistical analysis also was conducted in amplitude values.

Topographic results: as seen in figure 4, activity in posterior regions is more than other regions in all categories in reading task. But, active regions in posterior for neutral words are larger than emotional words. On the other word, there is diffused activity in emotional words in the brain. There is more and focused activity in right frontal in positive words.

Plot results: As seen in figure 3, scalp was divided into 11 regions according to recording wave patterns. Amplitude and latency will be analyzed in each region.

Figure 3: topography of emotional and neutral words in reading aloud task

Figure 4: Scalp regions
As seen in chart 1, all charts have a valley in beginning in prefrontal region. There is more fluctuations with larger amplitude in positive words in prefrontal. However, the fluctuations is nearly the equal in negative and neutral words and they have similar pattern.
As seen in chart 2, all categories have similar fluctuations in frontal region. The amplitude of these peaks is larger in positive words. Negative words pattern were different from neutral and positive words at the end of recording near to articulation.
As shown in chart 3, there is fluctuations in recording waves in all word categories in right frontal region. Although, more fluctuations are recorded in positive words and the peaks and valleys have larger amplitude in positive words in right frontal (motor) region.
Chart 4: Average ERP waveforms in left frontal region for three word categories

Chart 4 illustrated that positive and negative words have approximately similar pattern with the equal number of peaks and valleys in left frontal and it is differ from neutral words. Also negative words has larger peak to peak distance, from +0.5 microvolt to -1 microvolt.
Chart 5 shows that emotional words have the same fluctuation in central region. There is larger amplitude and peak to peak distance in positive words, ranged from +0.5 to -0.3. Neutral words have smaller amplitude until about 620 ms, after that larger amplitude is appeared.
As illustrated in Chart 6, negative words have a totally different pattern with more fluctuations in the left temporal regions. On the other hand, positive and neutral words have relatively similar fluctuation with an equal number of peaks and valleys with a larger amplitude in positive words. Peak to peak distance is larger in positive words.
As seen in Chart 7, right temporal activity in neutral words is completely different from emotional words with more fluctuations. Positive words have larger fluctuation amplitude and peak to peak distance, ranged from +0.8 to -0.6.
Chart 8: Average ERP waveforms in parietal region for three word categories

As shown in chart 8, there is difference in the number fluctuations in neutral, negative and positive words in parietal region. It is seen a positivity around 500 ms (P500) in neutral and positive words, while there is a negativity in negative words in this latency. Generally, there are some fluctuations in recorded waves in all word categories and the amplitude and peak to peak distance are larger in neutral words.
Chart 9 illustrated that neutral and positive words have similar pattern of fluctuations with larger amplitude in neutral words in left posterior region. Negative words have the largest peak to peak distance, about 2. There is reverse pattern in negative words at the end of wave, near to articulation.
Chart 10: Average ERP waveforms in right posterior region for three word categories

Chart 10 shows that negative and positive words have relatively similar fluctuations pattern near to articulation, positive words has larger amplitude. However, reverse pattern is seen in neutral words.
Chart 11: Average ERP waveforms in occipital region for three word categories

As seen in chart 11, there is many fluctuations in all word categories, such as a positivity in negative and positive words around 460 ms, the reverse pattern is seen in neutral words. Fluctuations in positive words have larger amplitude.

As seen in table 1, differences between word categories is significant in prefrontal and right posterior. Multiple comparison showed that positive words have smaller amplitude in right posterior. Absolute value of amplitude is larger in positive words in prefrontal.
Table 1. Comparison between word categories and regions

<table>
<thead>
<tr>
<th>Word Category</th>
<th>Negative (N)</th>
<th>Positive (P)</th>
<th>Neutral (Neu)</th>
<th>P</th>
<th>Pairwise comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prefrontal</td>
<td>-3.78 (2.57)</td>
<td>-2.43 (2.78)</td>
<td>-3.15 (1.89)</td>
<td>0.033</td>
<td></td>
</tr>
<tr>
<td>Frontal</td>
<td>-1.74 (1.22)</td>
<td>-1.6 (0.78)</td>
<td>-1.9 (0.83)</td>
<td>0.643</td>
<td>-</td>
</tr>
<tr>
<td>Right Frontal</td>
<td>-2.26 (0.94)</td>
<td>-2.29 (1.03)</td>
<td>-2.00 (0.97)</td>
<td>0.572</td>
<td>-</td>
</tr>
<tr>
<td>Left Frontal</td>
<td>-2.35 (0.99)</td>
<td>-2.17 (0.80)</td>
<td>-2.77 (0.80)</td>
<td>0.103</td>
<td>-</td>
</tr>
<tr>
<td>Central</td>
<td>-1.60 (0.75)</td>
<td>-1.40 (0.96)</td>
<td>-1.79 (0.71)</td>
<td>0.690</td>
<td>-</td>
</tr>
<tr>
<td>Left Temporal</td>
<td>-1.56 (0.77)</td>
<td>-1.57 (0.41)</td>
<td>-1.40 (0.76)</td>
<td>0.737</td>
<td>-</td>
</tr>
<tr>
<td>Right Temporal</td>
<td>-2.07 (0.84)</td>
<td>-1.59 (0.60)</td>
<td>-1.84 (0.77)</td>
<td>0.345</td>
<td>-</td>
</tr>
<tr>
<td>Parietal</td>
<td>-1.38 (0.76)</td>
<td>-1.56 (0.77)</td>
<td>-1.24 (0.63)</td>
<td>0.875</td>
<td>-</td>
</tr>
<tr>
<td>Left Posterior</td>
<td>-1.67 (1.48)</td>
<td>-1.66 (1.04)</td>
<td>-1.29 (1.53)</td>
<td>0.527</td>
<td>-</td>
</tr>
<tr>
<td>Right Posterior</td>
<td>-1.77 (1.23)</td>
<td>-1.18 (0.84)</td>
<td>-1.37 (1.35)</td>
<td>0.437</td>
<td>-</td>
</tr>
<tr>
<td>Occipital</td>
<td>-2.24 (1.51)</td>
<td>-2.68 (1.58)</td>
<td>-2.05 (0.68)</td>
<td>0.512</td>
<td>-</td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prefrontal</td>
<td>1.71 (1.28)</td>
<td>1.31 (1.45)</td>
<td>1.06 (1.64)</td>
<td>0.303</td>
<td>-</td>
</tr>
<tr>
<td>Frontal</td>
<td>1.89 (0.87)</td>
<td>1.77 (0.85)</td>
<td>1.91 (0.37)</td>
<td>0.876</td>
<td>-</td>
</tr>
<tr>
<td>Right Frontal</td>
<td>1.16 (0.76)</td>
<td>1.54 (0.96)</td>
<td>1.03 (0.63)</td>
<td>0.545</td>
<td>-</td>
</tr>
<tr>
<td>Left Frontal</td>
<td>1.50 (0.96)</td>
<td>1.50 (0.59)</td>
<td>1.42 (0.71)</td>
<td>0.924</td>
<td>-</td>
</tr>
<tr>
<td>Central</td>
<td>1.88 (0.89)</td>
<td>1.41 (1.24)</td>
<td>1.72 (1.18)</td>
<td>0.373</td>
<td>-</td>
</tr>
<tr>
<td>Left Temporal</td>
<td>1.91 (1.33)</td>
<td>1.56 (0.70)</td>
<td>1.91 (0.84)</td>
<td>0.333</td>
<td>-</td>
</tr>
<tr>
<td>Right Temporal</td>
<td>1.70 (0.68)</td>
<td>1.87 (0.67)</td>
<td>2.23 (1.07)</td>
<td>0.167</td>
<td>-</td>
</tr>
<tr>
<td>Parietal</td>
<td>2.32 (1.16)</td>
<td>1.91 (1.21)</td>
<td>2.44 (1.24)</td>
<td>0.351</td>
<td>-</td>
</tr>
<tr>
<td>Left Posterior</td>
<td>2.78 (1.04)</td>
<td>2.57 (1.06)</td>
<td>2.70 (1.02)</td>
<td>0.662</td>
<td>-</td>
</tr>
<tr>
<td>Right Posterior</td>
<td>3.12 (1.07)</td>
<td>2.28 (1.16)</td>
<td>2.88 (1.35)</td>
<td>0.013</td>
<td>P&lt;Neu, Neu</td>
</tr>
<tr>
<td>Occipital</td>
<td>3.83 (1.69)</td>
<td>3.88 (2.20)</td>
<td>3.9 (1.41)</td>
<td>0.318</td>
<td>-</td>
</tr>
</tbody>
</table>

Values are given as Mean (SD)

*Repeated Measures ANOVA

5. Discussion

The main aim of present study was investigation of phonological processing (-100, -400 ms before onset of articulation) in emotional words and neutral words in normal Persian speaking children. Our data analysis showed that positive words (high valence) have the most accurate words, after that neutral words and finally negative words (low valence). It suggested that high valence words are recognized more accurate than neutral and low valence words. As well as, Positive words have smaller RT than negative words. On the other words, high valence words are recognized faster than low valence words. These results is consist with the results of study which emphasize on importance of valence on word recognition[7]. Apparently, pleasant words are better recognized.

We found that there is larger amplitude in positive words in prefrontal, frontal, right frontal and left frontal (anterior) areas by visual inspection. Larger amplitude is seen in central for neutral words. These results of Persian speaking children with reading task are in the line with the results of Polish speaking adults with reading task [8]. Also larger amplitude indicated more neural activity in positive words in anterior areas, which are motor regions. Then, it seems that high valence words have more neural activation in phonological processing in speech motor and emotional areas. It could be why high valence words are better recognized. Right temporal, right posterior, left temporal and occipital have also larger amplitude in positive words. Topography also showed diffuse activity in emotional words in brain. These are consist with the results of other studies which declare emotion enhances brain activity [9, 12]. Then emotion likely increase language processing in some regions in the brain.

Conversely, emotional content helps to phonological processing and emotional content words have smaller...
amplitude in central region. It can be explained by minimum involvement of central regions in speech processing in reading task [22].

P1, P2, N1 and N2 were not recorded in the time range which is defined in the present study as phonological processing time.

As said in results, negative words (low valence) were totally different in left temporal and left posterior regions which are involved in phonological and conceptual processing[22]. It is suggested that low valence words might be completely different in conceptual and phonological processing.

There were significant difference between negative, positive and neutral words in prefrontal and right posterior. Positive words had significantly larger amplitude in prefrontal region and significantly smaller in right posterior region. Low valence increase the amplitude in right posterior region. It is the only region which shows increasing with low valence. This results is not consist with other studies which suggested that high valence enhances amplitude[12]. It might be have been due to the task, reading[22]. Prefrontal has role in complex cognitive and speech monitoring[23], more significant prefrontal activity in positive words maybe shows that emotion has significant effect on word processing in this region.

**Acknowledgement:** we would like to thank to signal processing section in National Brain Mapping Lab (NBML) for helping us to analyze the recording ERP.

**Appendix 1: Range Of Interest (ROI)**

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

**References:**


