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The influence of affective state on sensory and emotional perception: Application of the Sense'n Feel™ method

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Abstract

Emotions play a key role in our daily life through their control over our thoughts and behaviors. While it is commonly accepted that depressive patients have emotional perception disorders, it is important to know how these disorders affect patients' sensory perception to develop products to provide them with better support. In this study, we first examined the existence of modifications in the emotional perception of subjects with minor depressive symptoms (MDS, $n = 80$) compared with healthy controls (HC, $n = 80$) using a nonverbal method based on pictures to measure projected emotions and personality traits: the Sense'n Feel™ method. The investigated stimuli were two unpleasant and two pleasant odors and one pleasant food product: a madeleine. Second, we investigated the hedonic, familiarity and intensity olfactory perceptions of the subjects using the same stimuli. No significant difference was found in any olfactory qualities between the two groups. Concerning the pleasant olfactory stimuli, however, we did note that the MDS subjects had a significantly lower score for the positive emotion of joy/happiness than the controls. Additionally, the MDS group's attribution of some positive personality traits for the three pleasant stimuli was significantly weaker than that in the HC group. These results could be explained by the affective state of the MDS subjects; they were more anxious and more alexithymic compared with the controls. Further research is needed to validate our study in clinically depressed individuals and to determine whether the modifications of the emotional olfactory perception are due to the disease and/or to neuropsychological alterations.

KEYWORDS

anxiety, depressive symptoms, emotion, olfaction

Abbreviations: ANOVA, analysis of variance; BEN, benzaldehyde; BUT, butyric acid; DDF, difficulty in describing feelings; DIF, difficulty in identifying feelings; EOT, externally oriented thinking; GAR, garlic aroma; HC, healthy controls ; MAD, madeleine; MDS, minor depressive symptoms; QIDS-SR, quick inventory of depressive symptomatology self-report; *SD*, standard deviation; SHAPS, Snaith–Hamilton pleasure scale; STAI, state-trait anxiety inventory; STR, strawberry aroma; TAS-20, 20-item Toronto alexithymia scale.

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1 | INTRODUCTION

Depression is one of the most common psychiatric illnesses. This disease involves two major symptoms, mood disorder and anhedonia (i.e., a loss of interest in or pleasure from daily activities; American psychiatric association (2013), and it affects a subject's ability to recognize emotions (Miwa et al., 2001). Depression states are classically associated with an increased sensitivity to negative emotional events and a reduced salience of positive emotional events (Gotlib & Neubauer, 2000; Yoon, Joormann, & Gotlib, 2009). These findings were observed using principally visual stimuli (as written words, images, videos…; Dietrich et al., 2000; Lee et al., 2007; Schneider et al., 2012). However, olfaction has rarely been used to investigate emotional perception in depression (Pause et al., 2003), despite the close anatomical links between the olfactory system and the brain circuits involved in emotion. The common brain structures between these two processes are the amygdala, the hippocampus, the orbitofrontal cortex, the insula and the anterior cingulate cortex (Carmichael, Clugnet, & Price, 1994; Gottfried, 2010; Haberly, 2001; Lane et al., 1997; Schultz, 2000; Soudry, Lemogne, Malinvaud, Consoli, & Bonfils, 2011; Zald & Pardo, 2000; Zatorre, Jones-Gotman, & Rouby, 2000). The functioning of these brain areas is also modified in depressive conditions (Campbell, Marriott, Nahmias, & MacQueen, 2004; Drevets, 2003; Lemogne et al., 2006; Rogers et al., 2004). Odors have been demonstrated to induce a positive or negative affect as well as to modulate behavior, autonomic parameters and cerebral activity (Alaoui-Ismaïli, Robin, Rada, Dittmar, & Vernet-Maury, 1997; Gottfried, Deichmann, Winston, & Dolan, 2002; Lorig, Huffman, DeMartino, & DeMarco, 1991). In addition, some evidence for an impact of emotional induction on olfactory function in healthy subjects has been reported (Chen & Dalton, 2005; Pollatos et al., 2007). It appears, therefore, that the use of olfactory stimuli could be a reliable method by which to study the emotional response in individuals with affective disorders. Indeed, the presence of olfactory alterations (e.g., concerning hedonic aspect and threshold) in depressive patients has been widely demonstrated (Croy & Hummel, 2017; Kazour et al., 2017; Naudin et al., 2012; Rochet, El-Hage, Richa, Kazour, & Atanasova, 2018). One study suggested that some of these olfactory disorders (i.e., a decrease in olfactory sensitivity) could also appear in healthy subjects with minor depressive symptoms (Pollatos et al., 2007). Moreover, one recent study showed that the influence of minor depression on emotional perception may be significant and in some cases comparable in magnitude to that of major depression (Wu et al., 2016). Furthermore, several studies have revealed that "subclinical depression" is a significant risk factor for major depression (Cuijpers & Smit, 2004; Kessler, Zhao, Blazer, & Swartz, 1997). Therefore, in the present study, we investigated the emotional perception of healthy subjects with minor symptoms of depression in response to olfactory stimuli. The intimate characterization of this aspect may potentially have clinical implications and might help to elucidate new therapeutic strategies involving both olfactory and emotional functions. We also added as a stimulus one food product, a madeleine, because in everyday life, individuals are confronted with complex odors and flavor combinations (e.g., food, beverages, perfumes, flowers, etc.). Moreover, the importance of using complex sensory stimuli (odorant mixtures) for a better understanding of olfactory perception in mood disorders was also suggested in a previous study (Naudin et al., 2012).

To study the emotional olfactory perception of individuals, we chose to use a recently developed nonverbal method called Sense'n Feel™ (Mérieux NutriSciences, France) based on visual stimuli (boards with different pictures) (Dreyfuss & Brémaud, 2011; Tahiri, Dreyfuss, & Nicod, 2009). The using of pictures avoids the responsiveness of certain respondents to the measurement process and preventing individuals from being aware of the measure in which they are involved. Compared with the most common nonverbal self-report method, the Self-Assessment Manikin (Bradley & Lang, 1994), the Sense'n Feel™ method allows for the measurement of distinct emotions and not only generalized emotional states (in terms of underlying dimensions such as pleasantness and arousal). Moreover, the Sense'n Feel™ method is language-independent and can be used in different cultures (Tahiri et al., 2009). This nonverbal self-report method has never been used clinically; it was designed expressly for sensorial consumer studies and/or for marketing research. However, it is user-friendly and a quick measure of emotional response; no complex tools or programs are required, which makes this method easy to use and suitable for large-scale research, including clinical research.

Therefore, the purpose of this study was twofold. The main aim was to examine the existence of modifications in the emotional perception during the presentation of stimuli of subjects with minor depressive symptoms compared with those in a control population using the Sense'n Feel™ method. The second aim was to investigate olfactory perception in subjects with minor depressive symptoms by studying the evaluation of the hedonic aspect, familiarity and intensity perception of the stimuli. We hypothesized that subjects with minor depressive symptoms would have less emotional perception of positive-valence stimuli and, conversely, more emotional perception of negative-valence stimuli compared with the control subjects. We also expected to observe an alteration in hedonic perception in the population with minor depressive symptoms compared with the controls.

2 | MATERIALS AND METHODS

2.1 | Participants

One hundred and sixty healthy volunteers recruited mainly at the University of Tours participated in the study. The participants were divided into 2 groups according to their score on the Quick Inventory of Depressive Symptomatology Self-Report (QIDS-SR) (Rush et al., 2003): (a) 80 subjects with mild (82.5%) or moderate (17.5%) depressive symptoms with a QIDS-SR score between 6 and 15 (MDS group), and (b) 80 subjects with minimal depressive symptoms, that is, healthy controls with a QIDS-SR score less than 6 (HC group). The QIDS-SR is based on a 16-item scale with scores ranging from 1 to 27 (scores from 1 to 5: minimal depressive symptoms; scores from 6 to 10: mild depression; scores from 11 to 15: moderate depression; scores from 16 to 20: severe depression and scores from 21 to 27: very severe depression). It is a self-report measure of depressive symptom severity derived from the Inventory of Depressive Symptomatology (IDS). The QIDS-SR scores highly correlate with the Hamilton Rating Scale for Depression (HAM-D) total scores (Rush et al., 2003). Thus, the QIDS-SR is an appropriate psychometric measure in this population even though the study lacks other scales measuring different aspects of mental health. The optimal cutoff score of the QIDS-SR16 for a current MDE was 13 (Surís, Holder, Holliday, & Clem, 2016). Our MDS group presented significantly higher depressive symptoms compared with the controls ($t_{158} = 16.79$, $p < .001$). The MDS group participants were also more anxious ($t_{158} = 4.23$, $p < .001$) (State–Trait Anxiety Inventory (STAI), Spielberger, Gorsuch, & Lushene, 1970)). They had a higher overall alexithymia score ($t_{158} = 4.64$, $p < .001$) compared with the control group (used scale: TAS-20; Taylor, Ryan, & Bagby, 1985; Bagby, Parker, & Taylor, 1994; Taylor, Bagby, & Parker, 1997). Concerning the subdimensions of alexithymia, the evaluations revealed that the individuals in the MDS group had more difficulties than those in the control group in describing ($t_{158} = 4.23$, $p < .001$) and identifying feelings ($t_{158} = 4.50$, $p < .001$). However, no significant difference between groups was found for the tendency of individuals to focus their attention externally ($t_{158} = 0.10$, $p = .92$). Additionally, no significant difference was observed between the groups on the pleasure scale ($t_{158} = 1.66$, $p = .10$; used scale: the French version of the 14-item Snaith–Hamilton Pleasure Scale (SHAPS), (Snaith et al., 1995)). The two groups were matched according to gender ($\chi^2_1 = 0.3$, $p = .6$), age ($t_{158} = -0.7$, $p = .48$), smoking status ($\chi^2_1 = 0.2$, $p = .7$) and education level ($p = .06$). The psychometric and demographic characteristics of the participants (mean values with the standard deviations for both groups concerning all scales) are presented in Table 1.

TABLE 1 Demographic and psychometric characteristics

	Subjects with minor depressive symptoms (MDS) ($n = 80$)	Healthy controls (HC) ($n = 80$)	*P*-value
Female/male ratio	58/22	55/25	ns[a]
Mean age, years (*SD*)	31.45 (13.55)	32.95 (12.06)	ns[b]
Age range, years	18–59	19–58	
Smoker/no smoker ratio	14/66	12/68	ns[a]
Educational level: primary/ secondary/university ration	3/8/68	3/1/76	ns[a]
Psychometric scales			
QIDS-SR, mean score (*SD*)	8.33 (2.38)	3.01 (1.53)	<0.001[b]
QIDS Range	6–15	0–5	
STAI-State (*SD*)	38.00 (11.52)	30.63 (10.51)	<0.001[b]
SHAPS (*SD*)	0.95 (1.33)	0.65 (0.92)	ns [b]
TAS-20, mean score (*SD*)	49.91 (9.67)	43.61 (7.35)	<0.001[b]
Difficulty describing feelings (DDF), mean score (*SD*)	14.80 (4.0)	12.30 (3.45)	<0.001[b]
Difficulty identifying feeling (DIF), mean score (*SD*)	17.03 (4.88)	13.79 (4.21)	<0.001[b]
Externally oriented (EOT) thinking, mean score (*SD*)	18.09 (4.55)	18.03 (3.53)	ns[b]

[a]Chi-squared test.

[b]Student's *t* test (nondirectional); ns, not significant; QIDS, Quick Inventory of Depressive Symptomatology; *SD*, standard deviation; SHAPS, Snaith–Hamilton Pleasure Scale; STAI-State, State and Trait Anxiety Inventory; TAS, Toronto Alexithymia Scale.

In the recruitment process, all of the participants responded to a detailed questionnaire concerning their health and possible drug treatments. All the subjects declared that they had no personal history of psychiatric disorders. One subject in the MDS group suffered from point sinusitis, but this was not the case during the measurement session. Two additional subjects in the MDS group had an antihistamine treatment, and one subject had a penicillin treatment. Concerning the control group, one subject was diabetic and was treated with Stagid, and one subject had an antihistamine treatment. The subjects were excluded from the study for the following reasons: (a) a history of neurological and psychiatric disorders or traumatic brain injury, (b) major medical problems, (c) allergy to some odors and/or foods, (d) current substance abuse, (e) current cold, (f) other conditions known to affect olfactory and/or gustatory functioning (i.e., upper respiratory tract infection), and (g) anosmia to the olfactory stimuli used in the present study. Concerning this last point, one subject who had difficulty perceiving butyric acid was excluded from the study. Smokers were instructed not to smoke for at least 30–40 min before testing.

2.2 | Sensory stimuli

Five sensory stimuli were used as follows: (a) two chemical food-grade certified molecules (odorants) supplied by Sigma-Aldrich (Illkirch, France): one pleasant (bitter almond, benzaldehyde, BEN) and one unpleasant (rancid odorant, butyric acid, BUT); (b) two food aromas (odors), (Meilleur du chef. com, Bassussarry, France): one pleasant (strawberry, STR) and one unpleasant (garlic, GAR) and (c) one food product: a madeleine (MAD). BEN and BUT were chosen because previous studies have demonstrated a modified perception of these compounds in depressed patients compared to controls (Atanasova et al., 2010; Naudin et al., 2012). STR and GAR were chosen because they are very familiar odorants for consumers and are more complex stimuli (a mixture of several compounds) compared to pure chemical molecules. Throughout the manuscript, the term "odorant" will correspond to benzaldehyde and butyric acid since they are single molecules, while the term "odor" will correspond to the two food aromas since they are a mixture of molecules. Finally, the madeleine was chosen because it is a food product commonly consumed by French people. They are available individually packaged and with a long expiration date, which preserves their organoleptic and hygienic qualities and facilitates their preservation.

The concentrations of the four olfactory stimuli were chosen to be approximately iso-intense and at the supra-threshold level: benzaldehyde, 0.5 ml/L; butyric acid, 1.6 ml/L; strawberry aroma, 500 ml/L and garlic aroma, 500 ml/L. BEN, BUT and STR were diluted in distilled water, and GAR was diluted in nonodorous mineral oil (Sigma-Aldrich, Illkirch, France). The odorous solutions were poured into 15-ml brown glass flasks (2 ml per flask), and each flask was coded with a random three-digit number. The madeleine was presented on a plate coded with a three-digit number.

2.3 | General design

The present study was conducted in accordance with Good Clinical Practice procedures and the Declaration of Helsinki. Ethical approval was obtained (Ethics Committee in Human Research, Tours, France). The experimental procedure was clearly explained to all participants, and written informed consent was obtained prior to testing. The participants were informed of the option to discontinue testing at any time.

Before testing began, all tasks (olfactory and emotional measurements and psychometric scales) were explained to the participants. The order of the different tests carried out with the subjects is described below. First, the subjects were asked to smell (or taste in the case of the madeleine) the odors and to evaluate their olfactory qualities (hedonicity, familiarity and intensity). The evaluation of each olfactory quality lasted approximately 30–40 s.; this duration was sufficient to avoid habituation and adaptation to the odors. Subsequently, the subjects were asked to smell (or taste) again each stimulus and to evaluate the emotions felt when smelling the tested stimuli by using boards of images representing different emotions and personality traits (Sense'n Feel™ method). Knowing that the emotion elicited by the odor may wane after some time, the subjects were allotted unlimited time for sniffing, and they could smell (or taste in the case of the madeleine) each stimulus several times during the emotional test. Indeed, previous experiments have shown that each individual optimizes his/her parameters of sniffing to obtain maximum sensitivity (Laing, 1983). Finally, the participants completed the psychometric scales. The measurement session lasted approximately 45–55 min (approximately 5–7 min/stimulus and approximately 3–4 min/psychometric scale), and the different tasks were carried out in the same order for all participants. The order of presentation of the 4 olfactory stimuli was balanced across the stimuli and for all subjects, and it was identical for the groups. The subjects carried out the olfactory and emotional measurements for each stimulus presented one after the other (monadic sequential presentation). The madeleine was presented last because it was a more complex sensory stimulus and to prevent it from influencing the olfactory perception of the other "simple" stimuli. The subjects consumed the madeleine at their own pace to evaluate its hedonic aspect and its familiarity and then to answer the Sense'n Feel™ questionnaire. Before the measurements, the subjects were informed that they must take the flavor of the product into account in their evaluation.

2.4 | Emotional test: Sense'n Feel™ method

The Sense'n Feel™ method (Mérieux NutriSciences, France) is an emotion measurement tool based on visual stimuli; it includes two sets of 10 boards each containing 9 to 10 pictures. Each of these 9 to 10 images on the same board represents a specific emotion or personality trait. They are used to measure projected emotions and personality traits related to the presented stimulus (Dreyfuss & Brémaud, 2011; Tahiri et al., 2009). Here, personality trait refers to the personality one could attribute to the stimulus if it was considered to be a person. This denomination is used to make a distinction between primary emotions, which are known to be universal, such as joy, anger or sadness, and secondary emotions, which are more complex, multidimensional and culture-dependent, such as glamorous, magic or secret. The 10 boards of the first set represented 6 positive emotions (tenderness, trust, curiosity, desire, joy/happiness and surprise) and 4 negative emotions (disgust, anger/nervousness, embarrassment/shame and sadness/nostalgia). The 10 boards of the second set represented the following personality traits: soft/tender, refined, glamorous, tonic/dynamic, soothing/calm/natural, magic/unreal, adventurous/wild, secret/mysterious, cheerful/warm and oppressive/irritating. The 20 boards were presented to the subjects in random order. These pictures of different boards were very diverse and could represent objects, people, animals, landscapes or reproduce situations common in daily life. The reason why one emotion or personality trait is not translated by one unique picture is the fact that studied emotions are multidimensional, that is, they can be associated with various representations. For the emotions boards, the subject scored the appropriateness of the board presented to describe the emotion felt during smelling the odor or eating the madeleine. With regard to the personality traits boards, the participants had to imagine if the board presented matched a personality trait that might be associated with the stimulus. In both cases, scores ranged from 1 to 7.

2.5 | Olfactory test

First, the subjects were invited to smell (odors and odorants) or taste (the madeleine) the five sensory stimuli and to evaluate the pleasantness, familiarity level and intensity of the perceived stimuli on a 10-cm linear scale labeled at each end (highly unpleasant/highly pleasant, unfamiliar stimulus/very familiar stimulus and weak intensity/very strong intensity) and in the middle (neither pleasant nor unpleasant, neither familiar nor unfamiliar and neither strong nor weak intensity). The resulting response was expressed with a score ranging from 0 to 10. In the case of the madeleine, only the pleasantness and the familiarity level were evaluated.

2.6 | Statistical analysis

Emotion and personality trait measurements were computed separately for each stimulus with a two-way analysis of variance (ANOVA) using 2 factors, group and emotion (or personality trait), and their interaction (group*emotion) (or group*personality trait). When a significant effect of group*emotion (or group*personality trait) interaction was found, the post hoc Bonferroni test permitted a two-by-two comparison between groups for each emotion (or personality trait). The significance level was corrected for multiple comparisons using Bonferroni correction (Bonferroni-adjusted α-level = 0.005).

Concerning the olfactory tests, for each characteristic of the stimulus (pleasantness, familiarity and intensity), two-way analysis of variance (ANOVA) was carried out to determine the overall significance for the main effects (group: MDS and HC; stimulus: BEN, BUT, STR, GAR and MAD) and their interaction (group*stimulus). As significant effects of stimulus and group*stimulus interaction were found, a two-by-two comparison between groups for each stimulus was carried out using Bonferroni post hoc tests. The significance level was corrected for multiple comparisons using Bonferroni correction (Bonferroni-adjusted α-level = 0.005 for pleasantness and familiarity and 0.008 for intensity).

The Pearson correlation coefficient was used to study the relationship between the subjects' emotional and affective state (evaluated with the psychometric scales) and their olfactory and emotional perceptions of the stimuli. The Pearson coefficient was calculated for the two groups and the significant results obtained in the different tests and scales.

The collected data were analyzed using XLSTAT®-Pro software (Addinsoft, version 2019.1.2.). The α-level was set to 0.05.

3 | RESULTS

3.1 | Emotional test: Sense'n Feel™ method

Concerning emotions and the BEN odorant, there was a significant effect for the emotion factor ($F_{9,1,580} = 63.88$, $p < .001$), no significant effect for the group factor ($F_{1,1,580} = 0.40$, $p = .53$) and a significant group*emotion interaction ($F_{9,1,580} = 2.65$, $p = .0048$). Comparing the emotional responses of subjects with minor depressive symptoms and the controls (two-by-two comparisons between groups for each emotion) revealed that, for one emotion only (joy/happiness, $p < .001$), the mean values of MDS (3.35 ± 1.91) were significantly weaker than those of healthy subjects (4.40 ± 1.89; Figure 1). For the two unpleasant stimuli (BUT and GAR) and the madeleine (MAD), a significant effect was demonstrated for the emotion factor (BUT: $F_{9,1,580} = 187.76$,

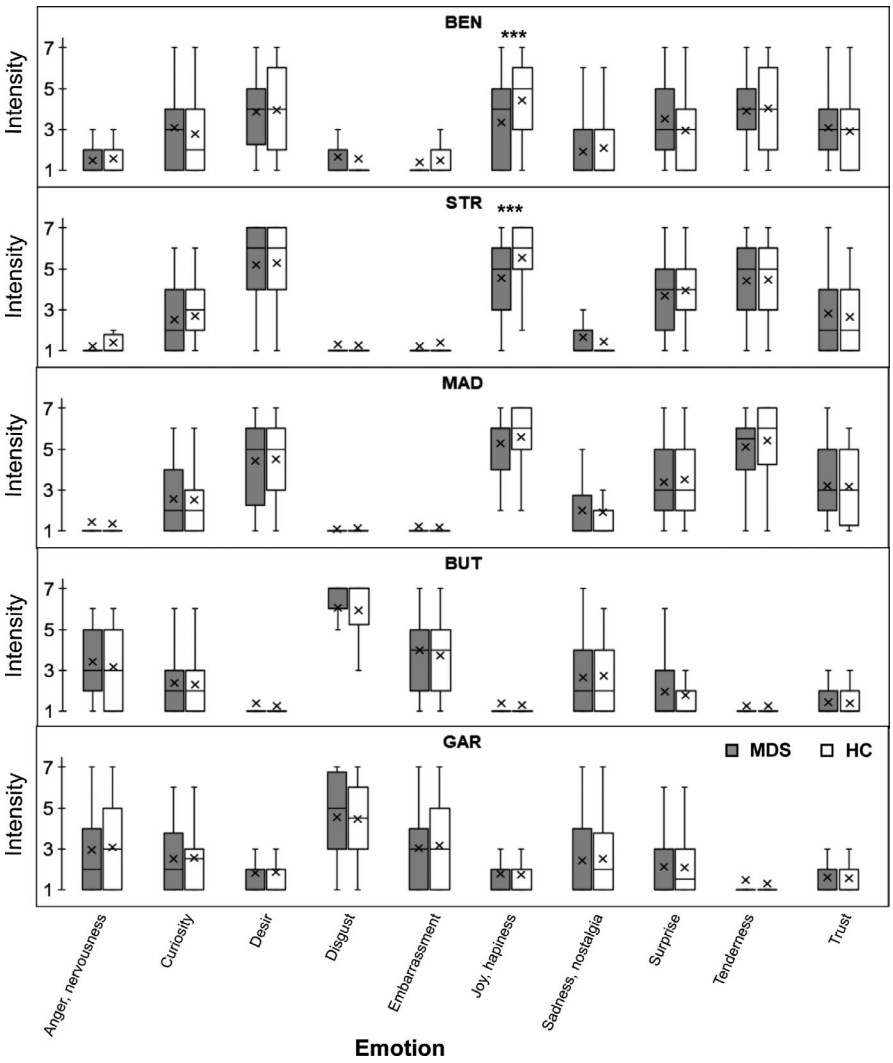

FIGURE 1 Between-groups comparison of intensity scores of the ten emotions (Sense'n Feel™ method) for the five stimuli (BEN: benzaldehyde; STR: strawberry aroma; MAD: madeleine; BUT: butyric acid and GAR: garlic aroma) evaluated in subjects with minor depressive symptoms (MDS) and in healthy controls (HC) (Bonferroni test; ***: $p < .001$). The level of significance was set at $p = .005$ to avoid error due to multiple comparisons

$p < .001$; GAR: $F_{9,1,580} = 56.76$, $p < .001$; MAD: $F_{9,1,580} = 196.36$, $p < .001$), but no significant effect was highlighted for the group factor (BUT: $F_{1,1,580} = 2.51$, $p = .11$; GAR: $F_{1,1,580} = 0$, $p = 1.00$; MAD: $F_{1,1,580} = 0.63$, $p = .43$) or the group*emotion interaction (BUT: $F_{9,1,580} = 0.22$, $p = .99$; GAR: $F_{9,1,580} = 0.13$, $p = .99$; MAD: $F_{9,1,580} = 0.40$, $p = .93$; Figure 1). Regarding STR, a significant effect was demonstrated for the group ($F_{1,1,580} = 3.99$, $p = .046$) and emotion ($F_{9,1,580} = 197.39$, $p < .001$) factors and for their interaction ($F_{9,1,580} = 2.29$, $p = .02$). A comparison of the emotional responses (Bonferroni test) of both groups showed that only joy/happiness ($p < .001$) corresponded significantly less to the felt emotion for subjects with minor depressive symptoms (4.55 ± 1.90) than for the controls (5.56 ± 1.40; Figure 1).

Concerning the personality traits, no significant effect was found for BEN or STR for the group factor (BEN: $F_{1,1,580} = 0.05$, $p = .82$; STR: $F_{1,1,580} = 1.27$, $p = .26$), but a significant effect was demonstrated for the personality trait factor (BEN: $F_{9,1,580} = 50.26$, $p < .001$; STR: $F_{1,1,580} = 84.40$, $p < .001$) and for the interaction (BEN: $F_{9,1,580} = 5.81$, $p < .001$; STR: $F_{9,1,580} = 2.38$, $p = .01$). Comparing the personality trait responses of both groups for the BEN odorant and for each personality trait showed that the mean values of the subjects with minor depressive symptoms were significantly weaker than those of the controls for only two parameters (cheerful/warm, $p < .001$; MDS: 4.09 ± 1.75; HC: 5.13 ± 1.66 and soothing/calm/natural, $p < .001$; MDS: 3.71 ± 2.10; HC: 5.175 ± 1.74; Figure 2). A significantly weaker mean value of subjects with minor depressive symptoms (4.10 ± 1.92) compared to controls (5.13 ± 1.57) was also observed for the cheerful/warm ($p < .001$) personality trait concerning the STR stimulus. Regarding the MAD stimulus, the two-way ANOVA with interaction indicated a significant effect of the group ($F_{1,1,580} = 4.22$, $p = .04$) and personality trait ($F_{9,1,580} = 116.98$, $p < .001$) factors and their interaction ($F_{9,1,580} = 3.15$, $p = .001$). The Bonferroni test showed a significant difference between both groups only for the refined personality trait ($p < .001$); thus, this personality trait was better associated with the madeleine for the controls (3.98 ± 2.05) compared to the subjects with minor depressive symptoms (2.63 ± 1.79; Figure 2). For the two unpleasant olfactory stimuli (BUT and GAR), a significant effect was

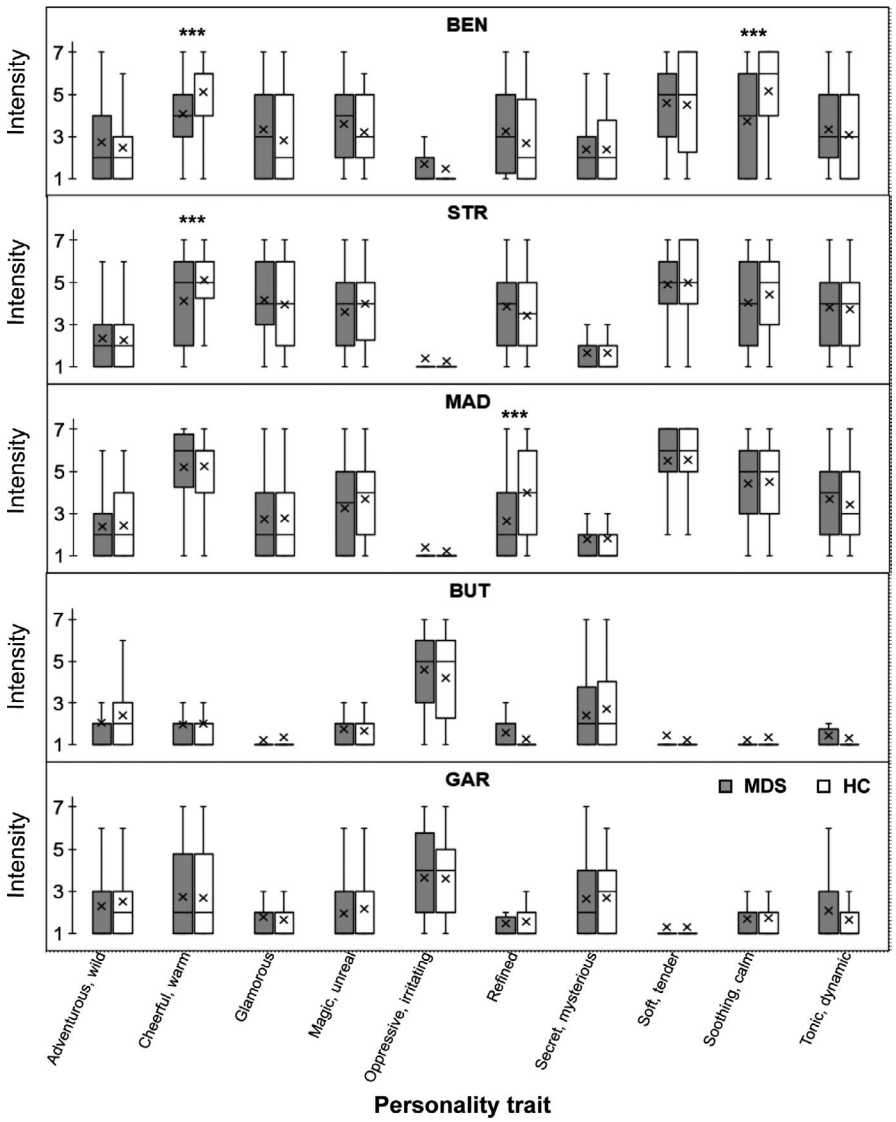

FIGURE 2 Between-groups comparison of intensity scores of the ten personality traits (Sense'n Feel™ method) for the five stimuli (BEN: benzaldehyde; STR: strawberry aroma; MAD: madeleine; BUT: butyric acid and GAR: garlic aroma) evaluated in subjects with minor depressive symptoms (MDS) and in healthy controls (HC) (Bonferroni test; ***: $p < .001$). The level of significance was set at $p = .005$ to avoid error due to multiple comparisons

shown for the personality trait factor (BUT: $F_{9,1,580} = 89.12$, $p < .001$; GAR: $F_{9,1,580} = 35.34$, $p < .001$), but no significant effect was highlighted for the group factor (BUT: $F_{1,1,580} = 0.03$, $p = .86$; GAR: $F_{1,1,580} = 0.01$, $p = .93$) or the group*personality trait interaction (BUT: $F_{9,1,580} = 1.47$, $p = .16$; GAR: $F_{9,1,580} = 0.55$, $p = .84$; Figure 2).

3.2 | Olfactory test

The two-way analysis of variance with interaction indicated a significant effect of stimulus for all olfactory qualities (pleasantness: $F_{4,790} = 322.95$, $p < .001$; familiarity: $F_{4,790} = 94.78$, $p < .001$; intensity: $F_{3,632} = 25.14$, $p < .001$). However, no significant effect was demonstrated for the group factor (pleasantness: $F_{1,790} = 0.002$, $p = .96$; familiarity: $F_{1,790} = 0.16$, $p = .69$; intensity: $F_{1,632} = 3.26$, $p = .07$) or the group*stimulus interaction (pleasantness: $F_{4,790} = 1.07$, $p = .37$; familiarity: $F_{4,790} = 0.54$, $p = .71$; intensity: $F_{3,632} = 1.00$, $p = .39$) concerning all olfactory qualities. The hedonic, familiarity and intensity scores of the four stimuli by two groups are presented in Figure 3.

Regarding the hedonic perception of the stimuli by the participants, the two-by-two multiple comparisons of the means showed that BUT (1.79 ± 1.94) had the lowest hedonic score, followed by GAR (3.75 ± 2.74). The stimuli BEN (7.86 ± 2.13), STR (8.51 ± 2.02) and MAD (8.46 ± 1.99) were evaluated to be more pleasant stimuli. Concerning the familiarity perception of the stimuli, the Bonferroni test demonstrated that BUT (5.35 ± 2.95) was perceived as the least familiar stimulus, followed by GAR (7.69 ± 2.85). STR (9.02 ± 1.44), while MAD (9.51 ± 1.0) was the most familiar stimuli, and BEN (8.79 ± 1.83) had an intermediate level of familiarity; this odorant was perceived to be as familiar as STR but less familiar than MAD. Finally, concerning the intensity evaluation, 3 stimuli were perceived as iso-intense

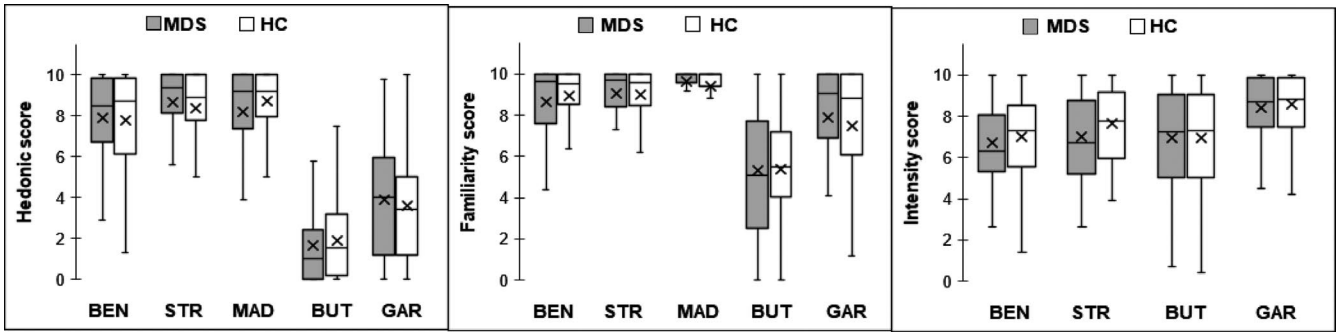

FIGURE 3 The hedonic, familiarity and intensity scores of the stimuli (BEN: benzaldehyde; STR: strawberry aroma; MAD: madeleine; BUT: butyric acid and GAR: garlic aroma) obtained by the two groups of subjects: subjects with minor depressive symptoms (MDS) and healthy controls (HC)

(BEN: 6.86 ± 1.81; BUT: 6.97 ± 2.36 and STR: 7.33 ± 1.86), and GAR (8.50 ± 1.47) was perceived as significantly more intense than the other 3 stimuli.

3.3 | Correlations

Concerning the emotional responses of the Sense'n Feel™ method, the mean of the three positive stimuli was used for the computation of the correlation coefficient. For the personality trait responses, the mean of two positive olfactory stimuli (BENZ and STR) was used for the computation of the correlation coefficient.

For the MDS group, a negative significant correlation was observed between the difficulty describing feelings (DDF) score and the personality trait score for positive olfactory stimuli ($r = -0.26$, $p = .02$). A significant positive correlation was observed between the QIDS score and the personality trait score for positive olfactory stimuli ($r = 0.30$, $p = .01$). Regarding the HC group, a negative significant correlation was demonstrated between the STAI score and the emotion score for the positive olfactory stimuli ($r = -0.25$, $p = .03$). The scatterplot for the correlation data is presented in Figure 4.

4 | DISCUSSION

The main goal of the present pilot study was to explore the emotional perception of subjects with minor depressive symptoms compared with a control population using the innovative Sense'n Feel™ method. The second aim was to investigate the olfactory perception in subjects with minor depressive symptoms by studying the evaluation of the hedonic aspect, the familiarity and the intensity perception of the stimuli. This second aim was explored because the olfactory qualities of the stimuli cited above could influence the emotional perception of the stimuli.

First, concerning the hedonic perception of the stimuli, as expected, the subjects evaluated benzaldehyde, the strawberry aroma and the madeleine as being significantly more pleasant than the butyric acid and garlic aromas. However,

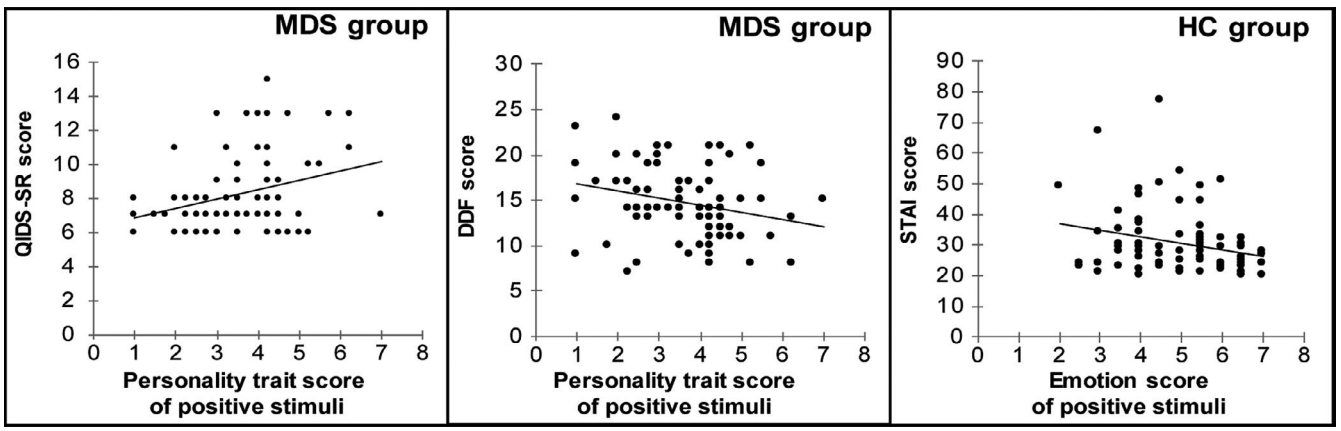

FIGURE 4 Scatterplot for the correlation data. Relationship between emotional olfactory rating (Sense'n Feel™ method) and psychometric variables for subjects with minor depressive symptoms (MDS) and healthy controls (HC). QIDS-SR: depression score; DDF: difficulty in describing feelings; STAI: anxiety score

no significant difference between the groups was observed for any stimulus concerning the hedonic aspect. These results do not correspond to our initial hypothesis, which was to observe an alteration in hedonic perception in subjects with minor depressive symptoms compared with controls. Indeed, previous studies have demonstrated the presence of olfactory anhedonia (less pleasant perception of a pleasant odorant) (Naudin, Carl, et al., 2014; Naudin et al., 2012) and negative olfactory alliesthesia (more unpleasant perception of an unpleasant odorant) (Atanasova et al., 2010; Naudin, Carl, et al., 2014) in depressed patients. However, a recent study has shown that the severity of depressive symptoms does not affect olfactory function but that the evolution and duration of depression have an effect on olfactory function (Pabel, Hummel, Weidner, & Croy, 2018). It would be interesting to follow our DLM population of subjects over a longer period to study an eventual incidence of depressive symptoms on olfactory function.

Concerning the intensity perception, no significant difference was observed between the two groups of subjects, which is a finding that corroborates most of the previous data observed in major depression (Clepce, Gossler, Reich, Kornhuber, & Thuerauf, 2010; Lombion-Pouthier, Vandel, Nezelof, Haffen, & Millot, 2006; Naudin, Mondon, et al., 2014; Pause, Miranda, Göder, Aldenhoff, & Ferstl, 2001; Thomas, Fries, & Distel, 2002). Likewise, no significant difference was observed between the two groups concerning the perception of the familiarity level of the stimuli. The data in the literature show contradictory results; some authors could not find any change in familiarity ratings associated with depression (Naudin, Carl, et al., 2014; Naudin, Mondon, et al., 2014; Thomas et al., 2002), whereas others found lower familiarity ratings in depressed patients compared with controls (Naudin et al., 2012). Future studies are needed to clarify this aspect of olfaction in depression and in a subclinical degree of depressive symptoms in healthy subjects.

Second, the results of the emotional responses from the Sense'n Feel™ method support our initial hypothesis of lower emotional perception for positive-valence stimuli in MDS subjects compared with controls. Indeed, we found a significantly lower score for the positive emotion of joy/happiness concerning the pleasant olfactory stimuli BEN and STR in the MDS group. Moreover, this group also perceived as weaker some positive personality traits for the three studied pleasant sensory stimuli, such as cheerful/warm concerning BEN and STR, soothing/calm/natural concerning BEN and refined concerning MAD. Additionally, our results demonstrated that these data could not have been influenced by the intensity, the pleasantness or the familiarity of the stimuli perceived by participants because no significant difference between the two groups was observed for these three olfactory qualities. These results suggest the presence of positive attenuation at the emotional olfactory level, which may be explained by the affective state of our MDS group. Indeed, even if the MDS subjects were not suffering from a major depressive episode, they had significantly more depressive symptoms compared with the controls. The anhedonic level of the MDS group seems not influence these results (no difference in the pleasure score was found between the two groups). The absence of anhedonia in our MDS group is consistent with the symptoms described in subsyndromal depression in which depressed mood and anhedonia are excluded (Bali & Jiloha, 2008; Sadek & Bona, 2000). There are no similar studies carried out with subjects with minor depressive symptoms. However, studying emotion in olfactory perception, Naudin, Carl, et al. (2014) showed that depressed patients cited significantly more negative emotions such as disgust and sadness compared with controls (Naudin, Carl, et al., 2014). The authors suggested that these results could be explained by the dysfunctional and maladjusted cognitive schema in depression (Beck, 1976). However, the impairment in emotional olfactory perception vanishes with antidepressant treatment, suggesting that it is specific to the major depressive episode. In the present study, no significant difference between the two groups was observed for negative emotions, but the differences were highlighted for one positive emotion and for several positive personality traits concerning pleasant stimuli. These inconsistencies might be partly due to differences in the subjects' affective level, the sample characteristics and the methodology (e.g., the method used to evaluate the emotion and the nature of the stimuli). Moreover, contrary to our expectations, a significant positive correlation was observed between the depression level (QIDS score) and the positive personality trait score for pleasant stimuli in the MDS group. The overevaluation of pleasantness perception for positive odors has previously been observed in patients with major depression (Lombion-Pouthier et al., 2006; Pause et al., 2001). Further research comparing the olfactory emotional perception between the subjects with minor symptoms of depression and with a major depressive episode is necessary to clarify this aspect.

Knowing that emotional processing plays a central role in both depression and anxiety, we could assume that the significantly higher anxiety level of participants in the MDS group compared with the controls could also partially explain the decrease in the emotional perception of the pleasant stimuli in this population. Our observations are consistent with previous studies demonstrating altered olfactory processing in healthy anxious subjects (Chen & Dalton, 2005; Takahashi et al., 2016). Moreover, a significant negative correlation is highlighted between the STAI score and the emotion score for pleasant olfactory stimuli in our control group, demonstrating the strong influence of anxiety on emotional olfactory perception. In the present study, the MDS subjects had a higher overall alexithymia score compared to the controls and had more difficulties in

describing and identifying feelings. Alexithymia has been described in many psychiatric disorders (e.g., eating disorders, depression) and appears to be significantly correlated with depressive states (Hendryx, Haviland, & Shaw, 1991; Luminet, Bagby, & Taylor, 2001). Moreover, Lombion *et al*. (2010) reported that alexithymic patients (depressive and anorexic) overevaluated the intensity and hedonic aspect of odorants compared to nonalexithymic (depressive and anorexic) or control subjects. For our MDS subjects, the personality trait scores for pleasant stimuli correlate negatively with their DDF score. This result suggests that the decrease in the score of the positive personality traits of pleasant stimuli for the MDS group compared to controls may also be affected by the difficulty of MDS individuals describing (or understanding) emotions conveyed by pictures. To test whether the MDS subjects have difficulties in understanding and correctly detecting the intended emotion (or personality trait) conveyed by the pictures on the boards, we carried out a supplementary experiment with 20 subjects with minor depressive symptoms (group MDS') and 20 healthy individuals (group HC'). The participants of the two groups had similar demographic and psychometric characteristics as those of the subjects in the principal study. The results of the supplementary experiment showed that both groups correctly detected the emotion (or personality trait) represented by each board, and no significant difference was observed between the MDS group and controls (see the Appendix S1 file, part I). This observation suggests that the decrease in the score of the positive emotion/personality traits of pleasant stimuli for MDS subjects is not probably due to difficulty in using pictures conveying joy/happiness or other positive personality traits. However, it must be noticed that these results were obtained with additional 40 participants, which were not those that were initially tested, and thus, the type of question used with those participants may be lead to floor effects. Our observations are moderately consistent with previous studies demonstrating that alexithymic individuals show reduced affective priming with both facial expressions (Vermeulen, Luminet, & Corneille, 2006) and emotional words (Suslow, 1998) when compared to nonalexithymic individuals. Conversely, a recent study (Cecchetto, Rumiati, & Aiello, 2017) carried out with healthy subjects with different levels of alexithymia (high, medium and low) revealed exaggerated physiological responses to olfactory stimuli for subjects with high and medium alexithymia compared to the low alexithymia group. Future studies are needed to clarify the using of the boards of Sense'n Feel™ method by individuals with disorders at emotional level.

The Sense'n Feel™ method has never been used in a subclinical population, and it is therefore unknown whether it is suitable for this type of subject. For instance, when using the boards of pictures, the subjects could evaluate the emotional perception conveyed by the pictures and not by the perceived olfactory stimulus. To try to understand the underlying mechanisms behind the respondents' answers in the present study and eventually exclude this bias, we compared the evaluation of the five stimuli for each emotion and personality trait to verify that the subjects were not always reacting in the same way when faced with the same board of pictures. The results showed that the subjects of the two groups gave different scores to all boards of emotion (except that of curiosity) and for all personality traits (except that of adventurous/wild) when the stimuli changed. This finding seems to confirm that the respondents reacted to these stimuli and not to the pictures (see the Appendix S1 file, part II).

Another possible bias of using the Sense'n Feel™ method in subjects with minor depressive symptoms and especially alexithymic individuals is that the task requires subjects to make an evaluation with pictures that are supposed to convey an emotion and that this emotion may by itself be difficult to read and understand for these subjects. To check this aspect, the MDS group was divided into 3 subgroups of subjects with different levels of alexithymia according to the cutoff scoring in the French version of the TAS-20 (Loas et al.,1996). We compared the scores of these 3 subgroups and the HC group concerning the emotions/personality traits and stimuli with significant results. The results highlighted no significant difference between the 3 subgroups of subjects for all stimuli and the emotions/personality traits. However, the HC group evaluated as significantly more intense the positive emotions/personality traits for pleasant stimuli than some subgroups of MDS subjects (see the Appendix S1 file, part III). In some cases, these results have been observed between HC group and the subgroup of nonalexithymic individuals with minor depressive symptoms, suggesting that in this case the level of alexithymia of the subjects could not affect the obtained results. Thus, the decreased scores of the positive emotion/personality traits of pleasant stimuli for MDS subjects could also be due the presence of minor symptoms of depression and to their higher level of anxiety. Our results corroborate the observations in the literature. Indeed, Sloan et al. (1997) showed, using the Self-Assessment Manikin, that depressed patients rated positive slides as less pleasant and less arousing, but the difference between depressives and controls for unpleasant slides was not significant. However, the groups did not differ in facial expression (objective method) to positive stimuli. Thus, our observations obtained with the subjective Sense'n Feel™ method need to be confirmed by further studies using objective methods to investigate the emotional perception of sensory stimuli (e.g., studying the facial expression of the subject or using a measure of the physiological parameters that reflect the subject's emotional reactivity). Future studies are also needed to validate the clinical application of the Sense'n Feel™ method.

Some limitations of the present study merit discussion. First, we used only five sensory stimuli; such a limited number of measures could decrease the reliability of the results and increase the noise. Thus, the observations of the present study need to be confirmed by further studies using several other olfactory stimuli with different pleasantness levels that evoke different positive and negative emotions. Furthermore, it could be relevant to use several concentration levels of the chemical products, which might make the test more sensitive to small impairments and may help to increase the number of trials. It could also be relevant to carry out measures comparing the time of sniffing between the subjects to see whether this affects the results. It could be useful to create standardized instruments using pure chemical molecules and sensory stimuli reflecting a more typical olfactory and gustatory environment. Moreover, to generalize our findings, we need to confirm them with a larger sample including several age ranges. Finally, the overall olfactory function (including olfactory threshold, identification and discrimination) in the participants was not studied using a standardized test such as Sniffin' Sticks (Hummel, Sekinger, Wolf, Pauli, & Kobal, 1997). Indeed, the evaluation of the overall olfactory function in future studies could provide important information concerning its influence on the emotional perception conveyed by odors or more complex stimuli (e.g., a madeleine) since a reduced olfactory sensitivity has already been demonstrated in individuals with symptoms of minor depression (Pollatos et al., 2007).

In conclusion, using the Sense'n Feel™ method to investigate the influence of the affective state on emotional olfactory perception, we found a lower perception of positive emotions and personality traits in subjects with minor depressive symptoms concerning pleasant stimuli (olfactory stimuli and a madeleine). However, no significant difference between subject groups was found concerning the stimuli's olfactory qualities evaluated with self-rating scales. It would be interesting in future longitudinal studies to follow-up over time the evolution of the affective state and the olfactory emotional perception of the participants with minor depressive symptoms to detect individuals potentially at risk of developing depression. Furthermore, it would be interesting to extend our study to include a clinically depressed population to determine whether the modifications of the emotional olfactory perceptions are due to the disease and/or to neuropsychological alterations (anxiety, alexithymia and anhedonia), which would help to clarify their roles in the pathophysiological mechanisms that unite both olfactory emotion perception and depressive disorder.

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CONFLICT OF INTERESTS

The authors have no conflicts of interest to report related to this manuscript.

AUTHOR CONTRIBUTIONS

BA, LD, MR and WEH conceived and designed the experiments. BA and MR performed the experiments. BA, LD and MR analyzed the data. BA, LD, MR and WEH wrote the paper.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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