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The Effects of Anxiety Induction on Olfactory Function in Healthy Young Adults

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Abstract

There is significant overlap in the neural structures involved in the human limbic (emotion) and olfactory systems, and prior research findings have suggested both positive and negative associations between anxiety and odor detection sensitivity (threshold), odor identification accuracy, and odor hedonic ratings (Havlicek et al., 2012; Krusemark et al., 2013). However, knowledge about whether anxiety causes changes in olfactory perception remains unclear due to limited research findings. The present study aimed to extend the literature on olfaction and state anxiety by investing the impact of an anxiety induction on odor detection sensitivity, odor identification accuracy, and odor hedonic ratings. It was hypothesized that post-induction: 1) Participants in the anxiety induction group would exhibit a significant decrease in post-induction odor detection sensitivity scores, show a significant increase in their post-induction odor identification accuracy scores, would rate odors that are normatively neutral as more unpleasant post-induction. The sample included 46 undergraduate students at a Midwestern university who were assigned to one of two conditions: 1) an anxiety induction paradigm that involved autobiographical recall of a stressful event (N = 22) and a free-form coloring control task (N = 24). Before and after both conditions, participants completed a self-report measure of state and trait anxiety, and underwent assessments of odor detection sensitivity, odor identification, and hedonic response to odor. The anxiety-induction paradigm did not work as predicted; however, results suggest that the free-form coloring control condition significantly reduced state-anxiety scores post-induction. Exploratory analyses revealed that reduced state-anxiety levels in the control group resulted in an increase in an odor identification. No changes were observed for odor detection sensitivity and hedonic ratings. Results suggest that which free-form coloring may have a stress-relieving effect within the young adult population, and further support the presence of olfaction-anxiety interaction. Future research should take care to examine the impact of anxiety-reduction on an individual's odor detection sensitivity and hedonic ratings.

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UNIVERSITY *of* DAYTON

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Introduction

In general, anxiety is characterized as a negative emotional state that consists of both physiological arousal and contextually-dependent cognitions (Spielberger, 1972). Charles Spielberger (1972) divided this emotional phenomenon into two distinct subtypes, which he labeled “state anxiety” and “trait anxiety”. The term state anxiety refers to a transitory negative emotional response to specific stressful, or even threatening, conditions or stimuli. Conversely, the term trait anxiety refers to an individual’s enduring predisposition to respond to certain stimuli or conditions in an anxious manner (Spielberger & Gorsuch, 1983).

Olfaction, the sense of smell, has been shown to significantly interact with aspects of the human emotional experience, as a result of significant structural overlap found to exist between the two neural processing systems (Soudry et al., 2011). Results yielded from several research studies suggest that anxiety has a significant impact on an individual’s olfactory performance and abilities (Havlicek et al., 2012; Krusemark et al., 2013; La Buissonniere Ariza et al., 2013; Takahashi et al., 2015), however research literature on the particular topic is limited. Accordingly, the aim of the present study is to extend the literature on the relationship between olfaction and anxiety by investigating the impact of heightened levels of state anxiety on an individual’s odor detection sensitivity, odor identification accuracy, and odor hedonic ratings within a sample of undergraduate students.

Anxiety

Anxiety is a universal and natural multisystem human response to a perceived threat within an individual's internal or external environment, consisting of intense physiological arousal and contextually-dependent cognitions (Davidson, 2002; Spielberger, 1972). Anxiety has long been distinguished from other unpleasant affective and emotional states, such as fear and worry, based on its unique combination of physiological and behavioral qualities (Freud, 1936, as cited in Spielberger, 1972). Despite its universality, anxiety has proved difficult to define in a clear and concrete manner, due to the fact that the triggers and experiences of anxiety are unique to the individual and circumstance (Endler & Kocovski, 2001; Soudry et al., 2011). To capture the unique qualities of anxiety, Spielberger (1972) proposed a division of sub-clinical presentations of anxiety into two distinct categories: state anxiety and trait anxiety.

State and trait anxiety. According to Spielberger (1972), state anxiety is a temporary emotional condition, characterized by intense unpleasant and apprehensive feelings, in addition to autonomic nervous system arousal, in response to perceived aversive contextual stimuli. Levels of state anxiety may fluctuate over time, and differ across varying environmental contexts (Pinel & Barnes, 2013). Furthermore, this transient experience has the potential to elicit significant emotional, behavioral, physical, and cognitive changes, that can have both short-term and long-term effects on an individual's functioning (Lench et al., 2011).

In contrast, trait anxiety is described as an individual's general tendency to respond anxiously to perceived threats in one's internal or external environment. Characterized as an enduring predisposition, levels of trait anxiety are relatively stable over time (Spielberger, 1972). Research findings suggest that an individual's level of trait anxiety, in combination with present environmental stimuli, is the most critical component in determining an individual's experience of state anxiety (Endler and Kocovski, 2001; Tovilovic et al., 2009).

The neurophysiology of anxiety. The limbic system of the human brain is often referred to as the neural "emotional control center" (Pinel & Barnes, 2013). Neural structures that make up the limbic system function concurrently to process incoming stimuli from the body's external environment, in addition to determining and regulating the bodies internal and external responses to said stimuli (University of Wisconsin, 2006). Numerous cortical and subcortical structures of the limbic system, including the amygdala, the hippocampus, and the orbitofrontal cortex, play a significant role in the individual's experience of negative emotional states, particularly anxiety (Davidson, 2002; Gray, 1978; Soudry et al., 2011).

Human Olfactory Function

Sensory perception marks the beginning of interactions between an organism and its external environment (Krusemark et al., 2013). Although not as advanced nor as heavily relied upon in humans as it is in other mammals, olfaction plays an important role in providing individuals with information that is imperative for effective functioning and interaction with changes within one's environment (Goldstein & Brockmole, 2014). Olfaction impacts human social behavior, mood, and cognition, and has also been demonstrated to interact with the brain's emotional (limbic) and memory systems (Stockhurst & Pietrowsky, 2004).

Peripheral and central order olfactory processing. Primitive cortical areas of the brain are responsible for the unconscious perception of olfactory stimuli, referred to as the peripheral level of olfactory processing, which involves an individual's odor detection sensitivity (Pollatos et al., 2007; Rodriguez-Gil, 2010). Odor detection sensitivity is defined as the lowest odorant concentration at which one can reliably detect and differentiate an odor (Havlicek et al., 2012).

In contrast, neocortical areas of the brain are responsible for conscious odor perception of olfactory stimuli, referred to as the central level of olfactory processing (Pollatos et al., 2007; Rodriguez-Gil, 2010), which involves odor identification and the attribution of emotional value to perceived odorants (odor hedonics) (Gottfried, 2010; Soudry et al., 2011). Odor identification involves the correct verbal labeling of a given odor and is evaluated as such in clinical and experimental settings; odor hedonic evaluation is a measure/rating of the pleasant and unpleasant effects actually experienced by one's exposure to a particular odor (Havlicek et al., 2012).

The neurophysiology of olfactory processing. The olfactory tract serves as the connection between the olfactory bulb and the cerebral hemispheres of the human brain. Each olfactory tract directly projects to several structures of the medial temporal lobes, such as the piriform cortex and the amygdala, collectively referred to as the olfactory cortex. This projection is unique to the olfactory system, as it is the only system that involves direct sensory input to portions of the cerebral cortex without first passing through the thalamus (Gottfried, 2010; Pinel & Barnes, 2013; Stockhurst & Pietrowsky, 2004).

The Neurophysiology of Olfaction-Emotion/Anxiety Interactions

Findings yielded from various neuroimaging studies have identified a significantly high level of functional connectivity existing between the olfactory and emotional (limbic) systems of the brain (Haberly, 2001; Krusemark et al., 2013; Zald & Pardo, 1997), and have further identified specific structures that interact during the perception and neural processing of both olfactory and emotional stimuli (Soudry et al., 2011). As a pervasive emotional state, the structures and systems involved in the human anxiety response also demonstrate significant neurophysiological overlap with the olfactory system (Krusemark et al., 2013; Soudry et al., 2011). These primary neural structures include the orbitofrontal cortex (OFC), the hippocampus, and the amygdala (Carmichael et al., 1994; Davidson, 2002; Haberly, 2001; Zald & Pardo, 1997), all of which play a significant role in unconscious and conscious odor perception (Gottfried, 2010) and the experience of anxiety (Gray, J., 1978) in human beings (Goldstein & Brockmole, 2014).

Olfaction and Emotion

The overlapping neurophysiology of the human olfactory and limbic systems suggests that the experience of intense emotional states (i.e. anxiety) has an impact on an individual’s olfactory perception and capabilities at both the peripheral and central processing levels (Krusemark et al., 2013; Pinel & Barnes, 2013; Soudry et al., 2011). The results of a study examining changes in odor detection reaction time and perceived intensity of pleasant, unpleasant, and neutral odors in a healthy young adult sample indicate that an individual’s emotional state has the potential to affect one’s olfactory perception (Chen & Dalton, 2005). In particular, findings suggest that male participants’ perception of odor intensity is magnified by the experience of certain emotional states, such that males perceive greater odor intensity during the experience of intense emotion than they do during neutral emotional states, suggesting that emotional experiences can augment perceptual experiences. Furthermore, results indicate that neuroticism and anxiety modulate perceived olfactory intensity and reaction times in males, such that men who report high indices of neuroticism or anxiety tend to detect distinctly pleasant or unpleasant odors faster compared to neutral odors. Conclusively, these findings suggest that an individual's emotional state can directly influence olfactory perception, particularly in male young adults (Chen & Dalton, 2005). Additionally, results from another study examining the relationship between emotional stimuli and olfactory function indicate that an individual's odor detection sensitivity significantly decreases following the induction of an intensely negative emotional state. Furthermore, these results demonstrate that hedonic (pleasantness/unpleasantness) and intensity ratings of neutral odors are significantly related to the valence of the presented stimuli, such that, following the presentation of unpleasant stimuli, participants tend to rate odors as significantly less pleasant and more intense compared to baseline ratings. Combining these results suggests that the induction of negative emotional states is significantly associated with a disruption of olfactory perception and ability by means of reduced odor detection sensitivity and a propensity to perceive neutral odors as inherently unpleasant (Pollatos et al., 2007).

Olfaction and Anxiety

In accordance with its categorization as a negative emotional state, anxiety appears to have a significant impact on olfactory perception in human beings.

Findings yielded from a recent study examining the interactions of trait anxiety, operationalized by measured levels of neuroticism, and olfactory performance within a healthy young adult sample suggest that individuals who demonstrate high levels of neuroticism (i.e. trait anxiety) tend to exhibit significantly lower odor detection sensitivity scores and higher odor identification and discrimination accuracy scores than those who demonstrate lower levels of neuroticism (Havlicek et al., 2012). These results suggest that high levels of trait anxiety, a determinant of an individual's state anxiety level, may significantly disrupt unconscious olfactory perception and enhance conscious olfactory perception in healthy young adults. Furthermore, results from another study examining the differences in odor detection reaction times across varying levels of trait anxiety found that individuals who report high levels of trait anxiety tend to yield faster reaction times to odorant stimuli than individuals who report lower levels of trait anxiety, suggesting that a predisposition for high anxiety traits mediates enhanced olfactory performance at the peripheral processing level (La Buissonniere-Ariza et al., 2013).

Research findings yielded from studies focused on the relationship between levels of state anxiety and olfaction are limited. Results from a recent study examining changes in odor detection and recognition across varying levels of both state and trait anxiety demonstrate that participants who report high levels of state and trait anxiety tend to yield significantly higher odor detection sensitivity scores and lower odor identification accuracy scores compared to individuals who report lower levels of state and trait anxiety (Takahashi et al., 2015). Results from another experiment examining the neural mechanisms of anxiety-state-dependent olfactory processing demonstrate that, following anxiety induction, individuals tend to yield significantly lower odor detection sensitivity scores, significantly higher odor identification accuracy scores, and a notable tendency to rate normatively neutral odors as intensely unpleasant compared to baseline measures (Krusemark et al., 2013). These findings suggest that a significant increase in state anxiety levels significantly impacts olfactory perception at both processing levels by precipitating a deficit in one's odor detection sensitivity, an increase in one's ability to accurately identify odors, and a tendency to perceive neutral odorants as unpleasant.

The Present Study

There is significant overlap in the neural systems and structures involved in olfactory perception and the human anxiety response. Findings from several research studies suggest that an increase in an individual's experience of state anxiety may significantly alter their olfactory perception and ability at the peripheral (odor detection sensitivity) and central (odor identification accuracy and hedonic ratings) processing levels (Krusemark et al., 2013; Takashi et al., 2015); however, research literature on this topic remains limited. The present study aims to extend the literature on relations between heightened anxiety and olfactory perception by investigating the effects of anxiety induction on an individual's odor detection sensitivity, odor identification accuracy, and odor hedonic ratings within a sample of college students.

Specifically, the following hypotheses were proposed:

Hypothesis 1. Participants in the anxiety induction group will exhibit a significant decrease in post-induction odor detection sensitivity scores, compared to baseline scores, while odor detection sensitivity scores will remain stable in the control group.

Hypothesis 2. Participants in the anxiety induction group will exhibit a significant increase in their post-induction odor identification accuracy scores, compared to baseline scores, while odor identification accuracy scores will remain stable in the control group.

Hypothesis 3. Participants in the anxiety induction group will rate odors that are normatively neutral as significantly more unpleasant post-induction, while unpleasantness ratings will remain stable in the control group.

Methods

Participants

The sample included 46 male and female undergraduate students from a private Midwestern university who were between the ages of 18 and 22. Students were recruited by the University of Dayton's SONA system and received course credit for their participation. Participants were excluded if they were experiencing nasal congestion due to allergies, illness, or any other reason, due to the potentially impairing effects nasal congestion can have on olfaction.

Measures

State-Trait Anxiety Inventory for Adults. State and trait anxiety levels were measured using the *State-Trait Anxiety Inventory for Adults* (Spielberger & Gorsuch, 1983). The *STAI-AD* is a 40-item self-report measure that produces separate scores for state anxiety (based on self-reported intensity of anxiety symptoms) and trait anxiety (based on self-reported frequency of anxiety symptoms). In college students, test-retest reliability for the *STAI-AD* is excellent for the trait anxiety scale (*r*'s range from .73 to .86), suggesting that the scale is a valid measure of an enduring predisposition. The test-retest reliability for the *STAI-AD* is poor for the state anxiety scale (*r*'s range from .16 to

.62, with a median reliability coefficient of only .33), suggesting that the scale is a valid measure of fluctuating in-the-moment experiences of anxiety (Spielberger & Gorsuch, 1983). In college students, internal consistency is strong for the state anxiety scale (male Cronbach's α =.91; female Cronbach's α =.93) and internal consistency is equally as strong for the trait anxiety scale (male Cronbach's α =.90; female Cronbach's α =.91; (Spielberger & Gorsuch, 1983).

Sniffin' Sticks Odor Detection Sensitivity Test. Odor detection sensitivity, the peripheral level of olfactory processing, was measured using the *Sniffin' Sticks Odor Detection Sensitivity Test* (Burghart Instruments, Wedel, Germany). The test utilizes 48 pen-like odor-dispensing devices, 32 of which are blanks (no odor) and 16 of which contain *n*-butanol (alcohol) at varying concentrations. The test uses a single-staircase forced-choice design in which the test administrator presents odor triplets directly beneath the participant's nostril (two blanks, one with n-butanol), one at a time, in random order, for five seconds each. After each triplet presentation, the participant must choose which stick they believe contains the odor; correct and incorrect identifications are noted. Participants are blindfolded to prevent the visual identification of the odor-containing stick. Construct validity for the *Sniffin' Sticks Odor Detection Sensitivity Test* is moderately high, as preliminary tests aiming to identify which dilution ratio of *n*-butanol (1:2 or 1:3) was best suited for the assessment of olfactory detection sensitivity scores revealed that *n*-butanol concentrations necessary to produce detection sensitivity sensations were in approximately the same range for both sticks and squeeze bottles, and that sticks at a dilution of 1:2 exhibit the largest variation, indicating the greatest sensitivity to detect small differences in performance (Hummel et al., 1997). Test-retest reliability for the *Sniffin' Sticks Odor Detection Sensitivity Test* is strong (r = .92) (Haehner et al., 2009). Furthermore, in healthy populations, internal consistency for the *Sniffin' Sticks Odor Detection Sensitivity Test* is strong (Cronbach's α =.66) (Hummel et al., 1997).

Sniffin' Sticks Extended Identification Test. The ability to accurately identify common odors, the central level of olfactory processing, was assessed using the *Sniffin' Sticks Extended Identification Test* (Burghart Instruments, Wedel, Germany), which includes two sets of pens, each of which utilize 16 (32 in total) pen-like odor-delivering markers containing common odorants (e.g. orange, peppermint, rose, fish, etc.). Each odor-delivering pen is presented directly beneath the participant's nose, one at a time. After each marker presentation, the participant must first choose one of four possible choices for the name of the odorant, presented by the experimenter verbally, and then rate the pleasantness and unpleasantness of each odor by using two separate five-point Likert hedonic scales. The pleasantness scale ranged from 1 (not pleasant), to 5 (extremely pleasant); similarly, the unpleasantness scale ranged from 1 (not unpleasant), to 5 (extremely unpleasant). Construct validity for the *Sniffin' Sticks Extended Identification Test* is moderately high, as only odorants that had an identification rate of greater than or equal to eighty percent were included in the test (Hummel et al., 1997). Test-retest reliability for the *Sniffin' Sticks Extended Identification Test* is strong (r = .88) (Haehner et al. 2009). Internal consistency for the odor identification component of the test is strong (*Cronbach's* α = . 67), and internal consistency for the hedonics component of the test is also strong (*Cronbach's* α = .79) (Hummel et al., 1997).

Procedure

Prior to the experiment, participants were randomly assigned to either the experimental group or the control group. At the beginning of the study, participants were read and asked to sign a form of informed consent, followed by the completion of a demographic questionnaire consisting of questions about the individual's age (Doty & Kamath, 2001), sex (Larsson et al., 2000), race, smoking habits (Katotomichelakis et al., 2007), and, if the participant was female, menstrual cycle and hormonal contraceptive use (Doty & Cameron, 2009; Purdon et al., 2001), as all are factors that have been identified as having a significant effect on an individual's olfactory performance. Participants then completed the state and trait anxiety forms of the *STAI-AD*, followed by the assessment of odor detection sensitivity, odor identification accuracy, and odor hedonic ratings.

Following the completion of the baseline anxiety and olfactory measures, participants were given a set of instructions contingent upon their group membership assignment. Participants assigned to the experimental group were instructed to think about the time they felt most anxious, stressed, or fearful, and then write about it on a blank sheet of paper for exactly five minutes, with the assurance of confidentiality. This task has been shown to significantly increase state anxiety levels measured by the *STAI-AD* (Curry & Kassser, 2005). Conversely, participants assigned to the control group were instructed to color on a blank sheet of paper using five colored pencils (red, orange, yellow, green, blue, and purple) for exactly five minutes. This free-form coloring task has been demonstrated to have no significant effect on state anxiety levels measured by the *STAI-AD* (Curry and Kasser, 2005), and therefore served to maintain the state anxiety scores derived from the control participants from baseline to post-induction measurement.

Following the completion of either the anxiety induction task or control filler task, post-induction anxiety and olfactory measures were collected for the second time, utilizing a counterbalancing method to prevent potential order effects. At the conclusion of the experiment, participants were given copies of the debriefing and informed consent forms and granted research participation credit.

Results

Preliminary Analyses

IBM SPSS 23.0 statistical software was utilized for data analysis. First, kurtosis and skewness of all variables was examined and indicated that none of the variables measured exceeded the acceptable ranges; therefore, all variables were determined to be normally distributed. Each variable was also examined for outliers; results indicated that one participant's post-induction state anxiety score was greater than three standard deviations from the mean and determined to be an outlier. This participant's data was excluded in further data analysis.

Descriptive demographic data for the experimental group (N = 22) and for the control group (N = 24) are shown in Table 1. Analyses of the demographic data indicated that the groups did not significantly differ in sex, X^2 (2, N = 46) = 2.102, p = .147, age, $t(44)$ = -1.333, p = .182, or race/ethnicity, $X^2(6, N = 46)$ = 6.683, p = .351.

Table 1.

Demographic Characteristics by Group Membership

Characteristic	Control Group n	Control Group %	Experimental Group n	Experimental Group %
Sex				
Male	8	33.30	12	54.54
Female	16	66.70	10	45.45
Race/Ethnicity[a]				
American Indian / Alaskan Native	1	4.20	0	0.00
Asian / Asian American	0	0.00	2	9.09
Black / African American	1	4.20	14	63.63
Hawaiian / Other Pacific Islander	1	4.20	2	9.09
Hispanic / Latino	0	0.00	1	4.54
Non-Hispanic White	19	79.20	3	13.64
Other	2	8.30	0	0.00

Characteristic	Control Group n	Control Group *M*	Control Group *SD*	Experimental Group n	Experimental Group *M*	Experimental Group *SD*
Age	24	19.13	1.19	22	18.73	0.77

Note. [a]Percentage totals exceed 100 because of rounding.

A manipulation check was conducted to determine whether the anxiety induction task effectively produced a significant increase in post-induction state anxiety scores within the experimental group. A two (pre, post state anxiety) by two (experimental, control groups) repeated-measures analysis of covariance (ANCOVA), controlling for baseline trait anxiety, was used to determine whether or not state anxiety significantly increased in the experimental group post-induction. Table 2 displays the means and standard deviations for baseline and post-induction state anxiety scores by group membership. The groups did not differ significantly in baseline state anxiety scores, $t(44) = -.013$, $p = .989$. However, results indicated that there was a significant group by state anxiety interaction, Wilks' Lambda = .879, $F(1, 42) = 5.805$, $p = .020$, partial $\eta2= .121$. Within the control group, mean post-induction state anxiety scores significantly decreased compared to baseline scores, Wilks' Lambda = .881, $F(1, 42) = 5.664$, $p = .022$, partial $\eta2= .119$. Significant changes were not observed in the experimental group ($p = .271$), indicating that the anxiety induction paradigm was ineffective; therefore, the initial experimental hypotheses could not be tested. Instead, exploratory analyses were conducted to see if the significant reduction in post-induction state anxiety scores seen in the control group would have the opposite effect of what was predicted to occur in the experimental group.

Table 2.

Mean Baseline and Post-Induction State Anxiety Scores in Two Experimental Conditions

	Control Group			Experimental Group		
	n	*M*	*SD*	n	*M*	*SD*
Baseline	24	34.13	9.30	22	34.38	7.80
Post-Induction	24	30.13	8.56	22	36.38	10.55

Odor Detection Sensitivity Scores

A two (pre, post odor detection sensitivity scores) by two (experimental, control groups) repeated-measures ANCOVA, controlling for baseline trait anxiety, was used to determine whether or not mean odor detection sensitivity scores increased significantly in the control group post-induction. Table 3 displays the means and standard deviations for odor detection sensitivity baseline and post-test scores by group membership. The groups did not differ significantly in baseline mean odor detection sensitivity scores, $t(44) = 1.536$, $p = .132$. Results indicated that there was not a significant group by odor detection sensitivity interaction, Wilks' Lambda = .970, $F(1, 42) = 1.307$, $p = .259$, partial $\eta 2 = .030$.

Table 3.

Mean Baseline and Post-Induction Odor Detection Sensitivity Scores in Two Experimental Conditions

	Control Group			Experimental Group		
	n	*M*	*SD*	*n*	*M*	*SD*
Baseline	24	6.20	1.91	22	7.05	1.97
Post-Induction	24	5.73	2.18	22	5.91	2.11

Odor Identification Accuracy

A two (pre, post odor identification accuracy scores) by two (experimental, control groups) repeated-measures ANCOVA, controlling for baseline trait anxiety, was used to determine whether or not mean odor identification accuracy scores decreased significantly in the control group post-induction. Table 4 displays the means and standard deviations for odor identification accuracy baseline and post-test scores by group membership. The groups did not differ significantly in baseline odor identification accuracy scores, $t(43) = 1.387$, $p = .173$. Results indicated that there was a significant group by odor identification accuracy effect, Wilks' Lambda = .719, $F(1, 42) = 16.396$, $p = .0002$, partial $\eta 2 = .281$. Within the control group, odor identification accuracy scores significantly differed from baseline to post-induction, such that odor identification accuracy scores significantly increased from baseline to post-induction, Wilks' Lambda = .786, $F(1, 42) = 11.446$, $p = .0016$, partial $\eta 2 = .214$. Within the experimental group, post-induction odor identification accuracy scores significantly decreased from baseline scores, Wilks' Lambda = .875, $F(1, 42) = 6.002$, $p = .0185$, partial $\eta 2 = .125$.

Table 4.

Mean Baseline and Post-Induction Odor Identification Accuracy Scores in Two Experimental Conditions

	Control Group			Experimental Group		
	n	*M*	*SD*	*n*	*M*	*SD*
Baseline	24	10.96	1.39	22	11.57	1.57
Post-Induction	24	11.95	1.43	22	10.81	1.91

Odor Hedonics

A two (pre, post neutral odor unpleasantness ratings) by two (experimental, control groups) repeated-measures ANCOVA, controlling for baseline trait-anxiety, was used to determine whether or not unpleasantness ratings decreased for normatively neutral odors in the control group. Table 5 displays the means and standard deviations for odor hedonic baseline and post-test scores by group membership. The groups did not differ significantly in baseline unpleasantness ratings for normatively neutral odors, $t(29) = -1.687$, $p = .102$. Results indicated that there was no significant group by unpleasantness rating interaction for normatively neutral odors effect, Wilk's Lambda = .992, $F(1, 42) = .167$, $p = .685$, partial η2 = .004.

Table 5.

Mean Baseline and Post-Induction Odor Unpleasantness Ratings in Two Experimental Conditions

	Control Group			Experimental Group		
	n	*M*	*SD*	n	*M*	*SD*
Baseline	24	4.33	2.30	22	5.81	3.31
Post-Induction	24	4.29	3.16	22	5.52	3.63

Discussion

The present experiment aimed to test whether anxiety induction significantly alters an individual's odor detection sensitivity, odor identification accuracy, and odor hedonic ratings. Preliminary analyses results indicate that state anxiety scores did not significantly increase post-induction within the experimental group, but did indicate that state anxiety scores significantly decreased within the control group following the free-form coloring task. The results of exploratory analyses examining the effects of this anxiety reduction on the control group's olfactory perception indicate that reducing an individual's experience of state anxiety significantly increases odor identification accuracy.

The experimental and the control groups did not significantly differ in terms of age, sex, and race, thereby eliminating the possibility of confounding effects from each respective variable (Doty & Cameron, 2009; Doty & Kamath, 2014). Additionally, both groups did not differ significantly in baseline state anxiety scores, odor detection sensitivity scores, odor identification accuracy scores, and odor hedonic ratings, eliminating the possibility that group differences within those measures significantly affected post-induction outcomes.

Unfortunately, it was impossible to test the initial experimental hypotheses due to the fact that the results of the statistical analysis revealed that the anxiety induction paradigm used was unsuccessful in producing a significant increase in state anxiety scores within the experimental group. The ineffectiveness of the anxiety induction paradigm used is contradictory to several research findings. Findings from a study examining the effects of mandala coloring on state anxiety, measured by the *STAI-AD*, demonstrate that instructing participants to think about a time that they were most fearful and write about it for four minutes on a piece of blank paper was effective in inducing anxiety, such that the task successfully produced a significant increase in state anxiety scores from baseline to post-induction measurement (Curry & Kosser, 2005). Findings yielded from more recent meta-analyses of anxiety-induction methods emphasize the advantages of a lack of specific cognitive content and a reliance on real events that elicit intense emotion when using autobiographical recall to induce anxiety (Lench et al., 2011; Pennebaker & Chung, 2007). Conversely, meta-analyses also identified significant disadvantages in using autobiographical recall to induce anxiety, of which include the possibility that writing about a past emotional events may lessen the intensity of the emotional reaction to the event (Pennebaker & Chung, 2007), and that autobiographical recall methods are only effective if the participant is willing to engage in the recollection (Lench et al., 2011). These disadvantages may have contributed to the ineffectiveness of the induction paradigm utilized by the present study.

Surprisingly, results indicated that the free-form coloring control task had a significant effect on post-induction state-anxiety scores, such that it lowered state-anxiety levels in control participants. This finding is inconsistent with those yielded from a previous study, which found that free-form coloring did not precipitate a significant change in state anxiety scores, due to the lack of structure and direction provided by the task (Curry & Kosser, 2005). The anxiety-reducing effects of the free-form coloring task in the present study suggest that the activity may in fact have a stress-reducing effect on individuals, at least within the college population. The present finding is also supported by additional research findings demonstrating the anxiety-alleviating effect of free-choice coloring within a college sample (Eaton & Tieber, 2017) and other free-form art tasks, such as painting (Sandmire et al., 2016). As there is inconsistency in these results, additional research is needed to determine the exact effects of free-form coloring tasks on anxiety levels within the young adult population.

Exploratory analyses were conducted to examine whether the reduction in state anxiety scores within the control group would have the opposite effect of what was predicted for the experimental group, predicting that participants in the control group would exhibit a significant increase in post-induction odor detection sensitivity scores, a significant decrease in post-induction identification accuracy scores, and a significant decrease in unpleasantness ratings for normatively neutral odorants. Results indicate that reducing state anxiety levels significantly increases an individual's odor identification accuracy, contradicting our hypotheses, though suggesting that state anxiety directly impacts central level olfactory processing in college students. This finding is consistent with results of a study that indicate that higher levels of state anxiety are significantly associated with lower odor identification accuracy scores (Takahashi et al., 2015). Conversely, the present results are inconsistent with results from an experiment that found an increase in participants' odor identification accuracy following anxiety induction (Krusemark et al., 2015). It should be noted that the aforementioned studies were not specifically examining the effect of anxiety reduction as the present study explored, but rather, were focused on the effects of anxiety induction. Furthermore, in the present study, post-induction odor identification accuracy scores significantly decreased from baseline scores within the experimental group, which was surprising since there was no significant change in their state anxiety scores from baseline to post-induction, although scores did increase slightly.

The results of exploratory analysis also indicate that a decline in state anxiety scores does not have a significant effect on post-induction odor detection sensitivity scores within the control group. This finding is inconsistent with experimental findings reporting that a significant increase in one's level of state anxiety precipitates a significant decline in their odor detection sensitivity (Krusemark et al., 2013; Pollatos et al., 2007), thus implicating a disruption within the peripheral level of olfactory processing caused by anxiety induction.

Additionally, experimental findings indicate that a significant decline in state anxiety scores does not have a significant effect on unpleasantness ratings of normatively neutral odorants within the control group. The lack of a significant effect of anxiety reduction on odor hedonic ratings is inconsistent with findings from several experimental studies examining the effects of anxiety induction on odor hedonic ratings, reporting that increased levels of state anxiety following anxiety induction result in normatively neutral odors being rated as significantly less pleasant (Pollatos et al., 2007), or significantly more unpleasant (Krusemark et al., 2013), thereby implicating a disruption within central level olfactory processing.

Limitations

This study's findings were limited by the fact that the anxiety-induction paradigm utilized did not result in a significant increase in state-anxiety levels in a college student sample as intended. There are also limitations to the external validity of the findings from this study, as the sample included predominantly white students, all of whom were enrolled at a Midwestern, private, Catholic university, and were between the ages of 18 and 22; therefore, results cannot be generalized to a more diverse population. In addition, the small study sample size greatly limits statistical power, thus increasing the potential for Type II errors. It is important to note that three different individuals were involved in administering the experimental procedure; instrumentation differences in administering the *Sniffin' Sticks Tests*, as well as in administering the *STAI-AD* and providing instructions for the anxiety-induction and control-filler tasks may significantly limit the study's internal validity. Furthermore, the reliance on self-report measures of anxiety may potentially limit the reliability of these findings, as such self-report measures are subject to various flaws and significant response biases.

Conclusions

In conclusion, results from the present study indicate that a significant reduction in state anxiety levels may directly affect central level olfactory processing, resulting in significantly higher odor identification accuracy scores compared to baseline scores. Furthermore, these findings suggest that a reduction in state anxiety does not have a significant effect on peripheral level olfactory processing, by means of odor detection sensitivity, and an additional component of central level processing, odor hedonic ratings. The results of the present study support the notion that state anxiety can significantly impact odor identification accuracy within a college population.

In light of these findings, future research endeavors should focus on evaluating the use of anxiety induction paradigms within college populations, as well as further exploring the anxiety-alleviating effects of free-form coloring within college populations. Additional research should also be conducted to delineate the specific performance and neurological effects of anxiety reduction at both the peripheral and central processing levels of olfaction, particularly in terms of odor detection sensitivity and odor hedonics.

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