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TITLE:

Investigating the Effects of Emotion on Language Learning Using an Odor-Based Induction Method

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KEYWORDS:

odor, positive emotion, negative emotion, syntactic learning, language learning, emotion induction

SUMMARY:

Here, we present a protocol to measure the effects of emotional conditions on language learning, using an odor-based induction method which places participants in positive or negative emotional states by exposing them to a pleasant or unpleasant odor, and then asks them to perform a language learning task.

ABSTRACT:

Emotion has important influence on language learning. However, the effect of emotion on syntactic learning has been relatively under-researched. Most previous studies used affective pictures, music or videos to induce positive or negative emotions before having participants perform the language learning tasks. The use of these materials is an explicit induction method that might unintentionally alter participants' motivation or result in the problem of demand characteristics. To avoid such procedural artifacts, we adopted an odor-based induction approach to examining the influence of positive and negative emotions on language learning. We found that after the odor-based induction, participants in the positive-emotion group were significantly happier and those in the negative-emotion group were significantly sadder. Compared with participants in the positive emotion condition, those in the negative emotion condition performed more accurately in the assessment task, although no significant difference was found in reaction times. These findings suggest that the protocol is effective in identifying the effect of emotion on language learning. The implications of this experimental paradigm are discussed.

INTRODUCTION:

Language learning is the process of learning a second language through explicit instruction and education. Emotion has profound influence on various cognitive activities such as attention, perception, reasoning, problem solving and memorization. As language learning is a process involving attention, memorization and reasoning, emotion also has a major impact on the process and outcomes of language learning[1]. Most previous studies examined the relationships between learners' emotional conditions and vocabulary memorization or text comprehension[2]. These studies intended to find out whether emotional conditions influenced the memorization or processing of emotional-congruent information. However, there have been only a few attempts to explore the effect of emotion on syntactic learning[3,4,5]. How emotion influences syntactic learning is still an issue that requires further exploration and clarification.

Previous studies of the relationships between emotions and cognitive activities related to languages have adopted a wide variety of methods to place learners in a positive or negative emotional state, including affective pictures, videos, music, autobiographic recall tasks or writing tasks[6–10]. For example, Liu et al.[5] asked participants to listen to affective music and looked at affective pictures to induce positive and negative emotions and rated their emotional states before the language learning task was administered. In most prior studies, participants were required to evaluate affective films or pictures and rate their emotions before language tasks. However, these methods have several procedural artifacts that might affect the validity of the experimental results. First, these induction methods require the effortful processing of the affective materials[11]. Such processing might cause participants to guess the purposes of the experiment, which might result in the problem of demand characteristics[12]. In other words, once participants are aware of the experimental purposes, they might simply pretend to be in the desired emotional conditions to comply with the experimental demands[13]. Second, as the materials used in these tasks such as affective pictures, videos or writing tasks are rich in semantic information, they may interfere with the subsequent language learning tasks. For example, if a picture showing a girl with a smiley face is used to induce positive emotions, the words *face*, *smile* and *girl* will all be activated, and thus retrieved faster in the subsequent language learning process. If a video showing skinny children in tears is used to induce negative emotions, the words related to *children*, *skinny, cry*, *eye* and *tears* might all be pre-activated, facilitating the learning or processing of relevant information. As pictures and videos inevitably contain rich semantic information, the pre-activation of related concepts may result in biases in the outcomes of language learning. Third, the evaluation of emotional stimuli might unintentionally alter participants' motivation or alertness[11], which can cause some participants to perform unusually effortfully or actively. This may result in many confounding variables left uncontrolled such as arousal level, motivation or alertness, making the experimental results difficult to interpret.

In the present research, we adopted an odor-based method to induce emotions. Olfactory stimuli were used to place learners into positive or negative emotional conditions. Compared with other emotion induction approaches such as music or picture induction, the use of odors is a more implicit method to induce emotion[14]. Previous studies have found anatomical evidence showing that the brain structures involved in odor processing such as the amygdala and orbitofrontal cortices[15,16] are also implicated in the processing of emotional information[17-20].

Negoias et al.[21] have revealed that olfactory dysfunction was typically observed in patients with acute depression, which suggests a close connection between olfaction and emotional processing[22,23]. Apart from the anatomical and pathological evidence[14-20], there is also plenty of behavioral evidence which demonstrated that odors in the environments could shape individuals' affective states in an unconscious way[24]. Odors serve as effective affective carriers that modulate individuals' internal affective conditions[11]. Previous studies of emotion induction showed that people exposed to pleasant odors are more prone to have positive emotions, while those exposed to unpleasant odors are more likely to be in a negative emotional condition[25,26]. Odors are regarded as the ideal stimuli to manipulate the emotional state of participants largely because they are highly effective in emotion induction and they require little explicit cognitive involvement[14]. Therefore, odor-based induction methods enable us to investigate the effect of emotion on language learning without having to worry about the potential confounding factors such as motivation and alertness level.

So far, odor-based induction methods have rarely been used to examine the effect of emotion on language learning. Wang et al.[11] investigated the effect of odor-induced emotion on sentence comprehension using event related potentials. However, this study focused on the processing of participants' native language, rather than foreign language learning. Little research has been done to explore how odor-induced emotion may influence the learning of a foreign language. In this study, we intended to adopt an odor-based induction method to examine how learners in different affective states learn a foreign language differently. Compared with other induction methods, the odor-based induction method has the following three advantages. First, learners are less aware of the relationship between odor and language learning, so they are less likely to guess the purpose of the experiment. Second, as odors do not require effortful processing, participants could process them in a passive way, and thus their motivation and alertness levels are kept under control. Finally, the use of olfactory stimuli may reduce the perceptual artifacts resulting from the use of affective pictures or videos. As the olfactory channels activated by odors have no direct association with the processing of visual information, such sensory artifacts can be easily avoided, which can contribute to a more objective assessment of experimental outcomes.

Given the advantages discussed above, the odor-based induction approach might be a more effective method that enables us to identify the effect of emotion on language learning. In this study, we empirically tested the effectiveness of an odor-based induction method in the investigation into the effect of emotion on foreign language learning. The findings can also inform us of how learners in different affective states learn foreign languages differently.

PROTOCOL:

This study was approved by the Ethics Committee of Beijing Foreign Studies University and it was conducted in compliance with the guidelines for experiments with human subjects. Written informed consent was provided by all participants.

1. Preparation of olfactory stimuli

1.1. As this study intends to adopt an odor-based approach to emotion induction, use apple flavor to induce positive emotion and indole to induce negative emotion.

NOTE: Prior literature showed that other smells are also applicable to emotion induction. For example, the smell of orange, strawberry or vanilla can be used to induce positive emotions, and the fish odor can be utilized to induce negative emotions[27].

1.2. Mix 200 mL of propylene glycol with 4 mL of apple flavor in a bottle to create the smell of apple juice (the pleasant smell), and mix 200 mL of propylene glycol with 5 g of indole in another bottle to create the smell of animal dung (unpleasant smell).

NOTE: Odors that are too strong may result in the activation of the related semantic concepts. More research is needed to find out the optimal strength of odors in this type of research.

1.3. Ensure the bottles containing the two types of olfactory stimuli are identical.

1.4. Seal the bottles with stoppers to prevent odor emission.

2. Preparation of language stimuli

2.1. As the study focuses on syntactic learning, use experimental sentences that contain the syntactic rules of a foreign language and lexicon in participants' native language.

NOTE: As the participants in this study were native speakers of Chinese, experimental sentences were created with Chinese words, and the word order of Japanese, a foreign language that the participants had not learned before was used. Sample experimental sentences can be found in **Table 1**.

[Place **Table 1** here]

2.2. Include multiple word-order rules to ensure the comprehensive assessment of learning outcomes. Design at least 30 experimental sentences for each word-order rule, among which 20 sentences will be used in the training phase and 10 sentences will be used in the testing phase.

NOTE: As shown in **Table 1**, four types of structures were used in this study, including such structures as S[SOV]V and SIOV. A total of 128 sentences were developed, with 80 sentences used in the learning phase and 48 used in the testing phase.

2.3. Make sure there is no semantic relation between the two odors and the language stimuli. For example, avoid using the odor-related words such as *smell*, *apple* or *odor* in the experimental sentences.

2.4. Randomize the sentences before presenting them to participants visually on the computer screen. To do this, select the **Selection** tab of the Property Page in the stimulus presentation software (**Table of Materials**) and set the selection method to **Random**.

3. Participant recruitment and preparation for the experiment

3.1. Recruit participants who have no background of the foreign language that will be tested. Ensure participants have self-reported normal sense of smell and normal (or corrected-to-normal) vision.

3.2. Assign the participants into two groups, with each group containing at least 30 members. Make sure the two groups do not differ in years of education and gender ratio. Exclude the participants who report any history of dyslexia.

3.3. Inform the participants that they should be free from exhaustion, hunger, illness or other conditions that make them uncomfortable on the day of the experiment.

3.4. Invite the participants in groups or individually to the laboratory.

4. Procedure

4.1. Invite subjects to the laboratory room and instruct them to sit down at the computer workplaces.

4.2. Present the written informed consent forms to subjects. Instruct them to read and sign the forms.

4.3. Present participants the pencil-and-paper version of the Self-Assessment Manikin (SAM) pictorial rating scale[28,29], and ask them to rate their baseline emotional conditions in terms of valence, arousal and dominance by marking with a pen.

4.4. Expose participants to the olfactory stimuli, using odor dispensers. Ask participants to familiarize themselves with the odor for 10 min. Make sure the length of exposure is the same for the positive-emotion group and the negative-emotion group.

4.5. Ask participants to rate their emotional conditions again using the SAM scale.

4.6. Ask participants to perform the training task.

4.6.1. Ask participants to read the instructions visually presented on the computer screens: “You will learn a new language which contains Chinese words and a new grammar. Next you will see some sentences in this language. Please observe them carefully and try to learn their grammatical structures. Press any key to start when you’re ready.”

4.6.2. Present experimental sentences on the computer screens and have the participants observe the sentences for syntactic regularities.

4.6.3. Present the following written instructions on the computer screen and ask participants to read them carefully: “Next you will see more sentences. Please read them carefully and decide whether they are grammatically correct. Press ‘1’ for grammatically correct sentences and press ‘0’ for incorrect sentences. You will see the correct sentences after your responses. Press any key to proceed to the experimental task.”

4.6.4. Ask the participants to judge the grammatical acceptability of the sentence on the computer screen by pressing a button (‘1’ for grammatical and ‘0’ for ungrammatical) and present feedbacks (‘CORRECT!’ or ‘INCORRECT!’) on the screen after each response. Present the correct structures after the feedbacks to reinforce the effect of learning.

4.6.5. Present the following written message on the computer screen to inform participants that the task is completed: “The learning task is completed!”

4.7. Instruct participants to rate their affective states with the SAM scale after they finish the learning task.

4.8. Ask participants to perform the testing task.

4.8.1. Present the following written instructions on the computer screen for participants to read: “Next you will see more sentences. Please decide whether they are grammatically correct. Press ‘1’ for grammatically correct sentences and press ‘0’ for incorrect sentences. You will have five seconds to respond to each question. Please try to respond as accurately and as quickly as you can. Press any key to start the experiment.”

4.8.2. Ask the participants to judge the grammatical acceptability of the sentence with a button press (‘1’ for grammatical and ‘0’ for ungrammatical).

4.8.3. Present the following message on the screen to inform participants that the experiment is over: “This is the end of the experiment. Thank you for your participation!”

4.9. Ask the participants to fill in the questionnaires about their demographic details such as age, education and gender, and answer a question concerning the possible purpose of the experiment.

4.10. Provide participants monetary compensation or rewards for their participation in the experiment.

REPRESENTATIVE RESULTS:

The results of emotion ratings are summarized in **Figure 1**. Repeated-measures ANOVA was performed with valence ratings as the dependent variable, and group (positive, negative) and

time (before induction, immediately after induction, after learning) as the independent variables. The results showed a significant effect of group, F (1, 58) = 24.71, $p < 0.05$, and a significant interaction effect between group and time, F (1, 58) = 28.56, $p < 0.05$. Further analysis indicated that the effect of group was not significant before the induction. After the induction, the participants in the positive-emotion group scoring significantly higher than those in the negative-emotion group ($p < 0.05$). After they completed the learning task, the effect of group remained significant ($p < 0.05$). The participants were significantly happier after exposure to the pleasant odor, and significantly sadder after exposure to the unpleasant odor ($p < 0.05$). These findings indicate that the odor exposure was effective in placing participants into the sustained positive or negative emotional conditions.

[Place **Figure 1** here]

Another repeated-measures ANOVA was performed with arousal ratings as the dependent variable, and group (positive, negative) and time (before induction, immediately after induction, after learning) as the independent variables. Results showed no significant effect of group, F (1, 58) = 0.31, $p = 0.583$, or time, F (1, 58) = 0.79, $p = 0.453$. The interaction between group and time was not significant either. This suggests that there was no significant difference between the two groups in arousal ratings before induction, after induction or after learning. The level of arousal was not altered by the odor exposure.

After the experiment, participants were required to report their guesses of the experimental purposes. Results showed that none of the participants reported that the experiment intended to explore the relationship between emotion and language learning, although some of them said that the study might be relevant to language learning and some expressed confusion about the purpose of this investigation.

The average accuracy of responses and reaction times by the two groups are presented in **Figure 2**. To examine whether participants in the positive emotion condition and the negative emotion condition performed differently in syntactic learning, we performed an ANOVA with the accuracy of responses as the dependent variable and group (positive, negative) as the independent variable. Results showed a significant effect of group, F (1, 58) = 42.68, $p < 0.05$. The participants in the negative emotional condition had a higher level of accuracy than their positive-emotion counterparts.

[Place **Figure 2** here]

The accuracy of learning by word order and group were shown in Figure 3. To explore whether the observed group difference in accuracy varied with word order, we performed a repeated-measures ANOVA with accuracy as the dependent variable and group and word order as the predictors. Results showed that there was a significant main effect of group, F (1, 58) = 60.1, $p < 0.05$, and a significant main effect of word order, F (1, 58) = 44.52, $p < 0.05$. There was no significant interaction between word order and group ($p = 0.078$). Participants in the positive emotional condition performed worse than those in the negative emotional condition. The

S[SOV]V and SIOV structures were responded less accurately than the SVO and OSV structures. No interaction was found between group and word order, which suggested that the effect of emotion did not vary with the type of word order. Participants in the negative emotion condition performed better in learning all the syntactic rules in the foreign language.

[Place **Figure 3** here]

We performed an ANOVA analysis with reaction times as the dependent variable and group (positive, negative) as the predictor. Results showed that there was no significant group effect (p = 0.342), which suggested that the two groups did not differ significantly in the speed of reaction.

FIGURE AND TABLE LEGENDS:

Figure 1: The valence (left) and arousal (right) emotion ratings of the two groups of participants. Error bars represent the standard error of the data.

Figure 2: The overall average accuracy rates (left) and reaction times (right) of the positive-emotion group and the negative-emotion group. Error bars represent the standard error of the data.

Figure 3: The average accuracy rate for each type of word order in the positive-emotion group and the negative-emotion group. Error bars represent the standard error of the data.

Table 1: Sample experimental sentences used in the present study. (a) The experimental sentence, (b) the transliteration, and (c) its English equivalence. SOV: Subject–Object–Verb; OSV: Object–Subject–Verb; SIOV: Subject–Indirect Object–Object–Verb; S[SOV]V: Subject[Subject–Object–Verb]Verb. The sentences were adapted from our previous study[5].

DISCUSSION:

This study investigated the effect of emotion on the learning of syntactic rules in a foreign language, using an odor-based emotion induction approach. We tested the learning performance in a positive-emotion group and a negative-emotion group. Participants were first exposed to a pleasant odor or an unpleasant odor. Then they were instructed to learn the syntactic rules of a foreign language. Finally, a grammaticality judgment task was administered to assess their learning outcomes. The critical step within this protocol is the exposure of participants to pleasant or unpleasant odor stimuli. Results indicated that positive or negative emotions were successfully induced by pleasant or unpleasant odors with no significant changes in arousal level. Participants in the positive-emotion group were significantly happier after being exposed to the pleasant odor, whereas those in the negative-emotion group were significantly sadder after their exposure to the unpleasant odor. The emotional conditions were sustained throughout the learning phase. This finding showed that the odor-based induction approach was effective in placing participants in the intended emotional condition, a finding which supports Wang et al.[11] that odor is the optimal material in emotion manipulation procedures.

This study found that participants in the negative affective state performed more accurately than their positive-emotion counterparts in learning all syntactic structures. This finding is largely consistent with Liu et al.[5]. This finding can be accounted for by the affect-as-information hypothesis[30], according to which emotion is a kind of information that affects the use of processing strategies. The processing strategies facilitated by positive emotions may not be compatible with those typically used in grammar learning. The finding supports the view concerning the important role of sense-related emotions in learning. Recent studies showed that emotioncy, the emotions invoked by the senses from which inputs are received, is closely associated with learning[31,32]. It should be noted that no significant effect of emotion was found in reaction times, which suggests that the effect of emotion induced by odors might not be as strong as that in previous studies adopting music-based induction approaches. The emotions invoked by different sensory stimuli may not have exactly the same effect on learning. Further research is needed to explore the relationship between learning and emotions communicated through different sensory modalities.

The major limitation of the odor-based induction method is that it is rather difficult to induce neutral emotion with odor stimulus. Therefore, the odor-based method is more applicable to examine the relative effect of emotion on language learning, or the differential effect of positive emotion and negative emotion. However, this protocol is less applicable to the investigation into the absolute effect of emotion on language learning. To explore the absolute effect of emotion (e.g., positive emotion vs. neutral emotion), we need to adopt the traditional induction approaches such as music induction or video induction.

The findings above suggest that the protocol is effective in identifying the effect of emotion on syntactic learning. As odors can easily change mood or emotion[33], they can be used to place participants in the intended emotional condition. Compared with the previous research which has used affective music or pictures in the induction procedures, the use of olfactory stimuli is a more subtle way of emotion manipulation and can prevent participants from trying to interpret the purpose of the experiment. Besides, as odors are less relevant to language learning, the motivation and alertness of participants are less likely to be altered by the emotion manipulation. Therefore, the protocol allowed us to minimize the influence of these confounding variables on the experimental results. Although the odor-evoked emotions are implicit, they could still have significant impact on learning outcomes. Taken together, the present research has provided the evidence showing that the odor-based induction method is a reliable and effective approach to examining learners' individual differences in affective states in foreign language learning.

As this study only examined the use of this protocol in syntactic learning, more research is needed to find out whether it is useful and effective in other aspects of language learning such as vocabulary learning or discourse comprehension. This protocol might be used to investigate the effect of induced emotion on various dimensions of foreign language learning.

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None.

DISCLOSURES:

The authors have nothing to disclose.

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Figure 1

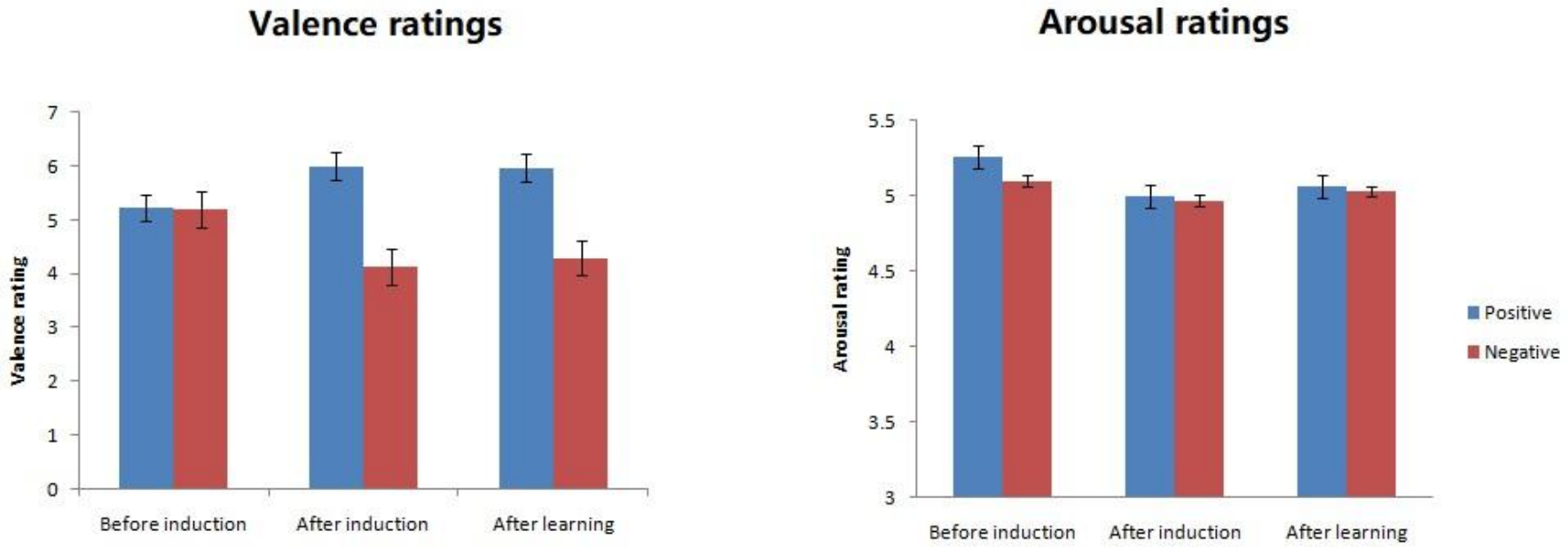

Figure 2

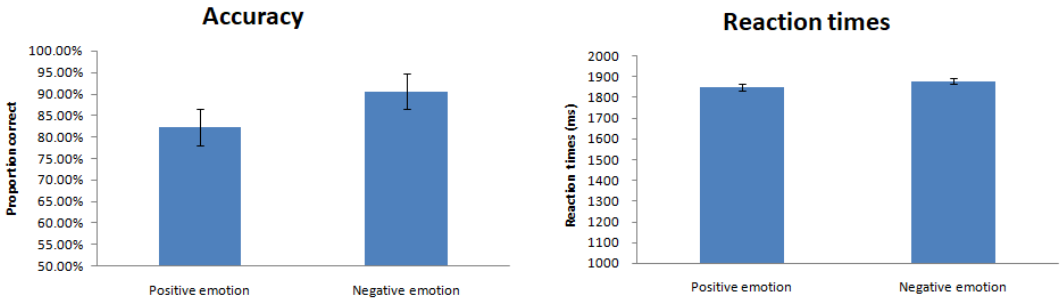

Figure 3

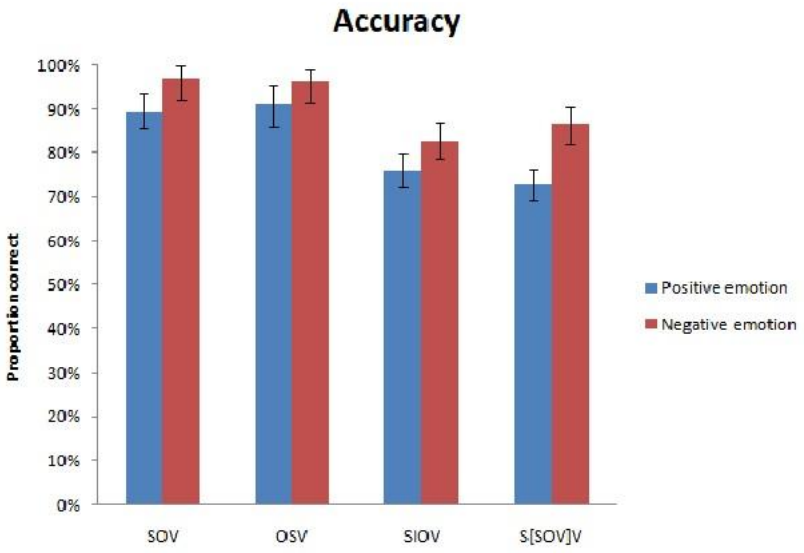

Table 1. Sample experimental sentences used in the present study

Word order	Experimental sentence
SOV	(a). 小偷 钱包 偷走了
	(b). thief wallet stole
	(c). The thief stole the wallet.
OSV	(a).歌曲 演员 演唱了
	(b). song actor sang
	(c). The actor sang a song.
SIOV	(a). 老师 学生 奖牌 颁发了
	(b). teacher student medal granted
	(c). The teacher granted the student a medal.
S[SOV]V	(a). 小明 妈妈 房间 打扫了 说
	(b). Xiaoming mother room cleaned said
	(c). Xiaoming said that his mother cleaned the room.

Name of Material/Equipment	Company	Catalog Number	Comments/Description
Apple flavor	Givaudan	N/A	Used to induce positive emotion
Computers	N/A	N/A	Used to present stimuli and record subjects' responses.
E-prime	PST	2.0.8.22	Stimulus presentation software
Indole	Taida	N/A	Used to induce negative emotion
Self-Assessment Manikin (SAM)	N/A	N/A	Used to assess subjects' affective states. From Lang (19

80).

Dear editor and reviewers,

Thank you for giving us the chance to revise the manuscript. We have followed the reviewers' suggestions to revise the manuscript. All comments have been addressed. Below we listed our responses point by point.

Editorial Comments:

Please take this opportunity to thoroughly proofread the manuscript to ensure that there are no spelling or grammatical errors.

Authors' response: Thank you. We have proofread the manuscript thoroughly and carefully. The spelling and grammatical errors have all been corrected.

Protocol Numbering: Please adjust the numbering of your protocol section to follow JoVE's instructions for authors, 1. should be followed by 1.1. and then 1.1.1. if necessary and all steps should be lined up at the left margin with no indentations.

Authors' response: We have revised the numbering of the protocol. The indentations have all been removed.

• *Discussion: JoVE articles are focused on the methods and the protocol, thus the discussion should be similarly focused. Please ensure that the discussion covers the following in detail and in paragraph form (3-6 paragraphs): 1) modifications and troubleshooting, 2) limitations of the technique, 3) significance with respect to existing methods, 4) future applications and 5) critical steps within the protocol.*

Authors' response: We have reorganized the discussion section to cover the above aspects. We also removed the irrelevant information to make it more focused.

If your figures and tables are original and not published previously or you have already obtained figure permissions, please ignore this comment. If you are re-using figures from a previous publication, you must obtain explicit permission to re-use the figure from the previous publisher (this can be in the form of a letter from an editor or a link to the editorial policies that allows you to re-publish the figure). Please upload the text of the re-print permission (may be copied and pasted from an email/website) as a Word document to the Editorial Manager site in the "Supplemental files (as requested by JoVE)" section. Please also cite the figure appropriately in the figure legend, i.e. "This figure has been modified from [citation]."

Authors' response: None of the figures has been published in other places. This is an entirely new research.

Reviewers' comments:

Reviewer #1:

Manuscript Summary:

This paper describes a mood induction method using odor stimuli and reports the effect of

odor-induced positive and negative moods on foreign language syntactic learning.

Authors' response: Thank you for the summary.

Major Concerns:
I agree with the authors that presenting odor stimuli is an effective and less obtrusive method for mood induction. However, it should heavily depend on the strength or density of the odor. The authors may want to add some discussion on this issue in the protocol section because this is a critical point that the readers want to know more precisely. For example, if an odor is dense enough, it will be easily named and activate the related semantic concepts (i.e., apple and stool in this paper), which the authors want to avoid.

Authors' response: Thank you. In designing the experimental stimuli, we have avoided using the related semantic concepts such as apple, odor or stool. So even if the concepts were activated, it would not affect our experimental effects. In the discussion section, we have added more information to clarify this (line 373-376).

Minor Concerns:
Clarifications are desirable in the following points.
1. Introduction, line 70. I don't think most of the existing mood induction methods require explicit evaluation of the eliciting affective materials. Rather, if one really wants to avoid any biases due to conscious thinking, they should not ask the participants about their mood states explicitly, at least before conducting the experimental task.

Authors' response: The reviewer is correct in pointing out that we should not ask participants about their emotional conditions if we want to prevent them from realizing the purpose of the study. However, if we do not ask participants about their emotional conditions, we cannot know whether the emotion induction is successful or not. If we want to study the effect of emotion, we need to make sure participants are in the intended emotional conditions. In this way, it is still necessary to ask participants to explicitly evaluate their emotional conditions.

2. Line 133. What does "individual differences in affective states" mean here?

Authors' response: It refers to the different emotional states individuals are in when they perform cognitive activities. To make it easier to understand, we have used "learners in different affective states" instead in the revised manuscript.

3. Line 173. What is the rationale of this minimal number of experimental sentences (30)?

Authors' response: The number of experimental items is based on the attentional span of the participants and the previous studies.

4. Line 197. What is the rationale of this minimal number of participants?

Authors' response: The minimal number of participants is based on the previous studies and the results of power analysis.

5. Line 214. Is the dominance scale of the SAM needed? No results are reported here.

Authors' response: The dominance scale was not needed in this study, although it was measured. We did not report the results because it was not relevant to our study.

6. Line 217. Is there any evidence showing that the 10-minutes exposure to an odor is optimal?

Authors' response: There is no specific evidence showing this, but previous studies showed that the exposure to an odor should not exceed 20 minutes, as sensitivity is greatly reduced after constant exposure to an odor for more than 20 min (Herz, 2016).

References:

Herz R. S. (2016). The Role of Odor-Evoked Memory in Psychological and Physiological Health. Brain sciences, 6(3), 22. doi:10.3390/brainsci6030022

7. Line 308 and later. Please explain what the second F value (F2) indicates.

Authors' response: F2 value is to the value of by-item ANOVA analysis.

Reviewer #2:

Manuscript Summary: The present study investigates the role of odor in language learning.

Authors' response: Thank you for the summary.

Major Concerns:

Although the topic is very interesting, there are some changes that need to be done before proceeding to the next step. First of all, the introduction needs to be modified in some parts because it does not stay focused to the intended point. There were some highlighted parts, the reason behind which was not apparent. Moreover, the concept of language learning was not clearly discussed, and it should be elaborated more. The conclusion section needs more elaboration, and more up to date references to new works conducted in the realm of emotions in general, such as mentioning the newly developed concept of emotioncy and olfactory sense in particular, should be added.

Authors' response: Thank you. We have revised the introduction section to highlight the intended point. We have added a definition of the concept "language learning" at the beginning of the introduction to clarify its meaning. We also followed the reviewer's suggestion to add more up-to-date studies regarding the concept of emotioncy and olfactory sense. Specifically, the following references have been added:

1. Pishghadam, R., Jajarmi, H., & Shayesteh, S. Conceptualizing sensory relativism in light of emotioncy: A movement beyond linguistic relativism. *International Journal of Society, Culture*

& Language **4**, (2), 11-21 (2016).
2. Pishghadam, R., & Abbasnejad, H. Emotioncy: a potential measure of readability. *International Electronic Journal of Elementary Education* **9**, (1), 109-123 (2016).

Reviewer #3:

Manuscript Summary:

The authors show how positive and negative odors can change the valence of the feelings experienced by participants and that this can affect subsequent syntactic language learning. This is an interesting paper that goes along previous research published by the same authors.

Authors' response: Thank you for the summary.

Major Concerns:

Methods

This is the most problematic part of the paper. It is very unclear to me what the task is. In Step 2 much more information is needed about the stimuli and how they are presented. And the fact that there is a training and a test phase, which comes out of the blue in point 2. I understand that the format of the journal is especial but it took me a lot to understand what the task is, what is expected of the participants and what do they learn. Which are the four types of word? Why four? The instructions for the task which are explained somehow on Step 3 (this should be step 4, there are two Steps 2). In this Step 3 (procedure) I think it would be helpful to better explain the task. There is a moment in which it is said "6.2 Ask participants to read the instructions visually presented". Which where these instructions for example? And then in point 8 the test phase comes out of the blue but it is not explicit that is a test phase. I really recommend a full reworking of these parts so that the reader can understand what is going on. Also, if they ask for demographics (point 9) at the end of the process, how are the groups selected in advance without this info?

Authors' response: We made the following changes to improve the clarity of the protocol:

1. We provided more information about the stimuli and the way they are presented in step 2. We did not elaborate on how they were presented because Step 2 mainly focused on the preparation of experimental stimuli.
2. We have specified in 4.8 that this step is about the testing phrase.
3. We have specified the four types of word order in Table 1. We also explained the reasons for including four types of word order in 2.2.
4. We have specified the specific content of the instructions in 4.6.2
5. Point 9 is a process to reconfirm the demographic details of the participants. They had already been asked to provide the information before the experiment began.

Discussion:

"This finding can be accounted for by the affect-as information hypothesis28, according to which emotion is a kind of information that affects the use of processing strategies. Individuals in positive affective states are more likely to engage in heuristic processing which relates the incoming information to their existing knowledge. Positive emotion enhances heuristic processing,

resulting in a top-down processing style. Contrarily, negative emotion promotes the analytical processing or a bottom-up processing style29. Individuals in negative emotional conditions are more detail-oriented and tend to learn languages by focusing on detailed information such as syntactic categories and analyzing their relationships. As this study exposed participants to experimental sentences which were independent from prior discursive or sentential contexts, contextual information was not very helpful to master the syntactic rules, and thus participants were more likely to rely on an analytical approach in the learning process."
I find this paragraph very speculative. The authors cite a chapter from a book from 2012 and a trends paper from 2007. Is there more evidence for this interpretation? I think more work is needed here to justify this interpretation of the results.

Authors' response: We agree that the paragraph above is too speculative and there is a lack of sufficient evidence to support the interpretation. Therefore, in the revised manuscript, the statement was removed. The removal of this paragraph also has the benefit of making the discussion section more focused on research methodology.

Minor Concerns:
Intro:
"Second, as the materials used in these tasks such as affective pictures, videos or writing tasks are rich in semantic information. These may interfere with the subsequent language learning tasks." This should be one sentence.

Authors' response: We have corrected it.

"Previous studies have found anatomical evidence showing that the brain structures involved in odor processing such as the amygdala and orbitofrontal cortices are also implicated in the processing of emotional information15-18"
Most of the references here are for neuroimaging of emotional processing but I do not see references for which regions are activated for odor processing. This needs to be completed appropriately

Authors' response: We have added more references to illustrate the amygdala and orbitofrontal cortices are activated for odor processing. Specifically, the following references have been added:

Soudry, Y., Lemogne, C., Malinvaud, D., Consoli, S. M., & Bonfils, P. Olfactory system and emotion: common substrates. *European Annals of Otorhinolaryngology, Head and Neck Diseases* **128**, (1), 18-23 (2011).

Wilson, D. A., Rennaker, R. L. Cortical activity evoked by odors. In *The Neurobiology of Olfaction,* edited by Menini, A., Boca Raton (FL): CRC Press/Taylor & Francis (2010).

Methods
What do the authors mean by "dominance" in Step 3 Procedure point 3?

Authors' response: Dominance is a dimension of emotion, which reflects the extent to which individuals are in control. We did not define this concept in the manuscript because it was not

needed in this study, although it was measured as an essential aspect of the SAM scale.

Results

For the valence ratings the authors show that the odors induce a difference in valence after the induction that stays after learning. But is there a difference, for each group, between pre and post valence ratings. If you do a paired t-test for each group between the baseline valence and the valence after induction, is it significant?

Authors' response: Yes, it is significant. We have run the t test recommended by the reviewer and the results showed that there is a significant difference between the pre and post valence ratings in the positive emotion group and the negative emotion group. So in the Results section, we have stated that "The participants were significantly happier after exposure to the pleasant odor, and significantly sadder after exposure to the unpleasant odor".

Could the authors share some of the guesses that the participants gave for the purpose of the study?

Authors' response: Some participants mentioned that the study might be relevant to language learning, and some said they were very confused about the purpose of this investigation. But none of them reported that the experiment intended to explore the relationship between emotion and language learning.

"Pair-wise comparison showed that the participants in negative affective states performed significantly faster than those in the positive affective states. S[SOV]V and SIOV structures were responded more slowly than SVO and OSV structures." Could the authors provide the p-values for these comparisons?

Authors' response: It is difficult to provide the exact p values here because they are lower than 0.001. The standard practice in statistical reporting is to simply report them as p <.001.

I might be mistaken about this because I am not sure I fully understand the task. But it seems to me that the learning phase involves making judgments for each sentence which are followed by feedback. My guess is that participants use this feedback to get better at doing the task, trial by trial. So, potentially, one could bin the learning phase in, for example, 8 bins (10 sentences per bin) and plot the % of correct responses per bin. Then you could see the learning trajectory of each participant. Where there any differences in the learning curves during the learning phase between groups?

Authors' response: The reviewer's suggestion is enlightening. However, after careful consideration, the authors found that it was not very feasible. This is because the experimental stimuli were four types of sentence structures which differed in structural complexity and difficulty of learning. The structurally more complex sentences were more difficult to learn than the less complex ones, and therefore the accuracy was lower. All these sentences were randomized when presented to each participant. If we bin the learning phase in, the sentences in

each bin are different in structural complexity. So the learning trajectory is different for each participant. The accuracy of learning these structures in each bin is not comparable between participants.

Discussion

"Participants were first exposed a pleasant odor (apple flavor) or an unpleasant odor (indole)"
Typo: to a pleasant

Authors' response: We have corrected it.

How are their results different or similar to when people use music/films before the learning? The authors have a recent paper showing the same effect of negative valence on a different type of learning but do not really comment if the effects are greater/smaller when using odors. What about other works using film/music? Even if it is not the same type of learning, this could really improve the discussion.

Authors' response: Thank you. The effects were smaller than other studies using music/film, especially in the speed of reaction. In the discussion section, we have added the following information:
"It should be noted that no significant effect of emotion was found in reaction times, which suggests that the effect of emotion induced by odors might not be as strong as that in previous studies adopting music-based induction approaches. The emotions invoked by different sensory stimuli may not have exactly the same effect on learning. Further research is needed to explore the relationship between learning and emotions communicated through different sensory modalities."