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Multisensory Learning and Vocabulary Retention: An Emotiocy-Based Study with the Stroop Task

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Abstract The present study aimed to examine the impact of multisensory learning based on the emotioncy model, namely audio-visual and discovery learning of vocabulary on EFL learners. In doing so, 60 participants were selected from Iranian English learners. To compare the vocabulary knowledge of the instructed words from both behavioral and cognitive aspects, after a two-week interval from the instruction, participants received a vocabulary knowledge test along with a newly-designed e-Stroop task. The obtained results of the two groups disclosed that the interference score in the discovery approach was higher than the one in the audio-visual group implying that the attentional bias increased with higher levels of involved senses and emotioncy. Moreover, the paired sample t-test indicated that there was a significant difference between the obtained mean scores of these two approaches. Finally, the findings of the Chi-square test revealed that discovery learning stimulates positive emotions towards the instructed words in learners.

Keywords: *Multisensory learning, Emotioncy, e-Stroop, Vocabulary Retention, Language education*

1. Introduction

Selective attention is believed to play a primary role in second language learning (Schmitt, 2008; Steele et al., 2012; Truscott & Smith, 2011). Attention is necessary to encode the incoming information into memory, and the quality of the encoded information relies heavily on the quality and quantity of attention (Logan, 1988). As vocabulary learning and, subsequently the retention of the previously acquired lexical items is demanding for foreign language (FL) learners (Nation, 2001), selective attention declines the risk of attending to irrelevant stimuli and enhances the integration of incoming information with prior knowledge (characterized in long-term memory) in the process of vocabulary learning (Schweppe & Rummer, 2014). In this regard, many scholars have paid great concerted attention to the role of selective attention in language learning, specifically vocabulary learning (e.g., Anderson, 2019; Everaert et al., 2013; Vogt et al., 2013).

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Being involved in this cognitive process while learning new vocabulary, FL learners are also required to manage the heavy load of new words and attain a specific vocabulary threshold to be competent language users (Kritikou et al., 2010). As mentioned by Wilkins (1972), without knowing grammar, it is possible to convey very little, but without vocabulary, nothing can be conveyed. In this regard, a myriad of ways and approaches were proposed by several practitioners in the field of SLA over the course of time to provide learners with efficient practice to enhance vocabulary retention (Chiu & Liu, 2013). Some cases included meaning-focused and contextualized vocabulary learning (Baleghizadeh & Shahry, 2011), strategy-based vocabulary learning (Trujillo et al., 2015), retrieval practice of instructed vocabulary items (Karpicke & Roediger, 2008), and employing the multimedia technology (Shi, 2017). Among these, the multisensory approach has recently gained recognition for enacting more senses of language learners (Rains et al., 2008). This idea that teachers need to involve at least three basic senses (auditory, visual, and tactile) during teaching to enhance the learning process is a common thread among researchers (Pitts, 2012). Manifestly, learning through activating all the senses is a prevalent concept and a hot buzzword in pedagogy, which is beneficial in fortifying memory. In this light, the recent findings in the field of brain, diverse pedagogical approaches and, more specifically, multisensory teaching gained neurological support in the rapidly expanding field of cognitive neuroscience (Hamedi & Pishghadam, 2020; Lacey & Lawson, 2013; Pishghadam, Daneshvarfard, et al., 2021; Shams & Seitz, 2008).

So as to add a further dimension to the previous findings on multisensory studies, it is hypothesized that experiential sensory information, along with the vocabulary items toward which the learners were developing emotion, can automatically act on the learners' attentional engagement (captured by RT). Accordingly, the Stroop effect might demonstrate meaningful changes with regard to different sense combinations. Since longer response RT to the Stroop stimuli reflects a higher level of vocabulary retention, it is posited that learners in the discovery approach (complete sensory involvement level) reflect longer RT, compared to those being taught by audio-visual (limited sensory involvement). Considering the scores on a vocabulary test, discovery learners might be expected to outperform their counterparts in the audio-visual learning approach. Regarding learners' emotioncy after instruction, it is proposed that the discovery approach stimulates learners' emotions, whether positive or negative.

2. Theoretical Framework

In the quest for an appropriate method of teaching vocabulary, multisensory learning can facilitate vocabulary learning by attracting learners' attention (Massaro, 2004; Pishghadam, Jajarmi, et al., 2021; Tabatabaee et al., 2020), which provides fertile soil for vocabulary retention and accordingly successful communication. Quak et al. (2015) support the importance of multisensory learning by emphasizing the link between working memory, inner attention, and multisensory processing. This implied that multisensory information requires more attention and accordingly helps later free-recall and retention. Senses as modalities of acquiring new information can affect the quality and richness of sensory inputs learners receive from the environment, meaning that single-sense input may lead to a different memory formation compared to the combination of several senses (Pilehvar et al., 2017). Activating more senses results in learning new information more naturally and efficiently (Hamilton, 2016). It is suggested that information from more sensory modalities entails the undemanding and less internal concentration of the brain during L2 comprehension (Pishghadam, Daneshvarfard, et al., 2021). Therefore, various degrees of sensory enrichment can affect the way new vocabularies are perceived and retained.

Based on the interactive nature of senses and emotions and their influence on cognition and learning, the sensory-oriented model of emotioncy can answer the question of whether the combination of information from different sensory modalities can lead to different levels of vocabulary retention. Introduced by Pishghadam (2015), emotioncy is of six types, namely null, auditory, visual, kinesthetic, inner, and arch (see Figure 1). Emotioncy ranges from avolvement (null) and exvolvement (auditory, visual, and kinesthetic) to involvement (inner and arch). Exvolvement deals with the meaning of a language, whereas involvement has to do with the application (application and reflection) and appropriation. As a matter of fact, exvolvement is related to the linguistic features of language learning, but involvement deals with life concerns and issues. Accordingly, individuals may be avolved (null emotioncy), exvolved (auditory, visual, and kinesthetic emotioncies), or involved (inner and arch emotioncies) toward a particular concept. Pishghadam (2016) went further to explain that it would be possible to store and retrieve data based on the senses through which concepts are experienced in the real world. This means that comprehension is boosted depending on the number of senses that are involved and the quality of sensory experiences, for instance, seeing a real object or a picture of that. Within similar lines, Pishghadam, Adamson, et al. (2013) and Pishghadam, Tabatabaeyan, et al. (2013) considered emotioncy as playing a significant role in better and faster comprehension of words with more emotional weight, compared to words with a lower degree of emotional response. Therefore, since emotioncy deals with the degree of emotional response to words, it could be considered as a yardstick to determine the significance of a word for vocabulary teaching.

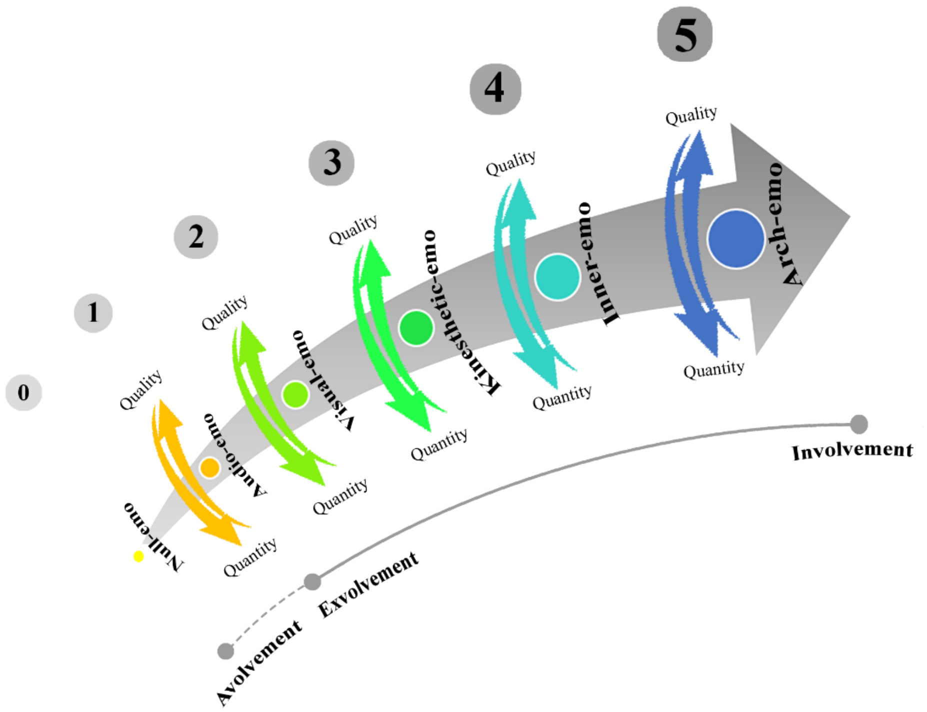

Figure 1

Emotioncy Levels

Note. Reprinted with permission from "Emotioncy, extraversion, and anxiety in willingness to communicate in English", by R. Pishghadam, 2016, Proceedings of the 5th International Conference on Language, Education, and Innovation. London, UK.

In this regard, the Emotional Stroop (e-Stroop task), the modified version of the classic Stoop, can be a good means to examine distraction for emotionally salient stimuli (Williams et al., 1996). The classic Stroop aims to check the degree of learners' selective attention capacity, especially when the Stroop effect occurs; the time the brain bumps into two stimuli opposing each other and has to pick out one of them, there will be a delay in the reaction time, as intentional reaction must first overcome the automatic reaction to give the correct response (Stroop, 1935). The modified version, however, targets not only attention but also response time (RT) to emotion-laden words (Sutton & Altarriba, 2008). Findings from e-Stroop studies disclosed that participants with a higher level of emotional functioning tend to have longer RT to those affective stimuli (e.g., Esmaeili, 2017; Mittershiffthaler, et al., 2008; Salehi & Ziaei, 2010). In fact, the e-Stroop is a prevailing test widely used in experimental and clinical studies since it can record the participants' lexical engagement by producing interference (Ben-Haim et al., 2016). As Williams et al. (1996) put it, an "Emotional Stroop effect" is developed to scrutinize the cognitive processes engaged in disregarding emotional load as well as how these processes fluctuate throughout clinical and non-clinical individuals. Indeed, the delayed ink color detection for affective and emotion-laden words was illuminated in terms of attentional bias (Williams et al., 1996). While attention has a central and vital role in vocabulary learning; therefore, the implementation of the Stroop task, which is attention-based, is admired. It is worth mentioning that the higher RT in saying the color of the instructed words that induce sensory emotions compared with the neutral words signifies the attentional bias and is termed an emotional interference score (McKenna & Sharma, 1995).

With this in mind, the emotional type of Stroop contributes more to the current study since it is an attempt to extend the prior observations and shed more light on multisensory learning by investigating how sense combinations modulate vocabulary learning and retention. So as to provide different degrees of sensory involvement during the experiment session, Pishghadam's (2016) sensory-oriented emotioncy model was implemented. Accordingly, a number of unknown concrete English vocabulary items were instructed through a combination of two (auditory and visual) and five senses (auditory, visual, olfactory, gustatory, and kinesthetic). On this account, the kind of information received from different sensory modalities during instruction may modulate the amount of attention learners pay during retention and comprehension (Hamedi & Pishghadam, 2020; Tsvetkova, 2016; Winskel, 2013). Hence, e-Stroop can be used as a means to gauge selective attention in case learners are subjected to learning vocabularies through the activation of different senses. With this in mind, the question arises whether sensory-oriented emotioncy can lead to different learning experiences through the combination of information from different sensory modalities. This means that combinations of senses act as a prerequisite for comprehension leading to emotional load. For instance, audio-visual assist learners in visualizing the instructed word by enacting both auditory and visual senses (Ashaver & Igyuve, 2013). The discovery learning approach, on the other hand, involves learners directly and individually by activating different senses, such as auditory, visual, smell, taste, and kinesthetic. To provide operational definitions as were used in the current study, audio-visual is indirect sensory involvement, and discovery learning is direct sensory involvement. In particular, the two levels of sensory instruction, including a limited sensory involvement (combination of two senses) and a complete sensory involvement level (combination of more than two senses), were exploited. A noteworthy consideration is that the emotioncy level of the words during the experiment is controlled and regulated. To be more specific, at the limited sensory level, the auditory and visual senses were activated, whereas, at the complete sensory level, all the senses were evoked and followed by independent research as the final level of involvement (last stage of emotioncy level). In this approach, learners directly experience the instructed vocabularies, while in audio-visual learning, learners had an indirect experience. In essence, the current comparative study was to enrich the literature on multisensory learning, vocabulary retention, and the e-Stroop paradigm by measuring the accuracy of vocabulary retention from two complementary perspectives (behavioral and cognitive). Previous studies on emotioncy investigated either the different combinations of senses or through different methods in vocabulary learning and retention (Borsipour, 2016; Karami et al., 2019; Makiabadi et al., 2019), while the present study compared a new set of senses in audio-visual learning approach to discovery learning approach (a movement from exvolvement to involvement). In fact, the chief question is whether the e-Stroop task along a vocabulary test reflects the distinction between various degrees of multisensory input or what we refer to as sensory enrichment in the process of vocabulary learning. This question may stem from the concept that individuals' sensory experiences impact their comprehension (Akbari & Pishghadam, 2022; Naji Meidani et al., 2022; Karami et al., 2019; Pishghadam et al., 2017; Pishghadam et al., in press; Shayesteh et al., 2020). In like vein, embodied cognition theory affirms that senses modify cognition (Adams, 2010; Leitan & Chaffey, 2014).

3. Methodology

3.1. Participants

A total of 70 EFL Iranian learners studying at university, including males (n = 41) and females (n = 29), took part in the pre-tests. After the homogenizing phase, 60 of those participants, 28 females (47%) and 32 males (53%), were recruited in the main experiment, and the other 42 were excluded due to missing data and homogenizing criteria. All the participants were native Persian speakers with an intermediate level of English. Their age ranged from 18 to 28 years (mean age = 20, SD = 1.93) with a working memory score range of 12-13. The participants were all right-handed, with no known language or neurological impairment, and with normal vision. Moreover, none of the participants suffered from color blindness. The participants were selected via convenience sampling among volunteers. It is worth mentioning that the participants took part in the current research based on their willingness to participate and received partial course credits. They were contacted in person by the researchers, who provided them with a thorough explanation of the research procedure. Participants were required to give written informed consent approved by the Ferdowsi University of Mashhad Ethics Committee, Mashhad, Iran, before taking part in the research.

3.2. Materials

3.2.1. Stimulus Materials

3.2.1.1. Target Words

Eight words were presented to the learners during the instruction according to Miller's (1956) "magic 7, plus or minus two" in vocabulary teaching. To come up with the eight null concrete words for the instruction, 90 individuals marked their sensory experiences with the items on the emotioncy scale. In fact, the emotioncy level of the null words is controlled by the emotioncy scale. Of the 17 concrete words, 8 words with which 95% of individuals had no sensory experience were extracted. The words were mangosteen, stevia, physalis, caper, rambutan, chia, nutmeg, and quinoa (Figure 2).

3.2.1.2. Stroop Filler Words

A 32-item emotioncy scale was designed to check participants' familiarity with the words in the list in order to specify the filler words of the Stroop task. The participants were supposed to rate the words based on their emotioncy level toward each item. Relying on the mentioned emotioncy scale, learners had no feeling toward the following words: curtain, ruler, ceiling, hanger, column, faucet, cupboard, and marker. Accordingly, these words were chosen as fillers in the Stroop task.

3.2.2. Pre-experimental Phase Materials

The following five measures were employed in the pre-experimental phase to ensure the homogeneity of participants. Worth mentioning, those participants who did not meet the following criteria of the study were excluded from the experiment.

3.2.2.1. Emotioncy Scale

The emotioncy scale (Borsipour, 2016) was employed to identify the participants' emotioncy level (i.e., null, auditory, visual, kinesthetic, inner, and arch) with the eight target words. The eight words were assumed to be unfamiliar to the participants. Each item measured the individual's familiarity with the words through a six-point Likert scale.

3.2.2.2. Oxford Quick Placement Test

Oxford quick placement test (Allan, 1992) was administered to ensure the homogeneity of the participants in terms of their English language proficiency level. The test was in multiple-choice format, and the allocated time for responding was 30 minutes. Those participants who obtained scores of 30 to 44 were ranked as intermediate learners and remained in the study.

3.2.2.3. The Digit Span subtest of the Wechsler Adult Intelligence Scale III

The digit span subtest of the Wechsler adult intelligence scale III (1981) was used to measure the participants' attentional capacity and temporary storage of information. The digit span measures immediate rote recall, memory span, and reversibility.

3.2.2.4. The Edinburgh Inventory of Handedness

The Edinburgh Inventory of Handedness (Oldfield, 1971) was employed to assess the dominance of a person's right or left hand in everyday activities. The inventory entails 10 questions, and the participants who did more than two of the mentioned activities with their left hand were eliminated from the study.

3.2.2.5. Spielberger's State-Trait Anxiety Inventory

The Spielberger's state-trait anxiety inventory (STAI; Spielberger et al., 1970) measured the participants' traits as well as state anxiety before the vocabulary instruction session. The scale consists of two parts of state and trait anxiety, with 40 items (20 items in each part). The items rating state anxiety are based on a Likert scale ranging from *not at all* to *very much* at four levels, and the items related to trait anxiety range from *almost never* to *almost always* at four levels. Of note, in the current study, the Persian version of the inventory (Mahram, 1993) was utilized to avoid any confusion for the participants. Since learning can be highly affected by anxiety (Horwitz, 1986; MacIntyre & Gardner, 1989), those volunteers who were categorized as low anxious and moderately anxious in both state and trait anxiety were recruited in the present study.

3.2.3. Experimental Phase Materials

3.2.3.1. Test of Emotions after Instruction

The five-point Likert scale of emotions after instruction was employed to measure the participants' emotions toward the newly instructed vocabulary items right after the instruction. In fact, this instrument was used to investigate the type of emotioncy learners gained through their learning experience of the words through which they had no feelings and emotioncies. The participants were scored based on their feelings after exposure to the newly instructed words, ranging from *strongly negative feelings* (1) to *strongly positive feelings* (5).

3.2.4. Post-experimental Materials

3.2.4.1. Vocabulary Knowledge Test

In the experimental phase of the study, VKT was employed to check the behavioral performance of the participants in terms of the knowledge and retention of the instructed null vocabulary items. Considering VKT, an open-ended questionnaire that entailed the eight instructed words, learners were asked to specify as many different features of the instructed words as they could recall. There was no time limit for the participants to complete the test. All of these features were categorized and ranked by the researchers. This test was carried out at the end of the experiment (after two weeks) to specify the behavioral performance of the participants. Later, besides the VKT, another test was administered to participants termed as e-Stroop.

3.2.4.2. Stroop Task

After reviewing the related literature and examining the methodological issues, a computerized version of the modified version of the Stroop task (Stroop, 1935) termed 'e-Stroop', was designed according to the e-Stroop guidelines (Ben- Haim et al., 2016). The designed e-Stroop task aimed to substantiate the cognitive evidence of the EBLI by studying distraction for emotionally salient stimuli (Williams et al., 1996). The face validity and content validity of the employed e-Stroop task were approved by the experts in the Educational Psychology Department of the Ferdowsi University of Mashhad.

3.3. Procedure

The present study was carried out in three phases, namely the pre-experimental phase, the experimental phase, and the post-experimental phase. In fact, in the pre-experimental phase, seven tests were given in order to homogenize the participants. After that, in the experimental phase, participants received audio-visual and sensory-oriented discovery learning instructions in learning the eight null concrete vocabulary items. After a two-week interval, in the post-experimental phase, participants were supposed to answer the VKT accompanied by the e-Stroop task related to those eight instructed vocabularies. When all the participants were homogenized, each learner took part in two tasks. To begin with, the participants attended a session in which the researcher instructed the target words through Pishghadam's (2016) emotioncy model. Of note, the target words were randomly classified into two groups, four audio-visual ones, and four discovery learning items. The null words in the audio-visual group (indirect sensory involvement) were instructed through enacting the auditory and visual senses of the learners by showing pictures, describing, and explaining the item through PowerPoint presentation by the instructor. However, in discovery learning (direct sensory involvement) the null words were taught by activating more senses, such as visual (seeing the real item), auditory (online dictionary), olfactory, gustatory, and kinesthetic through peeling, cutting, smelling, and tasting the object. Moreover, learners were provided with different online sources to do more research about the null instructed words in a 3-minute time. It should be noted the instruction of words to the participants did not follow a specific order, and they were counterbalanced across the participants to avoid any biases. Further, the required time for each teaching approach was approximately 15 minutes. Later, after a two-week time interval, to meet the behavioral aspect of the experiment on the vocabulary knowledge of the instructed words, the same participants were provided with an open-ended VKT in which they were required to write down whatever they could recall about the features and descriptions of the instructed words. Eventually, to substantiate the cognitive evidence of the EBLI, a new version of the e-Stroop task was designed to assess the Response Time (RT) and Response Accuracy (RA) of the instructed null vocabulary items. The instructed words were presented in four different colors, in response to which participants were required to press the pre-defined key of the keyboard as quickly and accurately as possible.

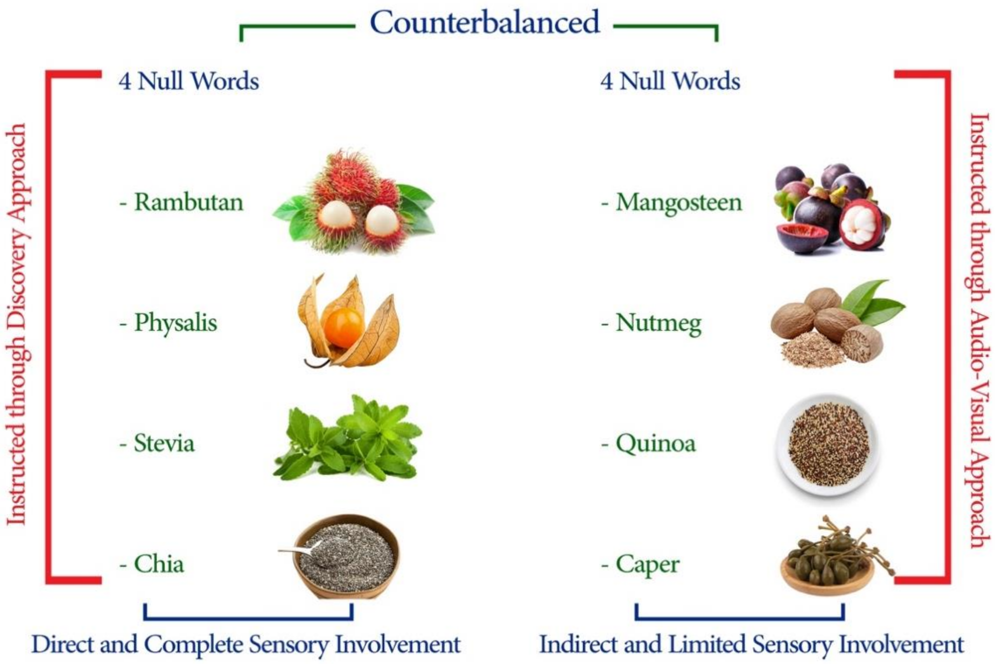

Figure 2
Sample Instruction Design

It should be noted that as the participant pressed the pre-defined key indicating the specific color, he/she saw on the monitor, the following word (a stimulant) was presented. The background of the stimulants was grey (see Figure 3), and between two presentations, a fixed white + appeared for 700 milliseconds for participants to prepare for the next stimulant and 1200 milliseconds of the stimulant followed by the participant's color-naming response (e.g., green, blue, yellow, red). Moreover, it must be noted that participants performed a trial run of the e-Stroop test. Only in this practice phase of the experiment were the participants provided with feedback. That is, when the participant's answer was correct, "True" appeared on the screen; for wrong answers, "False", and finally, for late responses, the word "Late" was displayed. The size and presentation time limit of the color stars were arranged according to the Stroop test's stimuli. Accordingly, SuperLab Pro SDK (Cedrus-Corporation, 1999) was used to run the computerized e-Stroop test. All stimuli were presented via a laptop on 15 inches computer screen that was located about 40 cm away from the participant's eyes. The input device was a standard keyboard with four of its keys marked with color stickers ("Z" for blue, "C" for green, "<" for yellow, and "?" for red).

To gauge the participants' cognitive performance in response to the e-Stroop task, the recorded RTs and RAs of the participants were imported to SPSS software, version 24. Accordingly, the e-Stroop interference score of each approach was calculated and compared. Further, a paired sample t-test was performed to compare the mean RTs of the participants in the two approaches. In order to evaluate the participants' behavioral performance, another paired sample t-test was conducted to find any difference between the mean scores of VKT concerning audio-visual and discovery learning. Finally, to assess the participants' emotions toward the instructed words, the Chi-square test was utilized.

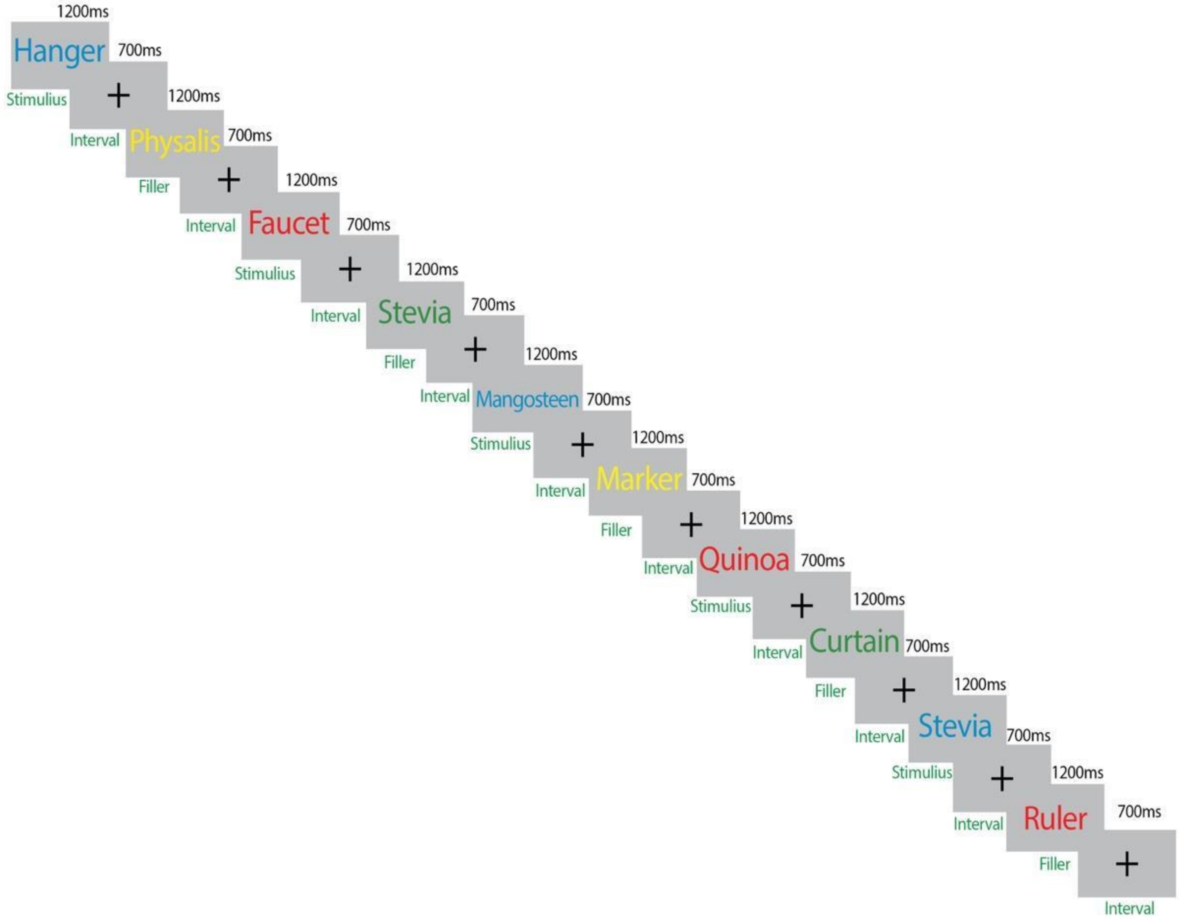

Figure 3
Screen Simulations and Temporal Sequence of the Emotiocy Stroop Task

4. Results

The analysis of the results began by considering the incorrect and no-response responses as errors and counting the correct responses. In addition, RTs less than 300 ms and over 1500 ms were treated as outliers (previous Stroop studies have employed a similar procedure, e.g., Egloff & Hock, 2003; Mohanty et al., 2005; Sutton et al., 2007). After the exclusion of the errors and outlier responses, the interference scores for each of the two groups of stimulants were calculated. The mean values of RT for correct responses to words taught through audio-visual and discovery approaches were 886.04 ms and 931.18 ms, respectively, and the mean reaction time to neutral words was 880.57 ms (see Figure 4). According to Williams et al. (1996), the interference score for each group of stimulants is calculated by subtracting the mean RT of salient stimuli (words instructed through audio-visual and discovery in this study) from the mean RT of neutral stimuli. The interference scores for audio-visual and discovery groups were estimated as 6 ms and 51 ms, respectively. Consequently, the interference score in the discovery approach was higher than in the audio-visual group.

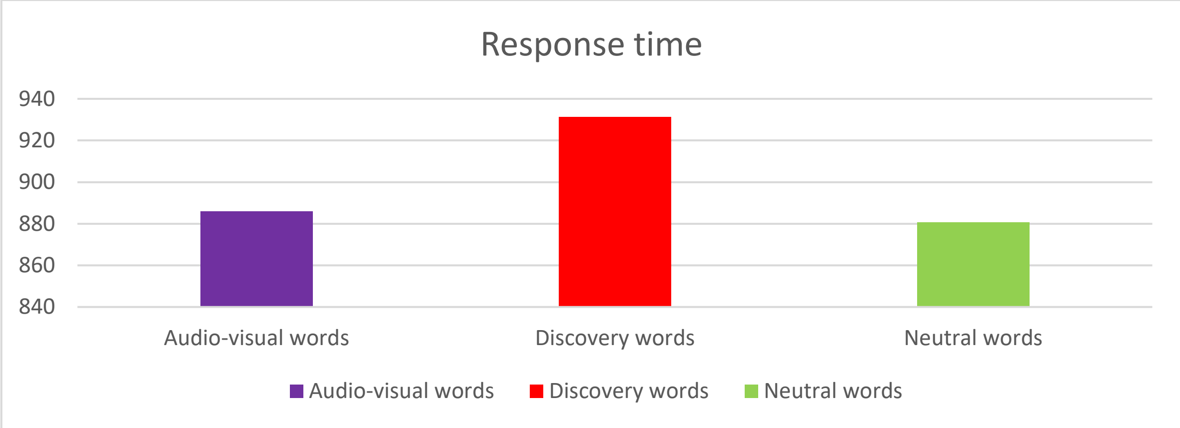

Figure 4
Response Time to Different Types of Words

Table 1 demonstrates the descriptive statistics of the employed approaches of vocabulary learning (audio-visual and discovery). As can be seen, the mean value of RT for words instructed through audio-visual and discovery learning was 886.04 and 931.18, respectively.

Table 1
Descriptive Statistics of RT Regarding the Audio-visual and Discovery Approaches of Vocabulary Learning

	N	Mean	SD	Skewness	Kurtosis
Audio-visual	60	886.04	163.48	0.76	1.63
Discovery	60	931.18	173.84	-0.02	-0.78
Valid N (listwise)	60				

Since all the requirements for normality related to both audio-visual and discovery approaches were satisfied, a paired sample t-test was conducted to find any difference between the RT mean values of audio-visual and discovery learning approaches. The findings indicated that there was a significant difference between the obtained mean RTs of these two approaches ($p< 0.05$).

Table 2
Paired Sample Statistics of RT Regarding the Discovery and Audio-visual Learning Approaches

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Discovery – Audio-visual	45.13	137.21	17.71	9.68	80.58	2.54	59	0.01

As shown in Table 2., the mean RTs of the learners in the discovery approach on the e-Stroop test were significantly higher than those in the audio-visual approach ($p= 0.01$). In fact, the mean increase of RT among learners being taught by the discovery approach was 45.13, with a 95% confidence interval ranging from 9.6 to 80.5. The obtained results suggested that teaching new vocabulary to Iranian EFL learners using the discovery learning approach led to longer RT, compared to the audio-visual learning approach. To be specific, the instructed and emotionalized words entailed in the e-Stroop task attracted the discovery approach learners' attention, so they failed to press the pre-defined keys without ignoring the meaning of the words. Accordingly, discovery learning can cause a higher level of vocabulary retention compared to those being taught through audio-visual.

Table 3 indicates the descriptive statistics of the employed approaches toward learning vocabulary in VKT. As can be seen, the mean scores of audio-visual and discovery learning were 6.18 and 7.20, respectively. To analyze the significance of the differences between these mean scores, inferential statistics were also applied.

Table 3

Descriptive Statistics of the Audio-visual and Discovery Learning Approaches in VKT

	N	Mean	SD	Skewedness	Kurtosis
Audio-visual VKT	60	6.18	1.52	-0.05	-1.53
Discovery VKT	60	7.2	1.03	-0.98	-0.36
Valid N (listwise)	60				

To further the statistical analysis, a paired sample t-test was conducted to find any difference between the mean scores of VKT regarding audio-visual and discovery learning. Consequently, from the obtained results of the paired sample t-test, it was found that there was a significant difference between the mean scores of these two approaches (p = 0.000).

Table 4

Paired Sample Statistics of Audio-visual and Discovery Learning Approaches in VKT

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Discovery – Audio-visual	-1.26	1.37	0.17	-1.62	-0.91	-7.13	59	.000

Table 4 tabulates the paired sample statistics of the VKT of the learners subjected to audio-visual and discovery learning approaches. As shown in Table 4., the mean scores of the learners in VKT were significantly higher than those in the audio-visual learning VKT ($p < 0.05$). In fact, the mean increase of scores among learners being taught by the discovery approach in VKT was -1.26, with a 95% confidence interval ranging from -1.62 to -0.91. Therefore, taking the results of the t-tests analysis into account, it seems that participants in the discovery learning approach outperformed their counterparts in the audio-visual learning approach in VKT.

Finally, the researchers delved into the type of emotions each instruction could develop in learners. In this regard, learners were asked to rate their emotions toward the neural words after the instructions, and then the frequency of their emotions towards the words was counted. To investigate the possibility of any significant difference between the learners' emotioncy after instruction with respect to the teaching approaches, the Chi-square test was used. Table 5 represents the results of the chi-square test of learners' emotioncy toward instructed words after instruction.

Table 5

Distribution of Chi-square Test of the Emotioncy Test After Instruction for Learners Taught by Audio-visual and Discovery Approaches

Score range	Audio-visual			Discovery			Sig.
	Observed N	Expected 48	χ^2	Observed N	Expected N	χ^2	
1	5	48	261.58	10	48	229.79	0.000
2	25	48		18	48		0.000
3	144	48		2	48		
4	49	48		99	48		
5	17	48		111	48		
Total	240			240			

*1: Strongly negative feelings; 2: Negative feelings; 3: No specific feeling; 4: Positive feelings; 5: Strongly positive feelings

As can be seen in Table 5., there is a significant difference between learners' emotioncy towards the instructed words after being taught by an audio-visual approach ($\chi^2 = 261.58$, $p < 0.05$). In other words, learners' neutral emotioncy (no specific emotioncy) was more than expected ($N = 144$) among EFL learners subjected to the audio-visual approach. Those who had positive and strongly positive feelings were 49 and 17 learners, respectively. On the other hand, running the Chi-square for the discovery approach also indicated a significant difference in learners' emotioncy after instruction ($\chi^2 = 229.79$, $p < 0.05$). More notable was the fact that learners with positive and strongly positive emotioncy were more than expected ($N = 99$, $N = 11$, respectively and only two learners (compared to 144 learners in the audio-visual approach) in EFL learners subjected to the discovery approach expressed no specific emotions. Therefore, it can be inferred that discovery learning stimulates learners' emotions, whether positive or negative. In the case of the present study, it provoked positive emotions.

5. Discussion

Vocabulary knowledge is a requisite module of language proficiency, and how words can efficiently be learned is one of the main challenges of language practitioners (Chiu & Liu, 2013; Kritikou et al., 2010). In this regard, neuroscience underscores senses and their aroused emotions as an integral component of cognition and learning which commences several worthy studies regarding the association between emotions, cognition, and learning (Rager, 2009). Considering the fact that sensory-induced emotions accelerate vocabulary learning (Pishghadam, Adamson, et al., 2013), the current study aimed to extend the literature on multisensory learning, specifically EBLI, by providing cognitive and experimental support in assessing the effect of involving different senses in the vocabulary learning process, namely audio-visual and sensory-induced discovery learning on the learners' cognition. To achieve the aims of the current study, a VKT was administered for the behavioral aspect, and e-Stroop was utilized for the cognitive aspect to check the LTM of vocabulary retention.

With respect to the first purpose of the study, which was to investigate the relationship between multisensory learning and attentional bias in vocabulary learning, a new version of the e-Stroop test was designed. In fact, e-Stroop was considered a valid measure of attentional bias and emotional information to evaluate the automated processing associated with emotions (Martin & Thomas, 2011; Sutton et al., 2007). The e-Stroop results obtained from the current study revealed that the learners in the discovery learning approach had a longer reaction time than those in the audio-visual learning approach. In better words, the attentional bias increased with higher levels of involved senses and emotioncy (discovery approach). Simply put, the enhancement of sensory level involvement increased the participants' RT. It possibly means that it was more challenging for discovery learners to ignore the meaning of the words and focus on responding to the ink color. One possible line of explanation may be that since more senses were integrated into the discovery approach and learners had a high level of emotioncy (direct sensory experiment), they enjoyed the more complex network of emotions intermingled with senses and consequently had deeper learning of the instructed words which were stored efficiently in the permanent memory (LTM). Accordingly, the deep and automatic processing of the word's meaning affects the less automatic cognitive process (responding to the ink color) while these two stimuli are taking place at the same time (Eiloa & Havelka, 2011). Indeed, the e-Stroop effect is renowned for its automaticity; that is, the more the interfering effect has happened, the longer it takes for the participant to identify the ink color, and subsequently, more attentional bias has been revealed (Matin & Thomas, 2011). In this respect, the interference score in the discovery approach was higher than in the audio-visual group. This finding was supported by Smith and Briggs Baffoe-Dian (2019), mentioning that e-Stroop interference can be affected by the depth of learning and retention, emphasizing the effect of language learning on the e-Stroop task (Hamedi & Pishghadam, 2020; Paas & Sweller, 2014; Sutton & Altariba, 2008; Winskel, 2013).

Concerning the positive relationship between lexical involvement and visual attentional engagement (captured by RT) findings of the current study disclosed that participants with less emotional interference effect (audio-visual approach in this study) are more expected to respond faster to the affective stimuli (instructed word), compared to more emotional interference effect (discovery approach). In this respect, the results of this study are in line with Bertels et al. (2010), Hamedi and Pishghadam (2020), and Sutton and Altariba (2008) that the emotional content of words could automatically impact the individuals' attention and emotional information. They disclosed that emotion-laden words construct the e-Stroop effect, while neutral words do not. In similar lines, Algom et al. (2009) attested that it took longer for the participants to detect the ink color of the negative words than the neutral words. With respect to EFL, although the present study was one of the first attempts to employ the Stroop paradigm in the language learning context, the findings lent support to Winskel (2013), Sutton et al. (2007), and Eilola and Havelka (2011), who investigated how emotions were represented in the words of Thai-English, Spanish-English, and Greek-English bilinguals, respectively. Their studies affirmed that by increasing levels of language proficiency, responses become more automated, and thereby an e-Stroop effect develops. In addition, the findings are compatible with those of Leroy and Kauchak (2014) and Sheikh and Titone (2013), who posit that word familiarity and sensory information could be considered as an accurate predictor of RTs in lexical decision task which consequently indicates an interplay between sensory experience and linguistic information. More specifically, when the learners are more sensory and emotionally involved with the lexical stimuli, they will inevitably demonstrate slower processing and longer RT to the words (Williams et al., 1996; Winskel, 2013). Therefore, it is justifiable to deduce that full sensory involvement boosts vocabulary learning and retention along with lengthening the RT (Hamedi & Pishghadam, 2020; PishghadamDaneshvarfard, et al., 2021). Noteworthy here is the fact that the e-Stroop task was performed two weeks after the instruction to cognitively assess the learners' delayed retention or LTM of the instructed words, as the primary aim of instruction in vocabulary learning is LTM (Paas & Sweller, 2014).

The second objective of the present study was to gauge the learners' behavioral performance in response to VKT. In fact, the results indicated the superior LTM retention of instructed words in full sensory involvement of the learners in the discovery approach. The results of the paired sample t-test revealed that the mean scores of discovery learners were significantly higher than those in the audio-visual approach. The findings are consistent with those of behavioral studies conducted by Jajarmi and Pishghadam (2019) and Lehmann and Murray (2005), who advocated that sensory experiences enhance learning by accelerating the retrieval of the encoded sensory experiences from the memory. A likely reason for the obtained results could be explained by embodied cognition paradigm, which claims that senses play a critical role in cognition by boosting the retrieval from memory through the interaction between the body and environment (Shapiro, 2011). In particular, activating more sensory channels triggers more brain areas. This might reinforce the instructed words' semantic representation and would result in more memory traces (D'Alesio et al., 2007). In the same vein, Vuilleumier (2005) asserted that selective attention is mediated by processing within the sensory channels. In effect, the learning process is enriched, resulting in longer retention of the information (Willis, 2009). In its very essence, in the multisensory approach, learning through all senses aids the learner to associate the new information with the existing one, and correspondingly they can learn the new words and recall them in future contexts more naturally and efficiently (Griva & Chostelidou, 2014; Hamilton, 2016). In the case of EFL/ESL, Jubran (2012) and Noel et al. (2017) advocated the prominence of utilizing senses in teaching English skills in general and vocabulary learning in particular. Similarly, Smith-Walters (2015), and Webb (2008), in their studies, maintained that employing different senses in the learning process facilitates vocabulary learning even for learners with low proficiency. The current study results provide empirical evidence that full sensory involvement facilitates vocabulary knowledge retrieval, which is, to a great extent, in congruence with those emphasizing the role of involving more senses in learning in general, along with the application of emotioncy to vocabulary teaching in particular. Along similar lines, Pishghadam and Shayesteh (2016) asserted that learners with a higher level of emotioncy recall the instructed words easier and achieve more satisfactory results. Pishghadam et al. (2016) also reported that as learners move from the exvolvement (auditory, visual, and kinesthetic) to involvement (inner and arch) levels of emotioncy, they gain a closer and more similar understanding of reality which leads to a superior comprehension of the concept. Taken together, the obtained results of both cognitive and behavioral methods suggested that learners in the discovery approach outdid their counterparts in the audio-visual approach in vocabulary retention and knowledge.

The third aim of the study was to investigate any significant difference between audio-visual and discovery approaches with respect to the learners' emotioncy after instruction. In this respect, the findings yielded a significant difference between learners' emotioncy after being taught by the two approaches. More specifically, the majority of learners in the audio-visual approach expressed no specific emotion towards the null instructed words; hence, in the discovery approach, all of the learners (except two participants who had no specific emotioncy) stated a kind of emotioncy. Worth mentioning is that the dominant emotioncy was positive feeling towards the instructed words. That is in the discovery approach since the learners are directly involved with the instructed items and all of their senses are activated by experiencing the materials, they would gain a kind of emotion towards them, but in the audio-visual approach, learners indirectly experience the instructed material just by seeing its picture and hearing about its features. In truth, the recent bulk of studies underpins that emotional experiences induced by senses are crucial in the learning process due to the fact that it may affect learners' cognitive processes, such as attention learning, perception, memory, and reasoning, so accelerate the efficient encoding and retrieval of information (Swain, 2013; Tyng et al., 2017). In this light, Thomson et al. (2010) asserted that the learning experience becomes considerably meaningful due to the resultant emotions induced by the senses. Besides, Jajarmi and Pishghadam (2019) support the position that senses may stimulate the evocation of particular emotions, which could shape cognition by leading to superior LTM retention of vocabulary items. Further, the results lent support to Geake (2009), who affirmed that emotionalization induces the learners' brains to release dopamine, the neurohormone, which is known as the happy hormone in the prefrontal cortex of the brain. In fact, dopamine is not only responsible for higher brain functions such as thinking and reasoning but also for our experiencing happiness. In particular, the release of dopamine stimulates the neural firing of brain cells, which results in the augmentation of the learners' motivation and interest along with their selective attention in the process of learning. In accord with Schutz and Pekrun (2007) and Brown and White (2010), who maintained that academic emotions are influential in the learners' academic engagement and accomplishment and advocated the necessity of paying more attention to the learners' emotional involvement throughout the language learning process, the current study signified that learners in discovery approach not only gained positive emotions through the instruction but also outdid their counterparts in audio-visual approach. As Pekrun (2014) mentioned, learning another language is not exclusively cognitive but emotional. In fact, emotions, as an integral part of the learners' identity, modify their individuality along with psychological and physical health. Similarly, the EBLI (Pishghadam, Adamson, et al., 2013) underscores the pivotal role of language learners' sense-induced emotions in enriching their cognitive and intellectual abilities, which proceeds their academic achievement. Further, Tabatabaee et al. (2020) have argued the primary role of activating senses, and the resulting emotions in word comprehension. Their study findings manifested that the learners' emotions variate along with the extent of their sensory experiences toward the instructed vocabulary items. In this regard, Karami et al. (2019) declared that learners who activate fewer senses during the learning process develop distal emotions, which may lead to weak processing of information while those learners who experience complete sensory involvement generate proximal emotions proceeding deeper and superior processing of information. Therefore, with regard to the emotioncy model, teachers are strongly recommended to assume the significant role of emotions in language teaching and learning and advised to simulate authentic situations by enacting learners' different senses (Pishghadam et al., 2017).

Over and above, the findings of the present study underpin the advantages of multisensory and direct sensory involvement and fulfill the main aim of pedagogy which is "the education of the senses" (Montessori & Gutek, 2004). Indeed, the results of the current research extend studies conducted by Baker and Jordan (2015) and Broadbent et al. (2019), who promoted the values of multisensory information over unisensory cues for learning. Further, since vocabulary learning is a common concern in EFL contexts, and the commonly used vocabulary learning strategies did not fulfill the teachers' and learners' needs, the present study aimed to shed extra light by extending the related literature on sensory-induced emotional vocabulary learning employing both behavioral and cognitive means. Moreover, the findings underline the obtained results of studies by Vigliocco et al. (2009) and Kousta et al. (2011), indicating that words are not just embodied in linguistic information, but they can also be represented via emotional and sensorimotor information. To be specific, an individual's experiential sensory information is dependent on both the sensorimotor demonstrations of sensory happenings in the external world and the emotional demonstrations of the states in the individual's inner world (Vigliocco et al., 2009).

In essence, the findings of the present study are of note since they can bridge the gap of lacking an objective measure to evaluate how sense combinations affect vocabulary learning. More importantly, this study explored the interplay between lexical involvement and visual attentional engagement in the process of vocabulary learning. The primary achievement of this study was the design of a newly-developed e-Stroop task which can be employed as a worthy objective measure in vocabulary learning assessments. Moreover, the present study was an attempt toward the impact of two sensory combinations of the emotioncy model on learners' vocabulary knowledge in terms of both behavioral and cognitive means, which adds weight to multisensory learning, emotioncy literature, and the EBLI. Last but not least, as the findings delineated, direct sensory, emotional involvement (emotioncy) supplies not only meaningful and accelerated language learning in general and vocabulary learning in particular but also generates positive feeling and emotions towards the instructed words. Hence, it is strongly recommended that the learners' senses and emotions in the process of language teaching, learning, and testing, along with material development, should be taken into account. In effect, language teachers, supervisors, and material developers who take on a primary role in accelerating language learning for the learners may gain a better insight into being more cautious and creative to supply the educational context by highlighting the learners' direct sensory involvement.

Considering the operational and technical challenges, some suggestions are made for subsequent studies. First and foremost, a larger sample size is suggested to be more representative of the target population. Moreover, the sample participants of this study consisted of adults. Thus, the results could be more enriched by replicating the current study on young children. It should be noted that various sense combinations are possible to be employed, among which only two were chosen in this study. Therefore, complementary experiments can be conducted on different sense combinations and explore the results accordingly. Last but not least, other cognitive measurements, such as eye-tracking along with the e-Stroop task, are recommended to triangulate the data collection to postulate more valid generalizations from the findings.

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