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Original Article

Assessing the impact of olfactory dysfunction on eating behavior: A systematic scoping review and call for standardized assessments

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SUMMARY

Olfaction plays a priming role in both the anticipation and consumption phases of eating behavior. Olfactory dysfunction can therefore lead to changes in various aspects of eating behavior, such as food choice, appetite, and food intake. In light of the increasing prevalence of persistent olfactory dysfunction among patients affected by Covid-19, providing proper care and dietary advice to individuals with olfactory dysfunction is imperative. Therefore, this scoping review seeks to gain a better understanding of the impact of olfactory dysfunction on eating behavior. Following the PRISMA guidelines, 49 papers were included, the outcomes were presented by dividing them into two categories: 1) anticipatory eating behavior, including (anticipatory) food liking, appetite and craving, food preferences, food neophobia, and cooking habits; and 2) consummatory behavior, including, food intake, consumption frequency, adherence to dietary guidelines, (experienced) food liking, food enjoyment, and eating habits. Our results show that in the anticipatory phase of eating behavior, food liking, and, food preferences, and in the consummatory phase, food enjoyment is most affected in people who experienced a sudden change in olfactory function rather than a gradual decline. Moreover, changes in food flavor perception due to olfactory dysfunction, result in a shift of food preferences towards more "taste-based" preferences, such as salty or savory (i.e., umami) foods. Subsequently, changes in preferences can affect food intake and adherence to dietary guidelines, but only to a limited extent. Appetite is more likely to be low in individuals with short-term olfactory dysfunction compared to those with long-term changes.

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Generally, eating behavior is more impacted in individuals with a distorted sense of smell than in those with smell loss, and the effect becomes more pronounced over time. Due to the heterogeneity of methods used to measure different aspects of eating behavior, this review stresses the importance of more research on olfaction and eating behavior using standardized and validated assessments. Such research is essential to better understand the effects of olfactory dysfunction on each aspect of eating behavior and provide effective interventions.

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Introduction

Olfaction is a crucial sense that plays a pivotal role in several essential functions in our daily lives. It assists in social communication, facilitates avoidance of environmental hazards, and contributes to eating behavior, such as the enjoyment of food [1]. Olfactory dysfunction has been linked to various disturbances in the three areas mentioned above, incorporating social issues related to hygiene and altered sexual behaviors [2], difficulty detecting hazardous smells or food, and reduced food enjoyment [3]. These deficits can have a profound impact on an individual's quality of life [4], including eating behavior, as olfaction is closely related to our sense of taste and is a significant factor in our perception of flavors. Moreover, recent reviews have shown a bidirectional relationship between olfaction and obesity. More specifically, findings point towards an impaired sense of smell in obese individuals and those with higher BMI, thus, further highlighting the importance of smell for eating behavior [5,6].

Olfactory dysfunction refers to a decreased ability or distorted ability to smell during sniffing (orthonasal olfaction) or eating and drinking (retronasal olfaction). It is typically divided into two categories: quantitative and qualitative dysfunction. Quantitative dysfunction can be divided into anosmia, a complete loss of sense of smell, and hyposmia, a reduced sense of smell. On the other hand, qualitative dysfunction is defined as a change in the quality of perceived odors and comprises parosmia, a distorted sense of smell, and phantosmia, odor hallucinations. The major difference between these two qualitative disorders is that these distorted olfactory sensations are experienced in the presence or absence of an odor, respectively [7,8].

It has been estimated that between 3-20% of the general population experiences either qualitative or quantitative olfactory dysfunctions [4,9]. Up to 1% of those individuals may have a congenital form, such as Kallmann's syndrome or isolated congenital anosmia [10]. Other causes for olfactory dysfunction include (1) head trauma, (2) other viral infections such as influenza [11], (3) nasal causes such as sinusitis or polyposis nasi, (4) aging, and, (5) age-related neurological illnesses such as Parkinson's and Alzheimer's disease [12]. Recently, COVID-19 has been linked to persistent loss and alteration of smell, leading to an increase in the number of individuals experiencing olfactory dysfunction [11,13,14].

To measure olfactory dysfunction, both subjective and objective measures can be used. Subjective measures of smell are typically questionnaires that ask individuals to rate their level of olfactory ability and can be completed in a person's own home or online. Objective measures, on the other hand, are mostly carried out under the supervision of a researcher or healthcare provider and typically consist of psychophysical tests developed to measure and quantify human responses to physical stimuli [15], like the Sniffin' Sticks test [16] or the UPSIT [17]. These tests can assess distinct aspects of olfactory function, such as the ability to detect, identify, or discriminate odors. Studies have consistently observed that subjective measures, self-evaluation, tend to underestimate the true prevalence of olfactory dysfunction when gauged against objective psychophysical assessments [18,15]. A potential reason for this is that individuals often confuse their sense of smell with their sense of taste due to the retronasal component of olfaction and its oral referral, leading to an overlap in the perception of flavor [19]. Eating behavior is influenced by physiological, psychological, and behavioral factors, elicited by the sensory and nutritional properties of foods [20]. For example, food choices and preferences can be shaped by food liking but also by food neophobia, the reluctance or fear of trying new or unfamiliar foods. This multifaceted process of eating behavior can be divided broadly into two distinct phases: the *anticipatory* and *consummatory phases* of eating behavior. In the *anticipatory phase*, which encompasses the pre-ingestive aspect of eating, the body prepares for eating by secreting hormones that increase hunger and stimulate the digestive system. In this phase, sensory cues, such as (orthonasal) ambient food odors, can have a substantial influence on appetite, cravings, food preferences, and decisions regarding food choice and consequently food consumption [21]. Additionally, the anticipatory phase comprises cooking habits, including food preparation.

Upon transitioning to the consummatory phase of eating behavior, the focus shifts to the *consummatory phase*. In this phase, retronasal odor, but also taste and texture, play a crucial role in overall flavor perception and determining the amount and type of food that is consumed. These factors contribute to food intake behavior, which includes nutritional intake, consumption frequency, and adherence to dietary guidelines. Moreover, the pleasure derived from consumed food during the consummatory phase is paramount, as it influences individuals' perception of the meal and subsequent dietary choices. Long-term eating habits, such as behaviors and routines individuals have when it comes to consuming food and the social aspects of eating, also play a crucial role in shaping individuals' overall consumption patterns, and meal planning [1].

When measuring eating behavior, the choice of techniques employed depends on the research purpose, study design, and the specific aspect of eating behavior being evaluated, such as food preference or food intake. These methods range from simple visual analog ratings of liking or appetite to more elaborate questionnaires or (behavioral) tasks to assess preferences, to food frequency questionnaires and food intake diaries [22]. Additionally, researchers must choose between laboratory-based studies and free-living studies to measure eating behavior, which often leads to a focus on specific subsets of eating behavior aspects.

While the importance of olfaction in eating behavior is well-established, the impact of olfactory dysfunction on distinct aspects of eating behavior is not yet fully understood. Thus, this scoping review sought to identify and summarize evidence on the impact of olfactory dysfunction on distinct aspects of eating behavior as alluded to above. By examining the effects of olfactory dysfunction on these various facets of eating behavior, this review aims to provide a comprehensive understanding of how olfactory impairment impacts individuals' overall eating behavior.

Materials and methods

Literature search strategy

The literature search and screening were performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (PRISMA) [23], as shown in Fig. 1. The search covered papers on human studies published between the earliest record and July 2022. This search was executed on the Scopus, Ovid MEDLINE, PubMed, and PsycINFO databases, chosen for their relevance and comprehensive coverage in the field. Additionally, a manual search in the reference list of the articles included was performed to identify further eligible studies. The general search strategy involved searching for title, abstracts, and keywords (or headwords on the PsycINFO database). The specific combinations of keywords used are detailed in Table 1, while database-specific search strategies can be found in Appendix 1. Results from each database are tabulated in Table 2.

We expanded our search criteria later in the process, as detailed in section 2.1.1. The result of the additional search is presented also in Table 2.

Extended literature search

At the outset of our scoping review, we conducted an initial search focusing on particular aspects of eating behavior. These aspects were chosen due to their well-established status as domains of eating

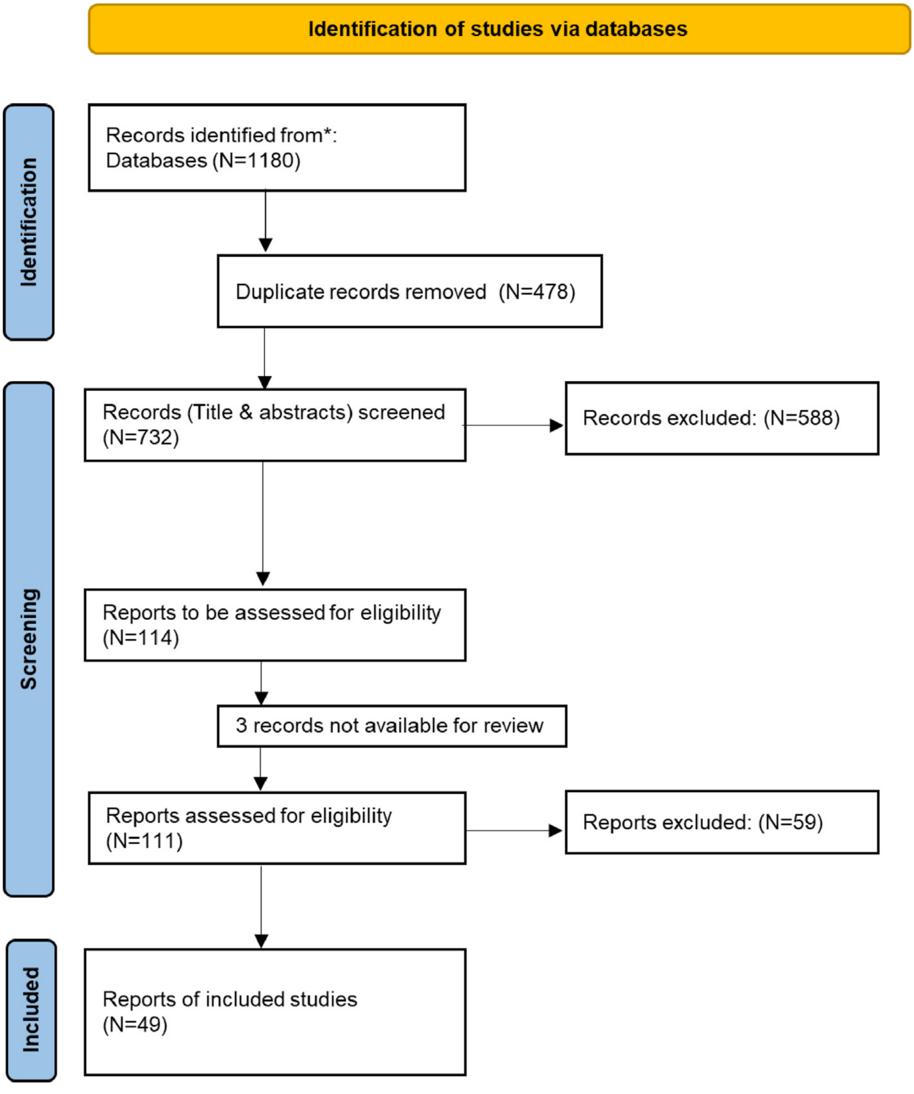

Figure 1. Flow chart showing the results of both the initial and the additional literature search on studies investigating the effect of olfactory dysfunction on eating behavior.

behavior extensively explored in the literature. However, as we reviewed the final selection of papers, it became evident that additional terms, such as food liking, (food wanting), and food neophobia, were identified as significant factors that had not been initially included in our categorization. Therefore, we broadened our search strategy to include these new terms in our scoping review, using the same conditions as mentioned in Section 2.1.

Study selection process

In the initial search, in total, 1062 results (see Table 2) were identified both using search strategies. After removing 404 duplicate records, the remaining 658 articles were assessed for eligibility by two independent reviewers (PP and EP), based on title and abstract. A selection of 40 articles was

Table 1
Main keywords for olfactory dysfunction and eating behavior used for the literature search

Keywords	Strings and combinations of keywords
Olfactory Dysfunction	((olfact* OR smell OR chemosensory OR odor) W/5 (disorder OR loss OR dysfunction OR changes OR deficit OR impairment OR decrease OR alter*)) OR TITLE-ABS-KEY ((anosmia OR hyposmia OR parosmia)) AND
Eating behavior	appetite OR diet* OR food OR eating OR feed*) W/5 (habit OR intake OR pattern OR preference OR pleasantness OR liking OR wanting OR neophobia OR choice OR enjoyment OR perception OR behavi* OR pleasure OR quality OR consumption)

screened by both reviewers, and Cohen's kappa was calculated. The inter-rater agreement for the exclusion of articles was high (K = 0.93; almost perfect agreement above 0.80 [24]. Next, both reviewers screened titles and abstracts of all 658 articles, using the exclusion criteria as mentioned in Fig. 1. We excluded studies on eating disorders as ‘not related to the research question’, as our primary focus was to investigate healthy eating behavior. See Table 3, for an overview of the excluded articles.

As the last step, both reviewers performed full-text screening for all articles that passed the abstract screening. In total, 108 full texts were reviewed, using the same exclusion criteria as used during the title and abstract screening, with ‘no English full text available’ added as an additional criterion. After review, 61 articles were excluded, resulting in 47 full-text articles for quality assessment and data extraction.

Additional literature search

In total, 118 articles were found, of which 44 new articles were identified after the removal of the duplicate articles from our previous search. The articles underwent the procedures outlined in Section 2.2. Following the title and abstract screening, 3 papers advanced to full-text screening and were included in the final selection for quality assessment and data extraction. See Table 3 for a list of excluded articles.

Quality assessment and data extraction

Quality assessment was done using the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies from the National Heart, Lung, and Blood Institute [25]. This tool contained 14 questions on the paper's quality that were answered for all included full texts using Yes, No, Cannot Determine, Not Applicable, or Not Reported (see Table A2.1 in Appendix 2).

Based on the established criteria, all papers were categorized as either Good, Fair, or Poor. Out of 47, 30 papers received a ‘Good’ rating, 17 were rated as ‘Fair’, and none were deemed ‘Poor’. As a result, no papers were excluded based on the Quality Assessment. Papers sourced from the additional search

Table 2
Search results per database for the initial and additional literature search

Database	Original # of items found (initial)	# of deleted duplicates (initial)	# of unique items found (initial)	Original # of items found (additional)	# of deleted duplicates (additional)	# of unique items found (additional)
Medline®	237	22	215	19	14	5
PubMed	265	98	167	18	15	3
PsycINFO®	95	5	90	14	13	1
Scopus	463	147	316	67	32	35
Manual Search	2	0	2	0	0	0
Check for external duplicates (all databases in one)	0	132	-132	0	0	0
Total	1062	404	658	118	74	44

were also subjected to a quality assessment: one paper was rated 'Good', another as 'Fair', and the third as 'Poor'. Consequently, the latter was excluded from the selection. A detailed breakdown of the ratings can be found in Table A2.2, Appendix 2. This process culminated in a final selection of 49 papers for the comprehensive review.

For the final selection of papers, all available data were obtained regarding the first author's name, year of publication, study design (e.g., cross-sectional or longitudinal), demographics of the participants (i.e., sample size, mean age ± SD/SEM, age range, gender, and characteristics of the study groups), type of olfactory function measures utilized (e.g., identification, discrimination, threshold, detection, self-report), eating behavior measures employed, and primary findings. Appendix 3 includes a full overview of the methods used to measure olfactory function.

Results: the impact of olfactory dysfunction on eating behavior

Study characteristics and design

The characteristics of the 49 studies included in the review are summarized in Table 4 and Table 5. The studies were conducted in multiple countries, including South Korea, The Netherlands, Germany, Italy, France, the USA, and Australia. Most studies were cross-sectional (N=44). Only Gopinath *et al.* [26], De Vries *et al.* [27,28] and Postma *et al.* [29] applied a longitudinal study design; Essed *et al.* [30] used a single-blind, within-subjects, cross-over design. Sample sizes varied between 15 cancer patients [27] and 24,490 participants from a population-based study in Korea [31]. Overall, study participants, including control groups, were divided into five populations (see Fig. 2): 16 studies included individuals with general olfactory dysfunction (quantitative as well as qualitative; N=3,175); 11 studies included older adults (N=3,071); 10 studies included cancer patients (N=933); and 8 studies included individuals with various underlying disorders causing the olfactory dysfunction (e.g., Covid-19 [32,33]; CHARGE[1] syndrome [34]; or diabetes [35], N=4,394). Additionally, there were 4 population-based studies (N=37,369).

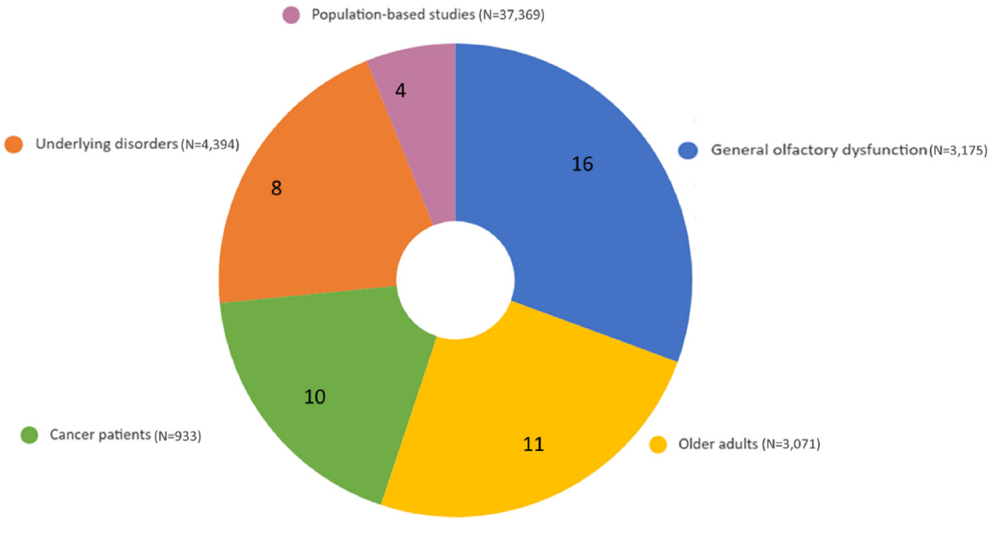

Figure 2. Distribution of populations across studies (Number of Studies by Category with Participant Counts).

[1] CHARGE is an abbreviation for several of the features common in the disorder: coloboma, heart defects, atresia choanae, growth retardation, genital abnormalities, and ear abnormalities.

Table 3
Exclusion numbers based on title and abstract screening for the initial search and the additional search

Exclusion criteria	Number of papers excluded (initial search)	Number of papers excluded (additional search)
Animal study	17	6
No eating behavior	97	2
No olfactory dysfunction	193	3
No original research article	176	5
Not related to the research question	35	24
Case study	22	0
Duplicates	7	0
Not available in English	0	1
Total number of papers excluded	547	41

Anticipatory phase of eating behavior

This category includes food neophobia, food preferences, (anticipatory) food liking, appetite and craving, and cooking habits. To explore these aspects more precisely and consistently, the following terminology will be employed in this context. *Food neophobia* is the reluctance to try new or unfamiliar foods [38]. The evaluative attitudes that people express toward foods are referred to as *food preferences* [73]; these are based on a variety of intrinsic and extrinsic factors, including personal preferences, cultural influences, nutritional concerns, and health status [74]. *(Anticipatory) food liking* refers to the anticipated pleasure (hedonic pleasure) derived from the food or its sensory properties [75]; this is one of the key drivers of food consumption [76]. *Appetite* is defined as a person's desire to search for, select, and consume foods in general [77]. On the other hand, a food *craving* is an intense urge to consume a specific food [78,79]. Cooking habits refer to the individual's practices and routines related to food preparation and cooking. In the context of this study, it includes aspects such as cooking for oneself and any difficulties or changes in cooking behavior due to the condition of olfactory dysfunction. Table 4 shows the articles that were included for the anticipatory phase of eating behavior per category.

Food neophobia

The general population [37] as well as older adults [36] with olfactory dysfunction are more neophobic than healthy controls. In contrast, this was not the case for younger participants [36]. In addition, older adults with olfactory dysfunction were equally willing to try new foods compared to healthy older adults and healthy young people. However, they were significantly more willing to try foods with an unpleasant odor than young adults, likely because they were unable to detect unpleasant aspects of food odor [38]. Lastly, there was no correlation between olfactory function and food neophobia score in children with and without Attention Deficit Hyperactivity Disorder (ADHD) [39].

To summarize, we found contrasting results on the effect of olfactory dysfunction on food neophobia. As food neophobia is a personality trait and depends on factors such as age [80], genetics [81], and sensory properties of food, such as texture and visual cues, the large variation in food neophobia among the population may account for these contrasting results.

Food preferences

There was no significant difference in food preferences (i.e., preferences for macronutrients [48]; vegetables, fruits, meat, fish, starchy foods, and dairy products [37]) between participants who lost their sense of smell during life and healthy controls [37,48]. However, individuals with acquired (i.e., quantitative and qualitative) olfactory dysfunction experienced a shift in preference from sweet, sour, bitter, and fatty tastes to a preference for salty and spicy tastes [1]. Moreover, etiology affected preference for foods high in fat, and preference for sweet foods differed between individuals with olfactory dysfunction and controls [48]. Individuals with congenital olfactory dysfunction were found to be more taste-oriented when eating compared to those with acquired smell loss [48].

In older adults, a lower olfactory function was associated with a change in sweet and salt preferences [47] and in older females, to lower preference for food with a sour or bitter taste or pungent taste

Table 4
Included articles for the anticipatory phase of eating behavior per category (food neophobia, food liking, food preferences, and appetite and craving)

Anticipatory phase of eating behavior					
Authors	Participants		Measurement methods		Result
	Sample	Age: mean ± SD (age range); Gender: F/M	Olfactory dysfunction	Eating behavior	
Food neophobia					
[36]	• Individuals from the general population (N=3685) • Older adults (N=202) (subgroup)	• (4–89); 2085F/600M • (60–89); 117F/85M	Identification Self-report	Food neophobia questionnaire	Older adults with olfactory dysfunction had a higher level of food neophobia; this was not the case for younger participants with and without OD.
[37]	• Individuals with olfactory dysfunction (N=39) • CG (N=40)	• 55.72 ± 2.08[a]; 22F/18M • 56.82 ± 1.84[a]; 22F/18M	Identification Self-report	Food questionnaire	Individuals with OD were more neophobic than control participants.
[38]	Community-dwelling adults; Experiment 1 (N=51) • Young adults with NOR (N=16) • Older adults with NOR (N=15) • Older adults with OD (N=20) Experiment 2 (sauce could not be smelled) (N=54): • NOR Young (N=15) • NOR Older adults NOR (N=15) • Older adults with OD (N=15)	• (18–25) • Older adults (62–85); 31F/20M • Young (19–34) • Older adults: (64–85); 28F/17M	Threshold	Four food stimuli, rated on familiarity, willingness to taste, and pleasantness of the food's odor	No significant effect of olfactory dysfunction on willingness to try new food in older adults compared to healthy older adults and healthy young people in both experiments; older adults with OD were significantly more willing to try the unpleasant-smelling foods than the young adults.
[39]	• Children with ADHD (N=36) • Children without ADHD (N=36)	• 14 (13–16); 7F/29M • 15 (13–16); 18F/18M	Identification; discrimination; threshold	Food Neophobia Test Tool	No correlation between olfactory function and FNTT-score in either group.
Anticipatory food liking					
[28]	• Women with breast cancer (N=28) • CG (N=28)	• 51.0 ±.1 • 51.8 ± 7.6	Identification; discrimination; threshold Self-report	Macronutrient and Taste Preference Ranking Task	A higher rating of subjective smell function was correlated with a higher liking of low-energy and sweet products.
[40]	Normosmic controls (N=166) Individuals with OD (N=522) • Olfactory loss (N=271) • Parosmia (N=251)	• 47 (37–58); 111F/55M • 47 (34–58); 417F/105M	Self-report	Questionnaire on liking of basic tastants and food items	Liking scores of food items were lower in participants with olfactory dysfunction compared with normosmic controls.
[41]	• Individuals with a distorted sense of smell (N=60)	• 54.3 ± 16.4; 31F/29M	Identification; threshold; Self-report	Dietary behavior questionnaire	Changes in food liking were more prominent in individuals

(*continued on next page*)

Table 4 (*continued*)

Anticipatory phase of eating behavior					
Authors	Participants		Measurement methods		Result
	Sample	Age: mean ± SD (age range); Gender: F/M	Olfactory dysfunction	Eating behavior	
	• Individuals with just smell loss (N=58) • CG (N=40)	• 50.0 ± 15.2; 28F/30M • 51.7 ± 17.8; 30F/10M			with a distorted sense of smell than only smell loss; the most avoided foods in individuals with distortion were sweets and meat.
[42]	Individuals with OD (N=389): • No diagnosis (N=48); HYP (N=64); ANS (N=106); DYS (N=30); PH (N=31); Multi-OD (N=31) • CG (N=79)	• 50.5 ± 15.7 (15–93); 168F/142M • 48.8 ± 18.8 (20–83); 37F/42M	Identification; detection Self-report	Questionnaire on dietary habits	Food dislike was most common in individuals with dysosmia, phantogeusia, and multiple disorders.
[43]	Anosmic individuals and healthy controls (N=174) USA • ANS (N = 22) • CG (N = 65) Germany • ANS (N = 22) • CG (N = 65)	USA • 55.7 ± 12.5 (36–76); 12F/10M • 34.7 ± 12.2 (21–63); 42F/23M Germany • 55.2 ± 16.4 (18.–82); 19F/12M • 36.5 ± 16.9 (20.0–81.0); 39F/17M	Identification; discrimination; threshold	Food preference ratings for a 15 foods; preference for certain components in foods	Individuals with OD from the USA had a lower overall liking for food stimuli compared to healthy controls, while no such difference was found in the German population.
[29]	Colorectal cancer patients; Longitudinal: • Patients undergoing chemo-therapy (N=15) • CG (N=20) Cross-sectional: • T1 (N=20); • T2 (N=20); • T3 (N=20)	Longitudinal: • 66 ± 7.7; 2F/13M • 67 ± 8.8; 6F/14M Cross-sectional: • T1:63 ± 9.1; 10F/10M • T2:65 ± 8.9; 7F/13M • T3:66 ± 4.7; 7F/13M	Identification; discrimination; threshold Self-report	Macronutrient and Taste Preference Ranking Task	No correlation between olfactory function and liking of macronutrients or taste qualities in all groups.
[44]	• Young adults with normal olfactory function (N=30) • Older adults with normal olfactory (N=30) • Older adults with OD (N=30)	• 22.6 ± 2.9 (18–30), 30F • 66.4 ± 3.7 (60–75), 30F • 67.8 ± 4.4 (62–79), 30F	Identification; discrimination; threshold	Rating of the pleasantness of green tea and brewed coffee (both in 3 concentrations)	Variations in the concentration of tea and coffee did not affect the pleasantness of these drinks in older adults with OD.
Food preferences					
[1]	Individuals with OD (N=176) • NOR (N=12); • HYP (N=75); • ANS (N=89)	• 57.4 ±14.1; 114F/86M	Identification; discrimination; threshold	Questionnaire providing a dietary alterations score (DAS).	After the onset of smell loss, there is a change in taste preferences towards more salty and spicy food. There was no significant difference between the three diagnostic groups.

[27]	Advanced oesophagogastric cancer patients (N=15)	• 61 ± 9.3; 14F/1M	Identification; discrimination; threshold	Macronutrient and Taste Preference Ranking Task	No correlation between olfactory function and food preferences.
[45]	Elderly women with high personal functioning (N=80)	• 76±6 (65–93)	Identification; detection	Survey on food behavior; food preference for 87 foods on a five-point hedonic scale,	The lower olfactory perception was associated with lower preference for foods with a sour/bitter taste or pungency.
[46]	Patients undergoing bariatric surgery (N=220)	• (19–68); 197F/23M	Self-report	Self-designed questionnaire on food preferences	Lower preference for cheese among patients with olfactory dysfunction.
[47]	• Elderly females (N=41) • Young female adults (N=41)	• 73.0 ± 1.1 • 24.4±0.2	Detection; threshold	Self-reported changes in dietary habits	Older adults with higher smell thresholds showed changes in sweet and salt preferences with age.
[37]	• Individuals with olfactory dysfunction (N=39) • CG (N=40)	• 55.72 ± 2.08[a]; 22F/18M • 56.82 ± 1.84[a]; 22F/18M	Identification Self-report	Food questionnaire	No significant consequences of dysosmia were found for most aspects of food preferences.
[48]	• Individuals with olfactory dysfunction (N=71) • CG (N=738)	• 58 ± 12 (22–82); 52F/19M • 55 ± 15 (19–84); 456F/282M	Self-report	Macronutrient and Taste Preference Ranking Task	Patients with congenital smell loss are more taste (sweet)- or nutrient (fat) oriented.
[29]	Colorectal cancer patients; Longitudinal: • Patients undergoing chemotherapy (N=15) • CG (N=20) Cross-sectional: • T1 (N=20); • T2 (N=20); • T3 (N=20)	• 66 ± 7.7; 2F/13M • 67 ± 8.8; 6F/14M • 1:63 ± 9.1; 10F/10M • 2:65 ± 8.9; 7F/13M • 3:66 ± 4.7; 7F/13M	Identification; discrimination; threshold Self-report	Macronutrient and Taste Preference Ranking Task	Food preferences were not correlated to olfactory function.
Appetite and craving					
[49]	Chronic hemodialysis patients (N=110)	• 64.6 ± 14.8; 40F/70M	Self-report	Hemodialysis Study Appetite questionnaire	Changes in smell were significantly higher in patients with a poor/very poor appetite compared to patients with a good/very good appetite.
[34]	• Children with CHARGE syndrome (N=14) • CG (N=25)	• (6–18 years); 8F/6M • (6–13 years); 14 F/11M	Identification; threshold	Questionnaire on child eating difficulty	No relation between olfactory deficits and the severity of

(*continued on next page*)

Table 4 (*continued*)

Anticipatory phase of eating behavior					
Authors	Participants		Measurement methods		Result
	Sample	Age: mean ± SD (age range); Gender: F/M	Olfactory dysfunction	Eating behavior	
					feeding disorders (including poor appetite).
[32]	Patients with a COVID-19 infection reported change in sense of smell (N=332)	• 41.57 ±13.72; 258 F/63M	Self-report	Questions regarding quality of life	55% of the patients reported a reduced appetite.
[50]	Cancer patients receiving chemotherapy (N=89)	• 66 ± 11.7; 52F/37M	Self-report	Questionnaire on food behavior	No significant effect of chemosensory profile on self-reported appetite.
[30]	Older adults with: • Normal olfactory + normal gustatory function (N=25), • Normal olfactory + low gustatory function (N=23), • Low olfactory + normal gustatory function (N=34), • Low olfactory + low gustatory function (N=38)	• 73 ± 6; 19F/6M • 70 ± 7; 19F/4M • 73 ± 6; 23F/11M • 72 ± 5; 21F/17M	Identification; detection	Rating desire for soup on a 10-point scale	No effect of flavor enhancement on the desire for soup in any of the groups.
[51]	Independently living older adults (N=99)	• (65–101 years); 66F/33M	Identification; discrimination; threshold Self-report	Questionnaire on diminished eating pleasure and appetite	Chemosensory impairment does not diminish appetite in independently living older adults.
[52]	Individuals with olfactory dysfunction (N=227) • Young (N=104) • Older adults (N=123)	• (25–45); 50F/54M • (>=60 years); 61F/62M	Identification; detection	Nutritional evaluation based on diet history, food-intake analysis, and weight record	66% of individuals with OD reported no change in appetite. Change in appetite was not dependent on age or duration of the OD. Those with a duration of OD > 3 years did not perceive a change in appetite.
[53]	Community-dwelling older adults (N=673)	• (57.8±63.1); 345F/328 M	Identification	Question from the Centre for Epidemiologic Studies Depression scale: “In the past week, I did not feel like eating, my appetite was poor.”	No association between olfactory function and appetite.
[54]	Community-dwelling older adults (N=359) • Hyp (N = 66) • Nor (N = 292)	• (69–77 years); 150F/209M • 75 (71–81); 22F/40M; • 72 (69–77); 123F/169M	Identification; discrimination; threshold Self-report	8-item Council of Nutrition Appetite Questionnaire	No association between olfactory function and appetite.

[47]	• Elderly females (N=41) • Young female adults (N=41)	• 73.0 ± 1.1 • 24.4 ± 0.2	Detection; threshold	Self-reported changes in dietary habits	51% of the older adults reported a decreased appetite.
[33]	Mild-to-moderate Covid-19 patients (N=417)	• 36.9 ± 11.4 (19–77); 263F/154M	Identification	The short version of the Questionnaire of Olfactory Disorders-Negative Statements	Patients with anosmia had significantly more loss of appetite than patients with hyposmia or patients with no OD.
[42]	Individuals with a chemosensory disorder (N=389) • No-Diagnosis (N=48); • HYP (N=64); • ANS (N=106); • DYS (N=30); • PH (N=31); • Multi-OD (N=31); CG (N=79)	• 50.5±15.7; 168F/142M • 28F/20M • 32F/32M • 55F/51M • 20F/10M • 21F/10M • 12F/19M • 48.8 ± 18.8 (20–83); 37F/42M	Identification; detection Self-report	Questionnaire on dietary habits	22% up to 48% of the individuals reported a decrease in appetite after the onset of OD.
[41]	• Individuals with a distorted sense of smell (N=60) • Individuals with smell loss (N=58) • CG (N=40)	• 54.3 ± 16.4; 31F/29M • 50.0 ± 15.2; 28F/30M • 51.7 ± 17.8; 30F/10M	Identification; threshold Self-report	Dietary behavior questionnaire	37% of the individuals with a distorted sense of smell reported a decrease in appetite, compared to 22% of individuals with just smell loss.
[55]	Individuals with smell loss and with nasal polyposis and asthma (N=50) • HYP (N=16) • ANS (N= 34)	• 50.5 ± 13.1; 21F/29M	Threshold	Questions about consequences of smell loss, QoL, psychological well-being and distress, and coping strategies	27% of patients reported worsened appetite.
[56]	• Advanced cancer patients (N=52) • CG (N=52)	• 63 (25–86); 21F/31M • 64 (26–81); 21F/31M	Self-report	NIS checklist (nutrition impact symptoms)	27% of the patients reported taste and smell alterations reducing their appetite.
Cooking habits					
[40]	Normosmic controls (N=166) Patients with OD (N=522) • ANS (N=271) • PAR (N=251)	• 47 (37–58); 111F/55M • 47 (34–58); 417F/105M	Self-report	Cooking and Food Provisioning Action Scale	Total CAFPAS score was significantly different between normosmic participants and participants with olfactory dysfunction. However, age and etiology of OD had no effect. Significant differences in cooking habits were found between individuals with smell loss and distorted sense of smell.

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Table 4 (*continued*)

Anticipatory phase of eating behavior					
Authors	Participants		Measurement methods		Result
	Sample	Age: mean ± SD (age range); Gender: F/M	Olfactory dysfunction	Eating behavior	
[37]	• Individuals with OD (N=39) • CG (N=40)	• 55.72 ± 2.08[a]; 22F/18M • 56.82 ± 1.84[a]; 22F/18M	Identification; Self-report	Food questionnaire	No differences in cooking habits between groups.
[55]	Individuals with smell loss, nasal polyposis, and asthma (N=50) • HYP (N=16) • ANS (N= 34)	• (50.5 ± 13.1); 21F/29M	Threshold	Questionnaire on consequences of smell loss	Difficulty in cooking was the most common interference.
[57]	• Patients with chronic rhino-sinusitis (N=70)	• (52.2±17.1); 32F/38M	Identification; discrimination; threshold	Factor 2 of Questionnaire of Olfactory Disorders Negative Statements	Patients with a lower threshold score had a higher chance of impaired eating-related QoL.

F (Female); M (Male); ADHD (Attention Deficit Hyperactivity Disorder), ANS (Anosmia); CG (Control Group); CAFPAS (Cooking and Food Provisioning Action Scale); CHARGE (coloboma, heart defects, atresia choanae); DYS (Dysosmia); GD (Gustatory dysfunction); HYP (Hyposmia); Multi-OD (Multiple diagnoses for olfactory dysfunction); NOR (Normosmia); OD (Olfactory dysfunction); PAR (Parosmia); PH (Phantosmia); QoL (Quality of Life); SD (Standard Deviation); SEM (Standard Error of Mean).

[a] Reported with SEM instead of SD.

Table 5

Included articles for the consummatory phase of eating behavior per category: nutritional intake, adherence to dietary guidelines, consumption frequency, experienced liking, food enjoyment, and eating habits

Consummatory phase of eating behavior					
Authors	Participants		Measurement methods		
	Sample	Age: mean ± SD (age range); Gender: F/M	Olfactory dysfunction	Eating behavior	Result
Nutritional intake					
[1]	Individuals with OD (N=176) • NOR (N=12); • HYP (N=75); • ANS (N=89)	• 57.4 ± 14.1; 114F/86M	Identification; discrimination; threshold	Specifically designed questionnaire providing a dietary alterations score	29% of all individuals with OD reported that they eat less since the onset of olfactory dysfunction.
[58]	Patients under investigation for suspected LC (N=215) • LC=117 • CG=98	 • 68 ± 9; 63 F/54 M •66 ± 10; 43F/55M	Self-report	Patient-Generated Subjective Global Assessment	Olfactory dysfunction decreases food intake in cancer patients.
[59]	•Adult advanced cancer patients (N=192)	•64.3 ± 12.4; 95F/97M	Self-report	Three-day dietary record	Chemosensory alterations were associated with decreased caloric and protein intakes.
[45]	•Elderly women with high personal functioning (N=80)	•76±6 (65–93 years);	Identification; detection	Food frequency questionnaire, 24-h food records (N=5)	The lower olfactory perception was associated with a higher intake of sweets and a lower intake of low-fat milk products.
[30]	Older adults with: •Normal olfactory + normal gustatory function (N=25), •Normal olfactory + low gustatory function (N=23), •Low olfactory + normal gustatory function (N=34) • Low olfactory + low gustatory function (N=38)	 •73 ± 6; 19F/6M •70 ± 7; 19F/4M • 73 ± 6; 23F/11M • 72 ± 5; 21F/17M	Identification; detection	Soup intake	No significant difference in intake between the plain soup and the flavor-enhanced soup in any of the groups.
[60]	• Lifelong ANS (N=9) • Mid-ANS (N=22) • Onset ANS (N=22) • CG= (N=33)	• 41.7 ±17.2; 3F/6M • 51.6 ± 13.41; 3F/9M • 50.2 ±17.5; 11F/11M • 49.9 ±16.2; 17F/16M	Identification; threshold	Nutrition interview; 24-hour recall, the two-day record of food intake	No differences were found in the nutrient intake between people with OD and the control group.
[52]	Individuals with olfactory dysfunction (N=227) • Young (N=104) • Older adults (N=123)	 •(25–45); 50F/54M •(>=60) 61F/62M	Identification; detection	Nutritional evaluation based on diet history, food-intake analysis, and weight record	62% reported no change in food intake.

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Table 5 (*continued*)

Consummatory phase of eating behavior					
Authors	Participants		Measurement methods		
	Sample	Age: mean ± SD (age range); Gender: F/M	Olfactory dysfunction	Eating behavior	Result
[54]	Community-dwelling older adults (N=359) • HYP (N = 66); • NOR (N = 292)	•(69–77); 150F/209M • 75 (71–81); 22F/40M; • 72 (69–7); 123F/169M	Identification; discrimination; threshold Self-report	Food frequency questionnaire	People with hyposmia and those with a normal sense of smell had similar total energy intake. Individuals with hyposmia consumed significantly less protein and alcohol and more carbohydrates
[61]	• Individuals with HYP (N=56) • CG (N=27)	• (46 ± 2); 33F/23M • 28 ± 2 (19–56); 22F/5M	threshold; rating	Questions on salt usage	In individuals with hyposmia, most of them estimated their salt usage increased on average 2.8 times compared to before their hyposmia onset.
[62]	• Advanced cancer patients (N=66)	• 65.4±12.4; 36F/30M	Self-report	Three-day dietary records;	Smell complaint scores were inversely related to energy intake and affected the macronutrient composition of the diet (lesser proportion of fat).
[47]	• Elderly females (N=41) • Young female adults (N=41)	• 73.0 ± 1.1 • 24.4±0.2	detection; threshold	Food interview; 24 hr-recall	Higher smell threshold results in lowering consumption of meats, eggs, and cereals and lowering calories, protein, fat, carbohydrate, and minerals.
[31]	Adults • OD (N=1,332) • CG (N=23,158)	• 14,663F/9,827M • mean age=54.7 • mean age=45.9	Self-report	24-hour recall	Olfactory dysfunction was associated with reduced fat intake for the whole group and showed differential effects depending on age and gender.
[37]	• Individuals with Dysosmic (N=39) • CG (N=40)	• 55.72 ± 2.08[a]; 22F/18M • 56.82 ± 1.84[a]; 22F/18M	Identification; Self-report	Food questionnaire	Individual with OD Increased use of condiments (sugar, mayonnaise, sour cream) for flavor enhancement
[36]	• Individuals from the general population (N=3685) • Older adults (N=202) (subgroup)	• (4–89); 2085F/600M • (60–89); 117F/85M	Identification; Self-report	Food questionnaire	Olfactory dysfunction led to greater consumption of dairy products and meat and lower consumption of vegetables in older adults but did not affect food intake in younger participants.

[41]	• Individuals with a distorted sense of smell (N=60) • Individuals with smell loss (N=58) • CG (N=40)	• 54.3 ± 16.4; 31F/29M • 50.0 ± 15.2; 28F/30M • 51.7 ± 17.8; 30F/10M	Identification; detection; Self-report	Food frequency questionnaire; 24-h recall; 2-d food record	Both individuals with a distorted sense of smell and those with just smell loss reported changes in intake (i.e., decreased or increased); Those who reported changes indeed consumed less nutrients.
[42]	Patients with a chemosensory disorder (N=389) • No-Diagnosis (N=48); • HYP (N=64); • ANS (N=106); • DYS (N=30); • PH (N=31); • Multi-OD (N=31); • CG (N=79)	• 50.5±15.7; 168F/142M • 28F/20M • 32F/32M • 55F/51M • 20F/10M • 21F/10M • 12F/19M • 48.8 ± 18.8 (20–83); 37F/42M	Identification; detection; Self-report	3-day food record;	There were significant differences in intake of carbohydrates, dietary fiber, and total sugars between patient groups and healthy controls. Increased use of sugar and salt was reported by 39–57% of the patients.
[63]	Individuals with chemosensory disorders (N=269)	• M (52.3 ± 12.3) • F (50.6 ±12.3), • 149 F/116M • Gender N/A (N=4)	Self-report	The questionnaire comprises six sections: eating with a smell and taste disorder	More patients reported eating less (18.6%) than eating more (7.3%).
[56]	• Advanced cancer patients (N=52) • CG (N=52)	• 63 (25–86); 21F/31M • 64 (26–81); 21F/31M	Self-report	NIS checklist (nutrition impact symptoms)	27% of the patients reported taste and smell alterations reducing their oral intake.
[35]	• Patients with diabetes (N=428) • CG (N=2776)	• 62.2 (11.2); 193F/235M • 58.1 (12.2); 231F/197M	Identification	Dietary Interview	Patients with OD had a lower daily caloric intake and a lower intake of carbohydrates and sodium. Controls with OD also had a lower daily caloric and fat intake compared to controls without OD.
[57]	Patients with chronic rhinosinusitis (N=70)	• 52.2 ±17.1; 32F/38M	Identification; discrimination;threshold	Questionnaire of Olfactory Disorders Negative Statements	Patients with a lower threshold score had a higher chance of impaired eating-related QoL.
[64]	Participants in the Beaver Dam Offspring Study (N=2838)	• 49 (21–84); 1545F/1293 M	Identification	Dietary choices were assessed by 4 questions.	Overall, olfactory impairment was not linked to the quantity of fruit or vegetable servings or how often salt or sugar was added to food.
[65]	Individuals with olfactory dysfunction (N=222) • Congenital (N=10) • Idiopathic (N=66) • Post-infection (N=63) • Sino-nasal disease (N=34) • Trauma (N=33) • Miscellaneous (N= 17)	• 55.6±16.5; 127F/95M	Identification; discrimination; threshold	The 26-item German version of the DFS (dietary fat and sugar scale) to assess intake of discretionary processed foods—a Western-style diet (rich in sugar, salt, and saturated fat)	The etiology-based approach revealed both positive and negative associations between olfactory performance and consumption of a WSD.

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Table 5 (*continued*)

Consummatory phase of eating behavior					
Authors	Participants		Measurement methods		
	Sample	Age: mean ± SD (age range); Gender: F/M	Olfactory dysfunction	Eating behavior	Result
Adherence to dietary guidelines					
[52]	Individuals with olfactory dysfunction (N=227) • Young (N=104); • Elderly (N=123)	 • (25–45); 50F/54M • (>=60); 61F/62M	Detection; Identification	Nutritional evaluation based on diet history, food-intake analysis, and weight record	Individuals with OD demonstrated a low intake of vitamin B6 and zinc intake was affected by age, gender, severity, and duration of the dysfunction.
[54]	Community-dwelling older adults (N=359) • HYP (N = 66); • NOR (N = 292)	• 69–77 years; 150F/209M • 75 (71–81); 22F/40M • 72 (69–77); 123F/169M	Identification; discrimination; threshold Self-report	Food frequency questionnaire	Hyposmics had worse scores for the AHEI and tended to have worse adherence to the MDS.
[26]	Blue Mountains Eye Study participants • Older adults with OD (N=89) • Older adults without OD (CG) (N = 468)	• 70.7 ± 6.5; 305F/252M • 74.0 (6.7); 34F/55M • 70.0 (6.3); 371/197M	Identification	Validated semiquantitative, food frequency questionnaire used to calculate adherence to dietary guidelines and total dietary score	Older adults showed a poorer adherence to dietary guidelines when they experienced olfactory dysfunction.
[48]	• Individuals with olfactory loss (N=105) • CG (N=738)	• 58 ± 12 (22–82); 77F/28M • 55 ± 15 (19–84); 457F/281M	Self-report	Adherence to Dutch Dietary Guidelines	Individuals with OD had lower adherence to the dietary guidelines for fiber, trans fatty acids, and alcohol.
[66]	Older adults from the NHANES survey • OD (N=1399) • CG (N=4957)	 • 58.6 ± 0.4 (SEM) • 57.7 ± 0.2 (SEM)[a]	Self-report	24 h dietary recall, used to calculate the Healthy Eating Index score	Individuals with OD have a lower diet quality and consume more foods with higher energy density, and have lower consumption of vegetables.
Consumption frequency					
[40]	Individuals with OD (N=522) • Olfactory loss (N=271) • Parosmia (N=251) • Normosmic controls (N=166)	• 47 (34–58); 417F/105M • 47 (37–58); 111F/55M	Self-report	Questionnaire on frequency of intake of basic tastants and food items	The difference in frequency of intake was not significant between individuals with OD and the normosmic controls.
[67]	• Individuals with OD (N=60) • CG (N=60)	• 59.8 ± 12.4; 43F/17M • 58.4 ± 14.6; 38F/22M	Identification; discrimination; threshold	Self-designed questionnaire for Dietary evaluation	Olfactory dysfunction was not associated with changes in the number of meals per day compared to healthy controls. Individuals with OD consumed alcohol less frequently than healthy controls.

[68]	Older adults with and without olfactory impairment (N=321) • NOR (N=213) • HYP (N=108)	 • 66.2 (5.5); 124F/89M • 68.3 (6.7); 47F/61M	Identification; discrimination; threshold	An extensive questionnaire containing various questions on eating behavior	No difference in eating frequency was observed between olfactory-impaired and unimpaired people.
[41]	• Individuals with a distorted sense of smell (N=60) • Individuals with smell loss (N=58) • CG (N=40)	• 54.3 ± 16.4; 31F/29M • 50.0 ± 15.2; 28F/30M • 51.7 ± 17.8; 30F/10M	Identification; threshold; Self-report	Food frequency questionnaire, 24-h recall, and 2-d food record	Intake frequency was lower in individuals with a distorted sense of smell compared to those with just smell loss or healthy controls.
[42]	Individuals with OD (N=389)	50.5±15.7; 168F/142M	Identification Self-report	Questionnaire on dietary habits	46% up to 77% of the Individuals with OD reported alterations in their eating patterns, mostly changes in eating frequency.
Experienced Liking					
[30]	Older adults with: • Normal olfactory + normal gustatory function (N=25) • Normal olfactory + low gustatory function (N=23) • Low olfactory + normal gustatory function (N=34) • Low olfactory + low gustatory function (N=38)	 • 73 ± 6; 19F/6M • 70 ± 7; 19F/4M • 73 ± 6; 23F/11M • 72 ± 5; 21F/17M	Identification; detection	Rating liking of soup on a 10-point scale	No effect of flavor enhancement on liking of soup in any of the groups.
[69]	• Older adults (N=52) • Young CG (N=55)	• 71.3 (61–86); 36F/16M • 22.7 (18–35); 31F/24M	Identification; detection	Liking of custard desserts and tomato drinks after applying flavor enhancement, textural change, and/or irritant addition	Multi-sensory enhancement did not affect increasing food liking in older adults with OD.
[68]	Young and older people with and without olfactory impairment (N=122) • Young consumers (N=38) • HYP old (N=43) • NOR old (N=41)	 • (32.3 ± 8.9); 22F/16M • (68.5 ± 5.9); 18F/25M • (65.1 ± 5.2); 28F/13M	Identification; discrimination; threshold	Food liking was assessed on a 100 mm horizontal visual analog scale	Older adults with and without OD increased food liking in multi-sensory enrichment in warm meal components.
[70]	• Individuals with congenital anosmia (N=15) • CG (N=15)	• 31.0 ± 9.9 (20–42); 3F/2M • 27.8 ± 5.2 (21–39); 2F/3M	Identification; discrimination; threshold	Rating the pleasantness of a stimulus (banana) during consumption on a 21-point scale	In individuals with congenital anosmia, the decline in pleasantness during consumption was lower than in healthy controls.
[44]	• Young adults with normal olfactory function (N=30) • Older adults with normal olfactory (N=30) • Older adults with OD (N=30)	• 22.6 ± 2.9 (18–30), 30F • 66.4 ± 3.7 (60–75), 30F • 67.8 ± 4.4 (62–79), 30F	Identification; discrimination; threshold	Rating of the pleasantness of green tea and brewed coffee (both in 3 concentrations)	Variations in the concentration of tea and coffee did not affect the pleasantness of these drinks in older adults with OD.

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Table 5 (*continued*)

Consummatory phase of eating behavior					
Authors	Participants		Measurement methods		
	Sample	Age: mean ± SD (age range); Gender: F/M	Olfactory dysfunction	Eating behavior	Result
Food enjoyment					
[51]	Independently living older adults (N=99)	(65–101); 66F/33M	Identification; discrimination; threshold Self-report	Questionnaire on diminished eating pleasure and appetite	Chemosensory impairment does not diminish eating pleasure in independently living older adults.
[32]	Patients with a COVID-19 infection reported change in sense of smell (N=332)	41.57 ±13.72; 258F/63 M	Self-report	Questions regarding the quality of life (QOL) and safety concerns	Reduced enjoyment of food was the most common complaint (87%).
[60]	• Lifelong ANS (N=9); • Midterm-ANS (N=22); • Onset ANS (N=22); • CG (N=33)	• 41.7 ±17.2; 3F/6M • 51.6± 13.41; 3/9 • 50.2 ±17.5; 11/11 • 49.9 ±16.2; 17/16	Identification; threshold	Score enjoyment between 1-5	The recent-onset and mid-term anosmics had experienced significantly lower food enjoyment compared to healthy controls, whereas individuals with life-long olfactory dysfunction did not.
[52]	Individuals with olfactory dysfunction (N=227) • Young (N=104); • Older adults (N=123)	 • (25–45); 50F/54M • (>=60); 61F/62M	Identification; detection	Nutritional evaluation based on diet history, food-intake analysis	In the total sample, food enjoyment was very great (27%) or somewhat (42%) decreased regardless of gender or seventy of smell disorder. Among older adults, food enjoyment was only diminished if the duration of OD was < 3 years.
[62]	Advanced cancer patients (N=66)	• 65.4±12.4; 36F/30M	Self-report	Three-day dietary records	Food enjoyment was lower among individuals with severe chemosensory complaints vs. patients with mild or moderate OD.
[71]	Individuals with smell loss (N=133) • HYP (N=61) • ANS (N=72)	• 55.9 ± 16.3; 81F/52M	Identification; discrimination; threshold	19-item Questionnaire of Olfactory Disorders	Self-perceived senses of taste and flavor are more dominantly associated with food enjoyment, in contrast to the patient-perceived sense of smell.
[37]	• Individuals with DYS (N=39) • CG (N=40)	• 55.72 ± 2.08[a]; 22F/18M • 56.82 ± 1.84[a]; 22F/18M	Identification; Self-report	Food questionnaire	Food enjoyment was lower in individuals with quantitative olfactory dysfunction
[36]	Individuals from the general population (N=3685)	(4–89); 2085 F/600 M	Identification Self-report	Food neophobia questionnaire	Better smell function was associated with greater food enjoyment.
[41]	Individuals with a distorted sense of smell (N=60) • Patients with smell loss (N=58) • CG (N=40)	• 54.3 ± 16.4; 31F/29M • 50.0 ± 15.2; 28F/30M • 51.7 ± 17.8; 30F/10M	Identification; detection Self-report	Dietary behavior questionnaire	Decreased food enjoyment was higher in individuals with distorted smell than in those with smell loss.

[42]	Individuals with OD (N=389) • No diagnosis (N=48); • HYP (N=64); • ANS (N=106); • DYS (N=30); • PH (N=31); • Multi-OD (N=31) CG (N=79)	50.5 ± 15.7 (15–93); 168F/142M • 28F/20M • 32F/32M • 55F/51M • 20F/10M • 21F/10M • 12F/19M 48.8 ± 18.8 (20–83); 37F/42M	Identification; detection Self-report	Questionnaire on dietary habits	Most individuals reported decreased food enjoyment; this was highest among people with multiple diagnoses and lowest in those with anosmia. Food enjoyment declined with the duration of OD.
[63]	Individuals with chemosensory disorders (N=269)	• M (52.3 ± 12.3) • F (50.6 ±12.3), • 149 F/116M • Gender N/A (N=4)	Self-report	The questionnaire comprises six sections: eating with a smell and taste disorder	The decreased pleasure from eating was the most common complaint. Duration of OD does not affect the declined pleasure.
[55]	Individuals with smell loss and with nasal polyposis and asthma (N=50) • HYP (N=16) • ANS (N= 34)	• 50.5 ± 13.1; 21F/29M	Threshold	Questions about consequences of smell loss; Quality of life questionnaire	68% of participants had diminished food enjoyment.
[72]	Members of the patient support organization Fifth Sense (N=496)	• 55 (8–95); 318F/178M	Self-report	The survey included questions on the quality of life, depression, and anxiety, impact, and allowed free text entries	People with qualitative disorders have less enjoyment of food in terms of flavor perception, eat unhealthily, and eat less.
[48]	Individuals with olfactory loss (N=105)	• 58 ± 13 (14–87); 73F/32M	Self-report	Questions on food enjoyment	People with OD enjoy eating food less than they did before the onset of their smell loss.
[57]	Patients with chronic rhinosinusitis (N=70)	• (52.2 ±17.1); 32F/38M	Identification; discrimination; threshold	Factor 2 of Questionnaire of Olfactory Disorders Negative Statements	Of the potential effects of their decreased olfaction on QOL, the enjoyment of food and eating was missed the most.
[64]	Participants in the Beaver Dam Offspring Study (N=2838)	• (21–84, mean 49); 1545F/1293 M	Identification	Two questions on the impact of olfactory impairment on food enjoyment	Participants with olfactory impairment were less likely to report that food tasted as good as it used to, or that they experienced food flavors the same.
Eating habits					
[1]	Individuals with OD (N=176) • NOR (N=12); • HYP (N=75); • ANS (N=89)	• (57.4±14.1); 114F/86M	Identification; discrimination; threshold	Specifically designed questionnaire providing a dietary alterations score.	Olfactory dysfunction negatively affects social food-related activities
[72]	• Members of the patient support organization, Fifth Sense (N=496)	• 55 (8–95); 318F/178M	Self-report	Survey including questions on the quality of life; depression and anxiety; impact; free text entries	Patients reported avoidance of birthdays, family events, dinner parties, and eating out.

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Table 5 (*continued*)

Consummatory phase of eating behavior					
Authors	Participants		Measurement methods		
	Sample	Age: mean ± SD (age range); Gender: F/M	Olfactory dysfunction	Eating behavior	Result
[52]	Individuals with OD (N=227) • Young (N=104) • Elderly (N=123)	 • (25–45 years); 50F/54M • (>=60 years); 61F/62M	Identification; detection	Nutritional evaluation based on diet history, food-intake analysis, and weight record	67% of the individuals reported changes in eating habits. The severity of smell loss has no effect.
[67]	• Individuals with OD (N=60) • CG (N=60)	• 59.8± 2.4; 43F/17M • 58.4± 14.6; 38F/22M	Identification; discrimination; threshold	Self-designed questionnaire	No effect of OD on eating habits.
[33]	• Mild-to-moderate Covid-19 patients (N=417)	• (36.9±1.4); 263F/154M	Self-report	The short version of the Questionnaire of Olfactory Disorders-Negative Statements	Patients with anosmia ate out significantly less than patients with hyposmia or patients with no OD.
[57]	• Patients with chronic rhinosinusitis (N=70)	• (52.2±17.1); 32F/38M	Identification; discrimination; threshold	Factor 2 of Questionnaire of Olfactory Disorders Negative Statements	Patients with a lower threshold score had a higher chance of impaired eating-related QoL.

F (Female); M (Male); ANS (Anosmia), CG (Control Group); DYS (Dysosmia); GD (Gustatory dysfunction); HYP (Hyposmia); LG (Lung Cancer); MDS (Mediterranean Diet Score); Multi-OD (Multiple diagnoses for olfactory dysfunction); NOR (Normosmia); OD (Olfactory dysfunction); PAR (Parosmia); PH (Phantosmia); QoL (Quality of Life), SD (Standard Deviation); SD (Standard Deviation); SEM (Standard Error of Mean); WSD (Western Style Diet).

[a] Reported with SEM instead of SD.

[45]. In contrast, neither colorectal cancer patients [29] nor patients with advanced esophagogastric cancer [27] showed a correlation between olfactory dysfunction and food preferences. On the other hand, bariatric surgery patients who exhibited olfactory dysfunction were found to have a reduced preference for cheese [46].

Overall, olfactory dysfunction leads to changes in food preferences, likely to compensate for the changed flavor perception. This is most prominently seen in individuals with congenital anosmia, who are more taste (sweet)- or nutrient (fat) oriented than individuals with acquired olfactory dysfunction or individuals with a normal sense of smell [48]. However, congenital anosmia does not produce noticeably abnormal food preferences [82]. The exact mechanism of the effect of olfactory dysfunction on flavor perception and subsequent food preferences needs further investigation. There are contrasting results on the effect of olfactory dysfunction itself on taste ability [83], [84], but olfactory and taste dysfunction are often seen in combination, for example in Covid-19 patients [85] or cancer patients [18]. Lastly, individuals with olfactory dysfunction have been found to have a reduced sensitivity to the spiciness of the food, as those with anosmia showed reduced oral irritation in response to chili powder [86] and a decreased sensitivity towards trigeminal stimuli [87,88]. This reduced sensitivity may also contribute to the changes in flavor perception (during the consumption phase) that drive future food preferences in these individuals.

Food (anticipatory) liking

The effect of olfactory dysfunction on the liking of food can differ across cultures. A study conducted in the United States indicated that individuals with olfactory dysfunction had a lower overall liking for food stimuli than healthy controls, whereas no significant difference was found between groups in a German population [43]. Also, the nature of the olfactory dysfunction affects food liking. In individuals with smell loss and distorted smell changes in food liking were particularly pronounced in individuals within the latter group with sweets and meat being the most disliked food categories [41]. In addition, it was observed that food aversions were more frequent among individuals experiencing a distorted sense of smell and those with multiple diagnoses (e.g., hyposmia and phantosmia) [42].

Olfactory dysfunction can affect food liking in cancer patients undergoing chemotherapy. Among women with breast cancer, a lower self-reported sense of smell was correlated with a lower liking of low-energy and sweet products [28]. However, in colorectal cancer patients, olfactory (dys)function was not correlated with food liking [29]. Moreover, in individuals with smell loss and distorted sense of smell following a Covid-19 infection, food liking was significantly lower compared to controls [40].

Overall, most studies show that olfactory dysfunction affects anticipatory food liking. Its effect depends on the nature of olfactory dysfunction. Furthermore, external factors such as culture [43], or treatment in cancer patients [89], can also impact the liking of food.

Appetite and craving

In individuals with olfactory dysfunction, the prevalence of decreased appetite ranges from 22-48% [42,55,52]. Changes were not dependent on age or the extent of the dysfunction, and individuals with long-lasting olfactory dysfunction (more than three years) did not perceive a change in appetite [52]. Moreover, changes in appetite were more common in individuals with a distorted sense of smell (37%) than in individuals with smell loss (22%) [41]. Similarly, more individuals with smell distortion (25%) than with smell loss (19%) reported the development of food cravings [41].

Studies in older adults show mixed findings regarding the relationship between olfactory function and appetite. While some studies found no impact of olfactory function on appetite [51,54,53], one study among Korean elderly women showed that between 51% and 62% of the participants reported a decreased appetite [47]. Additionally, olfactory function did not affect the desire for plain soup versus flavor-enhanced soup in older adults [30].

Among advanced cancer patients, 27% reported diminished appetite due to their smell alterations [56]. However, another study showed no significant effect of smell alterations on appetite in patients undergoing chemotherapy [50].

Among Covid-19 patients with olfactory dysfunction, 55% reported a reduced appetite [32]. However, the reduction in appetite was lower in those with anosmia than in those with hyposmia and without olfactory dysfunction [33]. In chronic hemodialysis patients, there were more changes in smell in patients with a poor appetite compared to those with a good appetite [49]. Among children with CHARGE syndrome, no relation between olfactory deficits and the severity of feeding disorders (including poor appetite as part of abnormal feeding behavior) was found [34].

The results of these studies suggest that the nature of olfactory dysfunction (qualitative vs quantitative) and its duration can lead to differences in appetite. For instance, it is more likely to experience a decrease in appetite in individuals with short-term olfactory dysfunction, while those with long-term olfactory dysfunction may develop coping strategies [90]. This is reflected in a higher quality of life in individuals with long-term dysfunction [91]. Furthermore, while more research is needed, it can be speculated that qualitative olfactory disorders, which typically have more significant effects on eating behavior, may lead to food craving.

Cooking habits

Comparison of individuals with olfactory dysfunction to healthy controls revealed no differences in cooking habits, i.e., cooking for oneself and eating prepared meals [37]. However, another study found that among individuals with smell loss, difficulty in cooking was the most common interference [55]. Additionally, individuals with olfactory dysfunction after a Covid-19 infection had lower scores on skills and self-efficacy, and attitude related to cooking compared to healthy controls [40]. However, individuals' age and etiology of the olfactory dysfunction (i.e., Covid-19 vs non-Covid-19 (long duration)) have no effect [40].

Generally, individuals experiencing olfactory dysfunction face challenges while cooking, including a lack of comfort and inspiration in the kitchen and difficulty in preparing new dishes. Individuals with distorted sense of smell have more challenges with respect to individuals with smell loss, such as a reduced confidence in the ability to deal with unexpected results, and a wish for more time for planning meals.

Consummatory phase of eating behavior

Within the consummatory phase, we defined the following categories: nutritional intake, adherence to dietary guidelines, consumption frequency, (experienced) food liking, food enjoyment, and finally eating habits. *Nutritional intake* is the sum of foods and beverages consumed by a person, including carbohydrates, proteins, fats, vitamins, and minerals [92]. *Adherence to dietary guidelines* is defined as following the recommendations for daily nutrient intake as set by national or international health organizations [93]. *Consumption frequency* refers to how often food is consumed during a specified time [94]. We defined the *experienced food liking* as individuals' actual liking and sensory satisfaction with the taste, flavor, and texture of the food during consumption. *Food enjoyment* is the overall satisfaction and pleasure derived from consuming food [73] including feelings of pleasure, satisfaction, and well-being during the meal. And last but not least, *eating habits* refer to the behaviors and routines individuals have when it comes to consuming food, and the social aspects of eating, such as eating alone or with others [95]. Table 5 shows the articles that were included for the anticipatory phase per category.

Nutritional intake

Most studies demonstrated an effect of olfactory dysfunction on food intake among the general population. In particular, 29% of individuals reported having reduced their intake since the onset of their olfactory dysfunction [1]. Furthermore, individuals reporting intake changes consumed fewer nutrients [41]. Notably, a higher proportion (18.6%) reported decreased consumption compared to those increasing intake (7.3%) [63]. In South Korean adults, olfactory dysfunction was associated with lower fat intake [31]. Moreover, age and gender were identified as factors that can influence the effect of olfactory dysfunction on food intake, as young males with olfactory dysfunction were found to consume less protein compared to their healthy counterparts [31]. Also, significantly lower consumption of carbohydrates, dietary fiber, and total sugars was observed in individuals with olfactory dysfunction with multiple diagnoses compared to healthy controls. However, no marked deficiencies or clinically relevant excesses were found [42].

In contrast, other studies revealed that 62% of the individuals with olfactory dysfunction did not exhibit any changes in food intake [52]. In addition, no significant difference in nutritional status was observed between individuals with anosmia and healthy controls [60] nor was an association found between olfactory impairment and the consumption rate of vegetables or fruit [64]. Moreover, no association between a Western-style diet (i.e., high in sugar, salt, and fat) and olfactory dysfunction was identified among the study's population. However, for the separate subgroups for etiology, various associations were observed between olfactory function and consumption of a Western-style diet [65].

Most studies reported increased usage of condiments [37] and additional foods among individuals with olfactory dysfunction: 15% up to 57% reported altered use of spices [1,63]. Individuals with hyposmia reported an average increase of 2.8 times in the use of salt when compared with before their smell loss [61]. However, another study found no association between the frequency of adding sugar or salt to food and olfactory function [64]. Furthermore, a slightly higher rate of change in the use of spices was observed among individuals with a distorted sense of smell (43%) compared to those with smell loss (40%) [41].

Older adults with olfactory dysfunction have been observed to experience changes in their nutritional intake. Studies among elderly women revealed that lower olfactory perception was associated with a higher intake of sweets and a lower intake of low-fat milk products, leading to a nutrient intake profile pointing towards a higher risk for cardiac disease [45] and negatively correlated with the consumption of meats, eggs, cereals, and caloric intake, as well as intake of protein, fat, carbohydrates, and minerals [47]. Older adults with olfactory dysfunction were found to choose different snacks than their unimpaired peers [68] and to consume significantly less protein and alcohol, and more carbohydrates than their normosmic counterparts, though their total energy intake was similar [54]. Additionally, older adults with olfactory dysfunction tended to consume more dairy products and meat, and fewer vegetables than younger participants [36], and used more spices to enhance appetite and food intake [47]. Notably, olfactory function did not affect the intake of plain soup versus flavor-enhanced soup [30].

Among advanced cancer patients, chemosensory alterations were found to have a negative impact on energy and macronutrient intake, including protein [59] and fat [62], with 27% of these patients reporting reduced intake [56]. Furthermore, lung cancer patients with smell and taste alterations reported significantly lower food intake than those without such alterations [58]. Additionally, diabetic patients with olfactory dysfunction had a decreased daily caloric, carbohydrate, sodium, and fat intake when compared with those without olfactory dysfunction. In the same study, controls with olfactory dysfunction also had a lower daily caloric intake and lower fat intake compared to the control group without olfactory dysfunction [35].

To summarize, the literature shows that, regardless of etiology, olfactory dysfunction can lead to a decrease in food intake, potentially resulting in inadequate nutrient intake and deficiencies. Individuals with distorted olfactory function reported avoiding eating because food had an unpleasant flavor, while those with only smell loss reported reduced pleasure as the reason for avoiding eating [41]. The effects of olfactory dysfunction do not seem to lead to marked deficiencies in the general population, probably because individuals compensate for the effect of olfactory dysfunction by the increased use of condiments and additional foods. However, olfactory dysfunction may put older adults at risk of inadequate food consumption, including a decrease in intake and less healthy dietary patterns. Contrary to the findings of Essed *et al.* [30], the study by Mathey *et al.* revealed that flavor enhancement can improve dietary intake in older adults [96]. This indicates that other factors may also influence nutritional intake, as Essed *et al.* administered the products in a laboratory setting, while Mathey *et al.* provided meals during lunch at nursing homes.

Adherence to dietary guidelines

Individuals with olfactory dysfunction had a lower diet quality than healthy individuals, consuming more foods with higher energy density, such as saturated fats and added sugars, as well as having a lower consumption of vegetables [66]. In contrast, another study showed that there was no difference in *total* adherence to dietary guidelines between individuals with olfactory dysfunction and healthy controls. However, individuals did have significantly lower adherence to the guidelines for dietary fiber, trans fatty acids, and alcohol, and better adherence to salt [48]. Furthermore, adequate adherence to dietary recommendations was reported, except for a low intake of vitamin B6 and zinc in individuals with olfactory dysfunction [52].

Older adults with olfactory dysfunction showed a poorer adherence to dietary guidelines compared to those without olfactory dysfunction [26,54]. The self-reported poor smell was associated with lower scores on dietary quality indexes [54] and female individuals with moderate or severe olfactory dysfunction had significantly lower adherence to dietary guidelines than those without olfactory dysfunction five years later [26].

Overall, these results show that individuals with olfactory dysfunction have lower adherence to (components of) dietary guidelines, leading to a less healthy diet. Factors that influence adherence include etiology [48], duration [26,52] and severity [52] of olfactory dysfunction, and age and gender [26,52,66]. Therefore, tailored advice for people with olfactory dysfunction, taking factors like the age of the individuals and duration of the olfactory dysfunction into account, is necessary to improve adherence to dietary guidelines. Such advice can be derived from more generic strategies employed by individuals with olfactory dysfunction, such as focusing on food texture or the visual aspects of food [40,52].

Consumption frequency

Olfactory dysfunction does not necessarily lead to changes in eating frequency among individuals with acquired olfactory dysfunction, as it was not associated with the number of meals per day nor with the average time spent per meal [67]. Moreover, there was no difference in eating frequency among older adults with olfactory dysfunction when compared to older adults with a normal sense of smell, while those with olfactory dysfunction did consume less varied meals [68]. Moreover, alcohol consumption was less frequent in individuals with olfactory dysfunction than in healthy controls [67]. Other research showed that up to 77% of individuals with olfactory dysfunction reported alterations in their eating patterns, mostly changes in eating frequency, with the highest incidence seen in those with multiple diagnoses (e.g., combining hyposmia and phantosmia) [42]. Additionally, intake frequency was lower in individuals with a distorted sense of smell compared to those with just smell loss or healthy controls [41], while among individuals with olfactory dysfunction after a Covid-19 infection no changes in frequency of intake were found [40].

Concluding, these findings indicate that changes in eating frequency are related to the nature of olfactory dysfunction (i.e., quantitative or qualitative), with a lower consumption frequency observed in those with a distorted sense of smell. This is further supported by evidence from recent work among individuals with a distorted sense of smell after a Covid-19 infection, who indicated that distorted food odors were also mostly perceived as unpleasant [97].

Experienced food liking

The hedonic value of food typically decreases during consumption; however, in individuals with congenital olfactory dysfunction, this decline in pleasantness was lower than in healthy controls [70]. In older adults with olfactory dysfunction, variations in the concentration of tea and coffee did not affect the pleasantness of these drinks [44]. While older adults with and without olfactory dysfunction increased food liking in response to multi-sensory enrichment in warm meals (i.e., visual and flavor enrichment in mashed potato) [68], no effects on food liking were observed for flavor and texture enhancement in older adults with olfactory dysfunction [30,69]. However, changes in the texture affected food pleasantness more in older adults with low olfactory ability compared to older adults with a medium or high olfactory ability [69].

Overall, most studies show that olfactory dysfunction affects food liking. However, it can be assumed a gradual decline of olfactory function, which is common in older adults, has a minor effect on the liking of food, while a sudden change in olfactory function is likely to have a greater effect. This is supported by the finding that olfactory function is not associated with nutritional status [98] or total energy intake [45]. Thus, further research should consider other factors that may affect the liking of food in individuals with olfactory dysfunction, such as the heterogeneity of olfactory dysfunction among older adults [30].

3.3.5. Food enjoyment

Food enjoyment, and eating-related quality of life, were found to be positively associated with olfactory function [37,36,48,55,60,57,64]. While individuals with acquired olfactory dysfunction had significantly lower food enjoyment compared to healthy controls, those with life-long olfactory dysfunction did not [60]. Reduced food enjoyment was also observed in 87% of the individuals in a cohort of Covid-19 patients with olfactory dysfunction [32].

While one study found that decreased food enjoyment declined with the duration of olfactory dysfunction [42], another study found no effect of duration [63]. Individuals with multiple diagnoses related to smell (e.g., hyposmia and phantosmia) [42] and patients with qualitative disorders [41,72] reported decreased enjoyment of food more often compared to those solely suffering from smell loss. The difference between individuals with qualitative and quantitative dysfunctions was most pronounced in those with long-term (>1 year) problems [41]. Additionally, olfactory dysfunction was identified to reduce the enjoyment of food in younger cohorts [52,63], regardless of gender or severity of the disorder [52].

The results obtained for older adults were inconsistent. In one study, over 70% of the participants responded that food enjoyment had diminished to some extent or significantly since the emergence of their olfactory dysfunction [52], while another study found that only 18% of the individuals reported a decrease in eating pleasure [51]. The decrease in food enjoyment did, however, diminish as olfactory dysfunction duration increased [52]. In addition, food enjoyment was lower in patients with advanced cancer who had severe chemosensory complaints compared to those with less severe complaints [62].

Together, these results indicate that olfactory dysfunction leads to a decline in food enjoyment, in which young individuals are more affected than older adults. The decline in food enjoyment seems to become less pronounced over time, likely due to the development of coping mechanisms [52]. Moreover, the nature of olfactory dysfunction is an important factor in food enjoyment. In individuals with a distorted sense of smell, food enjoyment is more severely impacted, possibly because qualitative olfactory dysfunction likely has a greater impact on flavor perception than quantitative olfactory dysfunction. This was further corroborated by recent studies on parosmia in patients after Covid-19 infections [97,99]. Moreover, the importance of flavor perception in food enjoyment is supported by the finding of Liu *et al.* [71], who found that food enjoyment was more strongly associated with self-perceived taste and flavor than with smell perception. Also, this is further evidenced by the fact that individuals with lifelong olfactory dysfunction did not show reduced food enjoyment [60]. These individuals were never able to perceive the flavor of food fully. This suggests that alternative strategies to enhance the enjoyment of the flavor of food, either through coping strategies (e.g., focusing on other sensory aspects of the food) or by innovative food products (e.g., new food designs), are important to increase overall food enjoyment in patients with olfactory dysfunction.

Eating habits

A comparison of individuals with olfactory dysfunction to healthy controls revealed no differences in eating habits, such as emptying a food plate although full [67]. However, another study found that 67% of the individuals reported changes in eating habits [52], mostly by younger females or older adults with shorter olfactory dysfunction duration. olfactory dysfunction negatively a affect socially related eating habits, such as going out for dinner [1,33,72,57]. Individuals reported employing coping strategies, including emphasizing the social aspects of the meal [52], to cope with their altered flavor perception.

Concluding, these findings suggest that individuals with olfactory dysfunction experience the most difficulty with social activities related to eating, impacting their quality of life [10,72]. To cope with the altered perception of flavor, individuals can use a variety of strategies, such as eating with family and friends, altering the quality of spices to stimulate the trigeminal sensation, and focusing on the texture, temperature, and visual presentation of the food. These coping strategies could contribute to a better quality of life, as they might improve social interactions during eating.

Discussion and conclusion

This systematic scoping review with its primary objective of exploring the range and nature of studies investigating the effect of olfactory dysfunction on distinct aspects of eating behavior reveals a crucial need for standardized assessments in this research area. So far, the exact relationship between olfactory dysfunction and eating behavior has been poorly understood. This may partly be attributed to the complexity of olfactory dysfunction, which can affect eating behavior in multiple ways, as well as a lack of harmonized assessment methods for the distinct aspects of eating behavior. Our analysis of existing literature indicates that this variability can range from self-reported questionnaires to more objective measures like psychophysical tests. Such divergence makes it challenging to draw definitive conclusions or compare results across studies. For example, while some studies used validated tools like food frequency questionnaires, others relied on less standardized methods. This inconsistency highlights the urgent need for standardized, validated tools in this research area.

In discussing the impact of olfactory dysfunction on eating behavior, we note that the heterogeneity in study populations and methodologies leads to diverse findings. However, it can be concluded that there are implications for individuals experiencing olfactory dysfunction, of which decreased food enjoyment is the most outstanding. Moreover, our results show that in the anticipatory phase of eating behavior, food preferences and food liking are most affected in people who experienced a sudden change in olfactory function rather than a gradual decline, probably as the latter group adapts to their decreased olfactory function over time. Moreover, changes in odor perception due to olfactory dysfunction alter the perception of food flavors, resulting in a shift of food preferences towards more taste-based preferences, like salty or savory (i.e., umami). Appetite is more likely to be low in individuals with short-term olfactory dysfunction compared to those with long-term changes. This is because individuals with long-term olfactory dysfunction may habituate to their altered sense of smell. Moreover, individuals with olfactory dysfunction associate cooking with a lack of comfort and inspiration and an inability to make new foods successfully.

Subsequently, changes in preferences in the anticipatory phase can affect food intake and adherence to dietary guidelines in the consummatory phase. This is likely only to a limited extent because food intake is not only regulated by sensory perception but also by other factors, including hunger state and eating habits [100]. Additionally, eating behavior is more impacted in individuals with a distorted sense of smell than in those with smell loss; this effect is more pronounced over time [41]. Moreover, food enjoyment is most affected in people who experienced a sudden change in olfactory function rather than a gradual decline.

The findings of this review reveal that specific characteristics of olfactory dysfunction influence its impact on eating behavior. For instance, the *duration* and *nature* of dysfunction (sudden versus gradual onset, total loss versus distortion of smell) significantly influence eating behavior. However, the lack of standardized measures makes it difficult to systematically compare these impacts or to understand the complex interplay of factors influencing eating behavior in individuals with olfactory dysfunction. The current result shows that in individuals with a distorted sense of smell, pleasantness, food enjoyment, appetite, consumption frequency, and cooking habits [40] are more affected than in individuals with smell loss. Associating an unpleasant smell (e.g., garbage) with a food item (e.g., coffee) creates an unpleasant sensory experience that can disrupt expectations and create a sense of unease or discomfort in individuals with a distorted sense of smell [99]. This will make it difficult to enjoy the food and will lead to a lack of appetite. Additionally, the presence of a strong, unpleasant smell can be a distraction and make it difficult to focus on the taste of the food itself. A distorted sense of smell has been linked to a lower overall quality of life [101], which is also reflected in eating behavior, including but not limited to decreased enjoyment of food and a decreased consumption frequency.

However, the *duration* of olfactory dysfunction emerges as a central determinant. For instance, as time progresses, individuals with a distorted sense of smell experience a more pronounced effect on their eating behavior compared to those with a complete loss of smell [41]. Appetite and food enjoyment are low in individuals with short-term olfactory dysfunction, while in individuals who experience long-term olfactory dysfunction, the reduction in food enjoyment will diminish over time. Most likely, this is because they develop coping strategies to deal with their olfactory loss or adapt to it. However, it is noteworthy that such coping strategies, such as focusing on the texture, temperature, and visual presentation of the food, are not only adopted by individuals living with long-term olfactory dysfunction [90] but also by those with short-term changes, for instance, patients undergoing chemotherapy [102].

In most studies with a heterogeneous population, the effect of *etiology* of olfactory dysfunction on eating behavior was not investigated, mostly because subgroups were too small to compare. Further research involving large-scale studies with diverse etiologies might provide a more comprehensive insight into the effect of the etiology of olfactory dysfunction on eating behavior. However, the effect of duration of olfactory dysfunction might overrule the effect of etiology. This is supported by the evidence shown for the differential impact of acquired versus congenital olfactory dysfunction on eating behavior. Individuals with congenital (i.e., lifelong) anosmia tend to focus more on basic tastes during eating [48], do not show lower food enjoyment, and experience less decline in pleasantness during consumption (i.e., experienced liking) compared to those with acquired dysfunction [60] and healthy controls [70]. As individuals with congenital olfactory dysfunction were never able to fully perceive the flavor of food, they may have developed coping strategies [103] and do not know what they are missing; however, they do report difficulties related to their dysfunction, such as an inability to identify spoiled food [90]. Moreover, it can be debated if it is the etiology of olfactory dysfunction that affects eating behavior. For example, in cancer patients who experience olfactory dysfunction, the disease itself could also influence their eating behavior. However, in most studies, a control group was included, either consisting of patients with no olfactory dysfunction or healthy controls with a normal sense of smell, which increases the likelihood that the effects on eating behavior in these individuals are caused by the olfactory dysfunction itself. However, in future research, this should be a point of attention, and control groups should therefore be carefully chosen.

In the studies included in this review, a wide range of approaches were employed to assess various aspects of eating behavior. Standardized measures, such as food frequency questionnaires and dietary recalls, are routinely utilized and validated methods for assessing dietary intake. However, as these can also be laborious and time-consuming, in some studies, other measures were used as proxies to measure these aspects of eating behavior. Most of the measures employed in studies were based on surveys, including just a few validated instruments, such as the Questionnaire of Olfactory Disorders [104] and the Macronutrient and Taste Preference Ranking Task [105]. Yet, most studies relied on self-developed questionnaires, also because of the unavailability of validated instruments suitable to assess the eating behavior in question. For example, Rowan *et al.* [57] utilized quality-of-life eating-related questions due to the absence of a validated instrument to measure individuals' food enjoyment.

The evaluation of appetite in the context of olfactory dysfunction was addressed in several studies, with some utilizing a single question to assess this aspect of eating behavior. For instance, Fluitman *et al.* [53] applied the following question to evaluate appetite: *"In the past week, I did not feel like eating, my appetite was poor"*. It can be debated whether a single question may be sufficiently sensitive to accurately detect changes in appetite, particularly when comparing it to the situation before the onset of olfactory dysfunction. In addition, some studies employed lab-based settings to measure eating behavior, such as having individuals rate their food desire and liking. These results may not be directly applicable to real-world situations. Hence, it is complex to compare results from various studies due to the use of different methods to assess the same eating behavior aspect such as appetite.

Therefore, we suggest developing standardized questionnaires to measure various aspects of eating behavior in individuals with olfactory dysfunction during both anticipatory and consummatory phases of eating behavior. To measure food intake and adherence to the dietary guidelines, already existing methods, such as food frequency questionnaires [106], or digital dietary assessment tools such as Traqq [107] can be applied. To assess food liking, appetite, and food preferences, questionnaires need to be standardized and validated. These can then serve as the foundation for future research and, if needed, be extended with additional questions to meet the objectives of specific studies, while still allowing for the comparison of results across studies. Moreover, these questionnaires can include measures that are not included in the current research, such as eating rate.

Additionally, articles included in this review demonstrate a wide range of methodologies employed to measure olfactory function. While some studies incorporated psychophysical tests to objectively diagnose olfactory dysfunction, most studies relied on subjective measures, such as self-reported olfactory function through questionnaires (e.g., AHSP: Appetite, Hunger, and Sensory Perception [108]) and self-report ratings, or incorporated one or more questions on olfactory function into an existing questionnaire. Utilizing objective testing when investigating the effect of olfactory dysfunction on eating behavior will improve the accuracy of the prevalence of smell loss, as already has been demonstrated in Covid-19 patients with olfactory dysfunction [15]. The emergence of low-cost, at-home tests for olfactory function during the Covid-19 pandemic, such as the SCENTinel [109], further increases the feasibility of objective testing in studies conducted in a home setting. While at-home tests serve as valuable initial screening tools, more comprehensive insights into olfactory function often require a well-established and validated method such as Sniffin Sticks that offers standardized and quantitative assessment across various olfactory dimensions. Researchers seeking an overview of olfactory assessment methods can refer to the comprehensive work of Parma *et al.*, [110].

Furthermore, the current body of research largely overlooks the long-term adaptations and coping strategies of individuals with olfactory dysfunction. While some studies hint at these aspects, a standardized approach to measure and evaluate these adaptations is missing. Individuals facing olfactory dysfunction often employ creative strategies to address the impact on their eating behavior. For instance, they may enhance the flavor through the increased use of spices and condiments, while also focusing on other sensory attributes, like temperature and texture [1,52], which can be applied in both the anticipatory and consummatory phase. These coping mechanisms play a pivotal role in the eating behavior of people with olfactory dysfunction since eating pleasure is associated with positive health outcomes [111]. Therefore, future research is needed to investigate how people with olfactory dysfunction can modify their diets to make eating enjoyable and palatable, despite their olfactory dysfunction. Most changes in the eating behavior of these individuals are related to changes in flavor perception, as smell is a major contributor to flavor. However, taste and trigeminal senses can also be affected in individuals with olfactory dysfunction. Here lay opportunities for multidisciplinary research, including chefs and food designers, to explore the potential of alternative strategies (e.g., through texture and taste) that people with olfactory dysfunction can apply to have a joyful food experience. Furthermore, research could explore how those with olfactory dysfunction can adjust the way they prepare, cook, and serve meals to enhance other senses, such as sound and touch. This can provide valuable input for promoting healthy eating practices, addressing dietary challenges, and improving overall well-being. Finally, research could study how people with olfactory dysfunction can use technology, such as virtual reality [112], to enhance the overall experience of eating.

The systematic scoping review underscores the intricate relationship between olfactory dysfunction and its profound influence on eating behavior, especially in the domains of food liking, preferences, and enjoyment. Qualitative smell loss emerges as a significant factor, with the duration and nature of the dysfunction further shaping its impact. There is a pressing need for further investigations using standardized and validated assessment tools to delve deeper into these findings. Significantly, this research also emphasizes the importance of crafting effective interventions to enrich the eating experience for those affected. By addressing and understanding these connections, we pave the way for enhanced interventions and the promotion of healthier eating habits in individuals with olfactory dysfunction.

Credit author statement

Conceptualization: PP, SB, EP; Data curation: PP, EP; Formal Analysis: PP, EP; Funding acquisition: SB; Investigation: PP, EP; Methodology: PP, SB, EP; Project administration: PP; Resources: PP, EP;

Software: PP, EP; Supervision: SB; Validation: PP, SB, EP; Visualization: PP, EP; Writing - original draft: PP, EP; Writing - review & editing: PP, SB, EP.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: This research was funded by an Aspasia grant of the Netherlands Organization for Scientific Research, awarded to SB. If there are other authors, declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix 1. Search strategies for the databases

Ovid MEDLINE

(Query for initial search)

((olfact* OR smell OR chemosensory OR odour) adj5 (disorder OR loss OR deficit OR dysfunction OR changes OR impairment OR decrease OR alter*).ti,ab,au) OR (anosmia OR hyposmia OR parosmia) AND (appetite OR diet* OR food OR eating OR feed*) adj5 (habit OR intake OR pattern OR preference OR choice OR enjoyment OR perception OR behavi* OR pleasure OR quality OR consumption).ti,ab,au.

(Query for additional search)

((olfact* OR smell OR chemosensory OR odour) adj5 (disorder OR loss OR deficit OR dysfunction OR changes OR impairment OR decrease OR alter*).ti,ab,au) OR (anosmia OR hyposmia OR parosmia) AND (diet* OR food OR eating OR feed*) adj5 (pleasantness OR liking OR wanting OR neophobia).ti,ab,au.

PsycInfo

(Query for initial search)

AB ((appetite OR diet* OR food OR eating OR feed*) N5 (habit OR intake OR pattern OR preference OR choice OR enjoyment OR perception OR behavi* OR pleasure OR quality OR consumption)) AND (AB ((olfact* OR smell OR chemosensory OR odour) N5 (deficit OR disorder OR loss OR dysfunction OR changes OR impairment OR decrease)) OR AB (anosmia OR hyposmia OR parosmia))

TI ((appetite OR diet* OR food OR eating OR feed*) N5 (habit OR intake OR pattern OR preference OR choice OR enjoyment OR perception OR behavi* OR pleasure OR quality OR consumption)) AND (TI ((olfact* OR smell OR chemosensory OR odour) N5 (deficit OR disorder OR loss OR dysfunction OR changes OR impairment OR decrease)) OR TI (anosmia OR hyposmia OR parosmia))

(Query for additional search)

AB ((diet* OR food OR eating OR feed*) N5 (pleasantness OR liking OR wanting Or neophobia)) AND (AB ((olfact* OR smell OR chemosensory OR odour) N5 (deficit OR disorder OR loss OR dysfunction OR changes OR impairment OR decrease)) OR AB (anosmia OR hyposmia OR parosmia))

TI ((diet* OR food OR eating OR feed*) N5 (pleasantness OR liking OR wanting Or neophobia)) AND (TI ((olfact* OR smell OR chemosensory OR odour) N5 (deficit OR disorder OR loss OR dysfunction OR changes OR impairment OR decrease)) OR TI (anosmia OR hyposmia OR parosmia))

Pubmed

(Query for initial search)

("feeding behaviour" [MeSH Terms] OR eating behav*[Text Word] OR food enjoyment [text word] OR appetite [text word] OR food consumption OR food intake) AND (("smell" [MeSH] OR olfact*[Text Word] OR chemosensory [Text Word] OR odour [text word]) AND ("physiopathology" [Subheading] OR dysfunction [Text Word] OR deficit [Text Word]) OR ("Anosmia" [Mesh] OR parosmia [Text word]))

(Query for additional search)

("food neophobia" [Text Word] OR "food pleasantness" [Text Word] OR "food wanting" [Text Word] OR "food liking" [Text Word]) AND (("smell" [MeSH] OR olfact*[Text Word] OR chemosensory [Text

Word] OR odour [text word]) AND (“physiopathology” [Subheading] OR dysfunction [Text Word] OR deficit [Text Word]) OR (“Anosmia” [Mesh] OR parosmia [Text word]))

Scopus

(Query for initial search)

(TITLE-ABS-KEY ((olfact* OR smell OR chemosensory OR odour) W/5 (disorder OR loss OR dysfunction OR changes OR deficit OR impairment OR decrease OR alter*)) OR TITLE-ABS-KEY ((anosmia OR ypos a OR parosmia)) AND T LE-A -KEY ((appetite OR diet* OR food OR eating OR feed*) W/5 habit OR intake OR pattern OR preference OR choice OR enjoyment OR perception OR beha* OR pleasure OR quality OR consumption))

(Query for additional search)

(TITLE-ABS-KEY ((olfact* OR smell OR chemosensory OR odour W/5 disorder OR loss OR dysfunction OR changes OR deficit OR impairment OR decrease OR alter*) OR (anosmia OR hyposmia OR parosmia)) AND TITLE-ABS-KEY ((diet* OR food OR eating OR feed* W/5 lik* OR want* OR pleasantness OR neophobia)))

Appendix 2. Quality assessment

Table A2.1
Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies

Quality assessment tool for observational cohort and cross-sectional studies	
1	Was the research question or objective in this paper clearly stated?
2	Was the study population clearly specified and defined?
3	Was the participation rate of eligible persons at least 50%?
4	Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?
5	Was a sample size justification, power description, or variance and effect estimates provided?
6	For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?
7	Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?
8	For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?
9	Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?
10	Was the exposure(s) assessed more than once over time?
11	Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?
12	Were the outcome assessors blinded to the exposure status of participants?
13	Was loss to follow-up after baseline 20% or less?
14	Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?

Table A2.2
Rating of the manuscripts

Group	Good	Fair	Poor
Older adults	10	1	1
Cancer patients	6	4	0
Underlying disorders	4	4	0
General olfactory dysfunction	8	8	0
Population-based studies	3	1	0
Total	31	18	1

Appendix 3. Detailed overview of olfactory function measures

Table A3.1
Overview of olfactory function measurements used in the articles included in the review

Olfactory outcome measurement	Articles	Category
Objective Measures		
Sniffin' Sticks	[1,15,27,28,29,113,43,80,81, 82,41,69,49,64,58]	Identification; discrimination; threshold
Odour identification task (OIT)	[36,39,46], [84,40]	Identification
San Diego Odour Identification Test (SDOIT)	[26,64]	Identification
Smell Identification Test (SIT)	[37]	Identification
University of Pennsylvania Smell Identification Test (UPSIT)	[91]	Identification
Scratch-and-sniff (UPSIT)	[83]	Identification
Smell component of the National Health and Nutrition Examination Survey (NHANES)	[50]	Identification
4-Item NHANES Pocket Smell Test (PST)	[35]	Identification
European Test of Olfactory Capabilities (ETOC)	[30,48]	Detection; identification
Odour detection threshold (ODT)	[36,39,46,40,89,59]	Detection
French Biolfa olfactory test (olfactory threshold and odor identification)	[34]	Identification; threshold
Butanol threshold test (BTT)	[60]	Identification; threshold
Connecticut Chemosensory Clinical Research Center olfactory test (CCCRC-OT)	[55]	Threshold
Subjective Measures		
Self-Reported Olfactory Loss (self-reported OL)	[15,29], [45], [36,39,83, 18,86,88,70,43,41·42,49, 60,62,93,94,61]	Self-report
Ratings of odour intensity, pleasantness, familiarity, irritation, and edibility (O_IPFIE)	[18]	
Individual self-reported smell perception scores (VAS)	[28,40]	
Taste and Smell Survey (TSS)	[59,58]	
CiTAS scale (Chemotherapy-induced Taste Alterations)	[50]	

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