Title: Sensory Emotion in Words: Evidence from an ERP Study in Light of the Emotioncyp

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Abstract

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

Methods: The present study implemented ERPs to provide evidence to the significance of employing emosensory instructional strategies in teaching vocabulary items. Hence, eighteen female participants were randomly instructed six English nouns toward which they had no prior knowledge and received no instruction for the other three words. Then, while the participants’ 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, the emotioncy-based language instruction could affect neural correlates of emotional word comprehension from the early stages of EEG recording. The findings of this study can shed light on the importance of including senses and emotions in language teaching, learning, and testing, along with materials development.

Keywords: Emotion, the Emotioncy-Based Language Instruction, N100, N480, P200.
Highlights

- Direct emosensory involvement can affect semantic processing of the word.
- 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 as 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 the emotions could affect processing and comprehending the words.
1. Introduction

Most scholars in the field of second or foreign language (FL) learning (e.g., Dörnyei, 2005; Imai, 2010; Oz, Demirezen, & Pourfeiz, 2015) hold that emotions play a key role in the field. To elaborate, emotion is considered as an affective, cognitive, and behavioral reaction which is invoked automatically and unconsciously by a specific stimulus regulating the ways we think or behave (Adolphs, 2017; Al-Nafjan et al., 2015; Kandel, Schwartz, Jessell, Siegelbaum, & Hudspeth, 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 are originated. While there are many language studies regarding various classifications such as automatic and reflective emotions (Imbir, Jarymowicz, Spustek, Kuś, & Źygierek, 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) (e.g., Citron, Weekes, & Ferstl, 2013; Fischler & Bradley, 2006; Kissler, Herbert, Winkler, & Junghofer, 2009; Palazova, 2014). Furthermore, it is believed that timing, locus, and direction of the ERP modulations in response to visual emotional words are not homogeneous (Kissler, Assadollahi, & Herbert, 2006). For instance, Zhang et al. (2014) who were inspired by the three-stage model of facial expression processing (Luo, Feng, He, Wang, & Luo, 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 in comparison with neutral words, and observed an 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 in comparison with neutral words (e.g., Herbert, Junghofer, & Kissler, 2008; Palazova, Mantwill, Sommer, & Schacht, 2011; Scott, O’Donnell, Leuthold, & Sereno, 2009). In a number of studies, there has been an increase in
LPC amplitude in response to emotional words (e.g., Fischler & Bradley, 2006; Yao et al., 2016; Zhao, Chen, Zhou, & Luo, 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 in comparison with positive and control words. Wu and Zhang (2019), corroborating Perez-Edgar and Fox (2003) in some ways, demonstrated smaller N100 for positive emotional words in comparison with 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 Huettig (2016) and Herbert, Kissler, Junghofer, Peyk, and Rockstroh (2006) could show that emotional words could elicit larger P200 amplitudes in comparison with neutral words. In addition, having a significant role in meaning processing (Kutas & Federmeier, 2011), the N400 component has been investigated in connection with emotion in different contexts. For instance, in an emotional Stroop task, West (2003) demonstrated that the amplitude of this component was more negative for the incongruent trials in comparison with the congruent ones. Furthermore, Van Hoof, Dietz, Sharma, and Bowman (2008) showed that the N450 component had more negative amplitude after negative words. On the contrary, examining the N400 component, Herbert et al. (2008) delineated ERP that pleasant adjectives retrieved reduced amplitudes for N400. Considering the effect of mood on N400 amplitude, Federmeier, Kirson, Moreno, and Kutas (2001) concluded that in sentences presented in the 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 could elicit larger N400 due to the need for more effort to evaluating them (Imbir, Jurkiewicz, Duda-Golawska, Pastwa, & Żygierewicz, 2018).
Inspired by Greenspan’s (1992) DIR model of first language acquisition, Pishghadam, Tabatabaeyan, and Navari (2013) introduced the concept of emotioncy to highlight the role of sense-induced emotions in language education (Pishghadam, Adamson, & Shayesteh, 2013). 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, Mahmoodzadeh, Naji Meidani, & Shayesteh, 2019). Emotioncy is established as different levels of emotion generated by the recruitment of our senses in understanding different concepts (Pishghadam, Tabatabaeyan et al., 2013). 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 exvolvement (auditory, visual, and kinesthetic emotioncies), and involvement (inner and arch emotioncies)” (Pishghadam, 2016, p. 1). While avolvement deals with a situation in which an individual has no knowledge of something, exvolvement happens when an individual has heard, seen, or touched something, and involvement, that is deepening the experiences of the intended concept (Pishghadam, Mahmoodzadeh et al., 2019), occurs when an individual has experienced (inner) or researched (arch) something (Pishghadam, Baghaei, & Seyednozadi, 2016; Pishghadam, Jajarmi et al., 2016). Figure 1 depicts the hierarchy from avolvement to exvolvement, and involvement with regard to 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, one can make a link among the three major components of emotioncy: frequency, sense, and emotion.

Figure 1

Later, based on the tenets of emotioncy, Pishghadam, Adamson et al. (2013) formulated the emotioncy-based language instruction (the 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 (e.g., Borsipour, 2016; Karami, Pishghadam, & Baghaei, 2019; Pishghadam, Baghaei et al., 2016; Shahian, 2016). In some of them, which are relevant to the purpose of the present study, the role of emotion has been examined (e.g., Borsipour, Pishghadam, & Naji Meidani, 2019; Pishghadam, Zabetipour, & Aminzadeh, 2016). In some other studies, the role of senses in shaping emotioncy has been targeted (e.g., Pishghadam, Shakeeaee, & Rahmani, 2019; Shayesteh, Pishghadam, & Khodaverdi, 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 there is only a neurocognitive study scrutinizing 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 foreign language, which could 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’ brain when they receive a vocabulary item through the EBLI.

2. Materials and Methods

2.1. Participants

Forty volunteers of the present study were selected through convenience sampling from whom 15 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 ($M = 22.39$, $SD = 2.68$). Since
English is considered to be a foreign language in Iran, all participants were EFL learners of intermediate level from Mashhad, a city in northeastern part of Iran, and were graduate and undergraduate university students of different educational fields. They were right-handed, had normal or correct to normal vision, all received some rewards for their participation, all provided a 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 like neurological and psychological diseases. All participants were clearly informed about 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 in Ferdowsi University of Mashhad, the ethical committee of this university verified the experimental procedure.

2.2. Instruments

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

2.2.1. Oxford Quick Placement Test (OPT)

The Oxford Quick Placement Test (OPT) is a language proficiency test which 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 in intermediate level were included in the present study. For the 18 participants of the study, the mean score \( M \) was 37.3, the standard deviation \( SD \) equaled 7.4, and the range score was from 30 (minimum) to 52 (maximum).

2.2.2. 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. Totally, the
participants’ range score could be from 0 to 17. In case of the present study, the volunteers who could score from 10 to 12 were included in the analysis.

2.2.3. 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 has been validated (Mahram, 1993). Cronbach’s alpha has been calculated to check the reliability of both state (.9084) and trait (.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: $M = 32.3$, $SD = 7.3$; trait anxiety: $M = 38.5$, $SD = 8.1$). Moreover, the Cronbach’s alpha equaled .92 for state anxiety and .89 for trait anxiety, respectively.

2.2.4. 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 one in Borsipour (2016). The participants could 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.

2.2.5. 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) that consists of 10 items ($\alpha = .88$). The scores on 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 ($\alpha = .78$). In the present study, the scores of the participants on
FNS had a mean of 32.44 and the standard deviation of 13.6. And, the mean and the standard deviation of the GNS were 25.17 and 9, respectively. Furthermore, the Cronbach alpha coefficient was .917.

2.2.6. 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 that the respondent feels he/she does not have a preference to do the activity with only one hand, both options can be marked. In case of the present study, the participants who had right hand preferences to do the activities were selected.

2.3. Stimulus Material
After selecting the nine target words (concrete nouns with two or three syllables from among fruits, vegetables, and foods), the stimulus material was prepared in the form of a sentence comprehension task. In order to study the emotional target nouns in relation with congruent and incongruent critical words in a context, sentence comprehension was selected for this analysis (Ding, Wang, & Yang, 2016). The sentences were presented applying Psychtoolbox. The task included 108 sentence triplets (324 sentences) plus 108 filler sentences (totally 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. With regard to 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 (totally 108 sentences). For example, “A cranberry is red”. One sentence included a pragmatic incongruity, i.e., it contained a world knowledge violation (totally 108 sentences). For example, “A cranberry is orange”. One sentence had a
semantic incongruity, i.e., it contained word knowledge violation (totally 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 with those of the task sentences. For example, “A panda is a bear”. Moreover, the filler sentences were not included in the final analysis.

2.4. Procedure

At first, nine target words were selected and the sentences of the task were prepared. Then, to test the quality of the stimuli, fifteen volunteers were selected for the pilot study. The target words were taught to them, and after that, they carried out the computer task without EEG recording. Based on the results of the pilot study, the items were reviewed and revised. The 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 only taught by hearing about, looking at, or touching the items. And, the participants heard about, saw, touched, smelled, and searched on the net for almost five minutes about the involved items. The instruction lasted almost 30 minutes.

After the instruction, the EEG cap was placed on the participants’ head 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 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 presented randomly 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 sentences the down button. If they did not know the answer, they were going to let the item pass with no response. After the response time, there was a screen with an eye shape on it lasting for 3000 ms that told the participants to blink if they required (Figure 2).

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

Figure 2

2.5. 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. As per the international 10-20 system, the following sites over the scalp 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 fronto-temporal 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 (EOGs) were recorded by three electrodes above and below the left eye, and to the left canthus.
2.6. EEG Analysis

The EEG data was imported to MATLAB software (version 2015a) and EEG Lab. The EEG data was band-pass filtered between 0.5-60 Hz. The EEG data was rereferenced to the mean of the linked mastoids. Then, poor EEG channels were interpolated. Applying Artifact Subspace Reconstruction (ASR), 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 that 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, exvolved, and involved target words and critical words for all 18 participants was put into analysis (the critical word was only analyzed in 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 run to find the possible significant differences of 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 using the Bonferroni method, and the Greenhouse-Geisser correction of $p$-values was applied.

3. Results

3.1. Behavioral Performance

3.1.1. Response Accuracy
A repeated measures ANOVA was conducted to analyze the effect of emotioncy types (avolvement, exvolvement, and involvement) on the accuracy of responses (RA) to the related items of the task. The results of the ANOVA revealed the significant main effect of the three emotioncy types \[F(2, 34) = 152.18, P = .00, \eta^2_p = .90\]. Pairwise comparison of the main effects showed that the accuracy of responses to the involved items (\(M \pm SD = 97.5 \pm 5.6\)) was significantly higher than the exvolved (\(M \pm SD = 93.6 \pm 6.1, P < .05\)) and the avolved (\(M \pm SD = 31.2 \pm 20.9, P = .00\)) ones; and, the accuracy of responses to the exvolved items was significantly higher than the avolved (\(P = .00\)) ones.

3.1.2. Response Time

To investigate the impact of the three emotioncy types on the response time (RT), a repeated measures ANOVA was used. The results of the statistical analysis demonstrated that the response time differed as a function of the emotioncy types \([F(2, 34) = 14.793, P = .00, \eta^2_p = .46]\). Further, pairwise comparison of the main effects revealed that RT for the items including the avolved (\(M \pm SD = 1.18 \pm .49\)) target words was significantly higher than the exvolved (\(M \pm SD = .90 \pm .24, P < .05\)) and the involved (\(M \pm SD = .84 \pm .23, P = .00\)) ones; and, the difference between RT to the exvolved and the involved items (\(P = .00\)) was significant, too.

3.2. 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 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 (e.g., Herbert et al., 2008; Kissler & Herbert, 2013; Perez-Edgar and Fox, 2003).

3.2.1. 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) = \ldots\])
4.27, $P < .05$, $\eta^2_p = .20]$, and the eleven electrodes [$F(10, 170) = 10.47, P = .00, \eta^2_p = .38]$. On the other hand, the overall ANOVA for emotioncy $\times$ electrode [$F(20, 340) = 1.23, P = .30, \eta^2_p = .07]$ 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 ($M \pm SD = -12.06 \pm .70 \mu V$) and the exvolved ($M \pm SD = -11.66 \pm .74 \mu V, P < .05$) words was significantly different. But, the avolved and the involved ($M \pm SD = -11.76 \pm .73 \mu V, P < .28$), and the exvolved and the involved ($P < 1.00$) target words did not have statistically significant differences. Figure 3 represents the ERP components at the eleven frontal electrodes, the N100 component at Fz channel, and the related barplot.

3.2.2. 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 ($M \pm SD =$ avolvement: $-9.38 \pm .58 \mu V$; exvolvement: $-9.49 \pm .62 \mu V$; involvement: $-9.32 \pm .75 \mu V$) was not significant [$F(2, 34) = .22, P = .70, \eta^2_p = .014]$. Nevertheless, the main effect of the electrode [$F(10, 170) = 5.98, P = .00, \eta^2_p = .26$] was significant. Furthermore, the interaction between emotioncy and electrode [$F(20, 340) = .80, P = .54, \eta^2_p = .04$] was not significant. Figure 4 shows N100 at Fz channel and the barplot for this channel.

Figure 3

Figure 4

3.2.3. 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 ($M \pm SD =$ avolvement: $13.12 \pm .81 \mu V$; exvolvement: $13.30 \pm .82 \mu V$; involvement: $13.16 \pm .77 \mu V$) was not significant
while the main effect of electrode was significant \[ F(10, 170) = 12.25, P = .00, \eta^2_p = .42 \]. Moreover, the overall ANOVA for emotioncy × electrode \[ F(20, 340) = 1.29, P = .28, \eta^2_p = .07 \] did not show a significant effect. The P200 at Fz and the related barplot is depicted in Figure 3.

3.2.4. 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 (M±SD= avolvement: -12.26± .71 µV; exvolvement: -12.06± .79 µV; involvement: -12.00± .79 µV) \[ F(2, 34) = 1.18, P = .31, \eta^2_p = .06 \] was not significant. On the other hand, the eleven electrodes \[ F(10, 170) = 3.56, P < .05, \eta^2_p = .17 \], and the interaction between emotioncy and electrode \[ F(20, 340) = 1.19, P < .05, \eta^2_p = .18 \] 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 \( P<.05 \) target words. Figure 3 represents the N480 ERP component for the three emotioncy types at Cz.

In order to find the relationship between the meaningful channel (i.e., Cz) and the behavioral data, Spearman Correlation Coefficient was used. The results indicated that the association between Cz and RT \( r=.81, p<0.05 \) and Cz and RA \( r=.85, p<0.05 \) was found to be 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 of the target words which were avolved, exvolved, 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, in order to compare the behavior of the sensory N100 component in 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.

4.1. Behavioral Analyses

With regard to behavioral results, the three emotioncy types represented significant differences in 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 in congruence with Shahian (2016) who showed that the learners who have been involved toward the topic had more successful performance on reading comprehension tests. By the same token, Pishghadam, Shayesteh, and Rahmani (2016) highlighted the role of higher emotioncy levels in vocabulary learning and retention. Recognition of emotional words have been studied in the work of Brierley, Medford, Shaw, and David (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 findings of the present study could be corroborated by Zhang et al.’s (2014) and Dresler, Meriau, Heekeren, and van der Meer’s (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 that of the neutral words (nonemotional). Generally, 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. Simply put, including more senses in learning vocabulary items and experiencing higher emotioncy levels (involvement) could cause a type of automaticity to identify the words and could reduce the time required for selecting the correct response. These findings are in line with those of Kissler and Herbert (2013) 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.

In sum, it can be stated that emotioncy (sensory involvement) in case of the present study and the emotion in 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 (e.g., Kissler et al., 2009; Palazova, 2014), or the congruency of vocabulary items (e.g., Wentura, 2000; West, 2003). In other studies, the variable of emotion has been linked to the words regardless of the fact that the intensity of these emotions may be different for different individuals. What the present study dealt with was to place further emphasis on the emotioncy factor and see the extent to which sensory experiences change the emotions for vocabulary items.

4.2. 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 in comparison with the exvolved and the involved ones. However, only the difference between the avolved and the exvolved target words was significant. The less negative amplitude of the exvolved words could be the result of higher emotional levels of the exvolved words in comparison with the avolved ones. Nevertheless, this finding is not in line with that of Herbert et al. (2008) who demonstrated more negative amplitude in response to emotional words in comparison with neutral words. Further evaluation manifested that there was no
significant difference between avolvement and involvement. It can be the case that the ERP modulation for the exvolved words (less negative amplitude) happened as the result of fewer number of senses employed to learn the words that demonstrated a negative aspect of sensory emotion. On the contrary, in case of involvement, all senses were employed to learn the vocabulary item, and in case of avolvement, none of the senses was involved to learn the word. That is to say, there was neither emotioncy for word form nor word meaning (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 number of 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 be able 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 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 were not significant. In essence, the critical words that are at the end of the sentences and did not carry specific emotions could not modulate the N100 component. On the contrary, the sensory emotion attached to the target words through the EBLI could beget the significant difference between avolvement and exvolvement.

4.3. 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. In spite of the fact that P200 modulations are linked to the effects of emotional stimuli in several studies (e.g., Chang, Zhang, Zhang, & Ying Sun, 2018; Kotz & Paulmann, 2011; Lai & Huettig, 2016; Stewart et al., 2010; Zinchenko, Obermeier, Kanske, Schroger, & Kotz, 2017), these effects were not observable 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 could not lead to significantly different attentional levels.

4.4. The N480 Component

Although it is stated that one of the characteristics of N400 is its relatively stable latency (Kutas & Federmeier, 2011), in 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 of learning 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 evolved 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 be different from involvement with the highest level of emosensory involvement, and the smallest amplitude. Being in line 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 more number of senses
involved) that could be traced in the smaller amplitude of N480. Furthermore, due to the direct involvement of senses and pertaining emotions, the episodic memory as the result of experiencing something (Wilson, 2002) may be activated. In consequence, the significant difference between avolvement and involvement could 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). In sum, having its roots in embodied cognition principles (Niedenthal, 2007) that emphasize the connection between sensorimotor activities and language comprehension (Jirak et al., 2010), the outcome of direct sensory involvement as the highest level of the EBLI could 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 for semantic processing. Moreover, there is no significant difference between involvement and exvolvement in N480. Therefore, although the EBLI emphasizes that the inclusion of senses enhances learning of the words (Pishghadam, Adamson, et al., 2013), it seems that more extended teaching session 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.

In sum, 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 findings 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.

**Disclosure statement**
No potential conflict of interest was reported by the authors.

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Figure 1. Emotioncy levels. Adapted from “Emotioncy, Extroversion, and Anxiety in Willingness to Communicate in English,” by R. Pishghadam, 2016, the 5th International Conference on Language, Education, and Innovation. p. 2.

Figure 2. Experimental procedure. 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.

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 emotioncy kinds.

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.
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