Chemosensory Perception (2019) 12:100–105
https://doi.org/10.1007/s12078-018-9253-y

# Association Between Olfactory Performance and Affective Symptoms in Children

Anne Schienle[1] · Carina Schlintl[1]

Received: 25 May 2018 / Accepted: 22 November 2018 / Published online: 4 December 2018


## Abstract

**Introduction** Correlations between olfactory performance and particular personality traits (e.g., disgust proneness), as well as symptoms of specific mental disorders (e.g., depression) have been found in numerous studies with adults. The present questionnaire study examined whether similar associations already exist in childhood.

**Method** The olfactory discrimination ability of 66 children (32 boys and 34 girls aged between 7 and 11 years) was tested. In addition, the children filled out screening questionnaires to assess the severity of symptoms related to depression, various anxiety disorders (e.g., panic disorder, social anxiety disorder), and disgust proneness. A multiple regression analysis was calculated with olfactory performance as criterion variable and questionnaire scores as predictor variables.

**Results** The results showed that depression and disgust proneness were negatively associated with olfactory discrimination ability. Moreover, high levels of social anxiety and low levels of panic symptoms were found to be positive predictors of olfactory performance.

**Conclusion** This investigation identified specific associations between olfactory performance and affective symptoms in children.

**Implications** Future tests with pediatric samples (children with anxiety disorders, depression) are recommended.

**Keywords** Olfactory discrimination · Children · Depression · Anxiety · Disgust

## Introduction

Odors are powerful stimuli that can evoke a variety of emotional states. Due to the anatomical overlap of brain areas, which are related to the sense of smell as well as to emotional processing (e.g., hippocampus, amygdala, anterior cingulate cortex, orbitofrontal cortex), most olfactory stimuli are immediately classified as "good" or "bad," "disgusting" or "pleasant" (Croy and Hummel 2017). However, individuals vary significantly in their classifications as well as in their olfactory performance (the capability for olfactory detection, identification, and discrimination).

In general, olfactory performance covers a wide spectrum that includes anosmia (loss of the sense of smell), hyposmia (reduced olfactory performance), normosmia (normal olfactory function), and hyperosmia (increased olfactory acuity; see Hummel et al. 2012). It has been argued that both reduced olfactory performance (anosmia/hyposmia) as well as hyperosmia are associated with altered emotional processing (e.g., negative mood, symptoms of anxiety disorders, and depression; Burón and Bulbena 2013).

Schienle et al. (2018) investigated specific associations between emotion-related personality traits (tendency to experience sadness and happiness in everyday life) and olfactory performance. They were able to show that patients with reduced olfactory performance (anosmia and hyposmia) reported higher levels of sad mood than normosmics. Croy et al. (2012) found that patients with anosmia had an increased risk to develop a depressive disorder compared to normosmic individuals. This type of olfactory dysfunction induces long-term impairments and reduces quality of life. This may lead to depression (Rochet et al. 2018). However, olfactory dysfunction can also be a marker (or symptom) of primary depression. Patients with a major depressive disorder sometimes show reduced olfactory function but only during a depressive episode. When the episode ends, olfactory performance returns to a normal level (Kohli et al. 2016).

✉ Anne Schienle
anne.schienle@uni-graz.at

✉ Carina Schlintl
carina.schlintl@uni-graz.at

[1] Clinical Psychology, University of Graz, Universitätsplatz 2/III, A-8010 Graz, Austria

In contrast to the findings on sadness and depression, results on the relationship between trait anxiety (the proneness of individuals to experience anxiety in their daily lives) and olfactory performance are inconsistent. For instance, Clepce et al. (2012) found that people with anxiety disorders showed reduced olfactory performance (specifically, difficulties in distinguishing odors). Lemogne et al. (2015), however, detected no differences in trait anxiety between anosmic and normosmic individuals. In contrast, Schienle et al. (2018) found that anosmic patients actually reported experiencing fewer somatic anxiety symptoms in their daily lives (reduced trait arousal) than normosmics.

Similar to the role of trait anxiety in altered olfactory performance, disgust proneness (the tendency of a person to experience disgust across different situations) has been investigated in only a few studies. The emotion disgust is rooted in the chemical senses (especially taste and olfaction). Disgust evolved as an oral-nasal rejection response to stimuli that signals toxicity or risk of infection (e.g., smell of spoiled food, aversive body odor associated with certain diseases; Rozin et al. 2008). Disgust (proneness) may heighten discernment of these olfactory cues. The findings on disgust proneness and olfaction are however heterogeneous. Schienle and Schöpf (2017) found no relationship between this personality trait and olfactory performance (threshold, discrimination, identification). In contrast, in a study by Ille et al. (2016), anosmic and hyposmic patients reported reduced disgust regarding spoiled food, but increased disgust with regard to poor hygiene. Finally, Croy et al. (2017) identified gender-specific effects; only in men but not in women was olfactory performance positively associated with disgust proneness.

Although the results have not been completely consistent, the examples discussed show that correlations between olfactory performance and affective symptoms in adults have been observed in numerous studies. These findings from adults however cannot simply be extrapolated to include children. Children differ from adults in that they experience many somatic, cognitive, and emotional changes as they progress through their natural growth and development. In a recent study, Nook et al. (2018) asked a sample including children, adolescents, and adults aged between 5 and 25 years to rate how much a series of aversive images made them feel angry, disgusted, sad, scared, and upset. The children tended to report feeling only one emotion at a time, producing specific but sparse affective experiences. Adults reported the presence of several emotions (Nook et al. 2018). Thus, emotion differentiation differed between children and adults.

There are also developmental changes in olfactory performance (for a review, see Cameron 2018). Odor identification (the ability to label odors correctly) improves as a function of age. This ability is however not independent of verbal functioning which is still developing in children. Findings on the ability to detect odors in childhood are heterogeneous. Some studies found higher odor thresholds in children compared to adults for specific odorants (e.g., Koelega and Köster 1974) while others even found lower thresholds (e.g., Solbu et al. 1990). Several investigators have reported no differences in thresholds between children and young adults (Cameron 2018). Olfactory tests that are less influenced by cognitive and linguistic demands, such as discrimination tasks, have only rarely been used in children (Hummel et al. 2007). We therefore focused on this indicator of olfactory performance in the present study. We investigated whether the tendency to experience symptoms related to depression and various anxiety disorders (panic disorder, separation anxiety, social phobia, school phobia, generalized anxiety disorder), as well as disgust proneness, is associated with olfactory discrimination in boys and girls aged 7 to 11 years. In addition, screening questionnaires for the aforementioned mental disorders were administered. For the data analysis, a multiple linear regression approach was chosen. Based on the results available for adults, it was assumed that depression constitutes a negative predictor and disgust proneness a positive predictor for olfactory performance. For the broad construct of anxiety disorders, we followed an exploratory approach.

## Method

### Participants

Sixty-six children (32 girls, 34 boys) with a mean age of 8.4 years (SD = 1.0, range = 7–11) participated in this study. They were recruited from an after-school day care program. The study was approved by the ethics committee of the University of Graz and was performed in accordance with the Declaration of Helsinki. Written informed consent was provided by the parents and the children. Exclusion criteria were reported chronic diseases (e.g., asthma) and acute nasal diseases (e.g., acute infections).

### Material and Procedure

The study consisted of the following two parts: the olfactory testing and the questionnaire assessment.

**Olfactory Testing** Olfactory function was assessed by means of the sniffin' sticks test (Burghart Ltd. Instruments, Wedel, Germany). This test has been used before in children, and normative data for the age group 5–15 years exist (Hummel et al. 2007). The complete test consists of the following three subtests: odor threshold, identification, and discrimination. Odor threshold refers to the lowest concentration of an odorant a person is able to perceive. It is assessed with *n*-butanol, which is presented in 16 dilutions in a staircase, three-alternative, forced-choice procedure. The concentration of *n*-butanol

is (repeatedly) increased following trials on which a subject has failed to detect the odorant and decreased following trials with correct responses. Odor discrimination ability is assessed by presenting 16 triplets of odorant pens; two pens contain the same odorant (e.g., α-Ionon: viola-like odor) and one pen contains a different odorant (e.g., eucalyptol: eucalyptus-like odor). The participants' task is to identify the different odor. Odor identification is assessed by means of 16 odors (e.g., coffee, cinnamon). Subjects' task is to identify the odors by selecting a label from a list of four descriptors.

We first conducted a feasibility trial with three children (aged 8–11 years) in which the complete sniffin' sticks test was administered. This pilot study showed that it was not possible to conduct all subtests within one session. The children were not able to show continued attention, especially during the threshold test. In addition, younger children experienced problems with the identification task, which requires odor labeling and is associated with verbal skills (Oleszkiewicz et al. 2016). Therefore, we decided to only administer the odor discrimination test. Gellrich et al. (2017) recently evaluated the discrimination task of the sniffin' stick test in a children sample (ages 5–17 years) and found sufficient retest reliability ($r = 0.69$).

During the study, the discrimination test was first shown and then explained to the children. They were told that the experimenter will present three pens to them, with two containing the same odor and one containing a different odor. Their task would be to identify the pen with the different odor. Each child was asked: "Imagine there are three pens. The first pen smells like strawberry, the second pen like vanilla and the third pen like strawberry. Which one has a different smell?" All children answered this question correctly. Then, the children were blind-folded and presented with 16 triplets of odorant pens (two pens contained the same odorant, the third pen contained a different odorant). The experimenter presented the pens one at a time for 3 s each. Subsequent to the presentation of a triplet, the child named the pen with the different odor (1, 2, or 3). This was followed by a waiting period of 30 s. Then, the next triplet was presented. The total duration of the discrimination test was 12 min.

Possible scores for the discrimination task range between 0 and 16 (with higher scores indexing better olfactory discrimination ability). The children were tested individually in a quiet and well-ventilated room during the after-school day care program.

**Questionnaires** The children answered German versions of the "Screen for Child Anxiety and Related Emotional Disorders" (SCARED child version; Essau et al. 2002), the "Depression Inventory for Children and Adolescents" (DICA; Stiensmeier-Pelster et al. 2000), and the subscale "core disgust" of the "Questionnaire for the Assessment of Disgust Proneness for Children" (QADP-C; Schienle and Rohrmann 2012). All questionnaires are reliable and validated scales for children and adolescents (aged from 8 to 17 years) with normative data available.

The SCARED is a self-report screening questionnaire for anxiety disorders (social phobia, separation anxiety disorder, panic disorder, school phobia, and generalized anxiety disorder). The 41 items of the questionnaire are rated on 3-point scales (0 = "not true or hardly ever true"; 2 = "very true or often true"; e.g., When I feel frightened, my breathing becomes difficult; I worry about what other people think of me).

The DICA is a 26-item screening instrument for depression. The items are rated via a three-alternative forced-choice format (e.g., most of what I do works out/a lot of what I do is wrong/everything I do is wrong).

The subscale "core disgust" of the QADP-C assesses aversion to spoiled food and poor hygiene. The eight items (e.g., someone with bad breath speaks to you) are rated on 5-point scales (0 = "not disgusting" to 4 = "very disgusting").

The questionnaires were filled out in randomized order in small groups (one to four children). The questions were read out to the children by the experimenter in a quiet room. The children were instructed not to talk to each other during the testing. Several breaks were incorporated into the study procedure (5 min after each questionnaire and 30 min between the questionnaire assessment and the olfactory testing).

### Statistical Analysis

To capture the association between olfactory performance (dependent variable) and the independent variables (predictors) SCARED-total (anxiety disorders), DICA (depression), and QADP-C (disgust proneness), a multiple linear regression with the enter method was calculated. We also entered gender as a predictor. Furthermore, we conducted a separate multiple linear regression analysis to capture the association between olfactory performance and the SCARED subscales (panic disorder, generalized anxiety disorder, and social phobia). The subscales separation anxiety and school phobia were excluded because of insufficient reliability (Cronbach's alpha < 0.60). The models were assessed for multicollinearity and residual distribution. The analyses were conducted with SPSS version 24 (IBM Corp. 2016).

## Results

Descriptive statistics for the olfactory test and the questionnaires are presented in Table 1. Scores for olfactory discrimination ranged from 6 (5th percentile) to 16 (maximal score). No statistically significant relationship was found between olfactory discrimination ability and age ($r = 0.21$; $p = 0.09$). Boys and girls did not differ in olfactory performance and self-reports regarding core disgust (QADP-C) and anxiety

**Table 1** Means (*M*), standard deviations (*SD*), and *t*-statistics for gender differences in olfactory performance and affective variables

| | Total sample *M* (*SD*) | Girls *M* (*SD*) | Boys *M* (*SD*) | Gender difference *t* (*p*) |
|---|---|---|---|---|
| Olfactory discrimination | 11.18 (2.36) | 11.16 (2.14) | 11.21 (2.58) | 0.085 (0.933) |
| QADP-C | 2.93 (0.68) | 3.00 (0.45) | 2.87 (0.85) | − 0.802 (0.426) |
| DICA | 10.88 (7.12) | 8.53 (5.77) | 13.09 (7.62) | 2.73 (0.008) |
| SCARED total | 29.00 (12.38) | 29.09 (9.98) | 28.91 (14.43) | − 0.059 (0.953) |
| Panic disorder | 6.92 (4.37) | 6.69 (3.90) | 7.15 (4.82) | 0.424 (0.673) |
| Generalized anxiety | 6.45 (3.84) | 6.34 (3.20) | 6.56 (4.47) | 0.226 (0.822) |
| Social phobia | 6.53 (3.20) | 6.75 (3.08) | 6.32 (3.34) | − 0.539 (0.592) |

SCARED, Screen for Child Anxiety and Related Emotional Disorders; DICA, Depression Inventory for Children and Adolescents; QADP-C, Questionnaire for the Assessment of Disgust Proneness for Children

disorders (SCARED subscales). Boys scored higher on the DICA (depression) than girls.

We compared the scores of the three questionnaires (QADP-C, DICA, SCARED) with the construction samples (normative data). Children of the current study scored significantly higher on all SCARED subscales ($ps < 0.05$) but did not differ from the construction samples with regard to the QADP-C and the DICA ($ps > 0.05$). The reliability (Cronbach's alpha) of the administered questionnaires in the present sample was as follows: SCARED-total = 0.87; DICA = 0.83; QADP-C = 0.69.

Compared to the norm values reported by Hummel et al. (2007), girls in the present sample achieved lower scores for olfactory discrimination performance ($t(55) = -2.217$; $p = 0.03$). The scores of boys did not differ from the norm values ($t(49) = -0.732$; $p = 0.47$).

The computed regression analyses revealed the following results: a significant regression equation was found for the association between olfactory performance (dependent variable) and the independent variables (predictors) SCARED-total (anxiety disorders), DICA (depression), QADP-C (disgust proneness), and gender ($F(4,61) = 3.44$, $p = 0.01$), with an $R^2$ of 0.184. Depression and core disgust were significant negative predictors of olfactory discrimination (Table 2). The SCARED-total score was a marginally significant positive predictor of olfactory discrimination.

**Table 2** Prediction of olfactory discrimination based on DICA, SCARED-total, QADP-C, and gender

| | *B* | *SE B* | 95% CI for *B* | *β* | *p* |
|---|---|---|---|---|---|
| Constant | 14.63 | 1.28 | [12.07, 17.18] | | |
| Gender | − 0.40 | 0.58 | [− 0.36, 1.71] | − 0.09 | 0.496 |
| DICA | − 0.11 | 0.05 | [− 0.20, − 0.02] | − 0.33 | 0.018 |
| SCARED-total | 0.05 | 0.03 | [− 0.004, 0.10] | 0.24 | 0.071 |
| QADP-C | − 1.17 | 0.43 | [− 2.02, − 0.32] | − 0.34 | 0.008 |

SCARED, Screen for Child Anxiety and Related Emotional Disorders; DICA; Depression Inventory for Children and Adolescents; QADP-C, Questionnaire for the Assessment of Disgust Proneness for Children

A second significant regression equation was found for the association between olfactory performance and the SCARED subscales panic disorder, generalized anxiety, and social phobia ($F(3,62) = 3.25$, $p = 0.03$) with an $R^2$ of 0.136. Panic disorder and social phobia were significant predictors of olfactory performance (Table 3). While panic disorder was a negative predictor, social phobia was a positive predictor.

## Discussion

In adults, it has already been well-established that olfactory performance is related to specific affective trait variables (e.g., disgust proneness) and vulnerability for different mental disorders, such as depression (e.g., Kohli et al. 2016; Croy et al. 2012; Schienle et al. 2018; Clepce et al. 2012; Ille et al. 2016; Croy et al. 2017; Croy and Hummel 2017). The current study investigated whether the severity of symptoms related to depression and various anxiety disorders and disgust proneness are associated with olfactory performance in childhood. Olfactory performance in the present sample was defined by the ability to differentiate between different odors. It had a wide range, so that both children with very good performance and poor performance were represented. On average, the children answered 11 out of 16 discrimination items correctly (hit rate = 70%). This score equals findings of Gellrich et al. (2017) for a sample of 51 children aged 5 to 11 years.

**Table 3** Prediction of olfactory discrimination based on the SCARED subscales

| | *B* | *SE B* | 95% CI for B | *β* | *p* |
|---|---|---|---|---|---|
| Constant | 10.44 | 0.68 | [9.08, 11.79] | | |
| Panic disorder | − 0.19 | 0.09 | [− 0.37, − 0.02] | − 0.36 | 0.031 |
| Generalized anxiety | 0.05 | 0.10 | [− 0.15, 0.24] | 0.08 | 0.634 |
| Social phobia | 0.27 | 0.10 | [0.07, 0.47] | 0.37 | 0.009 |

SCARED, Screen for Child Anxiety and Related Emotional Disorders

The main result of this study was that both disgust proneness and symptoms of depression were negative predictors of olfactory performance. With regard to depression, our study was able to replicate findings for adults (for a review, see Croy and Hummel 2017). Children with difficulties in olfactory discrimination reported an increased tendency to experience sadness. Two ways of explaining this finding are explored in the following. On the one hand, it can be assumed that the children first displayed olfactory dysfunction and as a result of this developed negative mood. For adults, it has been shown very consistently that reduced olfactory function is associated with reduced well-being and quality of life (e.g., because of reduced enjoyment of food or other pleasant odors). This may lead to symptoms of depression (for a review, see Boesveldt et al. 2017).

On the other hand, it is possible that children with a tendency to primary depression show olfactory dysfunction as one symptom of this disorder (proneness). For adults, it has already been shown that patients with major depressive disorder experience olfactory dysfunctions during an episode. When the depressive symptoms eventually disappear, olfactory performance returns to a normal level (Kohli et al. 2016). Longitudinal studies would be required in order to be able to detect changes in depressed mood in children that are directly associated with changes in olfactory function.

Disgust proneness was found to be a negative predictor of olfactory performance. Disgust proneness is defined as the tendency to feel disgust in response to stimuli that signal risk of contamination (Schienle et al. 2002). A major function of disgust is to protect the body from disease and poisoning (Rozin et al. 2008). The basic emotion of disgust elicits typical behaviors, such as distancing from the source of infection, avoidance, and cleaning/grooming (Davey 2011). These behaviors, especially avoidance, imply self-limitation of odor exposure (particularly for bad odors) and as a result may prevent (discriminatory) learning experiences with olfactory stimuli.

The exploratory regression analysis for the different types of anxiety disorders identified panic disorder as a negative predictor and social anxiety disorder as a positive predictor of olfactory performance. With regard to symptoms of panic disorder, our results were comparable to those reported by Clepce et al. (2012). In that study, adult anxiety patients (11 of the 17 patients had a diagnosis of panic disorder) showed reduced performance in odor discrimination compared to healthy controls. In contrast, other olfactory functions do not seem to be affected in panic disorder. For example, panic patients showed no deviations in odor threshold and identification (e.g., Buron et al. 2015; Clepce et al. 2012; Kopala and Good 1996). Thus, the tendency to experience panic symptoms seems to be a specific predictor of reduced olfactory discrimination performance.

One core pathological mechanism in panic disorder relates to poor identification and discrimination of unpleasant body sensations (Ehlers 1993). Typically, a panic patient first perceives an actually harmless somatic symptom (e.g., sweaty palms). This is, however, not identified as such; instead, this perception is followed by anxious catastrophizing cognitions, which in turn starts a positive feedback loop leading to a further increase of anxiety symptoms. It is of high clinical relevance to find out if panic patients might have general problems in sensory discrimination or if their heightened interoceptive awareness prevents adequate attention to and processing of external (olfactory) stimuli.

Finally, social anxiety disorder was a positive predictor of olfactory discrimination in the children. The sense of smell plays an important role for social behaviors, such as attachment between infants and caretakers and mating pairs. Moreover, based on olfaction, unfamiliar/familiar individuals can be recognized (Stevenson 2010). For example, several studies have demonstrated that familiar persons, especially relatives, can be distinguished from strangers based on their body odor (e.g., Hays 2003; Wysocki and Preti 2004; Olsson et al. 2006). Moreover, the smell of familiar persons as opposed to strangers can have a calming effect (z.B. Shoup et al. 2008). The core symptom of social anxiety disorder is fear of unknown people (and their negative evaluation). This is for example reflected in the SCARED item "I find it difficult to talk to people I do not know well." It seems likely that socially anxious children are especially sensitive to (body) odors because of their greater sensitivity in relation to ingroup–outgroup differentiation. This speculation has to be tested in a future study.

Although the exact reasons for the observed correlations are not known, it becomes obvious that specific anxiety symptoms are specifically related to olfactory performance. This may at least partly explain the inconsistent results that have been found to date between (pathological) anxiety and olfactory performance (Clepce et al. 2012; Lemogne et al. 2015; Schienle et al. 2018).

The following limitations of the current investigation need to be addressed. The results are specific to olfactory discrimination performance and cannot be generalized to other olfactory functions (threshold, identification). We did not assess attention and short-term memory that are possible moderator variables regarding olfactory performance. The questionnaires administered were screening instruments for mental disorders, but no clinical diagnoses were made. Therefore, studies with pediatric samples are recommended. Finally, since olfaction can be improved by olfactory training (e.g., Hummel et al. 2009; Cain et al. 1995), it should be tested whether the tendency to depression, panic symptoms, and disgust proneness can be reduced via repeated olfactory discrimination exercises.

## Conclusion

This questionnaire study identified specific associations between affective trait variables and olfactory discrimination ability in school children. High scores on the scales assessing depression, disgust proneness, and panic symptoms were associated with lowered olfactory performance; however, socially anxious

children tended to display better olfactory discrimination. Future studies with longitudinal designs, especially on olfactory training can help to further elucidate the relationship between olfactory performance and symptoms of mental disorders.

## Compliance with Ethical Standards

**Funding Information** Open access funding provided by University of Graz.

**Conflict of Interest** The authors declare that they have no conflict of interest.

**Ethical Approval** All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed Consent** Informed consent was obtained from all participants (each child and a parent) included in the study.



## References

Boesveldt S, Postma EM, Boak D, Welge-Luessen A, Schöpf V, Mainland JD, Martens J, Ngai J, Duffy VB (2017) Anosmia—a clinical review. Chem Senses 42(7):513–523

Burón E, Bulbena A (2013) Olfaction in affective and anxiety disorders: a review of the literature. Psychopathology 46(2):63–74

Buron E, Bulbena A, Bulbena-Cabre A (2015) Olfactory function in panic disorder. J Aff Disord 175:292–298

Cain WS, Stevens JC, Nickou CM, Giles A, Johnston I, Garcia-Medina MR (1995) Life-span development of odor identification, learning, and olfactory sensitivity. Perception 24(12):1457–1472

Cameron EL (2018) Olfactory perception in children. World Journal of Otorhinolaryngology-Head and Neck Surgery 4(1):57–66

Clepce M, Reich K, Gossler A, Kornhuber J, Thuerauf N (2012) Olfactory abnormalities in anxiety disorders. Neurosci Lett 511(1):43–46

Croy I, Hummel T (2017) Olfaction as a marker for depression. J Neurol 264(4):631–638

Croy I, Negoias S, Novakova L, Landis BN, Hummel T (2012) Learning about the functions of the olfactory system from people without a sense of smell. PLoS One 7(3):e33365

Croy I, Bendas J, Wittrodt N, Lenk M, Joraschky P, Weidner K (2017) Gender-specific relation between olfactory sensitivity and disgust perception. Chem Senses 42(6):487–492

Davey GL (2011) Disgust. The disease-avoidance emotion and its dysfunctions. Philos Trans R Soc B Biol Sci 366(1583):3453–3465

Ehlers A (1993) Interoception and panic disorder. Adv Behav Res Ther 15(1):3–21

Essau CA, Muris P, Ederer EM (2002) Reliability and validity of the Spence children's anxiety scale and the screen for child anxiety related emotional disorders in German children. J Behav Ther Exp Psychiatry 33(1):1–18

Gellrich J, Stetzler C, Oleszkiewicz A, Hummel T, Schriever VA (2017) Olfactory threshold and odor discrimination ability in children—evaluation of a modified "Sniffin' Sticks" test. Sci Rep 7(1):1928

Hays WST (2003) Human pheromones. Have they been demonstrated? Behav Ecol Sociobiol 54(2):89–97

Hummel T, Kobal G, Gudziol H, Mackay-Sim A (2007) Normative data for the "Sniffin' Sticks" including tests of odor identification, odor discrimination, and olfactory thresholds. An upgrade based on a group of more than 3,000 subjects. Eur Arch Otorhinolaryngol 264(3):237–243

Hummel T, Rissom K, Reden J, Hähner A, Weidenbecher M, Hüttenbrink KB (2009) Effects of olfactory training in patients with olfactory loss. Laryngoscope 119(3):496–499

Hummel T, Landis BN, Hüttenbrink KB (2012) Smell and taste disorders. GMS Curr Top Otorhinolaryngol Head Neck Surg 10:Doc04

Ille R, Wolf A, Tomazic PV, Schienle A (2016) Disgust-related personality traits in men with olfactory dysfunction. Chem Senses 41(5):427–431

Koelega HS, Köster EP (1974) Some experiments on sex differences in odor perception. Ann N Y Acad Sci 237:234–246

Kohli P, Soler ZM, Nguyen SA, Muus JS, Schlosser RJ (2016) The association between olfaction and depression. A systematic review. Chem Senses 41(6):479–486

Kopala LC, Good KP (1996) Olfactory identification ability in patients with panic disorder. J Psychiatry Neurosci 21(5):340–342

Lemogne C, Smadja J, Zerdazi E-H, Soudry Y, Robin M, Berthoz S et al (2015) Congenital anosmia and emotion recognition. A case-control study. In: Neuropsychologia, vol 72, pp 52–58

Nook EC, Sasse SF, Lambert HK, McLaughlin KA, Somerville LH (2018) The nonlinear development of emotion differentiation: granular emotional experience is low in adolescence. Psychol Sci 29:1346–1357

Oleszkiewicz A, Walliczek-Dworschak U, Klötze P, Gerber F, Croy I, Hummel T (2016) Developmental changes in adolescents' olfactory performance and significance of olfaction. PLoS One 11(6):e0157560

Olsson SB, Barnard J, Turri L (2006) Olfaction and identification of unrelated individuals. Examination of the mysteries of human odor recognition. J Chem Ecol 32(8):1635–1645

Rochet M, El-Hage W, Richa S, Kazour F, Atanasova B (2018) Depression, olfaction, and quality of life: a mutual relationship. Brain Sci 8(5):80

Rozin P, Haidt J, McCauley CR (2008) Disgust. In: Lewis JM, Haviland-Jones JM, Feldman Barret L (eds) Handbook of emotions, 3rd edn. Guilford Press, New York, pp 757–776

Schienle A, Rohrmann S (2012) Ein Fragebogen zur Erfassung der Ekelempfindlichkeit bei Kindern (FEEK). Klinische Diagnostik und Evaluation 4:379–392

Schienle A, Schöpf V (2017) Disgust-related olfactory processing. The role of gender and trait disgust. Perception 46(3–4):475–483

Schienle A, Walter B, Stark R, Vaitl D (2002) Ein Fragebogen zur Erfassung der Ekelempfindlichkeit (FEE). Z Klin Psychol Psychother 31(2):110–120

Schienle A, Wolf A, Tomazic PV, Ille R (2018) Affective personality traits in olfactory dysfunction. The role of dysthymia and arousal. Chemosens Percept 11:72–76

Shoup ML, Streeter SA, McBurney DH (2008) Olfactory comfort and attachment within relationships. J Appl Soc Psychol 38(12):2954–2963

Solbu EH, Jellestad FK, Strætkvern KO (1990) Children's sensitivity to odor of trimethylamine. J Chem Ecol 16:1829–1840

Stevenson RJ (2010) An initial evaluation of the functions of human olfaction. CHEMSE 35(1):3–20

Stiensmeier-Pelster J, Schürmann M, Duda K (2000) DIKJ: Depressionsinventar für Kinder und Jugendliche, 2nd edn. Hogrefe, Göttingen

Wysocki CJ, Preti G (2004) Facts, fallacies, fears, and frustrations with human pheromones. Anat Rec A Discov Mol Cell Evol Biol 281A(1):1201–1211