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Familiarity and identification of everyday food odors in older adults and their influence on hedonic liking

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A B S T R A C T
In an aging population, changes in sensory abilities can adversely affect enjoyment of a meal. Age-related changes in identification ability and familiarity of food odors may influence food intake since some foods become less recognizable and attractive, which may affect the individual’s health and nutritional condition. The aim of this study was to examine age-related changes in familiarity and the ability to correctly identify everyday food odors in older adults. We also aimed to establish the relationship between these changes and hedonic liking of food odors compared to young adults. The study included 335 participants, 246 older adults and 89 young adults. A positive relationship between familiarity and liking was observed across all food odors. Familiarity and odor identification ability declined with increasing age. The most significant loss in the ability to identify odors was observed for curry, fried meat, and toasted bread, while both age groups identified banana, orange, and vanilla equally well. For older adults with a diminished perception of familiarity and a reduced ability to identify odors correctly, increasing the concentration of the odor improved familiarity and enhanced their ability to identify odors. Our findings support the notion that the familiarity of food odors is an important parameter for the appreciation of food in older adults.

1. Introduction

Olfactory function is essential for how foods are perceived and experienced (Boesveldt & de Graaf, 2017; Gopinath et al., 2015). However, when people get older, olfactory functionality declines due to physiological changes in the peripheral and higher processing of chemosensory input (Kondo et al., 2020). These changes are especially evident for odor intensity perception, which declines from the age of 55 years (Doty et al., 1984), just as changes in identification ability and familiarity are well documented (Doty & Kamath, 2014a; Wehling et al., 2016). Central to a meaningful food odor experience, familiarity is likely to influence enjoyment and liking. Moreover, it plays an important role in supporting odor identification by directing attention based on previously acquired experiences with odors to retrieve the correct name (Larsson & Bäckman, 1998; Lehrner et al., 1999; Pliner, 1982; Royet et al., 1999; Schab, 1991). When odors are no longer recognizable enough to label accurately, they may still conjure a “feeling of knowing”, i.e. perceptual processing, even though higher level semantic processing, including contextual details and labelling (Lehrner et al. 1999), is lost. The consequences of age-related changes in familiarity and ability to identify food odors are chiefly associated with potential risks, such as ingesting spoiled foods and fire hazards (Van Regemorter et al., 2020). However, more importantly, the decline in familiarity and identification ability affect the ability to express preferences and experience the emotional aspects of familiar foods due to changes in perceptual input and semantic memory related to cognitive function (Poncelet et al., 2010). Sensory memory is primarily encoded to reject odors that do not match memories of previously encountered odors, making them become even less attractive and recognizable (Laureati et al., 2008; Möller et al., 2004, 2007). This change impacts the meal experience (Pützer & Wolf, 2021) because resistance to food intake is motivated more heavily by disliking than liking (Keller et al., 2022). Despite the lack of evidence on
the influence of chemosensory changes on declining food intake, appetite and malnutrition (Kremer et al., 2014; Rolls, 1999) and changes in familiarity and identification ability may lead to changes in food intake and appetite because they co-occur with other age-related events that affect the context and meal experience (Nyberg et al., 2018; Sulmont-Rosse et al., 2015). This, in turn, may lead to weight loss and malnutrition over time, or what is also known as the anorexia of aging (Landi et al., 2016), which can enormously influence health and quality of life (Doty et al., 1984; Hedner et al., 2010; Larsson et al., 2005; Larsson & Bäckman, 1997; Glopsson et al., 2016; Sohrabi et al., 2012; Stevens et al., 1990; Wehling et al., 2016).

The impact of age on odor intensity perception, identification, and familiarity, as well as how it affects the relationship between identification ability, is well documented (Doty & Kamath, 2014b; Konstantinidis et al., 2006; Larsson et al., 2000; Wehling et al., 2010, 2016). Among the first to study age-related changes in odor threshold for food odors, Schiffman et al. (1976) did not, however, evaluate hedonic liking in relation to odor perception. Other studies have addressed odor perception for everyday odors in relation to hedonic liking (Ayabe-Kanamura et al., 1998; Denzer-Lippmann et al., 2017; Distel, 1999; Thomas-Danguin et al., 2014), though not in older adults. Sulmont-Rosse et al. (2015) used food odors to study the age-related changes in odor perception that had little resemblance to food odors in an everyday diet for older adults. In most of the aforementioned studies, odors were based on single components, which prevented evaluation of the odor performance of naturally complex mixtures (S. S. Schiffman et al., 1994) (S. S. Schiffman et al., 1994) (S. S. Schiffman et al., 1994) (S. S. Schiffman et al., 1994) (S. S. Schiffman et al., 1994) Furthermore, there is a need for studies that use food odor targets that are closer to real life to estimate the importance of olfactory decline for food preferences.

The relationship between familiarity and liking is well recognized was first demonstrated by Zajonc (1968) who established evidence for the mere exposure effect. Since then, the role of repeated exposure for liking has been extensively studied in children and adults (Birch & Marlin, 1982; Cooke, 2007; Forestell & Mennella, 2007; Hartvig et al., 2015; Hausner et al., 2012; Liem & De Graaf, 2004; Pliner, 1982). However, less attention has been given to the relationship between familiarity and liking for food odors that are relevant to food intake and the pleasure of eating in older adults (Distel, 1999; Honnens de Lichtenberg Broge, Wendin, 2004; Thomas-Danguin et al., 2014). Since food pleasure plays a key role in maintaining food intake and meeting nutritional requirements in older adults (Pouyet et al., 2015), it is relevant to gain deeper insight into how age-related changes in familiarity and identification ability influence hedonic liking of food odors that resemble real products more closely (Distel, 1999; Honnens de Lichtenberg Broge, Wendin, Rasmussen, et al., 2021; Seow et al., 2016; Thomas-Danguin et al., 2014).

Familiarity in older adults is likely to be influenced by odor intensity due to increased odor input, which improves processing and interpretation, in addition to increasing liking (Pliner, 1982). Likewise, in food identification tasks, a higher familiarity rating is expected to lead to a higher score for correct identification. A decline in food odor familiarity in a cohort of older participants from a similar cultural population is, in contrast, expected to lead to reduced identification performance. This decrease would indicate a decline in odor processing ability for the particular food odor and may have an influence on hedonic liking. Thus, increasing odor intensity may support perception of familiarity due to an increase in associations with stronger stimuli intensity (Distel et al. 1999) and, in some cases, also hedonic liking (Schiffman & Warwick, 1993).

The aim of this study was to investigate the impact of age on familiarity and identification ability for everyday food odors, as well as to examine whether these changes were related to the hedonic liking. Establishing this relationship would provide a basis for making the food experience more familiar for older adults. This type of intervention could help compensate for functional losses in sensory and cognitive abilities and support hedonic liking. In contrast to earlier work, this study utilized everyday natural food flavorings for the study population, allowing examination of the possible relationships between food odor familiarity, identification ability, and hedonic liking.

2. Material and methods

This study investigated identification ability and familiarity for 14 food odors in older adults and a reference group of young adults. Results on intensity perception and liking for the same two groups of participants are published elsewhere (Honnens de Lichtenberg Broge, Wendin, Rasmussen, et al., 2021). All participants provided informed written consent and were informed about the purpose of the study and its test procedures. The Capital Region of Denmark Health Research Committee approved the study protocol (file no. 17000209).

2.1. Participants

We initially recruited 343 people comprising 251 older adults living independently (60–98 years of age) and a reference group of 92 young adults (20–39 years). Older adults were recruited through Future Consumer Lab at the University of Copenhagen, Denmark and senior citizen centers in the five regions of Denmark, while the young adults were recruited at the University of Copenhagen, Frederiksberg, Denmark.

The young adults were included based on no-known, self-reported genetic odor deficits, anosmia, and head traumas. The inclusion criterion for older adults was a minimum score of 25 on the Mini-Mental State Examination (MMSE), since a score of 25 – 30 is indicative of normal cognitive function (Folstein et al., 1975, 2001).

Five older adults were excluded due to MMSE scores below 25, while three young adults were excluded due to reported genetic odor deficits, resulting in a final sample size of N = 335 (n = 246 older adults, 74 % women, 26 % men) and n = 89 young adults, 73 % women and 27 % men). The mean age of the older adults was 74 ± 8 years with a mean MMSE score of 29 ± 1.2, while the mean age of the young adults was 27 ± 5 years.

2.2. Selection of food odors

Table 1 lists the specific food odors used in this study and the individual dilution levels, as specified in a previous study (Honnens de Lichtenberg Broge, Wendin, Hyldig, et al., 2021). The food odors were pre-selected based on frequent occurrence in meal plans delivered by a catering company supplying meals to older adults. The food odors selected represent commonly consumed foods among older adults to ensure their familiarity in meals and everyday context, just as they comprised a broad range of sensory characteristics. Thirteen different food odors were prepared from concentrations of various food odors (Meilleur du Chef, Bassussarry, France) of a natural or partially natural origin using primarily essential oils to capture the complex odorant composition of real foods.

2.3. Preparation of sniffing sticks

Each food odor was prepared in two different strengths, one of moderate odor intensity (dilution similar to 1-butanol at 125 ppm) and one of strong odor intensity (dilution similar to 1-butanol of 625 ppm). Propylene glycol (≥99.5 %, CAS: 57–55–6, Sigma-Aldrich, Denmark) was used as a solvent to dilute the aromas, though mushroom and fried meat odors were diluted in water (65 °C) since as they did not dissolve in propylene glycol. The coffee odor was prepared from a coffee ristretto (Frellsens kaffe, Roskilde, Denmark) with coffee extract from lightly roasted espresso brewed in a coffee machine (Jura WE6 Piano Black, Niederbuchsiten, Switzerland).

The food odors were presented using sniffing sticks (Burghardt® Wedel, Germany) approximately 14 cm long with an inner diameter of...
pared in accordance with the procedure described in (Honnens de Lichtenberg Broge, Wendin, Hyldig, et al., 2021). Twenty-eight sniffing sticks were pre-dilution and stored at 5 °C (Hummel et al., 1997). Each sniffing stick was filled with 4 ml of the respective food odor flavoring and was used for analysis and graphical illustrations. For Pearson correlation analysis, SPSS® was used (IBM SPSS Statistics for Windows, v24, IBM Corp., Armonk, N.Y., USA).

### 2.4. Test procedure

A trained experimenter presented the sniffing sticks one by one to the test person. The cap was removed for 3 s and held approximately 2 cm from the nostrils, identical to the procedure described by (Hummel et al., 1997). For each individual odor, the test was completed in the same sequence, proceeding from intensity (reported elsewhere), hedonic liking to familiarity to identification before moving on to the next odor. Hedonic liking was measured on a 10-cm visual analogue scale ranging from “Do not like at all” on the left to “Like very much” on the right. Familiarity was also rated using a 10-cm visual analogue scale ranging from “I’m not familiar with this odor” on the left to “I’m very familiar with this odor” on the right.

To test identification ability, the four-alternative forced choice (4AFC) method was used. Participants were asked to identify the name of the odor based on four options comprising one target and three distractors (Table 1). The four options were presented after the participant had smelled the odor. Distractors were selected among the odors used in the test but represented distinctive sensory characters to create sufficient contrast to distinguish clearly between correct and false identification.

The tests were performed in a quiet, neutral, and well-ventilated room, with the order of the sniffing sticks randomized between each participant. Each participant was assigned a unique ID, while the sniffing sticks were labeled with a random three-digit code to help blind the experimenter to the odor quality and intensity.

### 2.5. Data analysis

Analysis of variance (ANOVA) was performed using a linear mixed model with familiarity as the dependent variable; group, food odor, and intensity level as fixed effects; and assessors as random effect. To obtain a pairwise comparison between the young adults and the older adults for familiarity overall and for the individual odors, contrast analysis was applied. The ANOVA significance level was set at p < 0.05.

Pearson’s r values were obtained between joint familiarity scores for all 14 food odors and age, as well as between familiarity scores for individual food odors and age.

For the 4AFC odor identification test, critical values indicating the ability of the population to correctly identify beyond random guessing were calculated using the binomial probability distribution under null (guessing), assuming: \[ X \sim \text{Bin}(n, P_0) \], where X is the number of correctly identified odors, and n the population size. To investigate the ability to correctly identify food odors in old age, the older adult population was subdivided into age groups: 60 – 69 year olds; 70 – 79 year olds, and 80 – 98 year olds.

The proportion of discriminators (Pd) was calculated to compare the ability to correctly identify food odors in older adults. Pd was calculated by \[ Pd = (\text{probability of correct answer (PC)} - \text{probability of discrimination by chance (P0)})/(1-P0) \].

The coefficient of multiple determination (R²) was calculated to represent the proportion of data variation in liking and familiarity that could be explained by identification ability, familiarity, age, and sex on a 0 – 100 % scale. A high R² value suggests that the predictor is important for modelling the response.

R (v4.1.2) with the packages lme4 (v1.1–27.1), lmerTest (v3.1–2) (Kuznetsova et al., 2017), multcomp (v1.4–17) and ggplot2 (v3.3.5) was used for analysis and graphical illustrations. For Pearson correlation analysis, SPSS® was used (IBM SPSS Statistics for Windows, v24, IBM Corp., Armonk, N.Y., USA).

### 3. Results

Changes in familiarity and identification ability were investigated for 14 everyday food odors as a function of age in an older adult population 60 – 98 years of age (n = 246). Furthermore, changes in familiarity were investigated in relation to hedonic liking and identification ability to establish a relationship between these changes. The olfactory performance of older adults was compared with a group of young adults (n = 89) 20 – 39 years of age to ensure that comparison of olfactory capacity in older adults was compared to a group with intact olfactory function. Results for intensity perception and hedonic liking is reported elsewhere (Honnens de Lichtenberg Broge, Wendin, Rasmussen, et al., 2021).

#### 3.1. Impact of age on familiarity

An overall effect of group, food odor, and intensity level was observed for perception of odor familiarity (all p < .001). A significant group difference in overall familiarity ratings was also observed between the older and young adults, with the latter rating overall familiarity systematically higher than the former (mean difference = 1.16, p < .001). Both the older adults and young adults rated the strong odor intensity level systematically higher than the moderate one (mean difference = 2.17, p < .001). For the older adults only, a significant difference between the sexes showed that women reported systematically higher familiarity ratings compared to men (mean difference = 1.1, p < .001) (supplementary Table 1).

The age-related changes in familiarity were observed for 11 of the 14 individual food odors (Table 2), for which young adults generally scored familiarity higher compared to older adults. However, no significant group difference was observed for bacon, fried meat, and raspberry at both intensity levels, while no significant group difference was reported for banana, curry, and orange at the strong intensity level, as well as for

### Table 1

<table>
<thead>
<tr>
<th>Food odor</th>
<th>Reference Flavoring</th>
<th>Distractors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asparagus</td>
<td>Asparagus flavoring</td>
<td>Mushroom, Bacon, Orange</td>
</tr>
<tr>
<td>Bacon</td>
<td>Bacon flavoring</td>
<td>Cinnamon, Vanilla, Rose</td>
</tr>
<tr>
<td>Banana</td>
<td>Banana, natural</td>
<td>Bacon, Onion, Cinnamon</td>
</tr>
<tr>
<td>Cinnamon</td>
<td>Cinnamon, natural</td>
<td>Mushroom, Coffee, Orange</td>
</tr>
<tr>
<td>Coffee</td>
<td>Frellens coffee, 2</td>
<td>Cooked, Thyme, Orange</td>
</tr>
<tr>
<td>Curry</td>
<td>Curry, natural</td>
<td>Thyme, Mushroom, Flower-like</td>
</tr>
<tr>
<td>Fried meat</td>
<td>Grilled beef</td>
<td>Mushroom, Onion, Thyme</td>
</tr>
<tr>
<td>Mushroom</td>
<td>Button mushroom</td>
<td>Fried meat, Banana, Flower-like</td>
</tr>
<tr>
<td>Onion</td>
<td>Onion, natural</td>
<td>Raspberry, Coffee, Cooked fish</td>
</tr>
<tr>
<td>Orange</td>
<td>Orange, natural</td>
<td>Fried meat, Bacon, Mushroom</td>
</tr>
<tr>
<td>Raspberry</td>
<td>Raspberry, natural</td>
<td>Banana, Mushroom, Curry</td>
</tr>
<tr>
<td>Thyme</td>
<td>Thyme, natural</td>
<td>Cinnamon, Toasted, Mushroom</td>
</tr>
<tr>
<td>Toasted bread</td>
<td>Toasted bread</td>
<td>Mushroom, Orange, Vanilla</td>
</tr>
<tr>
<td>Vanilla</td>
<td>Tahitian vanilla</td>
<td>Banana, Cooked fish, Flower-like</td>
</tr>
</tbody>
</table>

1. Source: Meilleur du chef.
2. Source: Frellens kaffe; coffee extract from lightly roasted espresso.
asparagus, onion, thyme, and vanilla at the moderate intensity level. Table 2 also shows that older adults reported highest familiarity with orange, thyme and vanilla at strong intensity, and for banana, orange and vanilla at moderate intensity. Fried meat at strong intensity obtained the lowest scores, together with thyme at moderate intensity. An almost similar pattern was observed for the young adults, who reported almost similar pattern was observed for the young adults, who reported the lowest scores, together with thyme at moderate intensity. An almost similar pattern was observed for the young adults, who reported almost similar pattern was observed for the young adults, who reported.

To further study the impact of age on familiarity, we performed a correlation analysis. The result showed a weak negative correlation between age and familiarity \( r (6886) = -0.163, p < .01 \), indicating a decline in familiarity with increasing age. For the young adults, the correlation was \( r (2490) = 0.062, p = .01 \).

For the individual food odors, a significant negative correlation between age and familiarity was observed for most food odors (Table 3) at both moderate and strong intensity levels. Only for curry, coffee, mushroom and toast at the moderate intensity level and bacon at both intensity levels, familiarity was not significantly correlated with age (Table 3).

### 3.2. Impact of age on identification ability

Fig. 1A illustrates the percentage of correct identifications and shows that it declines with increasing age. A similar pattern was observed for individual food odors (Fig. 1B). However, overall, the various age groups were able to identify the odors above the 25 % chance level with a significance level of \( p < .001 \).

<table>
<thead>
<tr>
<th>Odor/Intensity</th>
<th>Young adults Mean (SD)</th>
<th>Older adults Mean (SD)</th>
<th>Diff. in means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asparagus Strong</td>
<td>7.6 (2.04)</td>
<td>5.9 (2.81)</td>
<td>-1.75***</td>
</tr>
<tr>
<td>Bacon Strong</td>
<td>6.2 (2.34)</td>
<td>5.3 (3.09)</td>
<td>-0.89</td>
</tr>
<tr>
<td>Banana Strong</td>
<td>7.8 (1.57)</td>
<td>6.9 (2.61)</td>
<td>-0.90</td>
</tr>
<tr>
<td>Cinnamon Strong</td>
<td>7.5 (1.86)</td>
<td>6.3 (2.78)</td>
<td>-1.14**</td>
</tr>
<tr>
<td>Coffee Strong</td>
<td>5.5 (2.76)</td>
<td>4.5 (2.93)</td>
<td>-1.00*</td>
</tr>
<tr>
<td>Curry Strong</td>
<td>6.1 (2.88)</td>
<td>4.3 (2.95)</td>
<td>-1.00**</td>
</tr>
<tr>
<td>Fried meat Strong</td>
<td>5.2 (2.29)</td>
<td>4.8 (2.69)</td>
<td>-0.4</td>
</tr>
<tr>
<td>Mushroom Strong</td>
<td>5.4 (2.42)</td>
<td>4.7 (2.80)</td>
<td>-0.71</td>
</tr>
<tr>
<td>Onion Strong</td>
<td>6.8 (2.35)</td>
<td>5.7 (2.86)</td>
<td>-1.07*</td>
</tr>
<tr>
<td>Orange Strong</td>
<td>8.1 (1.41)</td>
<td>7.3 (2.72)</td>
<td>-0.82</td>
</tr>
<tr>
<td>Raspberry Strong</td>
<td>7.6 (1.77)</td>
<td>6.7 (2.74)</td>
<td>-0.82</td>
</tr>
<tr>
<td>Thyme Strong</td>
<td>6.5 (2.54)</td>
<td>5.4 (3.01)</td>
<td>-1.12</td>
</tr>
<tr>
<td>Vanilla Strong</td>
<td>8.6 (1.35)</td>
<td>7.6 (2.38)</td>
<td>-0.97*</td>
</tr>
<tr>
<td>Moderate</td>
<td>6.7 (2.31)</td>
<td>6.2 (2.95)</td>
<td>-0.59</td>
</tr>
</tbody>
</table>

**SD** = standard deviation; **Diff.** = difference.

\( * p < .05; ** p < .01; *** p < .001 \).

The correct identification score of young adults was generally > 60 %, and most food odors were correctly identified > 90 % of the time: orange (100 %), banana (93 %), vanilla (97 %), coffee (93 %), asparagus (94 %), and mushroom (96 %). The lowest percentage was for bacon (66 %) and fried meat (60 %).

For older adults only, the various age groups were able to identify the odors above the 25 % chance level. Generally, the older adults identified banana, orange, and vanilla correctly most frequently. The least correctly identified odor was toast (52 %) for the 60 – 69 year olds, fried meat (44 %) for the 70 – 79 year olds, and cinnamon (41 %) for 80 – 98 year olds. However, when accounting for the 25 % chance level for correct identification, there was a pronounced decline in Pd with increasing age for cinnamon, mushroom, toast, curry, and fried meat at strong intensity, and for coffee, curry, toast, thyme, and cinnamon at moderate intensity (supplementary Fig. 1). A difference between the sexes was also observed. When comparing men and women in the older adult group, of the women were able to identify 68 % of the food odors compared to 64 % for men. For the individual odor intensity levels, women were able to correctly identify 76 % of the odors at the strong intensity level and 59 % of the odors at the moderate intensity level, while men had 71 % for strong and 56 % for moderate (data not shown).

### 3.3. Relationship between identification ability and familiarity of food odors

Correct identification ability was associated with significant higher familiarity ratings compared to misidentified food odors (mean difference 2.1, \( p < .001 \) (Fig. 2)). This was observed for both the strong (mean difference 1.7, \( p < .001 \)) and moderate intensity levels (mean difference 1.9, \( p < .001 \)) for most individual odors, indicating that poor identification ability is associated with low familiarity ratings (Fig. 2).

No significant difference in familiarity ratings was observed between correct- and failed identifications for onion, raspberry, orange and
cinnamon and fried meat at the strong odor intensity level, while a significant difference was observed at the moderate odor intensity level. The opposite pattern was observed for banana, thyme, and mushroom where a significant difference in familiarity ratings was observed at the strong odor intensity level but not at the moderate level. Moreover, it was observed that increasing the odor intensity level reduced the number of food odors with a significant group difference in familiarity ratings. This indicated that increasing the odor intensity levelled out the group difference for familiarity ratings. This indicated, despite the difference in identification ability. Fig. 3B (Fig. 3) depicts how most of the data variance ($R^2$) for familiarity ratings was explained by the ability to identify the food odors, with $\leq 25\%$ explain by some odors, while age and sex were explained $< 5\%$ of the variance in familiarity, except for raspberry.

3.4. Relationship between identification ability and hedonic liking

Results for the hedonic liking in relation to intensity of the food odors are published elsewhere (Honnens de Lichtenberg Broge, Wendin, Rasmussen, et al., 2021).

Overall, correctly identified food odors were rated significantly higher in liking compared to misidentified food odors (mean difference:
1.08, \( p < 0.001 \)). This was also true when looking at the two different odor intensity levels. However, when analyzing the individual food odors, the relationship between identification ability and liking was odor specific, as a significant difference was observed only for coffee and asparagus at the strong odor intensity level and for orange, vanilla, coffee, and raspberry at the moderate intensity level (Fig. 4). For the remaining food odors, lost ability to name the odors did not affect hedonic liking.

3.5. Relationship between familiarity and liking

To investigate the relationship between familiarity and liking for food odors, we performed a correlation analysis, which revealed a positive relationship at both strong \( r (3442) = 0.622, \ p < .01 \) and moderate \( r = (3442) = 0.6503, p < .01 \) intensity, indicating an increase in liking with increasing familiarity. Fig. 5 depicts a correlation between average familiarity and average liking for each odor at the two different odor intensity levels. The positive correlation was also observed for each individual food odor, which suggests a more general phenomenon. The weakest correlation was observed for fried meat and onion, while the strongest was observed for coffee, raspberry, orange, and vanilla (supplementary Fig. 2).

Further analysis of the relationship between familiarity and liking revealed that familiarity was the most important parameter for predicting liking in older adults, with 10 – 40 % of the variance explained as depicted in Fig. 3A, while identification and age explained only 0 – 12 % and 0 – 5 %, respectively (Fig. 3A).

4. Discussion

Age-related changes in odor perception may diminish recognition and familiarity, causing a diluted or blurred experience of the odor (Stevenson & Boakes 2003). However, the “feeling of knowing” the odor may retain the experience of liking and enjoyment when eating (Lehrner et al. 1999). However, the blurriness may not arise from cognitive...
decline alone as also reduced regeneration of olfactory receptor cells and decreasing odor input due to diminished odor intensity perception may disturb recognition of odor patterns (Kondo et al., 2020).

4.1. Familiarity

Familiarity of an odor is closely associated with learning and the frequency of exposure, which is why the ability to recognize odor patterns increases with increasing age and exposure (Cain et al., 1995), i.e. the ability to recognize odors is low in children but progresses with increasing age until it declines in older age due to alterations in brain functioning, which leads to less effective olfactory processing, including naming ability (Olofsson et al., 2013). In the present study, perception of familiarity declined with increasing age but varied between the sexes, with women outperforming men. Observations of social norms in organizing daily life, where women have taken a major role in meal preparation, may have contributed to women being more familiar with food odors than men in this generation of older adults. Furthermore, verbal properties also differ between the sexes, with women having superior verbal memory compared to men (Gur & Gur, 2002), which may also explain why women perform better in odor identification even though hormonal differences between the sexes have primarily been used to explained this (Ship et al., 1996; Toussaint et al., 2015). Nevertheless, obtaining familiar experiences primarily requires the ability to detect volatile aromas via receptors in the olfactory epithelium, and processing odor input in the piriform cortex to recognize and discriminate between odors. Recognition of odors relies on matching a neural representation of an odor with previous experiences of the same odor encoded in one’s memory (Ayabe-Kanamura et al., 1998). If the pattern of odor input is successfully matched, an odor will be experienced as familiar. However, when the ability to recognize an odor is lost and occurs simultaneously with declining familiarity, it affects the experience of pleasure and emotional processing of food odor perception (Pützer & Wolf, 2021).

In general, all food odors declined in familiarity with increasing age, except for bacon, coffee, curry, mushroom, and onion at moderate intensity, which may be ascribed by their trigeminal properties. Trigeminal sensation has been proposed to be less sensitive to aging (Laska, 2001). Moreover, since the trigeminal aspects are significant for the sensory characteristics of these food odors, such as smoke in bacon (Saldana et al., 2019), spiciness in curry, sulphur in onion, and caffeine in coffee (Mcgee, 2004), the trigeminal sensation may have supported the familiarity perception. The present study also demonstrated that familiarity was the most important parameter for prediction of overall liking, which is also supported by previous studies (Fondberg et al., 2021; Pliner, 1982). This notion was supported in the present study, which demonstrated that liking of food odors became more neutral when perception of odor familiarity declined. This suggests an important argument for supporting the perception of familiarity to improve liking. The solution may be to develop a more explicit concept to emphasize a familiar experience around food and meals, i.e., contextual information in terms of narrative support with rich sensory descriptions (Tuorila et al., 1994). Positive verbal labels (Herz & Von Clef, 2001) have previously demonstrated a positive effect on perceived familiarity for accessing the affective perceptual aspects of foods. Finally, the positive relationship between familiarity and liking was observed across all food odors, indicating that this was a general phenomenon for pleasant food odors as all odors were selected to represent liked food which is supported by previous studies (Ayabe-Kanamura et al., 1998; Delplanque et al., 2008; Distel, 1999; Distel & Hudson, 2001; Jellinek & Köster, 1983).

4.2. Identification

The age-related decline in identification of odors, which is generally well documented (Cain et al., 1995; De Wijk & Cain, 1994; Doty et al., 1984), was confirmed by the present study. Stratification of the older adults revealed that the very old (age 80–99) accounted for the largest proportion of misidentifications. Similar findings have previously been reported for older adults > 80 years of age (Larsson et al., 2016). Across all age group levels, all food odors could be identified above the chance level, but identification ability still revealed an odor-specific pattern across age groups that indicated that vanilla and orange were easier to identify compared to fried meat. Odor familiarity may partly explain the difference in identification ability as vanilla and orange were rated as the most familiar odors, in contrast to fried meat. Increasing the intensity level from moderate to strong improved Pd in older adults and thus identification ability, indicating that odor intensity plays a key role in odor identification, which is in line with previous findings (Distel, 1999). Song et al. (2016) also showed an increased effect of flavor compensation in making foods more attractive for elderly nursing home residents compared to elderly who are less frail and live independently. Since increased intensity contributes to enhancing odor familiarity and hedonicity, foods for older adults may benefit from flavor compensation strategies. A higher stimulus intensity would increase the number of older adults able to recognize food odors.

Correctly identified odors obtained higher ratings for both familiarity and hedonic liking, compared to misidentified odors. This finding is in line with Manesse et al. (2021), who reported that individuals evaluating smells as more familiar, more intense, and more pleasant performed better on test, possibly due to faster synaptic processing, which has previously been associated with speed and quality of test performance (Larsson et al., 2005). In addition, age deficits in semantic processing have been associated with declining identification ability (Hedner et al., 2010; Larsson & Backman, 1998; Lehrner et al., 1999; Royet et al., 1999; Schab, 1991; Sohrabi et al., 2012; Wehling et al., 2016).

According to dual process theory (Lehrner et al., 1999), familiarity and identification rely on two different processing pathways in the memory. The former primarily relies on processing perceptual characteristics of an odor, generated at an initial level of odor processing to make specific knowledge available at a second stage that enables identification of the odor by a specific name at the last stage (Schab, 1991), while the latter implies retrieval of contextual information and semantic knowledge, which is more cognitively demanding due to recalling precise information compared to processing a familiar odor. Consequently, assessing odor familiarity may be less affected than correct identification of an odor when aging affect brain function (Wehling et al., 2010).

Moreover, the difference between the impact of aging on identification and familiarity may reflect the way odors are encoded as verbal and nonverbal odor memories. These two parallel tracks of memories are important for understanding how to improve meal experiences for

Fig. 5. Correlation plot for average familiarity and liking. Correlation coefficients are based on raw data and given by Pearson’s r for strong (blue) (r = (3442) = 0.622, p < 0.01) and moderate (red) (r = (3442) = 0.6503, p < 0.01) odor intensity level. Each dot represent average familiarity and liking for individual food odors by intensity level.
older adults. Odors are commonly encoded incidentally, without explicit attention to specific characteristics (Mojet & Köster, 2002). In unconscious, nonverbal odor memory, the incidentally learned odors are primarily remembered spontaneously due to their link to the situation in which they were first encountered, while objectifying an odor by naming it is the result of conscious verbal encoding. Deficits in olfactory tasks related to cognitive processing may largely be ascribed to determination of conscious encoding efforts with age, which is more sensitive to aging due to the age-related differences in working memory (Malouin et al., 2010; Moller et al., 2004, 2007). In addition, the age-related changes in the conscious encoding of odor memory may influence the ability to express preferences. This is a challenge in terms of how to access and induce memories for a meaningful odor perception since they might be highly personal. Our findings suggest supporting familiarity to increase liking, just as increasing odor intensity level can improve perception of familiarity and recognition, which is in line with previous findings (Distel, 1999). Finally, contextual support has been demonstrated to play a central role in emotional perception, as loss of contextual support may impair memory-induced odor perception (Herz & Von Cif, 2001; Sze et al., 2008).

In this study, the food odors represented a simplified version of odor perception while eating, but more complex than single odor components, whereas real meals represent a multitude of sensations communicated via appearance, smell, taste, touch, texture, temperature and, in some cases, irritation/pain, all of which contribute to flavor perception (Delwiche, 2004; 5492, 2008). Furthermore, food odors presented out of context, as was the case in this study, may be perceived quite differently regarding pleasure and familiarity as the lack of context also limits emotional relevance, also depending on the ability to identify the odor or not. Our findings support this view and showed that correctly identified odors are associated with a higher rating of familiarity and hedonic liking.

5. Conclusion

This study investigated age-related changes in familiarity and the ability to correctly identify natural complex food odors. We observed a decline in familiarity ratings and the ability to correctly identify the food odors with increasing age. This decline was most prevalent for food odors presented at the moderate intensity level and less marked at the strong intensity level. Furthermore, losing the ability to find food odors familiar and identify them correctly identify food odors had negative implications for liking the odors.

When olfactory function is partly degraded or disturbed, it is essential to ensure familiarity of the food or meal for people to experience foods and meals as meaningful. Older adults with diminished perception of odor familiarity may thus benefit from sensory compensation of foods and from contextual support around particular foods to strengthen their experience of familiarity. Implementation of this kind of approach in designing meals for older adults could improve the appreciation of foods at mealtimes but would require a rapid testing of foods and from contextual support around particular foods to enhance foods and meals as meaningful. Older adults with diminished odors presented at the moderate intensity level and less marked at the strong intensity level. Furthermore, losing the ability to find food odors familiar and identify them correctly identify food odors had negative implications for liking the odors.

Our findings supported this view and showed that correctly identified odors are associated with a higher rating of familiarity and hedonic liking.

Data availability

Data will be made available on request.

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CRedit authorship contribution statement

Eva Honnens de Lichtenberg Broge: Project administration, Conceptualization, Methodology, Investigation, Writing – original draft. Karin Wendin: Supervision, Conceptualization, Methodology, Writing – original draft. Morten A. Rasmussen: Methodology, Visualization, Writing – original draft, Editing. Wender L.P. Bredie: Conceptualization, Methodology, Writing – original draft, Supervision, Funding acquisition.

Declaration of Competing Interest

The 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.


