Examining the Effect of Peppermint on Cognitive Functioning

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ABSTRACT. When odorant molecules enter the nose, they do more than create a sensation of smell. Previous research has documented the influence of odorants on mood, physiology, cognitive functioning, and behaviors. The current study investigated whether and how peppermint, an odor commonly described as alerting, and the expectation of its presence, would affect attention and working memory. Fifty female undergraduate students were randomly assigned to one of three conditions: peppermint (threshold odorant, no expectation), expectation (no odorant, expectation), and control (no odorant, no expectation). Participants completed the Stroop Color-Word Interference Test and memory span assessments while wearing facial masks that either had the odorant applied to them or had no odorant applied in accordance with their condition assignments. We found no significant differences in performance on the Stroop Test and the memory span assessments across all three conditions. We propose that peppermint odorants of higher concentration may be needed to produce enhancing effects on cognitive functioning. The current study contributed to the literature as a pilot study on the topic and posed questions for future researchers.

As the least studied of the five human senses, olfaction plays an important role in our perception of the world and has extensive, but often unnoticed, influence on our behaviors. Goldstein (2010) summarized the function of the olfactory system, saying that odorant molecules come into the nose and stimulate the receptor neurons in the olfactory mucosa, which send signals to the olfactory bulb. Neurons in the olfactory bulb then transmit signals to the priform cortex and the amygdala, and next to the orbitofrontal cortex.

However, the neurons in the orbitofrontal cortex do not always respond in the same manner to a certain odorant molecule. Other factors such as expectation can alter the perception of odorants and neural processing to create olfactory illusions. Herz and von Clef (2001) first demonstrated that the perception of the hedonics of odorants could be significantly affected by the accompanying odor labels. In some cases, the perception of an odorant was inverted by the labels. For example, a 1:1 combination of isovaleric and butyric acid (rated as having a "cheesy" smell by a separate set of observers) was rated neutral when labeled *parmesan cheese* and was rated extremely unpleasant when labeled *vomit*. Morrot, Brochet, and Dubourdieu (2001) found that adding red coloring to white wine led wine tasters to describe the aroma with terms that were usually associated with red wine. Similarly, a test odorant consisting of a mixture of sweat and cheddar cheese was rated more pleasant when it was labeled *cheddar cheese* than when it was labeled *body odor* (de Araujo, Rolls, Velazco, Margot, & Cayeux, 2005). Herz (2003) took a further step. She asked participants to evaluate the pleasantness, safety, and familiarity of eight odorants based on the odorants only, or the odor labels only, or both. The results showed that the ratings of odor hedonics

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were in accordance with the suggestions of the odor labels, whether or not the odorants were present, which demonstrated that verbal context may be more influential than an odorant itself in our olfactory perception. Bulsing and colleagues (2010) observed that an odorant was rated more negatively if it was expected to be irritating. By using electroencephalogram (EEG) to monitor olfactory event-related potentials, they found that the neural processing of the odorant was faster and more intense after participants perceived the odor of H2S with such expectation. The above findings all indicated that olfactory perception is determined by the interaction of the expectation and the chemical properties of the stimulus. Not surprisingly, there has not been an official or generally accepted classification system of odorants in terms of perceived quality and characteristics (Kaeppler & Mueller, 2013).

Researchers have also studied the effect of inhaling odorant stimuli on human behaviors and perception. Rotton (1983) found that participants reported worse moods and a decreased tolerance for frustration in the presence of a malodor. Likewise, in the presence of a pleasant ambient odor, participants reported higher self-efficacy and were more likely to adopt efficient strategies when they were working (Baron, 1990), were more likely to help a stranger in the mall (Baron, 1997), had more pleasurable shopping experience in a mall (Fiore, Yah, & Yoh, 2000), and evaluated the mall environment more positively (Michon, Chebat, & Turley, 2005). Participants also reported improved mood, and lowered anxiety and pain unpleasantness when exposed to painful heat (Villemure, Slotnick, & Bushnell, 2003) and generated narratives of dreams and childhood memory with more positive emotional content (Castellanos, Hudson, Haviland-Jones, & Wilson, 2010).

Some researchers investigated the effect of specific odors on motor behaviors. Raudenbush, Grayhem, Sears, and Wilson (2009) found that participants exposed to peppermint reported higher alertness and lower perceived workload, anxiety, frustration, and fatigue during simulated driving scenarios. Students could perform more push-ups and run faster when exposed to peppermint (Raudenbush et al., 2009). Lavender odor might have powerful effects as well. Sakamoto and colleagues (2012) studied the effect of lavender on preventing fall incidents of elderly adults and found that those who wore a lavender patch fell less often during a 1-year period than those who did not.

Additional evidence has demonstrated that olfactory stimuli could affect cognitive functioning. Bergamot was shown to impair visual vigilance as participants exposed to a bergamot odorant correctly detected fewer targets than those exposed to a peppermint odorant or a nonodorant. Their performance dropped from the first half to the second half of the experiment, which indicated that prolonged exposure to the odorant resulted in larger impairment (Gould & Martin, 2001). Ylang-ylang was associated with impaired memory accuracy and reduced speed of memory (Moss, Hewitt, Moss, & Wesnes, 2008). Martin (1998) observed that EEG theta activity decreased in response to the odor of chocolate in comparison with other odors or nonodor control, which may indicate lower levels of attention. Also using EEG, Diego and coworkers (1998) found that lavender induced drowsiness but led to more accurate and faster math computation of participants. In contrast, rosemary increased alertness and led to faster math computation with no effect on the accuracy. However, in a later study, lavender was linked with impaired working memory and longer response time on memory and attention tasks, and rosemary was shown to enhance the quality of memory though at the cost of speed (Moss, Cook, Wesnes, & Duckett, 2003). The effect of lavender and rosemary odorants on cognition seems inconsistent and needs further research to explain the contradiction.

On the other hand, the research on odors commonly associated with alertness (referred to as *alerting odors* in the rest of the paper) has produced more consistent results. The presence of the unpleasant hydrogen sulfide led to less interference on the Stroop Color-Word Interference Test and shorter response time to word stimuli in incongruent ink (Finkelmeyer et al., 2010). Peppermint was found to enhance memory accuracy based on the performance of participants on Cognitive Drug Research computerized assessment battery (Moss et al., 2008). The inhaling of peppermint also improved dual-task performance when the difficulty level was high (Ho & Spence, 2005). However, Ilmberger and his colleagues (2001) failed to observe the enhancing effect of peppermint on a simple reaction time task. They found no difference in performance of participants exposed to peppermint, jasmine, menthol, ylang-ylang, and cineole with those in the control group.

Decades of research on the interplay of

olfactory experience and human behaviors and cognition has demonstrated the powerful and far-reaching effects of olfactory stimuli. Herz (2009) conducted a literature review on the observed effects of odor on human mood, physiology, cognitive functioning, and behavior, and assessed the validity of the pharmacological hypothesis and the psychological hypothesis in explaining the mechanisms behind the phenomena. The pharmacological hypothesis claims that certain odorants can affect and interact with the central nervous system and/or the endocrine system, and that they exert their influence through their intrinsic pharmacological properties. However, this theory could not account for the results in studies where incongruent labels were provided for olfactory stimuli and participants' experience was in accordance with the labels.

In contrast, the psychological hypothesis proposes that odors exercise their influence through the emotions that people have learned to associate with them, which means the power of odors were endowed by the related emotions and not by their chemical structures. The psychological hypothesis possesses more explanatory power as previous research has shown that the perceived quality of the odors rather than the olfactory stimuli determine the effect on human mood and behaviors (Herz, 2009). Yet, further research is needed to create a more detailed picture of the process and to draw a conclusion.

One goal of this study was to find support for the psychological hypothesis. We noticed that few prior studies examined the effect of illusory odors on cognitive functioning. As Herz (2003) found that the ratings of hedonics were consistent with odor labels even when the odor was not present, we decided to explore whether expectation of the presence of an odor would affect cognitive functioning. The other goal of the study was to investigate the effect of the presence of peppermint odorant and the expectation of the presence of an alerting odorant on attention and working memory. We hypothesized that (a) exposure to peppermint odorant (with no expectation) would enhance attention and working memory, and (b) the expectation of experiencing an alerting odorant (with no actual exposure to such odorant) would enhance attention and working memory.

Method

Pilot Study

A pilot study was conducted to determine the detection threshold of the peppermint odor. Three women with a mean age of 20.67 (*SD* = 0.47) at the College participated in the pilot study. One of them was European American, one Asian, and one African American. Two of them were undergraduate students and one of them was a staff member. These three women were excluded from participating in the subsequent experiment.

The odorant was prepared by diluting the peppermint essential oil (NOW brand) in organic safflower oil (Spectrum Naturals brand). Five different concentrations of the peppermint essential oil were obtained (see Table 1). From each odorant sample, 2.5 ml was put into a 5 ml amber translucent bottle. The bottles were kept sealed except when the odorant was presented to the participants on a trial.

Each of the three participants was tested individually on separate days. They were invited to the laboratory room at 5:00 p.m. When a participant entered the laboratory, she was instructed to read and sign the informed consent and was informed about the general procedures of the study. She was then asked to put on the blindfold and sit at a table across from the researcher. The researcher then presented her with two odorants per trial for a total of 41 trials. On each trial, the peppermint odorant of a particular concentration was paired with pure safflower oil; the participant had to indicate which odorant smelled stronger. Pairs of odorant stimuli were presented in random order. The odorants were presented at the same height as the end of the nose of each participant and about 5 cm away. The researcher presented the odorants of different concentrations in a descending and then an ascending order alternately, starting at a different concentration for each series of trials (see Table 2 for the complete schedule). There was a 10 s gap between each trial and a 30 s gap between each series of trials when the participants smelled the coffee beans. Secundo and Sobel (2006) found that sniffs of coffee between sniffs

TABLE 1

Concentrations of Peppermint Odorant

Concentration Label	A	B	C	D	E	F
Peppermint Essential Oil (grams)	.056	.028	.028	.028	.028	0
Safflower Oil (ml)	25	25	50	75	100	25
Concentration (mg per ml)	2.24	1.12	.56	.37	.28	0

of fragrances preserved the perceived intensity of the fragrances, although sniffs of clean air reduced the perceived intensity. The participants' responses were recorded as "correct" or "incorrect" on each of the trials.

The detection threshold was defined as the concentration at which the stimulus can be detected 50% of the time. In forced-choice scenarios as in the current study, the detection threshold was established by determining the concentration of the peppermint essential oil at which the participants responded correctly 75% of the time because of a correction rate of 50% would be expected by chance (Goldstein, 2010).

Participants answered the question about the presence of the odorant correctly for Concentration A 86.67% of the time, Concentration B 90.48% of the time, Concentration C 87.50% of the time, Concentration D 91.67% of the time, and Concentration E 85.71% of the time. Because the correction rates on all concentrations were above 75%, we decided to use Concentration E in the experiment as it would be the closest to detection threshold.

The Experiment

Participants. A sample of 50 women participated in the experiment, which examined the effect of peppermint odor on attention and working memory. Their average age was 20.08 years (*SD* = 2.17 years). All of the participants were undergraduate students. The participants reported to be European American (22%), African American (34%), Asian (28%), Hispanic (4%), biracial (8%), and other (4%). Sixty-four percent of participants indicated that their native language was English and 36% indicated that their native languages were not English.

Participants in this study were recruited via e-mails and postings on social network website (i.e., Facebook®). Students enrolled in introductory psychology courses were encouraged to participate with course credits as an incentive. Students enrolled in other psychology courses were also encouraged, and some of them were offered extra credit. Participation in the study was voluntary. The study was approved by the institutional review board of the author's college before the recruitment began.

Materials and Measures

The Peppermint Odorant. In the experiment, 100 ml of peppermint odorant of Concentration E was prepared.

The Stroop Color-Word Interference Test. Originally developed by Stroop (1935), the Stroop Test was intended to explain interference and was considered "a hallmark measure of attention" by psychologists (MacLeod, 1991, p. 187). The standard version of the Stroop Test involved naming the colors of color-word stimuli with incompatible ink colors (experimental) and of those in black ink (control). In the original experiment, the stimuli were presented on 10 x 10 stimulus cards, and the response times to the experimental and control card were recorded.

The Stroop Color-Word Interference Test used in this study was a computer program accessible through a CD named "CogLab." It was an individual stimulus version and was the most commonly used variation from the standard version (MacLeod, 1991). Three colors and three words were presented in the test (red, green, and blue). Word stimuli appeared on the computer screen one at a time, and an examinee was instructed to press a key on the keyboard corresponding to the color of the stimulus. The examinee was immediately informed whether the answer was correct. If the answer was wrong, or the response time exceeded 5 s, the trial was discarded and repeated later in the test. The next stimulus appeared after the examinee pressed the space key. There were 30 word stimuli with incompatible ink colors and 15 word stimuli with compatible colors. The average response times to both types of word stimuli was recorded.

The Memory Span Assessment. The memory span assessment was a computer program accessible through the "CogLab" CD. It evaluated the working memory on five different item categories:

TABLE 2

Schedule of the Trials in Pilot Study

1	F	B	12	F	A	22	F	A	32	A	F
2	C	F	13	B	F	23	C	F	33	F	B
3	F	D	14	F	C	24	F	D	34	F	C
4	E	F	15	F	D	25	F	E	35	D	F
5	F	F	16	E	F	26	F	F	36	F	E
6	F	F	17	F	F	27	F	F	37	F	F
7	E	F	18	F	E	28	E	F	38	F	D
8	D	F	19	F	D	29	F	D	39	F	C
9	F	C	20	C	F	30	F	C	40	B	F
10	F	B	21	F	B	31	B	F	41	F	A
11	A	F									

numbers, letters that sound similar, letters that sound different, short words, and long words. The assessment consisted of a series of trials. On each trial, a list of items appeared on the monitor one by one, each lasting 1 s. After the presentation, examinees clicked on the buttons with items on them in the same sequence as they appeared during the presentation. Examinees were informed whether their responses were correct or incorrect right after they finished answering. If an examinee submitted a correct response, the number of items on the list of the next trial of the same item category grew by one. Otherwise, the number decreased by one. The maximum number of items on a trial was nine. Trials of different item categories were blended together. The assessment took at least 15 min to complete. The computer program then reported the maximum length of items that an examinee had submitted a correct response to on a trial for each item category.

The Participant Survey. The survey (see Appendix) was designed for the current study to gather the demographic information of the participants and their subjective experience of the odorant (or expected odorant) during the experiment. The demographics section requested sex, age, primary occupation, ethnicity, and native language of the participants. The olfactory experience section asked the participants to indicate whether they detected an odorant during the experiment, and if yes, whether the odorant was pleasant or unpleasant, and to circle the adjectives that described the odorant from a provided list.

Procedure

The experiment was run at 5:00 p.m. every day for four consecutive weeks. On each day, only one of the three conditions (peppermint, expectation, and control) was administered in order to prevent contamination of the testing environment and the data. The experiment room was about 160 sq ft with six carrels. Each participant was seated at a carrel to prevent observation of other participants during testing. There was an instruction sheet and a laptop in each carrel. Three packets of absorbent charcoal were placed in the room on the first day of the experiment and remained there for all four weeks of the experiment to remove the odor.

TABLE 3

Participants' Performance on Stroop Test by Condition

	Condition	*M*	*SD*	*F*	Sig.
Stroopsame (ms)	Control	763.22	214.73	2.04	.14
	Expectation	871.84	177.43		
	Peppermint	753.55	199.94		
Stroopdiff (ms)	Control	829.03	234.29	1.62	.21
	Expectation	968.75	249.45		
	Peppermint	858.85	240.36		
StroopEffect (ms)	Control	65.81	117.10	0.36	.70
	Expectation	96.91	163.88		
	Peppermint	105.30	101.66		

The participants signed up for a date of experiment at their convenience, and a maximum of six participants were allowed to sign up for one day. Participants were told that they could pick any carrel to sit at when they entered the room. The computer programs for assessment were started before the arrival of participants. When all participants who signed up for a specific day arrived, they were given informed consents to read and sign. After collecting the signed informed consents, the researcher introduced the general purpose and procedures of the experiment. Using an eye dropper, the researcher then placed two drops of the odorant (approximately 0.062 grams) onto the convex part of each facial mask and handed the masks to the participants. Participants were instructed to put on the face mask and to keep it on until they were told to take it off. Participants in the expectation condition were told that there was an alerting odorant on their masks. These participants wore masks with two drops of pure safflower oil on them. In the peppermint condition, participants were told that there may or may not be an odorant on their masks. They wore masks with two drops of peppermint odorant of Concentration E on them. And, in the control condition, participants were again told that there might be an odorant on their masks. Control condition masks had two drops of safflower oil on them.

After receiving the masks, participants were instructed to read the instruction sheet and to start the assessment. The researcher determined which of the two assessment tests participants would take first by flipping a coin before the experiment every day. The memory assessment tasks lasted between 20 min to 30 min, depending on the progress of individual participants.

When the participants completed the assessment, they were told to take off their masks and were handed the participant survey. Upon finishing the survey, the participants were given the debriefing sheet and were thanked and dismissed. In the debriefing sheet, participants in the peppermint and control condition were given more details of the experiment; participants in the expectation condition were informed that there was no odorant on their facial masks and were explained why they were led to believe so initially.

Results

Before testing the hypothesis, we checked the effectiveness of the manipulation. Four out of 14 participants in the control condition (no odorant, no expectation) indicated that they sensed an odor during the experiment, 10 out of 20 participants in the expectation condition (no odorant, expectation), and 11 out of 16 in the peppermint condition (odorant, no expectation) indicated the same. However, a chi-squared test revealed that the difference was not significant, though it was trending toward significance, $\chi^2(2) = 4.97$, $p = .08$.

To examine the hypothesis, we conducted one-way Analysis of Variance (ANOVA) to compare the performance of participants in three conditions on the Stroop Test and the memory span assessment. Table 3 and 4 display the descriptive statistics of participants' performance by condition and the *F* statistics for each measure. In this paper, *Stroopsame* is defined as the average response time for word stimuli with congruent colors, *Stroopdiff* as the average response time for word stimuli with incongruent colors, and *StroopEffect* as the differences between the two.

We observed that participants in the expectation condition tended to respond more slowly than those in the peppermint and control condition although their interference indicated by StroopEffect fell between that of the other two conditions. However, none of the results were significant. We then conducted 2 (whether the odorant was perceived) x 3 (condition) ANOVAs to investigate whether the sensory perception of participants and their experimental condition jointly affected their performance. We found no main effect or interaction of these two independent variables on any of the cognitive measures.

In our sample, there were 18 participants whose native language was not English. Ten of them spoke Chinese, four spoke other Asian languages than Chinese, one spoke Kurdish, one spoke Spanish, and two spoke African languages. In the process of analysis, we noticed a tendency for participants who were not English native speakers to perform better on the Stroop Test and to recall more numbers and letters that sound similar in the memory span assessment than did native speakers of English. To evaluate whether and how native language influenced the performance of participants, we conducted 2 (native language) x 3 (condition) ANOVAs for all cognitive measures. The results showed that native language had a main effect on memory span for numbers, $F(1) = 9.13$, $p = .004$, partial $\eta^2 = .17$, and on memory span for letters that sound similar, $F(1) = 14.64$, $p < .001$, partial $\eta^2 = .24$. Participants who did not speak English as a native language outperformed those who did on the above two tasks. The interaction between native language and condition was approaching significance for memory span for letters that sound similar, $F(2) = 2.76$, $p = .07$, and for StroopEffect, $F(2) = 2.30$, $p = .11$.

Discussion

The current study investigated whether and how an alerting odor would enhance cognitive functioning. Specifically, we examined the effect of the presence of peppermint and the expectation of such presence on attention and working memory. Our hypotheses were that (a) exposure to peppermint odorant (with no expectation) would enhance attention and working memory, and (b) the expectation of experiencing an alerting odorant (with no actual exposure to such odorant) would enhance attention and working memory. Neither of the hypotheses was supported. We found no

TABLE 4

Participants' Performance on Memory Span Assessment by Condition

	Condition	*M*	*SD*	*F*	Sig.
MS for number	Control	7.14	1.61	0.74	.48
	Expectation	6.50	1.54		
	Peppermint	6.88	1.50		
MS for letters that sound different	Control	5.86	1.17	0.09	.92
	Expectation	5.95	1.57		
	Peppermint	5.75	1.39		
MS for letters that sound similar	Control	5.43	1.51	1.56	.22
	Expectation	5.60	0.94		
	Peppermint	4.88	1.36		
MS for short words	Control	5.36	0.84	0.85	.43
	Expectation	5.80	1.24		
	Peppermint	5.38	1.26		
MS for long words	Control	4.50	1.23	0.09	.91
	Expectation	4.60	1.27		
	Peppermint	4.44	0.89		

significant difference in participants' performance on the Stroop Test and memory span assessment of different item categories among the peppermint, the expectation, and the control condition. However, we did find that participants whose native languages were not English outperformed English native speakers on memory span for numbers and for letters that sound similar, across conditions.

Although the enhancing effect of peppermint odorant on cognitive functioning was not observed in the current study, our results did not necessarily contradict findings of prior research. In the previous studies, the peppermint odorants were above threshold (Ho & Spence, 2005; Ilmberger et al., 2001; Moss et al., 2003; Moss et al, 2008) and there was no confusion regarding the presence of the odorants. In the current study, the concentration of peppermint odor was closer to detection threshold, and participants were not sure about the presence of the odorants. We suspect that the relatively low concentration of the odorant in our study might have contributed to the difference in our results compared to those of other studies. Unfortunately, due to the different methods used to deliver the odorants across studies, no quantitative comparison about the amount of odorants administered to a participant in any study can be made.

Another possibility that may explain the discrepancy is that the participants in the current study were not able to effectively perceive the odorant as alerting. Herz (2009) concluded that it is the perceived quality of an odorant that determines its effect. The concentration of an odorant needs to be four times the threshold concentration for people to recognize its quality (Dalton, 2002). However, only two participants in this study perceived the odorants as *alerting*. Therefore, participants might have failed to perceive the alerting quality of peppermint because of its low concentration.

The main effect of native language on the memory span for numbers and letters that sound similar is worth noticing. We propose that the phonetic structure of numbers in different languages may cause the difference in performance. For example, there were 10 Chinese native speakers (20% of the participants) in our sample. In Chinese, all numbers under 10 have only one syllable. It is likely that the Chinese participants were using their native language when memorizing the list of numbers, which may decrease the workload as each number would take up less space in the working memory or facilitate rehearsal as repeating numbers became more efficient. Likewise, the category for letters that sound similar was defined based on the pronunciations of letters in English, so their pronunciations might not be similar to each other in a different language. If non-English native speakers saw these letters in their home languages, they would outperform the native speakers because they essentially completed an easier task of letters that sound different.

The effect of native language on the Stroop interference was not significant. We expected to observe less interference with non-English native speakers because they were assumed to process the English color words less automatically than English native speakers (MacLeod, 1991). The participants' amount of experience with English and their proficiency was not evaluated because it was not the intended focus of the study. Nonetheless, all participants were attending a liberal arts college in the United States and were probably highly proficient with the language. They might have developed similar levels of automaticity of reading English as English native speakers, which could have led to their nondifferential performance on the Stroop interference.

The current study has several implications. This was not the only study where peppermint did not enhance information processing. Ilmberger and colleagues (2001) did not observe an effect on a simple reaction time task with peppermint odorants well above threshold, and they proposed that the strong peppermint odor might be distracting. Because the current study using a relatively low concentration of peppermint did not result in significant enhancement in performance, peppermint may only be an effective enhancer of cognitive functioning under moderate concentrations. Also, we found that participants in the expectation group tended to take longer to respond to Stroop Color-Word Stimuli, although the difference was nonsignificant. We suspect that the expectation of experiencing an alerting odorant may act as a distracter and lead to deteriorated performance. We intended to persuade participants that they were experiencing an alerting odorant with oral instruction. Unfortunately, the manipulation check showed that there were not significantly more participants who reported sensing an odorant in this condition. More elaborate cues than simply verbal labels may be required to produce a realistic experience of the suggested odorants in participants.

The current study added to the literature on the interplay of olfaction and cognitive functioning.

The direction of using expectation instead of actual olfactory stimuli employed in the current study was relatively new and needs more attention. Prior studies have shown that odor labels could alter the perception of the olfactory stimuli (de Araujo et al., 2005; Herz, 2003; Herz & von Clef, 2001; Morrot et al., 2001). Although the expectation of the presence of peppermint did not affect performance in the current study, it was not conclusive. Other manipulation procedures can be used to further explore the role of expectation. Meanwhile, we found a main effect of native language on the performance of two memory span assessments. It pointed to the potential biases of the assessments and called for attention to similar biases in other language-based cognitive assessments.

Limitations to this study are nonetheless worth analyzing. Due to the small size of the college, we were not able to attain a large sample. The small but very heterogeneous sample might have undermined the possibility of finding statistically significant results. Moreover, the memory span assessments we used did not provide good distinction between high and low performers. For example, on the memory span for long words, almost all participants (88%) successfully retained three to five items. This might have prevented finding a meaningful difference in the performance of participants in the different conditions. In addition, 36% of the participants did not speak English as their native language. Some of them might not have fully understood the oral instructions regarding their condition assignments and chose not to ask because it might signify their incompetency with the language. Lastly, most of the Chinese students who participated in the study had a personal relationship with the researcher, which might have affected their perception of the experiment and the level of effort exerted on the assessments. Their uneven representation in each condition (42.86% in the control condition, 10.00% in the expectation condition, and 12.50% in the peppermint condition) might also have led to biased results.

For future work, there are a few directions that researchers may take. They could recruit a large group of participants and apply the same procedures. In the current study, there were many results that were nonsignificant but trending. A large sample often helps clarify the trends. Also, given the fact that the participants in the current study were all women, it would be interesting to see whether men respond differently to the same stimuli and procedures, especially given the documented difference between men and women on the performance of the Stroop Test. Women tend to respond faster to the stimulus than men but there is no evidence on the differential interference between genders (MacLeod, 1991).

On the other hand, researchers may change the method of delivery of peppermint odorants, for example, diffusing peppermint essential oil in the experiment room with a diffuser, attaching a patch saturated with diluted peppermint essential oil to participants' clothes, or using an olfactometer. The method of delivery in the literature has been very inconsistent, which poses a challenge for researchers to effectively compare different studies. A standardized nonintrusive delivery method needs to be developed in order to facilitate research in this field.

Furthermore, it is necessary to use peppermint odorants of different concentrations, which would possibly reveal whether peppermint odor influences attention and working memory, and whether only peppermint odorants of a certain concentration produce an effect. A condition where participants are exposed to peppermint and receive expectation could also be included. Similarly, different assessments on attention and working memory or assessments on other areas of cognitive functioning could be employed to explore what peppermint odor can affect and what it cannot and the mechanism behind the divergence.

In conclusion, the current study contributed to the understanding of the effect of olfactory stimuli and olfactory expectation on cognitive functioning. We found that threshold concentration of peppermint odor did not affect participants' performance on attention and memory span assessments; neither did expectation of an alerting odor. Methodologically, the use of expectation is a direction that needs more attention in the research of olfaction. Therefore, this study explored that direction and presented a potential way of inducing expectation.

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APPENDIX

Participant Survey

1. Lab ID:

2. Sex   Woman   Man

3. Age:

4. Occupation
   a. Undergraduate Student
   b. Graduate Student
   c. Full-time/Part-time Professor
   d. Employees/Staff (General)

5. Ethnicity
   a. White
   b. African-American
   c. Latino/Hispanic
   d. Asian
   e. Native American
   f. Biracial
   g. Other:

6. Your Native Language:

Please answer questions below based on your experience in this experiment.

7. Do you smell any odorant during the experiment?
   a. Yes   b. No

8. If yes, is it a pleasant smell?
   a. Yes   b. No

If yes, please circle all the adjectives that you think describe the odorant:

acrid	alerting	antiseptic	bitter	burning
choking	clean	delicious	floral	fragrant
fresh	hazardous	horrid	irritant	medicinal
musty	natural	new	old	putrid
pungent	rancid	raw	rich	rotten
salty	smoky	soothing	sour	spicy
stale	stinky	strong	sweet	sweaty
uplifting	wild			