Research Paper

Sensory Emotion in Words: Evidence From an Event-related Potential (ERP) Study in Light of the Emotioncy Model

Sahar Tabatabaee Farani[1], Reza Pishghadam[1, 2*], Azin Khodaverdi[3]

1. Department of English Language and Literature, Faculty of Letters and Humanities, Ferdowsi University of Mashhad, Mashhad, Iran.
2. Gulf College, Muscat, Oman.
3. Cognition and Sensory Emotion Laboratory, Faculty of Letters and Humanities, Ferdowsi University of Mashhad, Mashhad, Iran.

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ABSTRACT

Introduction: Delving into the prominent role of emotions and senses in language is not something new in the field. Thereupon, the newly developed notion of emotioncy has been introduced to foreign language education to underscore the role of sense-induced emotions in the language learning and teaching process.

Methods: The present study implemented event-related potentials (ERPs) to provide evidence of the significance of employing emosensory instructional strategies in teaching vocabulary items. Hence, 18 female participants were randomly instructed on six English nouns toward which they had no prior knowledge and received no instruction for the other three words. Then, while the participants' electroencephalogram (EEG) was being recorded, they took a sentence comprehension task.

Results: Behavioral results demonstrated significant differences among the avolved, the exvolved, and the involved nouns. However, ERP analyses of target words indicated the modulations of N100 and N480 components while no significant effect was observed at P200. Further, the analysis of sensory N100 for the critical words revealed no significant effect.

Conclusion: In conclusion, emotioncy-based language instruction can affect neural correlates of emotional word comprehension from the early stages of EEG recording. The results of this study can clarify the importance of including senses and emotions in language teaching, learning, and testing, along with materials development.

* **Corresponding Author:**
Reza Pishghadam, Professor.
Address: *Department of English Language and Literature, Faculty of Letters and Humanities, Ferdowsi University of Mashhad, Mashhad, Iran.*
Tel: *+98 (915) 3073063*
E-mail: *rpishghadam@yahoo.com*

Highlights

- Direct emosensory involvement can affect word semantic processing.
- Indirect emosensory involvement can affect sensorial comprehension of the word.
- Direct sensory involvement may enhance the accuracy of the responses.
- Direct sensory involvement may reduce the response time.

Plain Language Summary

Nowadays, learning a foreign language is considered one of the challenges in our lives. It is believed that including senses and emotions in education can foster learning new words in a foreign language. One concept that focuses on the use of sensory emotions is called emotioncy. This study employed brain imaging to analyze the effects of teaching through emotioncy on related neural modulations. Based on the results of the study, higher levels of employing senses and emotions can affect the processing and comprehension of words.

1. Introduction

Most scholars in the field of second or foreign language (FL) learning (Dörnyei, 2005; Imai, 2010; Oz et al., 2015) believe that emotions play a key role in the field. To elaborate, emotion is considered an affective, cognitive, and behavioral reaction that is invoked automatically and unconsciously by a specific stimulus regulating the ways we think or behave (Adolphs, 2017; Al-Nafjan et al., 2015; Kandel et al., 2013; Scherer et al., 2001).

Research on emotional stimuli (faces, objects, and words) has introduced different classes of emotions based on the sources from which they originate. While many language studies are conducted regarding various classifications, such as automatic and reflective emotions (Imbir et al., 2015; Jarymowicz & Imbir, 2015), to date, many electrophysiological evaluations of words and other emotional stimuli have focused on two emotional dimensions, valence (positive or negative feelings) and arousal (the intensity of emotions) (Citron et al., 2013; Fischler & Bradley, 2006; Kissler et al., 2009; Palazova, 2014). Furthermore, it is believed that timing, locus, and direction of the event-related potential (ERP) modulations in response to visual emotional words are not homogeneous (Kissler et al., 2006).

For instance, Zhang et al. who were inspired by the three-stage model of facial expression processing (Luo et al., 2010) worked on emotional vocabulary items and identified a larger P1 component in response to negative words, larger N170 and EPN for emotional (positive and negative) words compared to neutral words, and observed an late positive complex (LPC) component for both emotional and non-emotional words along with positive and negative words. Relatedly, some emotional word studies found more negative EPN for emotional words compared to neutral words (Herbert et al., 2008; Palazova et al., 2011; Scott et al., 2009). In several studies, LPC amplitude in response to emotional words increased (Fischler & Bradley, 2006; Yao et al., 2016; Zhao et al., 2018). In terms of N100 in emotional word studies, Perez-Edgar and Fox (2003) found that the amplitude of N1 (N100) was smaller for negative words compared to positive and control words. Wu and Zhang (2019), corroborating Perez-Edgar and Fox in some ways, demonstrated a smaller N100 for positive emotional words compared to neutral words. On the contrary, Kissler and Herbert (2013) reported greater N1 amplitude (more negative-going) for negative words than for neutral words. Analyzing ERP modulations of emotional and neutral words, Lai and Huetting (2016) and Herbert et al. (2008) showed that emotional words can elicit larger P200 amplitudes compared to neutral words. In addition, having a significant role in meaning processing (Kutas & Federmeier, 2001), the N400 component has been investigated regarding emotion in different contexts. For instance, in an emotional Stroop task, West demonstrated that the amplitude of this component was more negative for the incongruent trials compared to the congruent ones. Furthermore, Van Hoof et al. (2008) showed that the N450 component has more negative amplitude after negative words. On the contrary, examining the N400 component, Herbert et al.

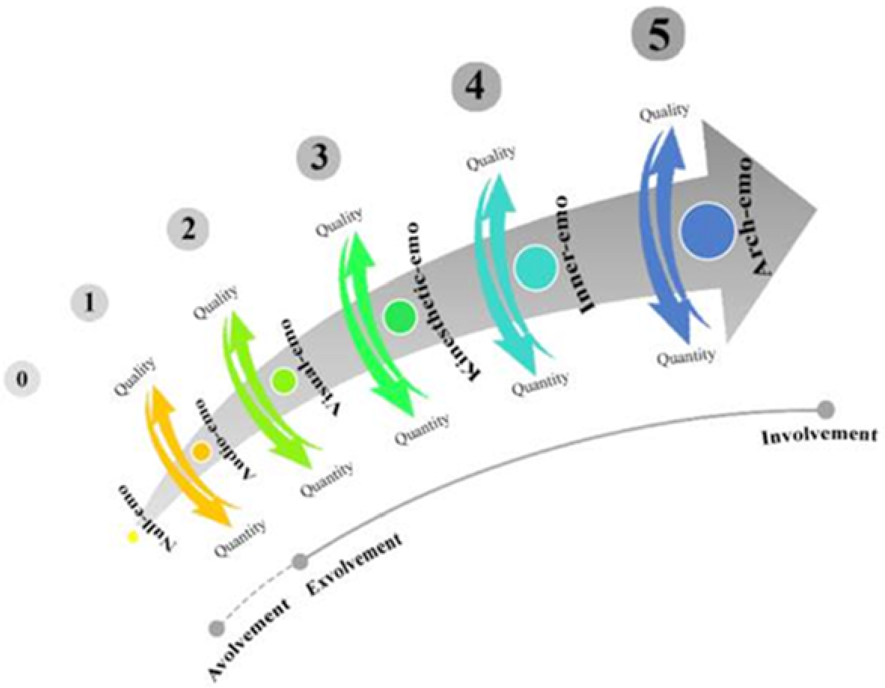

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Figure 1. Emotioncy levels adapted from "emotioncy, extroversion, and anxiety in willingness to communicate in English (Pishghadam, 2016)

(2008) delineated ERP that pleasant adjectives retrieved reduced amplitudes for N400. Considering the effect of mood on N400 amplitude, Federmeier et al. (2001) concluded that in sentences presented in a positive mood, the unexpected words elicited smaller N400 amplitudes. From another perspective, the N400 component was studied in response to reflective (reflective thinking stimulates emotion activation) and automatic (emotion activation is an automatic reaction) emotional words; the results revealed that the reflective ones can elicit larger N400 due to the need for more effort to evaluating them (Imbir et al., 2018).

Inspired by Greenspan's (1992) DIR model of first language acquisition, Pishghadam et al. introduced the concept of emotioncy to highlight the role of sense-induced emotions in language education (Pishghadam et al., 2013b). In other words, emotioncy is rooted in the theories of embodiment, highlighting the role that the sensorimotor experiences play in the formation of our cognition (Atkinson, 2010; Pishghadam et al., 2019b). Emotioncy is established as different levels of emotion generated by the recruitment of our senses in understanding different concepts (Pishghadam et al., 2013a). To state it differently, having emotion as one of its basic constituents, emotioncy focuses on "the emotions evoked by the senses", ranging "from avolvement (null emotioncy) to the exvolvement (auditory, visual, and kinesthetic emotioncies), and involvement (inner and arch emotioncies)" (Pishghadam, 2016). While avolvement deals with a situation in which an individual does not know something, exvolvement happens when an individual has heard, seen, or touched something, and involvement, that is deepening the experiences of the intended concept (Pishghadam et al., 2019a), occurs when an individual has experienced (inner) or researched (arch) something (Pishghadam et al., 2016a; Pishghadam et al., 2016b). Figure 1 shows the hierarchy from avolvement to exvolvement, and involvement concerning the emotioncy levels engaged in each stage. The emotioncy model presents a new classification of senses and emotions which is hierarchical and incremental. Examining the emotioncy model, it is possible to establish a link among the three main components of emotioncy, frequency, sense, and emotion.

Later, based on the tenets of emotioncy, Pishghadam et al. (2013a) formulated the emotioncy-based language instruction (EBLI), which suggested emotionalizing language through deep involvement of English as a foreign language (EFL) learners' emotions and senses in the process of learning and teaching.

Since the introduction of emotioncy to the field of FL teaching and learning, several studies have focused on this concept (Borsipour, 2016; Karami et al., 2019; Pishghadam et al., 2016c; Shahian, 2016). In some of them, which are relevant to the purpose of the present study, the role of emotion has been examined (Borsipour et al., 2019; Pishghadam et al., 2016d). In some other studies, the role of senses in shaping emotioncy has been targeted (Pishghadam et al., 2019a; Shayesteh et al., 2020).

Due to the nature of the EBLI which is related to sense-induced emotions, it seems that different levels of emotioncy in teaching vocabulary items will cause different emotional responses in learners toward those words. Moreover, although only a neurocognitive study scrutinizes the role of emotioncy in modulating FN400 and LPC in response to a sentence comprehension task (Shayesteh et al., 2020), there seems to be a paucity of neurocognitive evidence for the emotional dimension of the EBLI. Thus, this study examined different levels of emotioncy toward a word in a FL, which can modulate neural correlates of emotions during reading and comprehending the word. In other words, it can be worthwhile to examine what happens in the learners' brains when they receive a vocabulary item through the EBLI.

2. Materials and Methods

Participants

Forty volunteers of the present study were selected by convenience sampling method, 15 people were excluded according to the pretesting results, and the data of 7 participants was not included in the final analysis due to excessive muscle artifacts and eye movements. The age range of the remaining participants was between 19 to 29 years (Mean±SD, 22.39±2.68). Since English is considered to be a FL in Iran, all participants were EFL learners of intermediate level from Mashhad, a city in the northeastern part of Iran, and were graduate and undergraduate university students of different educational fields. They were right-handed, had normal or corrected-to-normal vision, all received some rewards for their participation, all provided written consent to take part in the study, and all were asked if they used special medications and had any specific type of health problems, such as neurological and psychological diseases. All participants were informed about the data collection procedure so that if they were not satisfied with the experience, they could refrain from participating. Since the data collection procedure was conducted at Ferdowsi University of Mashhad, the Ethical Committee of this university verified the experimental procedure.

Instruments

To homogenize the participants, the following tests and questionnaires were conducted before the experimental procedure:

Oxford quick placement test (OPT)

The Oxford quick placement test (OPT) is a language proficiency test that contains 60 multiple-choice vocabulary and grammar items. The scoring criteria categorize the test takers into four levels of English language proficiency, elementary (1-14), pre-intermediate (15-29), intermediate (30-44), and upper intermediate (45-50). Those volunteers who were classified at the intermediate level were included in the present study. For the 18 participants of the study, the Mean±SD was 37.3±7.4, and the range score was from 30 (minimum) to 52 (maximum).

Wechsler's adult intelligence scale (WAIS) III

To measure the participants' working memory level, the digit span part of the verbal section in Wechsler's adult intelligence scale (WAIS) III (1997) was used in this study. The participants' range score can be from 0 to 17. In the case of the present study, the volunteers who scored from 10 to 12 were included in the analysis.

The state-trait anxiety inventory (STAI)

The state-trait anxiety inventory (STAI), developed by Spielberger (1968), consists of 40 items in two equal parts, state anxiety and trait anxiety. This scale has been translated into Persian and validated (Mahram, 1993). Cronbach's α has been calculated to check the reliability of both state (0.9084) and trait (0.9025) scales. The scores in each part of the questionnaire can range from 20 to 80. The volunteers who were categorized as low anxious and moderately anxious in both state and trait anxiety were invited to participate in the study (state anxiety: Mean±SD, 32.3±7.3; trait anxiety: Mean±SD 38.5±8.1). Moreover, the Cronbach's α equaled 0.92 for state anxiety and 0.89 for trait anxiety, respectively.

The emotioncy scale

An emotioncy scale was developed for the nine target words of the study to ensure that the participants had null emotioncy (avolvement) toward them at the beginning of the procedure. This emotioncy scale was adapted from the Borsipour scale. The participants can choose one answer from the 6-point Likert-type scale based on their level of prior familiarity and feeling toward each item. Accordingly, those EFL learners who had no familiarity and feeling toward the items (avolvement) were selected to take part in the study.

The neophobia scale

The Neophobia scale (Pliner & Hobden, 1992) was used in this study to check the participants' willingness to experience new things. It is a 7-point Likert scale (with endpoints of extremely low and extremely high) with two parts and 18 items. The first part is the food neophobia scale (FNS) which consists of 10 items (α=0.88). The scores in this section can range from 10 to 70. The second part is the general neophobia scale (GNS), which includes eight items and the scores can range from 8 to 56 (α=0.78). In the present study, the scores of the participants on the food neophobia scale (FNS) had a Mean±SD 32.44±13.6. And, the Mean±SD of the general neophobia scale (GNS) was 25.17±9. Furthermore, the Cronbach α coefficient was 0.917.

The Edinburgh handedness inventory

The Edinburgh handedness inventory (Oldfield, 1971) assesses peoples' preference in using their right or left hand to do their everyday activities. It consists of 10 items and two separate questions. In each case, the use of one hand or the other should be specified. In cases where the respondent felt no preference to do the activity with only one hand, both options can be marked. In the case of the present study, the participants who had right hand preferences to do the activities were selected.

Stimulus material

After selecting 9 target words (concrete nouns with two or three syllables from fruits, vegetables, and foods), the stimulus material was prepared in the form of a sentence comprehension task. To study the emotional target nouns about congruent and incongruent critical words in a context, sentence comprehension was selected for this analysis (Ding et al., 2016). The sentences were presented by applying Psychtoolbox software, version 3. The task included 108 sentence triplets (324 sentences) plus 108 filler sentences (432 sentences). The sentences of a triplet included one of the target words as the first or the second word of the sentence. All sentences followed the same grammatical structures (affirmative sentences in simple present tense), contained three to eight words, and were the same in each triplet except for one critical word at the end of each sentence. Concerning the design of the task, one sentence in a triplet was both semantically and pragmatically congruent, i.e. it had neither word nor world knowledge violation (108 sentences). For example, "a cranberry is red". One sentence included a pragmatic incongruity, i.e. it contained a world knowledge violation (108 sentences). For example, a cranberry is orange". One sentence had a semantic incongruity, i.e. it contained word knowledge violation (108 sentences). For example, "a cranberry is noisy". To strike a balance between the number of sentences with or without violations, 108 filler sentences were designed. The fillers were correct sentences with no violations and were of the same length and complexity level as those of the task sentences. For example, "a panda is a bear". Moreover, the filler sentences were not included in the final analysis.

Procedure

At first, 9 target words were selected and the sentences of the task were prepared. Then, to test the quality of the stimuli, 15 volunteers were selected for the pilot study. The target words were taught to them, and after that, they carried out the computer task without electroencephalogram (EEG) recording. Based on the results of the pilot study, the items were reviewed and revised.

Nine target words were randomly assigned to each emotioncy group. It means that each of the avolvement, exvolvement, and involvement groups included three words. For example, if the word "mangosteen" was exvolved in one instruction group, it was involved in another group. The instructor did not teach the words in the avolvement group so that the participants did not know anything about them. The words in the exvolvement group were taught only by hearing, looking at, or touching the items. And, the participants heard, saw, touched, smelled, and searched on the net about the involved items for almost five minutes. The instruction lasted almost 30 minutes.

After the instruction, the EEG cap was placed on the participants' heads based on the international 10-20 system. They could see each trial presented word by word in black color at the center of the monitor with a gray background and the final word of each sentence was followed by a full stop. The font type was times new roman in size 60. The first block of the task started with a baseline of 600 ms. Each word in a sentence was randomly presented for a period of 750 to 850 ms (to avoid getting used to the presentation time) followed by an interstimulus interval of 300 ms. When the final word of a sentence disappeared, a blank screen was presented for 2800 ms as the response time. For the correct sentences, they were supposed to press the right button, and for the wrong sentence, the down button. If they did not know

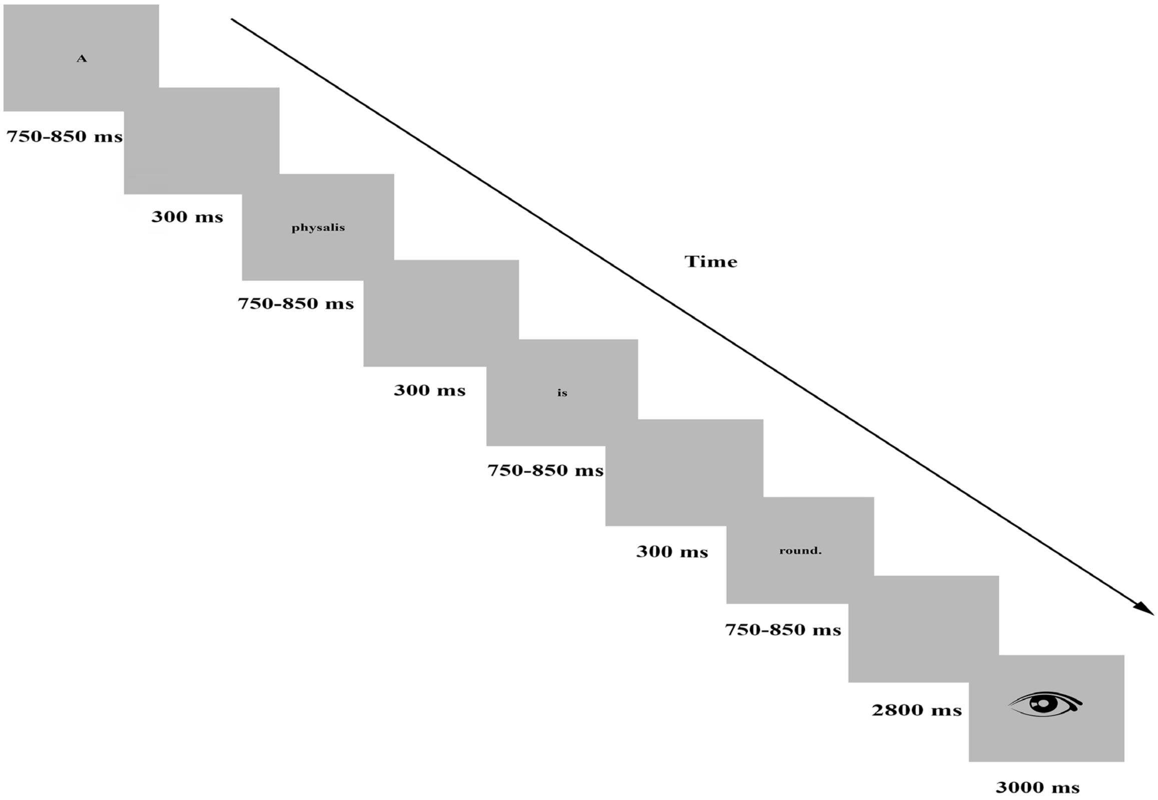

Figure 2. Experimental procedure

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Notes: A sentence, including three to eight words was presented to the participants that they had to decide whether it was correct, semantically incorrect, or pragmatically incorrect based on the information they have already received through the EBLI. Regarding the present study, the ERP analysis was time locked on the target word that was either the first or the second word of the sentence. For the N100 component, the critical word at the end of the sentences was also analyzed.

the answer, they would let the item pass unanswered. After the response time, a screen was observed with an eye shape on it lasting for 3000 ms telling the participants to blink if required (Figure 2).

Before starting the main task, the participants took a short training task with 12 items (like apple) to get used to the process. After the training session, the main task started. The whole task was divided into six blocks, each lasting almost 12 minutes and containing 72 sentences. After the end of each block, the participants had enough time to rest, and to get ready for the next trial.

EEG recording

The EEG data was recorded from 23 Ag/AgCl active electrodes mounted on a wireless 32-channel g.Nautilus EEG system with the notch filter set at 50 Hz. The EEG signals were sampled at 250 Hz, and the electrode impedances were kept below 5 kΩ. According to the international 10-20 system, the following scalp sites were selected for the EEG recording, two over anterior frontal sites (AF3, AF4), four over frontal sites (F3, F4, F7, F8), two over frontocentral sites (FC3, FC4), two on frontotemporal sites (FT7, FT8), two on central sites (C3, C4), four on parietal sites (P3, P4, P7, P8), two over parieto-occipital sites (PO7, PO8), and five on midline site (Fz, FCz, Cz, Pz, Oz). And, vertical and horizontal eye movements were recorded by three electrodes above and below the left eye, and toward the left canthus.

EEG analysis

The EEG data was imported to MATLAB software, version 2015a and EEGLAB toolbox version 13b. The EEG data was band-pass filtered between 0.5-60 Hz. The EEG data was re-referenced to the mean of the linked mastoids. Then, poor EEG channels were interpolated. Applying artifact subspace reconstruction, eye blinks and muscle artifacts were removed. Next, the remaining high frequencies were removed using a low-pass filter of 25 Hz. To elicit ERPs, the EEG data was epoched, and the epochs started 200 ms before the stimulus onset and lasted up to 1100 ms after the stimulus onset. The epochs that exceeded ±70 μV were rejected and removed. After that, to compute ERPs, the baseline correction was done by calculating the average of amplitudes between 0-200 ms and subtracting it from the ERP.

Regarding the present study, the epochs related to the target words (the words instructed through the EBLI) and the critical words (the final words of the sentences) were analyzed. The average of the peak amplitudes of the avolved, evolved, and involved target words and critical words were analyzed for all 18 participants (the critical word was only analyzed in the case of the sensory N100 component). The time window for each ERP component was specified, and the average peak amplitudes were calculated for each emotioncy type. Then, repeated measures analysis of variance (ANOVA) was performed to find the possible significant differences in peak amplitudes between the avolved, exvolved, and involved target words and critical words in different time windows. Wherever required, the post-hoc comparison of the significant main effects was performed using the Bonferroni method, and the Greenhouse-Geisser correction of P.

3. Results

Behavioral performance

Response accuracy (RA)

A repeated measures ANOVA was conducted to analyze the effect of emotioncy types (avolvement, exvolvement, and involvement) on the accuracy of responses (RA) to task-related items. The results of the ANOVA revealed the significant main effect of the three emotioncy types ($F_{(2, 34)}$=152.18, P=0.00, η^2_p=0.90). Pairwise comparison of the main effects showed that the accuracy of responses to the involved items (Mean±SD 97.5±5.6) was significantly higher than the exvolved (Mean±SD 93.6±6.1, P<0.05) and the avolved (Mean±SD 31.2±20.9, P=0.00) ones; and, the accuracy of responses to the exvolved items was significantly higher than the avolved (P=0.00) ones.

Response time (RT)

To investigate the impact of the three emotioncy types on the response time (RT), repeated measures ANOVA was used. The results of the statistical analysis demonstrated that the response time differed as a function of the emotioncy types ($F_{(2, 34)}$=14.793, P=0.00, η^2_p=0.46]. Further, pairwise comparison of the main effects revealed that RT for the items including the avolved (Mean±SD, 1.18±0.49) target words was significantly higher than the exvolved (Mean±SD 0.90±0.24, P<0.05) and the involved (Mean±SD 0.84±0.23, P=0.00) ones. The difference between RT to the exvolved and the involved items (P=0.00) was significant.

ERP data analysis

In this study, three components were analyzed regarding the target words (N100, P200, and N480) and one component for critical words (N100). These components were observable in the anterior frontal, frontal, frontocentral, and central regions. All components were selected based on the objectives of the study and according to the other studies that have worked on emotional words (Herbert et al., 2008; Kissler & Herbert, 2013; Perez-Edgar & Fox, 2003).

N100 (40-170 ms): Target words

The results of the overall repeated measures ANOVA for the N100 amplitudes of the target words demonstrated the significant main effect of the three emotioncy types ($F_{(2, 34)}$=4.27, P<0.05, η^2_p=0.20), and the eleven electrodes ($F_{(10, 170)}$=10.47, P=0.00, η^2_p=0.38). On the other hand, the overall ANOVA for emotioncy×electrode ($F_{(20, 340)}$=1.23, P=0.30, η^2_p=0.07) did not reveal a significant effect. Moreover, post-hoc comparison of the three emotioncy types over the eleven frontal channels showed that, due to the instruction type of the target words (avolvement, exvolvement, and involvement), the minimum amplitude of the avolved (Mean±SD -12.06±0.70 µV) and the exvolved (Mean±SD -11.66±0.74 µV, P<0.05) words was significantly different. However, the avolved and the involved (Mean±SD -11.76±0.73 µV, P<0.28), and the exvolved and the involved (P<1.00) target words did not have statistically significant differences. Figure 3 shows the ERP components at the eleven frontal electrodes, the N100 component at Fz channel, and the related barplot.

N100 (80-160 ms): Critical words

The results of the overall repeated measures ANOVA for the N100 amplitudes of the critical words revealed that the main effect of emotioncy (Mean±SD avolvement: -9.38±0.58 µV; exvolvement: -9.49±0.62 µV; involvement: -9.32±0.75 µV) was not significant ($F_{(2, 34)}$=0.22, P=0.70, η^2_p=0.014). Nevertheless, the main effect of the electrode ($F_{(10, 170)}$=5.98, P=0.00, η^2_p=0.26) was significant. Furthermore, the interaction between emotioncy and electrode ($F_{(20, 340)}$=0.80, P=0.54, η^2_p=0.04) was not significant. Figure 4 shows N100 at Fz channel and the barplot for this channel.

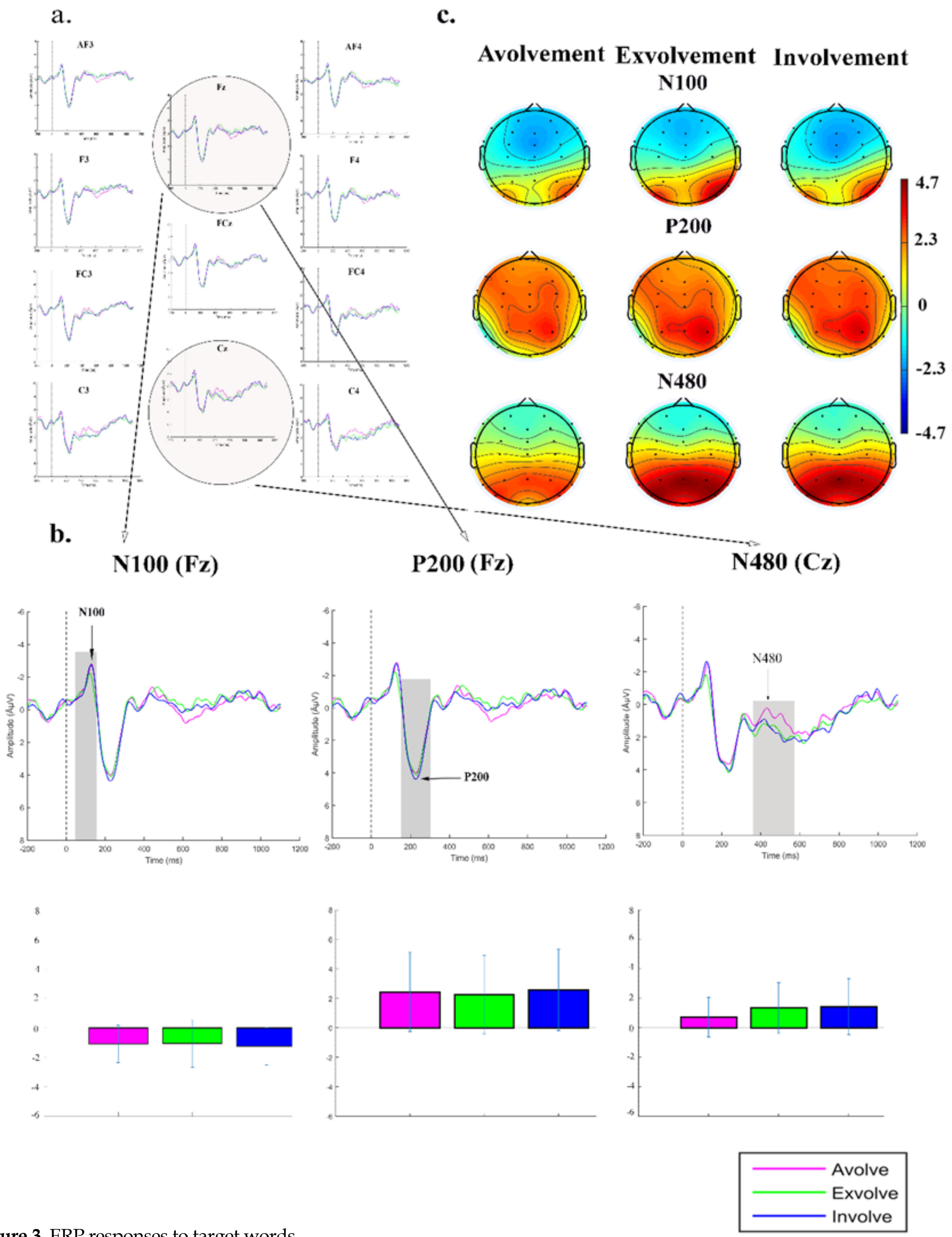

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Figure 3. ERP responses to target words

a) The N100, P200, and N480 ERP components at eleven frontal locations are represented, electrodes are arrayed as they were positioned on the scalp, stimulus onset is at 0 ms, the direction of negative components is up and positive components down, the horizontal axis represents time in milliseconds (ms), and the vertical axis demonstrates amplitude in microvolt (µV)

b) The N100 (at Fz), P200 (at Fz), and N480 (at Cz) ERP components are presented at the intended channels (the vertical axis represents amplitude in µV)

c) The topographical views (based on the mean amplitude) of the N100, P200, and N480 ERP components in response to target words are shown for the three emotiony kinds

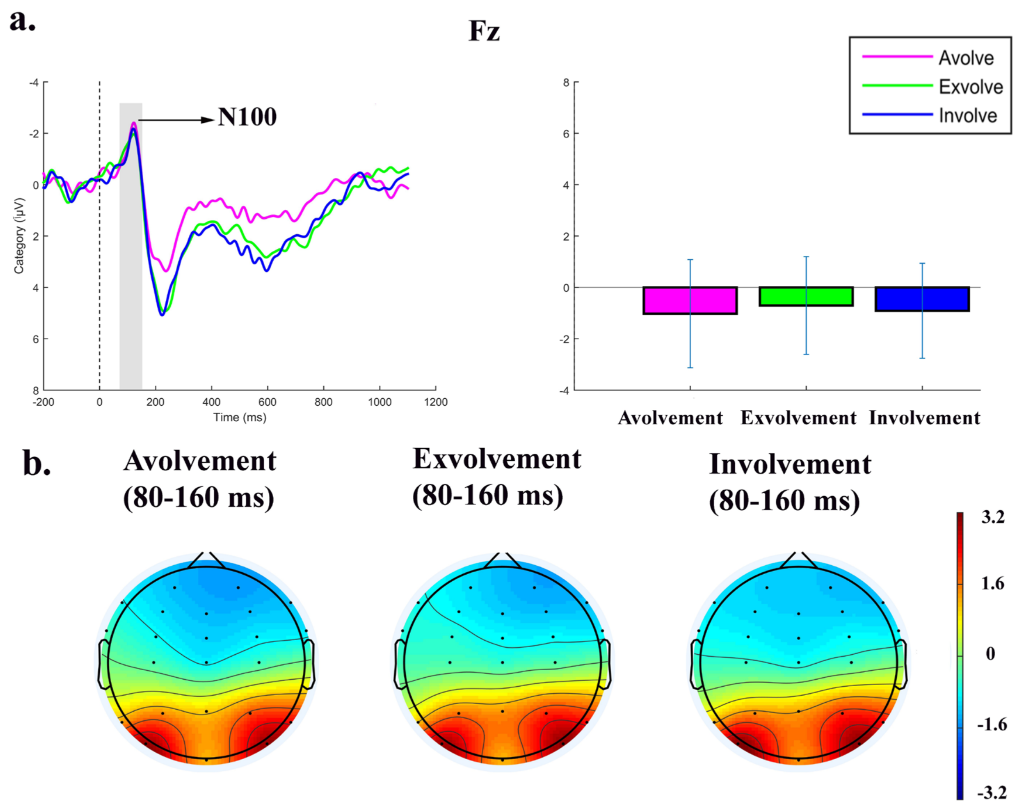

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Figure 4. The N100 ERP component at Fz channel

a) The N100 ERP component at Fz channel is illustrated in response to critical words, stimulus onset is at 0 ms, the direction of negative components is up and positive components down, the horizontal axis represents time in milliseconds (ms), and the vertical axis demonstrates amplitude in microvolt (μV)

b) The topographical view (based on the mean amplitude) of the N100 ERP component in response to critical words is shown for the three emotioncy kinds

P200 (160-300 ms): Target words

The results of the overall repeated measures ANOVA for the P200 amplitudes of the target words revealed that the main effect of the three emotioncy types (Mean±SD avolvement: 13.12±0.81 μV; exvolvement: 13.30±0.82 μV; involvement: 13.16±0.77 μV) was not significant ($F_{(2, 34)}$=1.00, P=0.36, η^2_p=0.06) while the main effect of electrode was significant ($F_{(10, 170)}$=12.25, P=0.00, η^2_p=0.42). Moreover, the overall ANOVA for emotioncy×electrode ($F_{(20, 340)}$=1.29, P=0.28, η^2_p=0.07) did not show a significant effect. Figure 3 shows the P200 at Fz and the related barplot.

N480 (380-580 ms): Target words

The results of the overall repeated measures ANOVA for the N480 amplitude of the target words showed that the main effect of the three emotioncy types (Mean±SD avolvement: -12.26±0.71 μV; exvolvement: -12.06±0.79 μV; involvement: -12.00±0.79 μV) ($F_{(2, 34)}$=1.18, P=0.31, η^2_p=0.06] was not significant. On the other hand, the eleven electrodes ($F_{(10, 170)}$=3.56, P<0.05, η^2_p=0.17), and the interaction between emotioncy and electrode ($F_{(20, 340)}$=1.19, P<0.05, η^2_p=0.18) demonstrated a significant effect. To examine the significant effect of emotioncy×electrode, each of the frontal locations was studied separately. Hence, Cz represented a significant difference between the peak amplitude of the avolved and the involved (P<0.05) target words. Figure 3 shows the N480 ERP component for the three emotioncy types at Cz.

To find the relationship between the meaningful channel (i.e. Cz) and the behavioral data, the Spearman correlation coefficient was used. The results indicated that the relationship between Cz and RT (r=0.81, P<0.05) and Cz and RA (r=0.85, P<0.05) was significant.

4. Discussion

To substantiate the emotional perspective of the EBLI model, a sentence comprehension task was designed to assess RA, RT, and the emotioncy-related ERP components in the target words in which they were avolved, evolved, and involved. In addition to the behavioral results, the analyses of ERPs yielded a pair of negative-going components and a positive-going one in the time windows of 40 to 170 ms (N100), 380 to 580 ms (N480), and 160-300 ms (P200). Furthermore, to compare the behavior of the sensory N100 component in the case of the target words with the critical words, this component has been studied separately in the time window of 80 to 160 ms over the critical words.

Behavioral analyses

According to the behavioral results, the three emotioncy types represented significant differences in the case of both RA and RT. The accuracy in responses to the involved target words was higher than those of the exvolved and the avolved words. This is consistent with Shahian who showed that the learners who have been involved in the topic had a more successful performance on reading comprehension tests. By the same way, Pishghadam et al. highlighted the role of higher emotioncy levels in vocabulary learning and retention (Pishghadam et al. (2013a). Recognition of emotional words has been studied in the work of Brierley et al. (2007) who concluded that emotional target words have been more successfully remembered than neutral ones and emphasized the role of emotion in enhancing memory for words. Moreover, the results of the present study can be corroborated by Zhang et al. (2014)'s and Dresler et al. (2009) experiments concerning emotional-nonemotional words. In these studies, the accuracy of responses to and the recognition of the emotional words were significantly higher than the neutral words (nonemotional). It can be confirmed that higher levels of emosensory (emotion created by sensory experiences) involvement lead to improved performance on the part of the learners.

The analysis of RT values (reaction time) bolstered the RA results. The RT indices for the items, including the involved target words were shorter than the time for the exvolved and the avolved ones. In simpler terms, including more senses in learning vocabulary items and experiencing higher emotioncy levels (involvement) can cause a type of automaticity to identify the words and reduce the time required for selecting the correct response. These results are consistent with those of Kissler and Herbert which confirmed that the differentiation between words and pseudowords occurred faster for emotional rather than neutral words. On the other hand, Fisher et al. (2014) contrary to the results of the present study, demonstrated that the RT did not differ significantly for emotional and nonemotional words.

The emotioncy (sensory involvement) in the case of the present study and the emotion in the case of the other related studies can affect the RT and the RA of the intended words in different ways. However, it should be mentioned that the objectives of the current study are different from the ones in other works that have concentrated on the emotional valence and arousal (Kissler et al., 2009; Palazova, 2014), or the congruency of vocabulary items (Wentura, 2000; West, 2003). In other studies, the emotion variable has been linked to the words even though the intensity of these emotions may be different for different individuals. What the present study dealt with was placing further emphasis on the emotioncy factor and observing the extent to which sensory experiences change the emotions for vocabulary items.

The N100 component

The ERP data demonstrated the N100 component through eleven electrodes in the anterior frontal, frontal, frontocentral, and central areas of the left hemisphere, right hemisphere, and midline region in response to the avolved, exvolved, and involved target words. Regarding the peak amplitude of N100 for the target words, the ANOVA showed a significant main effect for the three emotioncy types. To explicate, the avolved target words elicited larger N100 amplitudes compared to the exvolved and the involved words. However, only the difference between the avolved and the exvolved target words was significant. The less negative amplitude of the exvolved words can be due to the higher emotional levels of the exvolved words compared to the avolved words. Nevertheless, this result is inconsistent with the result of Herbert et al. who demonstrated more negative amplitude in response to emotional words compared to the neutral words. Further evaluation showed no significant difference between avolvement and involvement. It can be the case that the ERP modulation for the exvolved words (less negative amplitude) is a result of fewer senses employed to learn the words that demonstrated a negative aspect of sensory emotion. On the contrary, in the case of involvement, all senses were employed to learn the vocabulary item, and in the case of avolvement, none of the senses was involved in learning the word. That is, neither emotioncy for word form nor word meaning was observed (Karami et al., 2019). Hence, the negative aspect of sensory emotion related to exvolvement was not present for the avolved and the involved target words. In other words, people who employ fewer senses (auditory, visual, kinesthetic) to learn something develop distal emotions, and they may have weak processing of information; on the other hand, people who learn something through involvement (inner, arch) develop proximal emotions that enable them to have deeper processing of information (Karami et al., 2019). In addition, the insignificant difference between exvolvement and involvement can be ascribed to the length of the instruction, and the available time for the consolidation of the new form and its meaning. It seems that the participants required more time to differentiate the two types of instruction so that the difference can be seen in the peak amplitude of N100.

On the other hand, in the case of the N100 component for the critical words at the end of the sentences, the ANOVA revealed the significant main effect of the electrode while the main effect of emotioncy and the interaction effect of emotioncy by the electrode was not significant. In essence, the critical words at the end of the sentences that do not have specific emotions cannot modulate the N100 component. On the contrary, the sensory emotion attached to the target words through the EBLI can beget the significant difference between avolvement and exvolvement.

The P200 component

The ANOVA for the P200 component did not show the significant main effect of emotioncy and the interaction between emotioncy and electrode in this time window. Even though P200 modulations are linked to the effects of emotional stimuli in several studies (Chang et al., 2018; Kotz & Paulmann, 2011; Lai & Huettig, 2016; Stewart et al., 2010; Zinchenko et al., 2017), these effects were not observed in the present study. To elaborate, although P200 amplitude modulation can happen due to attention allocation (Crowley & Corlain, 2004) in response to emotional stimuli (Zinchenko et al., 2017), the three emotioncy types in teaching the words in this study cannot lead to a significant different attentional level.

The N480 component

Although it is stated that one of the characteristics of N400 is its relatively stable latency (Kutas & Federmeier, 2011), in the case of the present study, perhaps due to the novel nature of the instructed vocabulary items, the peak of the N400 component has appeared with an 80 ms delay at 480 ms. This delay in N480 latency can be the result of increasing memory load on the part of the participants since they had to learn all new items in one session, and they did not have the chance to learn the items with the same level of sensory involvement. The ANOVA analysis in the time range of N480 over the eleven frontal electrodes revealed no significant effect by emotioncy and electrode while the interaction between emotioncy and electrode was significant. The investigation of the eleven electrodes showed that in Cz, just the difference between the avolved and the involved target words was significant. It means that the semantic processing at N480 caused avolvement with no emosensory experience to show the highest amplitude, and to differ from involvement with the highest level of emosensory involvement, and the smallest amplitude. Consistent with the tenets of multisensory learning (Baines, 2008), employing more senses (involvement) in the process of learning the words resulted in invoking emotions (which may be positive due to the greater number of senses involved) that can be traced in the smaller amplitude of N480. Furthermore, due to the direct involvement of senses and pertaining emotions, episodic memory may be activated as the result of experiencing something (Wilson, 2002). In consequence, a significant difference between avolvement and involvement can be observed. That is, the N480 effect which is yielded for involvement reflects the facilitated semantic and lexical access due to the sense-induced emotion accompanying the words (Kanske & Kotz, 2007). Having its roots in embodied cognition principles (Niedenthal, 2007) that emphasize the relation between sensorimotor activities and language comprehension (Jirak et al., 2010), the outcome of direct sensory involvement as the highest level of the EBLI can manifest itself in both the behavioral analysis and the electrophysiological results. On the other hand, avolvement and exvolvement did not represent such a significant difference. That is, no sensory involvement or the involvement of the limited number of senses (indirect sensory involvement) in learning is not different from semantic processing. Moreover, no significant difference is observed between involvement and exvolvement in N480. Therefore, although the EBLI emphasizes that the inclusion of senses enhances the learning of the words (Pishghadam et al., 2013a), it seems that more extended teaching sessions or the repetition of the instruction is required for the difference to make a significant change in neurocognitive results of the exvolved and the involved items.

On the one hand, the teachers' and the material developers' awareness of emotioncy and the EBLI should be enhanced. On the other hand, based on the neurocognitive results of this study, highlighting the role of the

EBLI and focusing on the learners' senses and emotions in the process of teaching can be of great help to both language learners and teachers.

5. Conclusion

Overall, this study explored the impact of EBLI on sentence comprehension and primarily focused on recognition accuracy (RA), reaction time (RT), and ERPs related to emotions. Behavioral findings revealed that with the more active involvement of participants in a target word, higher accuracy and lower reaction times were observed as compared to less involved conditions. The results of the ERP analysis showed different trends in the N100, P200, and N480 components, suggesting how sensory emotion affected neurocognitive processing. Finally, this study calls attention to the necessity of sensory involvement compromising the process of vocabulary learning with implications for improving efficacy in teaching a language by combining sensory and emotional engagement within instructional designs.

Ethical Considerations

Compliance with ethical guidelines

This study was approved by the Ethics Committee of Ferdowsi University of Mashhad (Code: 42247).

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

References

Adolphs, R. (2017). How should neuroscience study emotions? by distinguishing emotion states, concepts, and experiences. *Social Cognitive and Affective Neuroscience, 12*(1), 24–31. [DOI:10.1093/scan/nsw153] [PMID] [PMCID]

Al-Nafjan, A., Al-Wabil, A. & Al-Ohali, Y. (2015). Augmenting speech language rehabilitation with brain computer interfaces: An exploratory study using non-invasive electroencephalographic monitoring. In A. Margeritha & S. *Constantine (Eds.), Universal access in human-computer interaction: Access to learning, health and well-being* (pp. 593-603). Switzerland: Springer. [DOI:10.1007/978-3-319-20684-4_57]

Atkinson, D. (2010). Extended, embodied cognition and second language acquisition. *Applied Linguistics, 31*(5), 599-622. [DOI:10.1093/applin/amq009]

Baines, L. (2008). *A teacher's guide to multisensory learning: Improving literacy by engaging the senses*. Alexandria: Association for Supervision and Curriculum Development. [Link]

Borsipour, B. (2016). Emotioncy and willingness to read: A case of Iranian EFL learners (Persian) (PhD Dissertation). Ferdowsi University of Mashhad, Mashhad, Iran.

Borsipour, B., Pishghadam, R., & Naji Meidani, E. (2019). The role of sensory emotions in increasing willingness to read in EFL learners. *Publicaciones, 49*(2), 169-189. [DOI:10.30827/publicaciones.v49i2.8094]

Brierley, B., Medford, N., Shaw, P., & David, A. S. (2007). Emotional memory for words: Separating content and context. *Cognition and Emotion, 21*(3), 495-521. [DOI:10.1080/02699930600684963]

Chang, J., Zhang, X., Zhang, Q., & Sun, Y. (2018). Investigating duration effects of emotional speech stimuli in a tonal language by using event-related potentials. *IEEEAcess, 6*, 13541-13554. [DOI:10.1109/ACCESS.2018.2813358]

Citron, F. M., Weekes, B. S., & Ferstl, E. C. (2013). Effects of valence and arousal on written word recognition: Time course and ERP correlates. *Neuroscience Letters, 533*, 90–95. [DOI:10.1016/j.neulet.2012.10.054] [PMID]

Crowley, K. E., & Colrain, I. M. (2004). A review of the evidence for P2 being an independent component process: Age, sleep and modality. *Clinical Neurophysiology, 115*(4), 732–744. [DOI:10.1016/j.clinph.2003.11.021] [PMID]

Ding, J., Wang, L., & Yang, Y. (2016). The dynamic influence of emotional words on sentence comprehension: An ERP study. *Cognitive, Affective & Behavioral Neuroscience, 16*(3), 433–446. [DOI:10.3758/s13415-016-0403-x] [PMID]

Dörnyei, Z. (2005). *The psychology of the language learner: Individual differences in second language acquisition*. Milton Park: Routledge Publication. [Link]

Dresler, T., Mériau, K., Heekeren, H. R., & van der Meer, E. (2009). Emotional Stroop task: effect of word arousal and subject anxiety on emotional interference. *Psychological Research, 73*(3), 364–371. [DOI:10.1007/s00426-008-0154-6] [PMID]

Federmeier, K. D., Kirson, D. A., Moreno, E. M., & Kutas, M. (2001). Effects of transient, mild mood states on semantic memory organization and use: An event-related potential investigation in humans. *Neuroscience Letters, 305*(3), 149–152. [DOI:10.1016/S0304-3940(01)01843-2] [PMID]

Fischler, I., & Bradley, M. (2006). Event-related potential studies of language and emotion: Words, phrases, and task effects. *Progress in Brain Research, 156*, 185–203.[DOI:10.1016/S0079-6123(06)56009-1] [PMID]

Fisher, J. E., Miller, G. A., Sass, S. M., Silton, R. L., Edgar, J. C., & Stewart, J. L., et al. (2014). Neural correlates of suspiciousness and interactions with anxiety during emotional and neutral word processing. *Frontiers in Psychology, 5*(596), 1-14. [DOI:10.3389/fpsyg.2014.00596]

Greenspan, S. I. (1992). *Infancy and early childhood: The practice of clinical assessment and intervention with emotional and developmental challenges*. Madison: International Universities Press. [Link]

Herbert, C., Junghofer, M., & Kissler, J. (2008). Event related potentials to emotional adjectives during reading. *Psychophysiology, 45*(3), 487–498. [DOI:10.1111/j.1469-8986.2007.00638.x] [PMID]

Imai, Y. (2010). Emotions in SLA: New insights from collaborative learning for an EFL classroom. *Modern Language Journal, 94*(2), 278-292. [DOI:10.1111/j.1540-4781.2010.01021.x]

Imbir, K. K., Jarymowicz, M. T., Spustek, T., Kuś, R., & Żygierewicz, J. (2015). Origin of emotion effects on ERP correlates of emotional word processing: The emotion duality approach. *Plos One, 10*(5), e0126129. [DOI:10.1371/journal.pone.0126129] [PMID] [PMCID]

Imbir, K. K., Jurkiewicz, G., Duda-Goławska, J., Pastwa, M., & Żygierewicz, J. (2018). The N400/FN400 and lateralized readiness potential neural correlates of valence and origin of words' affective connotations in ambiguous task processing. *Frontiers in Psychology, 9*, 1981. [DOI:10.3389/fpsyg.2018.01981] [PMID] [PMCID]

Jarymowicz, M. T., & Imbir, K. K. (2015). Towards a human emotions taxonomy (based on their automatic vs. reflective origin). *Emotion Review, 7*(2), 183-188. [DOI:10.1177/1754073914555923]

JJirak, D., Menz, M. M., Buccino, G., Borghi, A. M., & Binkofski, F. (2010). Grasping language--a short story on embodiment. *Consciousness and Cognition, 19*(3), 711–720. [DOI:10.1016/j.concog.2010.06.020] [PMID]

Kandel, E. R. (2013). *Principles of neural science*. New York: McGraw-Hill Education. [Link]

Kanske, P., & Kotz, S. A. (2007). Concreteness in emotional words: ERP evidence from a hemifield study. *Brain Research, 1148*, 138–148. [DOI:10.1016/j.brainres.2007.02.044] [PMID]

Karami, M., Pishghadam, R., & Baghaei, P. (2019). A probe into EFL learners' emotioncy as a source of test bias: Insights from differential item functioning analysis. *Studies in Educational Evaluation, 60*, 170-178. [DOI:10.1016/j.stueduc.2019.01.003]

Kissler, J., Assadollahi, R., & Herbert, C. (2006). Emotional and semantic networks in visual word processing: Insights from ERP studies. *Progress in Brain Research, 156*, 147–183. [DOI:10.1016/S0079-6123(06)56008-X] [PMID]

Kissler, J., & Herbert, C. (2013). Emotion, Etmnooi, or Emitoon?--Faster lexical access to emotional than to neutral words during reading. *Biological Psychology, 92*(3), 464–479. [DOI:10.1016/j.biopsycho.2012.09.004] [PMID]

Kissler, J., Herbert, C., Winkler, I., & Junghofer, M. (2009). Emotion and attention in visual word processing: An ERP study. *Biological Psychology, 80*(1), 75–83. [DOI:10.1016/j.biopsycho.2008.03.004] [PMID]

Kotz, S. A., & Paulmann, S. (2011). Emotion, language, and the brain. *Language and Linguistics Compass, 5*(3), 108-125. [DOI:10.1111/j.1749-818X.2010.00267.x]

Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: Finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology, 62*, 621–647. [DOI:10.1146/annurev.psych.093008.131123] [PMID] [PMCID]

Lai, V. T., & Huettig, F. (2016). When prediction is fulfilled: Insight from emotion processing. *Neuropsychologia, 85*, 110–117. [DOI:10.1016/j.neuropsychologia.2016.03.014] [PMID]

Luo, W., Feng, W., He, W., Wang, N. Y., & Luo, Y. J. (2010). Three stages of facial expression processing: ERP study with rapid serial visual presentation. *NeuroImage, 49*(2), 1857–1867. [DOI:10.1016/j.neuroimage.2009.09.018] [PMID] [PMCID]

Mahram, B. (1993). Rahnamaye azmoon e ezterab e (Ashkar va penhan) Spielberger [The guidebook of Spielberger's anxiety scale (state and trait) (Persian)]. Mashhad: The University of Mashhad.

Niedenthal P. M. (2007). Embodying emotion. *Science, 316*(5827), 1002–1005. [DOI:10.1126/science.1136930] [PMID]

Oldfield R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9*(1), 97–113. [DOI:10.1016/0028-3932(71)90067-4] [PMID]

Oz, H., Demirezen, M., & Pourfeiz, J. (2015). Emotional intelligence and attitudes towards foreign language learning: Pursuit of relevance and implications. *Procedia-Social and Behavioral Sciences, 186*, 416-423. [DOI:10.1016/j.sbspro.2015.04.118]

Palazova, M. (2014). Where are emotions in words? Functional localization of valence effects in visual word recognition. *Frontiers in Psychology, 5*, 1105. [DOI:10.3389/fpsyg.2014.01105] [PMID] [PMCID]

Palazova, M., Mantwill, K., Sommer, W., & Schacht, A. (2011). Are effects of emotion in single words non-lexical? Evidence from event-related brain potentials. *Neuropsychologia, 49*(9), 2766–2775. [DOI:10.1016/j.neuropsychologia.2011.06.005] [PMID]

Pérez-Edgar, K., & Fox, N. A. (2003). Individual differences in children's performance during an emotional Stroop task: A behavioral and electrophysiological study. *Brain and Cognition, 52*(1), 33–51. [DOI:10.1016/S0278-2626(03)00007-1] [PMID]

Pishghadam, R. (2016). Emotioncy, extraversion, and anxiety in willingness to communicate in English. Paper presented at; 5th International Conference on Language, Education, and Innovation, Mashhad, Iran, 28 May 2016. [Link]

Pishghadam, R., Adamson, B., & Shayesteh, S. (2013). Emotion-based language instruction (THE EBLI) as a new perspective in bilingual education. *Multilingual Education, 3*(9), 1-16. [DOI:10.1186/2191-5059-3-9]

Pishghadam, R., Baghaei, P., & Seyednozadi, Z. (2016). Introducing emotioncy as a potential source of test bias: A mixed rasch modeling study. *International Journal of Testing, 16*, 1-14. [DOI:10.1080/15305058.2016.1183208]

Pishghadam, R., Jajarmi, H., & Shayesteh, S. (2016). Conceptualizing sensory relativism in light of emotioncy: A movement beyond linguistic relativism. *International Journal of Society, Culture, and Language, 4*(2), 11-21. [Link]

Pishghadam, R., Mahmoodzadeh, M., Naji Meidani, E., & Shayesteh, S. (2019). Teacher as envolver: A new role to play in English language discussion classes. *Sri Lanka Journal of Social Sciences, 42*, 41-51. [DOI:10.4038/sljss.v42i1.7857]

Pishghasam, R., Shakeebaee, G., & Rahmani, S. (2019). Sensory capital in education: The missing piece? *Italian Journal of Sociology of Education, 11*(3), 265-282. [Link]

Pishghadam, R., Shayesteh, S., & Rahmani, S. (2016). Contextualization-emotionalization interface: A case of teacher effectiveness. *International and Multidisciplinary Journal of Social Sciences, 5*(2), 97-127. [DOI:10.17583/rimcis.2016.1907]

Pishghadam, R, Tabatabaeyan, M. S., & Navari, S. (2013). *A critical and practical analysis of first language acquisition theories: The origin and development.* Mashhad: Ferdowsi University of Mashhad Publications. [Link]

Pishghadam, R., Zabetipour, M., & Aminzadeh, A. (2016). Examining emotions in English language learning classes: A case of EFL emotions. *Issues in Educational Research, 26*(3), 508-527. [Link]

Pliner, P., & Hobden, K. (1992). Development of a scale to measure the trait of food neophobia in humans. *Appetite, 19*(2), 105–120. [DOI:10.1016/0195-6663(92)90014-W] [PMID]

Scherer, K. R., Schorr, A., & Johnstone, T. (2001). *Appraisal processes in emotion.* Oxford: Oxford University Press. [DOI:10.1093/oso/9780195130072.001.0001]

Scott, G. G., O'Donnell, P. J., Leuthold, H., & Sereno, S. C. (2009). Early emotion word processing: Evidence from event-related potentials. *Biological Psychology, 80*(1), 95–104. [DOI:10.1016/j.biopsycho.2008.03.010] [PMID]

Shahian, L. (2016). Examining the relationship between flow, emotioncy and reading comprehension: A case of Iranian EFL learners (Persian) (Msc thesis). Mashhad: Ferdowsi University of Mashhad, Mashhad.

Shayesteh, S., Pishghadam, R., & Khodaverdi, A. (2020). FN400 and LPC responses to different degrees of sensory involvement: A study of sentence comprehension. *Advances in Cognitive Psychology, 16*(1), 45–58. [DOI:10.5709/acp-0283-6] [PMID] [PMCID]

Spielberger, C. D., Lushene G. R. (1968). *Self-evaluation questionnaire (STAI Form X-1)*. Victoria: AbeBooks. [Link]

Stewart, J. L., Silton, R. L., Sass, S. M., Fisher, J. E., Edgar, J. C., & Heller, W., et al. (2010). Attentional bias to negative emotion as a function of approach and withdrawal anger styles: an ERP investigation. *International Journal of Psychophysiology, 76*(1), 9–18. [DOI:10.1016/j.ijpsycho.2010.01.008] [PMID] [PMCID]

Van Hooff, J. C., Dietz, K. C., Sharma, D., & Bowman, H. (2008). Neural correlates of intrusion of emotion words in a modified Stroop task. *International Journal of Psychophysiology, 67*(1), 23–34. [DOI:10.1016/j.ijpsycho.2007.09.002] [PMID]

Wechsler, D. (1997). *WAIS-III administration and scoring manual*. San Antonio: The Psychological Corporation. [Link]

Wentura D. (2000). Dissociative affective and associative priming effects in the lexical decision task: Yes versus no responses to word targets reveal evaluative judgment tendencies. Journal of experimental psychology. *Learning, Memory, and Cognition*, 26(2), 456–469. [DOI:10.1037//0278-7393.26.2.456] [PMID]

West R. (2003). Neural correlates of cognitive control and conflict detection in the Stroop and digit-location tasks. *Neuropsychologia, 41*(8), 1122–1135. [DOI:10.1016/S0028-3932(02)00297-X] [PMID]

Wilson, M. (2002). Six views of embodied cognition. Psychonomic *Bulletin and Review, 9*(4), 625-636. [DOI:10.3758/BF03196322] [PMID]

Wu, C., & Zhang, J. (2019). Conflict processing is modulated by positive emotion word type in second language: An ERP Study. *Journal of Psycholinguistic Research, 48*(5), 1203–1216. [DOI:10.1007/s10936-019-09653-y] [PMID]

Yao, Z., Yu, D., Wang, L., Zhu, X., Guo, J., & Wang, Z. (2016). Effects of valence and arousal on emotional word processing are modulated by concreteness: Behavioral and ERP evidence from a lexical decision task. *International Journal of Psychophysiology, 110*, 231–242. [DOI:10.1016/j.ijpsycho.2016.07.499] [PMID]

Zhang, D., He, W., Wang, T., Luo, W., Zhu, X., & Gu, R., et al. (2014). Three stages of emotional word processing: An ERP study with rapid serial visual presentation. *Social Cognitive and Affective Neuroscience, 9*(12), 1897–1903. [DOI:10.1093/scan/nst188] [PMID] [PMCID]

Zhao, W., Chen, L., Zhou, C., & Luo, W. (2018). Neural correlates of emotion processing in word detection task. *Frontiers in Psychology, 9*, 832. [DOI:10.3389/fpsyg.2018.00832] [PMID] [PMCID]

Zinchenko, A., Obermeier, C., Kanske, P., Schröger, E., & Kotz, S. A. (2017). Positive emotion impedes emotional but not cognitive conflict processing. *Cognitive, Affective & Behavioral Neuroscience, 17*(3), 665–677. [DOI:10.3758/s13415-017-0504-1] [PMID] [PMCID]