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Knaapila, Antti

2017-02-01

Knaapila , A , Laaksonen , O , Virtanen , M , Yang , B , Lagstrom , H & Sandell , M 2017 , ' Pleasantness, familiarity, and identification of spice odors are interrelated and enhanced by consumption of herbs and food neophilia ' , Appetite , vol. 109 , pp. 190-200 . https://doi.org/10.1016/j.appet.2016.11

http://hdl.handle.net/10138/307968
https://doi.org/10.1016/j.appet.2016.11.025

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Pleasantness, familiarity, and identification of spice odors are interrelated and enhanced by consumption of herbs and food neophilia

Antti Knaapila[a,1,] *, Oskar Laaksonen[a], Markus Virtanen[a], Baoru Yang[a], Hanna Lagström[b], Mari Sandell[c]

[a] Food Chemistry and Food Development, Department of Biochemistry, University of Turku, Vatselankatu 2, FI-20014 Turku, Finland.
[b] Child and Youth Research Institute, Department of Clinical Medicine, University of Turku, Lemminkäisenkatu 3, FI-20014 Turku, Finland.
[c] Functional Foods Forum, University of Turku, Itäinen Pitkäkatu 4, FI-20014 Turku, Finland.

* Corresponding author. Email address: antti.knaapila@helsinki.fi (A. Knaapila).

[1] Present address: Department of Food and Nutrition, University of Helsinki, Agnes Sjöbergin katu 2, FI-00014 Helsinki, Finland.

Abstract

The primary dimension of odor is pleasantness, which is associated with a multitude of factors. We investigated how the pleasantness, familiarity, and identification of spice odors were associated with each other and with the use of the respective spice, overall use of herbs, and level of food neophobia. A total of 126 adults (93 women, 33 men; age 25–61 years, mean 39 years) rated the odors from 12 spices (oregano, anise, rosemary, mint, caraway, sage, thyme, cinnamon, fennel, marjoram, garlic, and clove) for pleasantness and familiarity, and completed a multiple-choice odor identification. Data on the use of specific spices, overall use of herbs, and Food Neophobia Scale score were collected using an online questionnaire. Familiar odors were mostly rated as pleasant (except garlic), whereas unfamiliar odors were rated as neutral (correlation between pleasantness and familiarity, $r = 0.63$). We observed consistent and often significant trends that suggested the odor pleasantness and familiarity were positively associated with the correct odor identification, consumption of the respective spice, overall use of herbs, and food neophilia. Our results suggest that knowledge acquisition through repetitive exposure to spice odor with active attention may gradually increase the odor pleasantness within the framework set by the chemical characteristics of the aroma compounds.

Keywords: aroma, human, Food Neophobia Scale, olfaction, orthonasal, smell

Introduction

Olfaction (the sense of smell) is a central sensory modality guiding food preferences. The principal information that olfaction conveys is the hedonic value (valence, pleasantness) of an odor (Stevenson & Mahmut, 2013; Yeshurun & Sobel 2010). Humans are poor at naming odors, but it is usually easy to tell whether we like an odor or not. However, the hedonic value of an odor is subjective and changeable. It is modified by various environmental factors, including cognitive inputs. In addition, it has been shown that for some odorants, such as androstenone, genetic variation in the olfactory receptor for the odorant can account for some variation in liking for the respective odor (Keller et al. 2007). However, twin studies have observed that the total effects of environmental factors are usually higher than the total effects of genetic factors on the pleasantness of odors (Finkel et al. 2001; Knaapila et al. 2008; Knaapila et al. 2012). Thus, genetic factors may set the limits within which the environmental factors can modulate the hedonic value of an odor.

Rouby et al. (2009) organized the modulators of odor hedonics into three categories, (1) the stimulus itself (intensity and frequency of exposure), (2) the individual perceiver (e.g., sex, hormonal status, emotional state, physiological state, and sensory-specific satiety), and (3) the context in which the two are put in contact (experimental task, semantic knowledge, and cultural background). The authors recommended that all three categories of modulators should be considered, in addition to the route of stimulation (i.e., orthonasal/retronasal route), when planning sensory studies on foods.

Many studies have shown that the rated pleasantness and familiarity of odors are correlated, at least among neutral and pleasant odors (Delplanque et al. 2008; Distel et al. 1999; Ferdenzi et al. 2013; Royet et al. 1999; Sulmont et al. 2002). However, it is not completely understood how this association evolves: whether people tend to continually expose themselves to odors that they find pleasant at the first exposures, or whether they gradually start to like odors as they become more familiar (providing the odor source produces no adverse effects). Recently, Schloss et al. (2015) proposed that the hedonic value of an odor is based on the sum statistics of the valences of previous experiences related to that odor. The authors pointed out that the model they used (ecological valence theory) applies only to familiar odors. However, they speculated that preference for a truly novel odor should be neutral.

Another factor associated with odor preferences in food is food neophobia (for a review see Demattè et al. 2014). Food neophobia is defined as reluctance to eat and/or avoidance of novel foods (Pliner & Hobden 1992). Food neophobic children had less variety in their diet than did food neophilics (Falciglia et al. 2000) and food neophobia correlated negatively with the use frequency of several food categories in young adults (Knaapila et al. 2011). In a laboratory experiment, Raudenbush et al. (1998) demonstrated that food neophobics sniffed odor samples less vigorously than did food neophilics. Limited sniffing exploratory behavior, together with fewer contacts with new foods, can be assumed to limit exposure to food odors. Therefore, it can be hypothesized that food neophilics perceive food odors as less familiar and less pleasant than do food neophilics. Indeed, Raudenbush et al. (1998) observed that on average, food neophobics rated the sampled odors as less pleasant than did food neophilics. Furthermore, Demattè et al. (2013) showed that odor identification abilities of the neophobic participants were poorer than those of the non-neophobics. Based on the observation of Raudenbush & Frank (1999) that food neophobics responded more negatively to *unfamiliar* foods that did neophilics (but that both groups responded similarly to *familiar* foods), we analogously hypothesized that food neophobics differ from neophilics in their responses to unfamiliar (but not familiar) food odors.

Dried herbs and other odorous spices provide a versatile selection of natural odor stimuli to study human responses to (food) odors. Therefore, we tested our hypotheses using spices. We established our hypotheses on the previous findings that the rated pleasantness of an odor correlates with the familiarity of the odor, and both are associated with correct identification of the odor. First, we hypothesized that the habitual consumption of the spice (reflecting exposure to the odor source) is associated with both pleasantness, familiarity, and correct identification of the spice odor. Second, on a more general level, we hypothesized that the more frequently a person use herbs in cooking and baking, the higher she/he scores in the identification of spice odors. Third, we hypothesized that the level of food neophobia (or neophilia) is associated with responses to the spice odors, particularly in the case of odors that are rated, on average, as *unfamiliar*.

The present study aimed to test the hypotheses above listed in adults, to advance understanding of the relationships among overall and specific consumption of herbs/spices, responses to spice odors (pleasantness, familiarity, and identification), and food neophobia/neophilia.

Methods

Overview

This cross-sectional study consisted of two consecutive parts. First, an online survey and second, a laboratory study. Initially, we sent an invitation by email to 2379 adults (who were previously enrolled in a large family study unrelated to eating) to take part in the online survey that included questions related to olfaction, spices, eating, and demographics (detailed below). The survey was completed by 814 individuals (34.2% of the invited). Then, we invited the respondents who indicated a potential interest in a research visit (n = 618) to participate in the laboratory study. This part of the research included a visit to a sensory laboratory to assess a set of olfactory stimuli for pleasantness, familiarity, and identity, and complete a short questionnaire (detailed below).

Here, we analyzed the data from all the 126 individuals who completed the laboratory part of the study, including eight persons for whom the online survey data were not available. Instead, the data from the respondents of the online survey who did not participate in the laboratory part (N = 696) were excluded from the present analyses, together with some variables unrelated to the present topic (to be reported elsewhere).

Ethical aspects of the study protocol were evaluated and accepted by the Ethical Committee of the University of Turku. The participants of the study had the freedom to cancel their participation at any time. In the laboratory study, we collected a written informed consent from each participant prior to starting their data collection. We rewarded each participant in the laboratory study for her/his time and efforts with a movie voucher.

Participants

Demographics

We recruited the participants from the adults involved in the intensive follow-up group of the Steps to the healthy development and well-being of children (STEPS) study. The STEPS is an on-going longitudinal cohort study on children and their parents in Southwest Finland. The detailed cohort profile of the STEPS study, including ethical considerations, has been reported by Lagström et al. (2013). All participants lived in Finland and were Finnish-speaking (we communicated with them in Finnish only). Therefore, even if we did not ask their ethnicity, it is likely that most, if not all, participants were Caucasian and of Finnish descent.

A total of 126 individuals, 93 women (73.8%) and 33 men (26.2%), completed the laboratory study. Age of the participants ranged from 25 to 61 years. The mean age was 38.7 years (SD = 5.1) and the median was 38.0 years. The women were, on average, slightly younger than the men (mean ages 38.0 and 40.7 years, respectively; $t(124) = -2.63$, $p = 0.010$). Additional demographics, collected using the online survey, were available for 118 (93.7%) of the 126 participants in the laboratory study (**Table 1**).

Table 1. Demographics of the participants according to the online survey.

	Women		**Men**	
	n	**%[1]**	**n**	**%[1]**
Participated in the laboratory study	93	100.0	33	100.0
- Data from the online survey available	90	96.8	28	84.8
- Data from the online survey missing	3	3.2	5	15.2
Educational level[2]				
- Academic (BSc, MSc, PhD or such)	35	37.6	10	30.3
- Advanced vocational	31	33.3	9	27.3
- Basic vocational or none	24	25.9	9	27.3
Living environment[2]				
- Urban	26	28.0	10	30.3
- Suburban or semi-urban	39	41.9	9	27.3
- Rural	25	26.9	9	27.3
Dietary orientation[2]				
- Omnivorous (mixed)	69	74.2	25	75.8
- Mixed, but plant-based foods preferred	20	21.5	2	6.1
- Vegetarian or vegan	1	1.1	1	3.0
Smoking habits[2]				
- Non-smokers and never smoked	66	71.0	17	51.5
- Non-smokers but smoked in the past	23	24.7	10	30.3
- Smokers[3]	1	1.1	1	3.0

[1] Fraction of all participants within a gender (93 women/33 men).
[2] No data were available for three women and five men.
[3] The participants who reported smoking in the online survey may have quitted smoking prior to the laboratory study, because smoking was listed as an exclusion criterion.

Online survey

Procedure

An invitation to the online survey was emailed to all Finnish-speaking adults of the STEPS follow-up group for whom a valid email address was available, who had not refused to be contacted and to whom no other surveys were recently sent by the STEPS researchers. For practical reasons, no invitation was sent by mail and all communication was in Finnish only. It was possible to complete the survey during three months from the day the invitations were emailed (March 5th, 2014). After a little over a month from the first invitation, a reminder email message was sent.

The online survey was created using Webropol 2.0 online survey software (Webropol, Helsinki, Finland). In addition to collecting information on demographics and dietary orientation (reported above), we used the online survey to measure the participants' use of spices and level of food neophobia/neophilia (detailed below). The final question of the online survey probed the respondents' willingness to participate in the laboratory study.

Use of specific spices

The online survey inquired the use of 38 spices (**Suppl. Table 1**), including the 12 spices that were used as odor stimuli in the laboratory study (specified below). For simplicity, in this text, we call all samples as *spices*, although some of them are also *herbs*. For each spice, a respondent was asked to choose the most appropriate response from four options (modified from the five-option familiarity scale of Bäckström et al. 2004): (1) "I have not even heard about it", (2) "I know it by name, but I have not eaten it", (3) "I know I have eaten it", or (4) "I use it occasionally or regularly".

Food neophobia/neophilia

We used the Food Neophobia Scale (FNS) by Pliner and Hobden (1992) to measure the level of trait food neophobia/neophilia. The FNS consists of 10 items (statements, e.g., "I am afraid to eat things I have never had before") that are to be responded by one of the seven options ranging from "disagree strongly" (1) to "agree strongly" (7). Five of the items are worded in reverse to food neophobia (e.g., "I am constantly sampling new and different foods") and thus, scoring of these items have to be reversed as well, before the FNS score is calculated as a sum. Therefore, the potential range of the FNS score is 10–70. As per Knaapila et al. (2015), we regarded low FNS scores (10–24, i.e., the lowest quarter of the scale) as an indication of food neophilia (willingness to try new foods), rather than as a mere lack of food neophobia (indifference).

The Finnish translation of the FNS has been previously validated in a representative sample of the Finnish population (n = 1083, 53% women, age 16–80 years) by Tuorila et al. (2001). Here we used the translation with subsequent minor revisions in wording, as published in a Finnish textbook (Tuorila et al. 2008) as we did in a recent study in the same population of adults from Southwest Finland (Knaapila et al. 2015). A high internal consistency of the FNS in the present data (n = 118) was indicated by Cronbach's alpha of 0.84. This was similar as reported for FNS when the scale was developed (0.88; Pliner & Hobden 1992), validated in a Finnish sample (0.85; Tuorila et al. 2001), and used by us recently (0.88; Knaapila et al. 2015).

Laboratory study

Procedure

The online survey respondents who indicated an apparent or tentative willingness to visit the sensory laboratory to evaluate odors were invited to participate in the laboratory study by email in the fall of 2014. The exclusion criteria of the laboratory study were: (1) smoking, (2) chronic disorders and deficits of the sense of smell, (3) pregnancy, and (4) odorant intolerance (even self-diagnosed). The invitation message included practical information on the study and research visit, the exclusion criteria, with a note that any individual who met any of the criteria could not be included in the study, and a request to schedule an appointment to visit a sensory laboratory by either email or phone.

Each participant visited the laboratory once; the visit was typically 30–50 minutes. This part of the study was carried out at the sensory laboratory of the Functional Foods Forum, University of Turku (Turku, Finland) between late-October and mid-December 2014, which was 5–9 months after the participants responded to the online survey.

First, the laboratory visit included evaluation of 12 spice samples and then each participant was asked to complete a short questionnaire (detailed below). The questionnaire gave participants a break from sniffing and allowed some rest to the olfactory system before the final part of the study visit, that consisted of an evaluation of 12 (monomolecular) olfactory stimuli (the results to be reported elsewhere).

Odor evaluation of the spice samples

All participants sniffed (orthonasal olfaction) 12 spices in the following order: oregano, anise, rosemary, mint, caraway, sage, thyme, cinnamon, fennel, marjoram, garlic, and clove. These spices were purchased from a local supplier (Mauste-Sallinen Oy, Naantali, Finland). For a spice odor stimulus, approximately 5 mL (1 tsp) of dried spice material was placed in a transparent 30 mL plastic cup covered with a lid. Participants were instructed to first sniff a sample and then use the given labelled (structured) category scales to rate the pleasantness (9-point scale from -4 to 4) and familiarity (5-point scale from 0 to 4) of the odor, and finally attempt to identify the odor by choosing a response from among 17 given names of spices (including the 12 samples and 5 distractors) that were the same for all samples (for a complete list of response options see **Suppl. Table 2**).

Questionnaire

The questionnaire completed during the research visit to the sensory laboratory included the following question: “How often do you use fresh or dried herbs for seasoning when you cook or bake?” The response had the following options: “never” (1), “several times per year or more rarely” (2), “1–3 times per month” (3), “1–2 times per week” (4), “3–5 times per week” (5), “daily or almost daily” (6).

Statistical analyses

Methods

Although we used category scales to measure odor pleasantness and familiarity, we assumed that the underlying phenomena were continuous and normally distributed. Therefore, we mostly used parametric statistics (*t*-test, ANOVA, Pearson’s correlation) to analyze the data.

Dichotomous data was analyzed using Pearson's Chi^2 and Fisher's exact tests. The statistical analyses used software IBM® SPSS® Statistics, version 22 (Armonk, New York, USA). The statistical significance was set at $\alpha = 0.05$ while considering that the probabilities for type I errors ("false positives") could be higher due to the number of tests.

Segments based on the online survey

We classified participants based on their responses to the online survey (n = 118 from total n = 126) to compare these groups with their responses given to the spice odors in the laboratory study. We segmented the participants as "users" and "non-users" of a given spice, based on the data from the online survey: the four familiarity categories (above mentioned) were merged into two, so that participants with responses 1, 2 or 3 for a spice were labelled as "non-users" and the participants with response 4 ("I use it occasionally or regularly") as "users" of the spice in question. Then we compared the ratings for odor pleasantness and familiarity of users and non-users of the respective spice (*t*-test). In addition, we compared the proportion that correctly identified of an odor between users and non-users of the respective spice (Fisher's exact test).

We also segmented the participants based on their FNS score. No established criteria exist to classify individuals (for example, as "food neophobics") based on the FNS scores, while various splitting criteria have been applied (for further discussion, see Demattè et al. 2014, p. 1, and Knaapila et al. 2015, p. 2163). Here, we aimed to form two groups of similar size, with meaningful labels.

In our data, the distribution of the FNS scores was heavily right-sided (positive skew), i.e., the FNS score of most participants was on the "neophilic" side of the scale (median score was 22, while the center of the scale is 40). Therefore, we classified the participants with FNS score 10–24 (n = 66) as "food neophilics" (as Knaapila et al. 2015) and those with FNS score 25–70 (n = 52) as "others". Then we compared the groups for their ratings of odor pleasantness and familiarity (*t*-test). In addition, we compared the groups according to the proportion of group members who identified an odor correctly (success rate) and who reported (on the online survey) to use the respective spice/herb (Fisher's exact test).

Results

Online survey

Use of specific spices

The number of spices/herbs consumed occasionally or regularly (either as fresh or dried) by the respondents ranged from 3 to 36 (8–95% of n = 38 spice/herb items included in the survey, listed in **Suppl. Table 2**). The mean was 19.7 (SD = 7.2) and median 20. When only the 12 spices that were included in the laboratory study were considered, the number of consumed spices ranged from 1 to 12 (8–100%). In this case, the mean was 6.2 (SD = 2.9) and median 6. Women and men reported to consume a similar number of different spices (20.1 vs. 18.8, respectively, out of n = 38 included in the online survey, $t(116) = 0.83$, $p = 0.45$, and 6.3 vs. 5.8, respectively, out of n = 12 included in the sensory study, $t(116) = 0.81$, $p = 0.46$).

Of the 12 spices used as olfactory stimuli in the laboratory study, the proportions of the participants who reported using the given spice were as follows (in descending order of the proportion of users, indicated in parentheses): oregano (92%), garlic (90%), cinnamon (87%), thyme (70%), rosemary (59%), mint (45%), clove (44%), marjoram (42%), caraway (29%), sage (26%), fennel (22%), and anise (11%).

Food neophobia/neophilia

The FNS score ranged from 10 to 52. The mean score was 23.9 (SD = 10.1) and median 22. No difference in the FNS scores between women (24.3, SD = 10.7) and men (22.8, SD = 8.0) was observed ($t(116) = 0.69$, $p = 0.49$). Thus, the gender distribution across the segments formed by the FNS score was also even (the proportion of women was 76% in the “food neophilics” and 77% in ”others”).

Laboratory study

Frequency of overall use of herbs

Based on the questionnaire completed during the visit to the sensory laboratory, the distribution of the responses to the question regarding the overall use of fresh/dried herbs in cooking/baking was as follows (n = 126 participants): “a few times per year or more rarely”, 7.9% (n = 10; 70% women); “1–3 times per month”, 18.3% (n = 23; 74% women); “1–2 times per week”, 23.8% (n = 30; 67% women); “3–5 times per week”, 29.4% (n = 37; 70% women) and “daily or almost daily”, 20.6% (n = 26; 88% women). No one responded with the option “never”. We observed no significant difference in gender distribution across the response groups (Pearson’s $Chi^2(4) = 3.99$; $p = 0.41$).

Odor pleasantness and familiarity

The mean rating across all samples (n = 12 spices) and all participants of the laboratory study (n = 126) were 1.65 (SD = 1.02) for odor pleasantness (potential range: -4 to 4) and 2.51 (SD = 0.60) for odor familiarity (potential range: 0 to 4). On average, the odors were rated as more familiar by women than men (2.6 vs. 2.3, respectively, $t(124) = 2.33$, $p = 0.021$), while for the pleasantness the nominal difference between the genders was not statistically significant (1.7 vs. 1.4, respectively, $t(124) = 1.30$, $p = 0.20$).

The highest pleasantness ratings were given to the odors evoked by cinnamon (mean 3.3), mint (2.8), and oregano (2.7), and the lowest ratings to the odors of caraway (0.4), sage (0.6), and marjoram (0.7). The highest familiarity ratings were given to the odors evoked by cinnamon (3.9), garlic (3.7), and oregano (3.4), and the lowest familiarity to the odors of marjoram (1.2), sage (1.6), and caraway (1.7) (for the complete data on means see **Suppl. Table 3**).

As these values exemplify, the odors that were rated as the most familiar were often also experienced also as the most pleasant, and vice versa. The mean pleasantness and familiarity ratings correlated strongly (Pearson’s $r = 0.63$, $p = 0.029$, n = 12 odors). Regression analysis, using pleasantness as the dependent variable (y) and familiarity as the independent variable (x) yielded the linear regression equation $y = 0.70x - 0.10$ ($R^2 = 0.39$).

The only evident exception to the association between pleasantness and familiarity was observed with garlic: although its odor was rated as very familiar, it was not consistently experienced as pleasant. When we regarded garlic as an outlier and excluded it from the correlational analysis, Pearson’s correlation coefficient was 0.88 ($p < 0.001$, n = 11 odors). In this instance, the linear regression equation was $y = 1.04x - 0.77$ ($R^2 = 0.78$) (**Fig. 1**, for numeric data on means see **Suppl. Table 3**).

Odor identification

The score for correct odor identification ranged from 2 to 12 (potential range: 0 to 12; chance level 1/17 x 12 ≈ 0.7). The mean score was 7.40 (SD = 2.12) and median 7. Women identified more odors than did men (7.8 vs. 6.2, respectively, $t(124) = 4.17$, $p < 0.001$). Garlic and cinnamon were the most frequently correctly identified odors. Garlic odor was identified by all but one of the 126 participants in the laboratory study (99.2%) and cinnamon odor by all but three (97.6%). The least frequently identified odors were fennel (28.6%) and marjoram (31.0%). The remaining odors were identified correctly by 33.3–84.1% of the participants (**Suppl. Table 3**). The odor identification score correlated with the mean ratings for pleasantness ($r = 0.41$, $p < 0.001$) and familiarity ($r = 0.58$, $p < 0.001$).

Odor pleasantness and familiarity by odor identification

Analysis of the 10 samples showing a reasonable amount of variation in odor identification (excluding garlic and cinnamon odors, because virtually all participants identified them correctly) demonstrated consistently, that participants who identified an odor correctly also rated the odor (at least nominally) as more familiar and more pleasant than did those who misidentified the odor. The difference was significant ($p < 0.05$) for pleasantness ratings of 5 and familiarity ratings of 9 out of the 10 samples analyzed (**Fig. 2, Suppl. Table 4**).

Analyses of the joint data from survey and laboratory

Responses to the spice odors by the users vs. non-users

The users of a specific spice (i.e., those who reported consuming, e.g., rosemary, in the online survey) rated the odor of that spice (e.g., the odor from the rosemary sample at the sensory laboratory) at least nominally as more pleasant and more familiar than did the non-users. For 8 and 7 odors (total n = 12) the difference was statistically significant ($p < 0.05$) for pleasantness and familiarity, respectively (**Fig. 3, Suppl. Table 5**).

Similarly, the users of a specific spice correctly identified the odor of that spice more frequently than did the non-users, at least nominally, except in the case of anise. For 5 spices (clove, thyme, rosemary, sage, and marjoram), a significantly higher proportion of the users than non-users identified the odor correctly (**Table 2**).

Table 2. Proportion of participants who identified an odor correctly (in the laboratory study) among the users and non-users of the respective spice (by the online survey).

Odor[1]	Number of users/non-users[2]	Odor correctly identified by % of		Difference (users vs. non-users)[3]
		users	non-users	p
Garlic	106/12	100.0	100.0	NA
Cinnamon	102/15	98.0	93.3	ns
Oregano	109/9	84.4	77.8	ns
Mint	53/65	77.4	75.4	ns
Anise	13/105	53.8	74.3	ns
Clove	52/66	82.7	56.1	0.003
Thyme	83/35	62.7	28.6	0.001
Caraway	34/84	58.8	48.8	ns
Rosemary	70/48	60.0	33.3	0.005
Sage	31/87	71.0	23.0	< 0.001
Marjoram	50/67	56.0	11.9	< 0.001
Fennel	25/91	28.0	25.3	ns

[1] In descending order of proportion of correct identification in users.
[2] Number of users and non-users totals n = 116–118 individuals, including only participants for whom responses to both online survey and laboratory study were available.
[3] Fisher's exact test (2-sided).
NA, not applicable.
ns, not significant.

Associations with frequency of overall use of herbs

The self-reported frequency of overall use of any fresh/dried herbs in cooking/baking was associated with responses to the odors. First, frequent use of herbs was associated with higher average ratings for pleasantness (one-way ANOVA; $F(4,121) = 8.20$; $p < 0.001$) and familiarity of the spice odors ($F(4,121) = 5.73$; $p < 0.001$). In addition, frequent use of herbs was associated with a high odor identification score ($F(4,121) = 6.23$; $p < 0.001$). The participants who reported using herbs in cooking/baking daily or almost daily scored, on average, approximately two points more in the odor identification task than those who used herbs at the maximum twice a week (**Fig. 4**).

Frequent overall use of herbs was also associated with habitual consumption of a high number of different spices/herbs (i.e., wider variability). The participants who responded to the question regarding the overall use of herbs ("How often do you use fresh or dried herbs for seasoning when you cook or bake?") with "several times per year or more rarely", "1–3 times per month", "1–2 times per week", "3–5 times per week", or "daily or almost daily" were reported to consume (occasionally or regularly), on average, 11.4, 17.5, 18.9, 21.5, and 23.6 spice/herb items out of the 38 included in the online survey (**Suppl. Table 1**), respectively ($F(4,121) = 6.96$; $p < 0.001$).

In contrast, no significant association between the frequency of overall use of herbs in preparing meals and FNS score was observed ($F(4,113) = 1.96$; $p = 0.11$). Likewise, no difference in the overall use of herbs was found between the genders (Pearson's Chi^2, $p > 0.05$).

Associations with food neophobia/neophilia

The FNS score correlated negatively with the mean ratings of the odor pleasantness ($r = -0.25$, $p = 0.005$) and familiarity ($r = -0.25$, $p = 0.006$), and with the odor identification score ($r = -0.24$, $p = 0.009$). In addition, the FNS score correlated negatively with the total number of different spices consumed; the correlation coefficient was similar whether we included all the 38 spices in the online survey ($r = -0.39$, $p < 0.001$) or only the 12 spices that were also included in the sensory study ($r = -0.43$, $p < 0.001$).

To explore how food neophobia/neophilia was associated with responses to individual odors and use of individual spice items, we compared the participants classified into two groups (as detailed in the Methods section): the food neophilics (FNS score 10–24; n = 66) and others (FNS score 25–70; n = 52).

We observed that the food neophilics rated all odors, at least nominally, more pleasant and more familiar than did the others. However, the differences reached statistical significance mostly among odors that were rated, on average, proximate to the middle of the range (e.g. fennel for pleasantness and thyme for familiarity). In contrast, both groups uniformly rated cinnamon odor as highly pleasant and familiar (**Figure 5 a, b**).

For odors that were relatively *difficult* to identify (i.e., identified correctly by <60% of the participants), a larger proportion of the food neophilics than the others, identified a specific odor; the difference reached statistical significance for thyme and marjoram. In contrast, the food neophilics and the others reached similar success rates in identification of the odors that were, in general, relatively *easy* to identify (particularly garlic, cinnamon, oregano, and mint) (**Figure 5 c**). A larger proportion of the food neophilics than the others reported using the spices selected as the odor stimuli. The difference was statistically significant for all odors, except cinnamon (**Figure 5 d**).

In addition, the average score of correct odor identification was higher in the food neophilics than in the others (7.9 vs. 6.9, respectively; $t(116) = 2.62$, $p = 0.010$), in agreement with the aforementioned correlation between the FNS and identification scores.

Discussion

Relationships among responses to odors

Our results, regarding correlation between the familiarity and pleasantness of odors ($r = 0.63$–0.88) agreed with those previously reported by Distel et al. (1999) ($r = 0.55$–0.67), Royet et al. (1999) ($r = 0.79$), Sulmont et al. (2002) ($r = 0.73$), Delplanque et al. (2008) ($r = 0.75$–0.82), and Ferdenzi et al. (2013) (for pleasant odors r = 0.71–0.80). However, not all odors that were regarded as familiar were also rated as pleasant. This was demonstrated in the present study by garlic. It was the only odor of the 12 studied that was, on average, rated as highly familiar but only modestly pleasant. Conversely, none of the odors showed the opposite deviation from the general familiarity-pleasantness association: no odor was rated as unfamiliar but pleasant. The same result was recently observed in an exhaustive dataset of 1000 olfactory stimuli by Keller and Vosshall (2016).

Given that the primary functions of human olfaction are associated with ingestion and avoiding hazards (Stevenson 2010), it seems reasonable that a new food odor should not immediately be experienced as pleasant. Without further information, a person cannot be sure whether the new odor source (a new food) is safe. Therefore, it is reasonable that an individual perceives an odor as pleasant only if the source of the odor is deemed beneficial (delicious and not harmful) in the course of time.

Ultimately, after being exposed to initially unfamiliar food odors multiple times without adverse consequences, an individual may learn to like many of the odors. However, not all odors will become pleasant even after they had become familiar. Particularly, when an odor signals a risk (e.g., potentially harmful microbial spoilage) the odor should not become appetizing even when familiar. As Delplanque et al. (2008, p. 470) stated, “in theory, judging a malodor as less unpleasant following a few exposures could be unfavorable to individual survival.” Scatter plots for odor familiarity vs. pleasantness (hedonicity, liking) by Distel et al. (1999; Fig. 3c), Royet et al. (1999; Fig. 1c), and Sulmont et al. (2002; Fig. 1) implied a lack of correlation between odor familiarity and pleasantness among the unpleasant odors. Indeed, using a large set of odor stimuli, ranging widely in their observed pleasantness, together with cluster analysis to validate the classification of the odors, Delplanque et al. (2008) demonstrated that the correlation between the pleasantness and familiarity applied to the neutral and *pleasant* odors but not to the *unpleasant* odors. This result was subsequently replicated by Ferdenzi et al. (2013).

Our results cannot provide a conclusion regarding the hedonic value of a totally unfamiliar odor because we studied odors from spices commonly used in the culture of the participants. Even the least familiar odor in our study (marjoram) was rated, on average, as more than “slightly familiar”. However, we could speculate the pleasantness of an unfamiliar odor by extrapolating our data. If we assume a linear association between the odor pleasantness and familiarity, and interval-level measurement of the data, we can use the regression equations to approximate that the pleasantness of a totally unfamiliar odor would be somewhere between neutral and slightly unpleasant. This estimate is similar to that of Schloss et al. (2015), who speculated that the most obvious prediction, based on the ecological valence theory, might be that preference for a truly novel odor should be neutral. Also, a recent study by Keller and Vosshall (2016) demonstrated that unfamiliar odor stimuli tended to be neither pleasant nor unpleasant.

Pleasantness and familiarity ratings were also associated with identification of the rated odor. The participants who identified an odor correctly also rated it as more familiar than those who misidentified the odor, as also observed by Ferdenzi et al. (2013). In addition, in agreement with aforementioned correlation between the perceived pleasantness and familiarity of odors, the odors also tended to be rated as more pleasant by those who identified them correctly than by those who did not. This is consistent with findings that showed the strength of a hedonic rating (pleasantness of pleasant odors and unpleasantness of unpleasant odors) was higher among those who identified the odor. Knaapila et al. (2007) reported that the (pleasant) odors of banana, cinnamon, lemon, and rose were rated as more pleasant and the (unpleasant) odor of turpentine as more unpleasant by the participants who correctly identified them than those who did not. Likewise, Knaapila et al. (2008) observed that correct identification of an odor was associated with higher pleasantness for pleasant cinnamon and chocolate odors and with higher unpleasantness for unpleasant turpentine and sweaty (isovaleric acid) odors. However, Martinec Nováková et al. (2015) observed in 8–11 year-old children that the unpleasant odors of garlic and fish were rated as more pleasant (less unpleasant) by the children who identified the odor correctly, while no difference in identification was found for the other 14 studied odors.

Altogether, these results suggest that when an odor is correctly identified, it is likely to be familiar and has probably had acquired some of the hedonic value of its source. This is consistent with the results of Schloss et al. (2015), which demonstrated that the preferences for familiar odors were predicted by the average preferences for all things (objects/experiences) previously associated with the odors.

Molecular characteristics of odorants probably set the framework within which experience and learning can shape olfactory perception. Khan et al. (2007) used principal component analysis to reduce dimensionality of perceptual and physicochemical spaces of odorants. They demonstrated that the primary dimension (the first principal component) of physicochemical properties reflected that of the perception-based space, pleasantness. Kermen et al. (2011) suggested molecular complexity for providing a framework to explain the subjective olfactory experience. They showed that the molecular complexity of odorant, number of reported olfactory notes and odor pleasantness were associated with each other. Structurally less complex monomolecular odorants were rated as less pleasant than more complex ones. Recently, Keller and Vosshall (2016) replicated that general association and showed a variety of specific associations between a defined chemical structure and odor quality in a large dataset. For example, the more sulfur atoms an odorant had the more often the odor was described as “garlic”, “fish”, or “decayed”.

Consumption of spices vs. responses to their odors

Our hypothesis that habitual consumption of a spice is associated with responses to the odor of that spice seems true because the users of a spice rated its odor at least nominally more pleasant and familiar than did the non-users, although the association did not reach statistical significance for every odor. Similarly, at least a nominally higher proportion of users than non-users identified the odor correctly (except one odor, anise). Habitual consumption of a spice and, thus, exposure to its odor, may increase the pleasantness of the odor by the phenomenon referred to as mere exposure effect (Zajonc 1968). In addition to mere exposure effect, knowledge acquisition may lead to learning and deeper encoding of semantic features and names of odors when the odor becomes more familiar. As a result, users of a spice may learn to like the spice and its odor. This may explain, at least in part, the aforementioned correlation between the pleasantness and familiarity of odors. However, as discussed above, it is important to note that not all familiar odors are pleasant. Delplanque et al (2015) demonstrated that mere exposure mostly increased the hedonic value of the odors that were initially experienced as either neutral or mildly pleasant, whereas the unpleasant odors remained unpleasant despite exposure. Our data suggest that unfamiliar spice odors are experienced as rather neutral, inferring that the common spice odors, such as the ones used in the present study, could be affected by the mere exposure effects.

Our second hypothesis was a generalization of the first. Here we tested whether frequent use of herbs in the participant’s own cooking or baking activities (not only eating) was associated a with high odor identification score. Our results suggest that only heavy use of herbs in cooking/baking, on a daily or almost daily basis, results in higher ability to identify spice odors compared to people who use herbs twice a week at maximum. Although we cannot show that the use of herbs in cooking/baking lead to greater odor exposure than only eating foods containing herbs prepared by others, we speculate that the participants who frequently prepared food with herbs themselves had paid more attention to the odors than the others had (leading to greater acquisition of odor knowledge). We based our speculation on the suggestion by Prescott et al. (2008) that active attention to odor is an important determinant of exposure effects.

Third, we hypothesized that the level of trait food neophobia/neophilia is associated with responses to spice odors, particularly to unfamiliar odors. Although the differences between the food neophilics and the others reached statistical significance for some odors only, the overall trends were rather evident. As visualized in **Fig. 5**, the food neophilics appeared to experience spice odors as more pleasant and more familiar than the others. However, the role of stimulus familiarity (Raudenbush & Frank 1999) was most evident in odor identification. Virtually equal fractions of the neophilics and others correctly identified the most familiar odors (cinnamon, garlic, and oregano), whereas a significantly or nominally larger fraction of the neophilics, compared to the others, made a correct odor identification for the six least familiar odors (thyme, rosemary, fennel, caraway, sage, and marjoram). Overall, the food neophilics identified more odors correctly than the others did, which is similar to the result of Demattè et al. (2013).

Food neophilics also used spices more frequently than the others did. This may, in part, explain the tendency of the food neophilics to rate the spice odors as more pleasant and more familiar, and score more highly in the odor identification.

Methodological considerations

The present study has some limitations. First, the dried and powdered spices used as the olfactory stimuli were not visually masked. Therefore, it is possible the appearance of the stimuli influenced the ratings given for the respective odor. We assume, however, that the bias due to the visual cues was weak because at least the dried and ground herbs looked similar. Also, the identification task had 17 response options, so, the chance level (of accidental identification) was small compared to standard smell identification tests that usually use a multiple-choice with four options.

Second, although some of the spices included in our stimuli set (thyme, rosemary, and garlic) may be more typically used as fresh herbs, that evoke a somewhat different odor, for practical reasons we only used dried material. Real food materials, even dried spices that are relatively stable, cannot be as strictly chemically defined as pure laboratory chemicals. However, our primary purpose was to study human responses to odors, not the sensory characteristics of the spices as such. In the present study, the spices served mainly as a versatile source of relevant olfactory stimuli to humans. In addition, we assumed that real spices could yield more realistic odor perceptions than synthetic spice aromas.

Conclusions

People vary widely in how they experience odor pleasantness and familiarity and how well they identify odors. These tendencies are interrelated. Among neutral and pleasant odors, such as the ones studied here, odor pleasantness correlates with familiarity, and both are associated with correct identification. Our data suggest that odor pleasantness, familiarity, and identification of spices are, in turn, enhanced by consumption of the respective spice, total use of herbs, and food neophilia. These factors might have not only increased the exposure to the spice odors but also the active attention to the odors. Effects of mere exposure and knowledge acquisition may modify the pleasantness of spice odor within the framework set by the chemical characteristics of the odorants.

Acknowledgements

The authors thank all participants for their efforts in the study. We also thank Anne Kaljonen and Maija Leino for their valuable contribution to the data collection, management, and analysis, the midwives for recruiting the participants for the STEPS study and the whole STEPS study team for enabling the collaboration. This study was financially supported by the Academy of Finland (MAS, grant numbers 252005, 256176, 263747), (HL, grant number 121569), (AJK, grant number 267698); and the University of Turku. The STEPS study is mainly funded by the University of Turku, Åbo Academi University and the Turku University Hospital.

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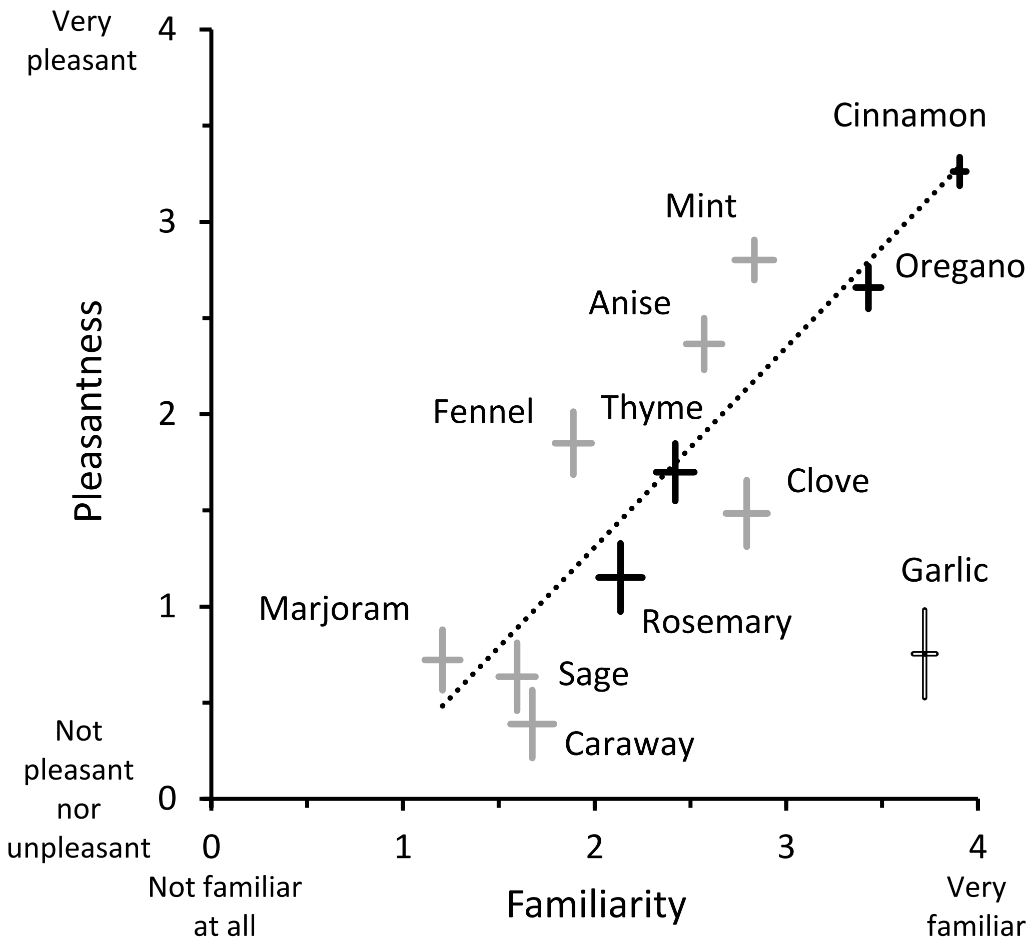

Figure 1. Pleasantness of the odors as a function of their familiarity. The odors of spices used by <50% and >50% of the participants (data from the online survey) are shown in gray and black, respectively. Error bars indicate SEM. Note: pleasantness was rated on a scale from -4 to 4, but the axis for pleasantness in the figure spans only from 0 to 4, to highlight differences. Garlic was considered as an outlier and excluded when the trend line resulting from the following linear regression equation was fitted to the data: Pleasantness = 1.04 * Familiarity - 0.77 (R^2 = 0.78).

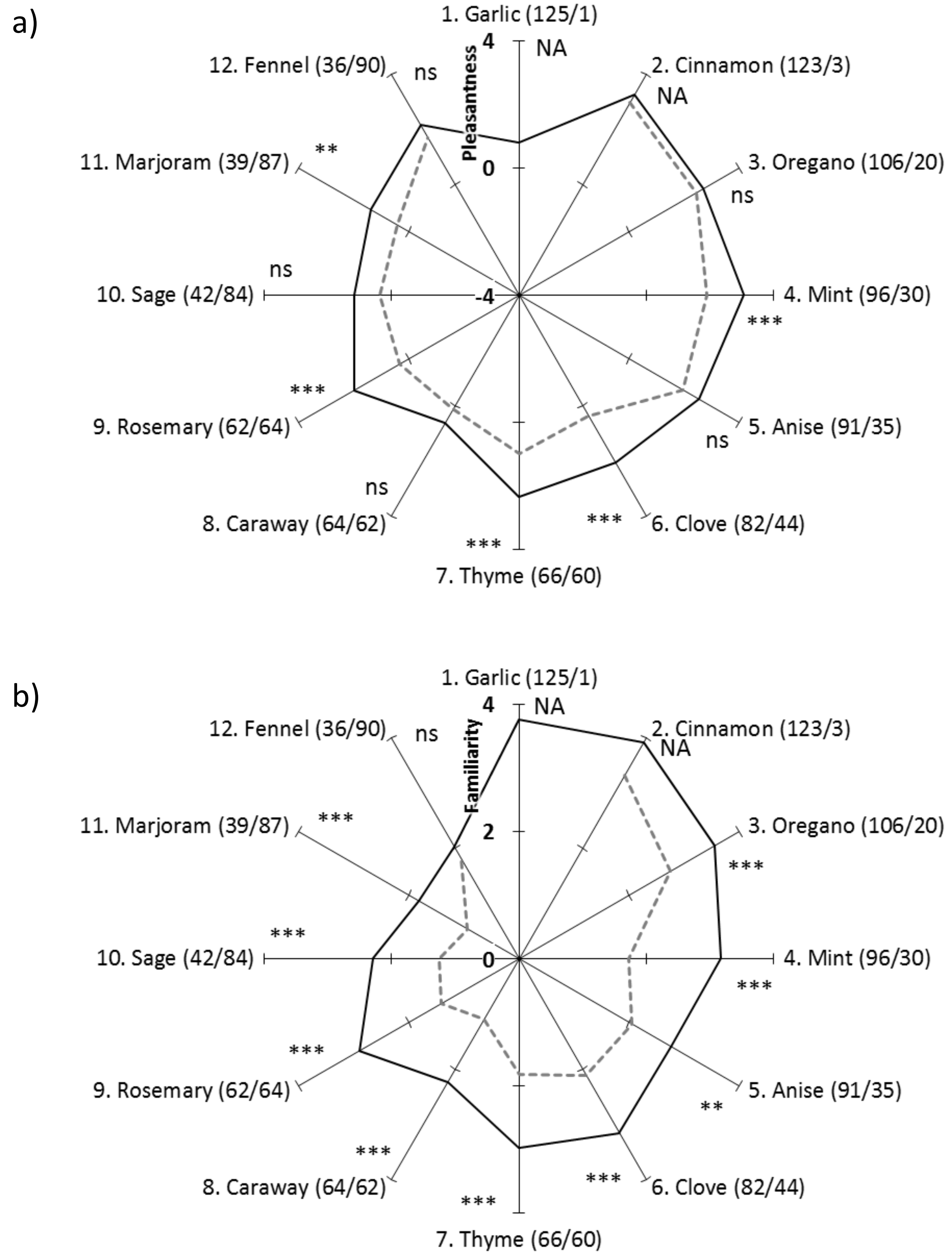

Figure 2. Mean odor pleasantness (a) and familiarity (b), compared between participants who identified (black line) and misidentified (gray dashed line) the respective odor. The number of participants who (mis)identified the odor is shown in parentheses ($n_{identified}/n_{misidentified}$). The odors are shown clockwise in the descending order of the proportion of participants with correct identification. *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$; ns, not significant (*t*-test).

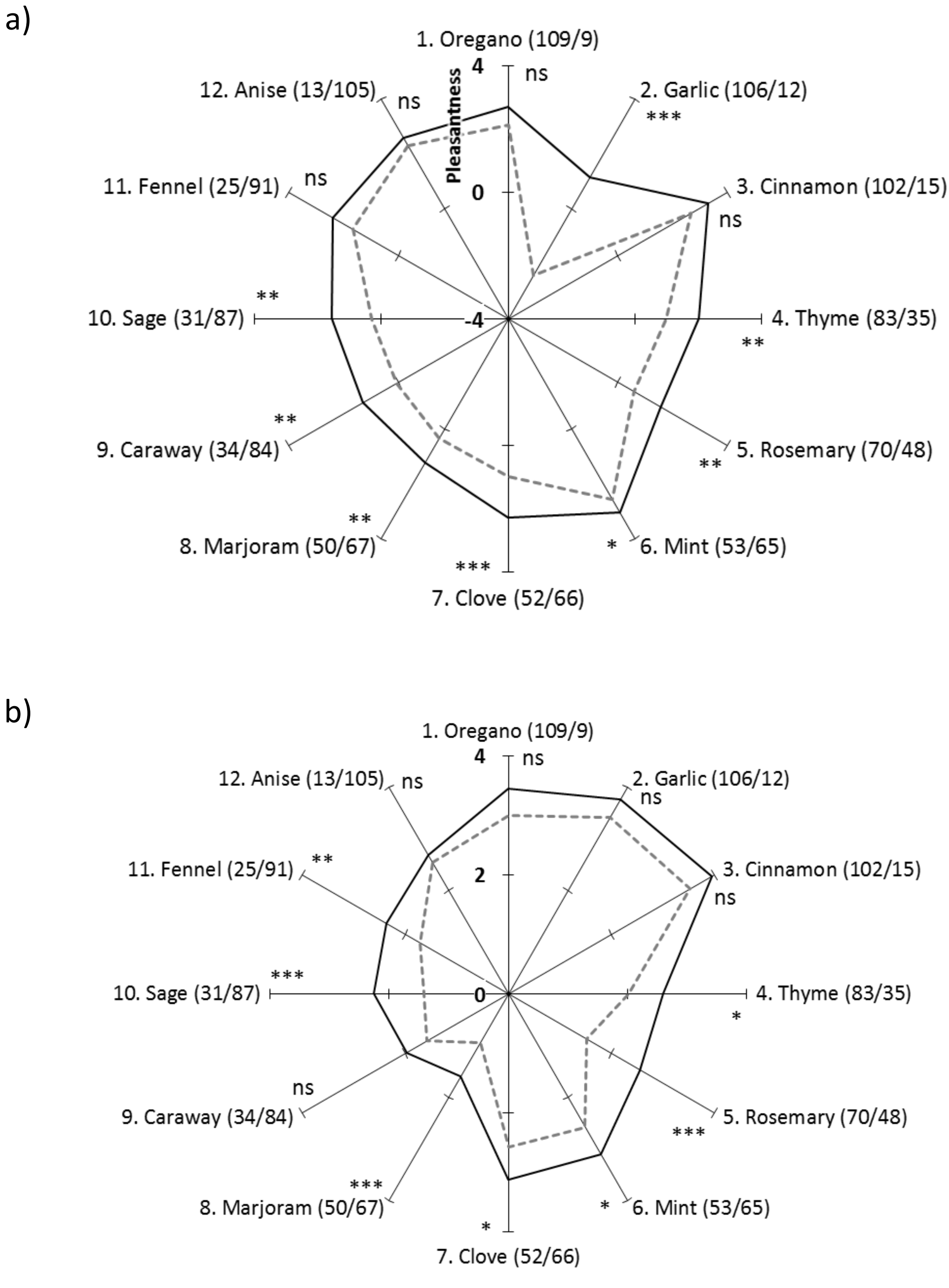

Figure 3. Mean odor pleasantness (a) and familiarity (b), rated in the sensory laboratory by users (black line) and non-users (gray dashed line) of the respective spices. The number of (non)users is shown in parentheses ($n_{users}/n_{non\text{-}users}$, according to the online survey). The odors are shown clockwise in the descending order of the proportion of users of the respective spice. *, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$; ns, not significant (*t*-test).

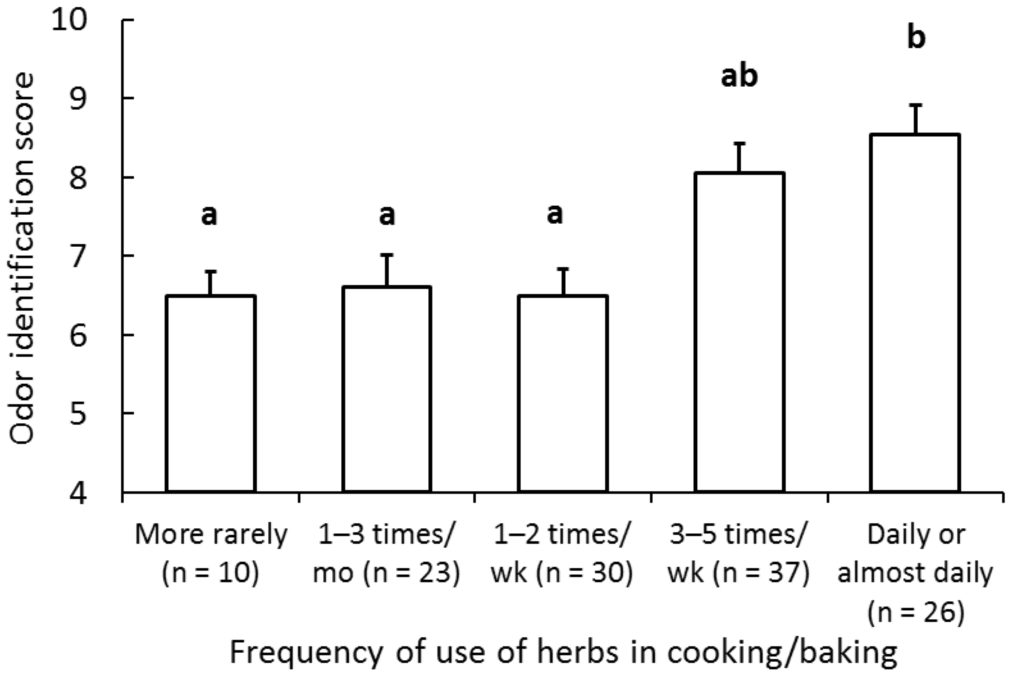

Figure 4. Odor identification scores by the self-reported frequency of use of herbs in cooking/baking. The score indicates the number of correctly identified odors out of the 12 stimuli. Note: the potential score range was 0–12, whereas the axis was truncated to 4–10, to highlight differences between the groups. Error bars indicate SEM. Means marked with different letters differ significantly (Tukey's test, $p < 0.05$).

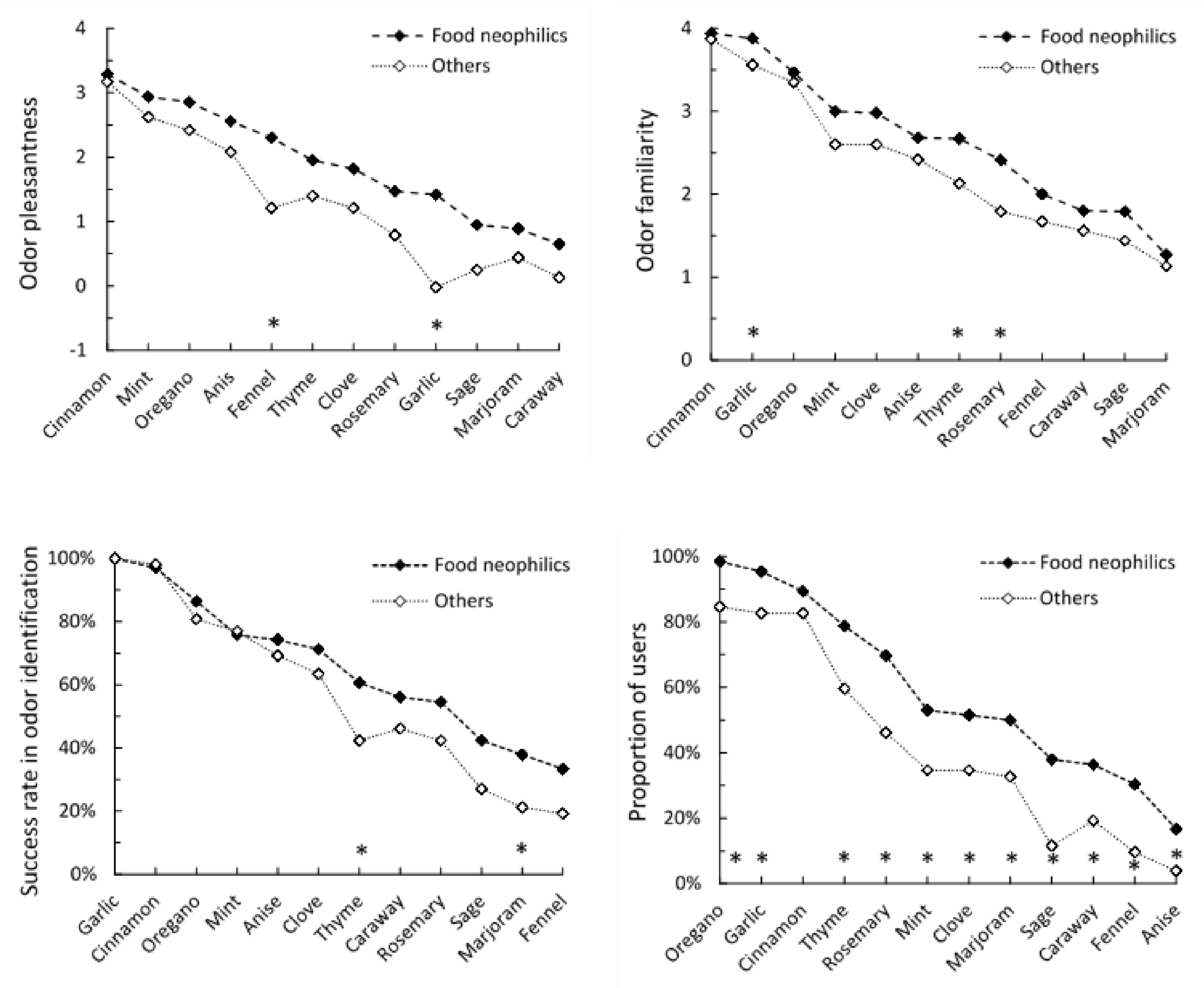

Figure 5. Item-wise comparison between the food neophilics (FNS score 10–24; n = 66) and the others (FNS score 25–70; n = 52) regarding the mean ratings they gave (in the laboratory study) for pleasantness (a) and familiarity (b) of the spice odors, the success rate in identifying the individual odors (c), and the proportion of the group members who reported using the respective spice (in the online survey) (d). The items are shown in descending order of the means/proportions (of food neophilics). Odor pleasantness and familiarity were rated on scales from -4 to 4 and from 0 to 4, respectively. The means were compared using independent samples t-test and the proportions using Fisher's exact test (1-sided). *, $p < 0.05$.

SUPPLEMENTARY TABLES

Supplementary Table 1 The 38 spice items included in the online survey (in alphabetical order). Twelve of them were used also as odor stimuli in the laboratory study.

Spice	Species (or genus) of the main/typical raw-material of the spice[1]	Odor stimulus in the laboratory study?[2]
Allspice	*Pimenta dioica*	No
Anise (aniseed)	*Pimpinella anisum*	Yes (2.)
Basil	*Ocimum basilicum*	No
Black pepper	*Piper nigrum* (cooked, dried unripe fruit)	No
Caraway	*Carum carvi*	Yes (5.)
Cardamom	Zingiberaceae family	No
Chervil (French parsley)	*Anthriscus cerefolium*	No
Chili	*Capsicum*	No
Chives	*Allium schoenoprasum*	No
Cilantro (coriander)	*Coriandrum sativum*	No
Cinnamon	*Cinnamomum*	Yes (8.)
Clove	*Syzygium aromaticum*	Yes (12.)
Curry powder	(a commercial mixture of spices)	No
Dill	*Anethum graveolens*	No
Fennel	*Foeniculum vulgare*	Yes (9.)
Garlic	*Allium sativum*	Yes (11.)
Ginger	*Zingiber officinale*	No
Green pepper	*Piper nigrum* (dried unripe fruit)	No
Hyssop	*Hyssopus officinalis*	No
Lavender	*Lavandula*	No
Lemon balm	*Melissa officinalis*	No
Lovage	*Levisticum officinale*	No
Marjoram	*Origanum majorana*	Yes (10.)
Mint	*Mentha*	Yes (4.)
Oregano	*Origanum vulgare*	Yes (1.)
Parsley	*Petroselinum crispum*	No
Rose pepper (Brazilian pepper)	*Schinus terebinthifolius*	No
Rosemary	*Rosmarinus officinalis*	Yes (3.)
Saffron	*Crocus sativus*	No
Sage	*Salvia officinalis*	Yes (6.)
Savory (summer/winter)	*Satureja*	No
Sour orange (bitter orange)	*Citrus × aurantium* (ground peel)	No
Star anise (star aniseed)	*Illicium verum*	No
Tarragon	*Artemisia dracunculus*	No
Thyme	*Thymus vulgaris*	Yes (7.)
Turmeric	*Curcuma longa*	No
Vanilla	*Vanilla planifolia*	No
White pepper	*Piper nigrum* (ripe fruit seed)	No

[1] When a spice can be derived from several species of a genus, only the name of the genus is given. Latin names were not shown to the participants of the study.
[2] The fixed order of presentation in parentheses.

Supplementary Table 2. Response options for evaluation of the spice odor samples.

Task (evaluated dimension)	Option		
	Value	Label in English	Label in Finnish
Pleasantness	4	Very pleasant	*Erittäin miellyttävä*
	3	Pleasant	*Miellyttävä*
	2	Rather pleasant	*Melko miellyttävä*
	1	Slightly pleasant	*Hieman miellyttävä*
	0	Not pleasant nor unpleasant	*Ei miellyttävä eikä epämiellyttävä*
	-1	Slightly unpleasant	*Hieman epämiellyttävä*
	-2	Rather unpleasant	*Melko epämiellyttävä*
	-3	Unpleasant	*Epämiellyttävä*
	-4	Very unpleasant	*Erittäin epämiellyttävä*
Familiarity	4	Very familiar	*Erittäin tuttu*
	3	Familiar	*Tuttu*
	2	Rather familiar	*Melko tuttu*
	1	Slightly familiar	*Hieman tuttu*
	0	Not familiar at all (totally unfamiliar)	*Ei lainkaan tuttu (täysin vieras)*
Identification	a	Anise	*Anis*
	b	Fennel	*Fenkoli*
	c	Ginger[1]	*Inkivääri*[1]
	d	Cinnamon	*Kaneli*
	e	Cardamom[1]	*Kardemumma*[1]
	f	Chervil[1]	*Kirveli*[1]
	g	Cilantro[1]	*Korianteri*[1]
	h	Caraway	*Kumina*
	i	Marjoram	*Meirami*
	j	Mint	*Minttu*
	k	Clove	*Neilikka*
	l	Oregano	*Oregano*
	m	Tarragon[1]	*Rakuuna*[1]
	n	Rosemary	*Rosmariini*
	o	Sage	*Salvia*
	p	Thyme	*Timjami*
	q	Garlic	*Valkosipuli*

[1] Distractor (not included as an odor stimulus).

Supplementary Table 3. The mean odor pleasantness and familiarity ratings, the proportions of correct identifications of the evaluated odors, and the proportions of users of the respective spices.

Odor[1]	Odor pleasantness[2]				Odor familiarity[2]				Odor identified by[3]	Spice used by[4]
	Mean	SEM	SD	Dif.	Mean	SEM	SD	Dif.	%	%
Cinnamon	3.262	0.074	0.831	a	3.905	0.035	0.388	a	97.6	87.2
Mint	2.802	0.105	1.173	ab	2.833	0.102	1.144	c	76.2	44.9
Oregano	2.659	0.111	1.240	ab	3.429	0.066	0.742	b	84.1	92.4
Anise	2.365	0.134	1.505	bc	2.571	0.093	1.046	c	72.2	11.0
Fennel	1.849	0.164	1.838	cd	1.889	0.095	1.067	ef	28.6	21.6
Thyme	1.698	0.149	1.675	cd	2.421	0.099	1.112	cd	52.4	70.3
Clove	1.484	0.173	1.942	d	2.794	0.108	1.215	c	65.1	44.1
Rosemary	1.151	0.177	1.988	de	2.135	0.114	1.280	de	49.2	59.3
Garlic	0.754	0.228	2.563	e	3.722	0.059	0.665	ab	99.2	89.8
Marjoram	0.722	0.157	1.765	e	1.206	0.092	1.038	g	31.0	42.7
Sage	0.635	0.177	1.982	ef	1.595	0.096	1.075	fg	33.3	26.3
Caraway	0.389	0.176	1.980	f	1.675	0.113	1.270	f	50.8	28.8

[1] The odors are listed in descending order of pleasantness.
[2] Potential range for pleasantness was from -4 to 4 and familiarity from 0 to 4 (n = 126). The means marked with different letters differ significantly according to Tukey's test ($p < 0.05$).
[3] Proportion of the participants in the laboratory study (n = 126) who identified the odor correctly.
[4] Proportion of the users of the respective spice according to the online survey (n = 118 participants for whom data from both the online survey and laboratory study were available).
SEM, Standard error of the mean; SD, Standard deviation

Supplementary Table 4. Mean odor pleasantness and familiarity ratings by identification of the respective odor.

Spice[1]	n (identified /misidentified)[2]	Odor pleasantness						Odor familiarity					
		When odor identified		When odor misidentified		Difference[3]		When odor identified		When odor misidentified		Difference[3]	
		Mean	SD	Mean	SD	t	p	Mean	SD	Mean	SD	t	p
Garlic	125/1	0.792	2.538	-4.000	NA	NA	NA	3.752	0.577	0.000	NA	NA	NA
Cinnamon	123/3	3.268	0.840	3.000	0.000	NA	NA	3.919	0.353	3.333	1.155	NA	NA
Oregano	106/20	2.698	1.243	2.450	1.234	-0.824	0.417	3.557	0.634	2.750	0.910	-3.792	<0.001
Mint	96/30	3.083	0.981	1.900	1.296	-4.606	<0.001	3.177	0.929	1.733	1.081	-6.595	<0.001
Anise	91/35	2.527	1.448	1.943	1.589	-1.895	0.063	2.769	0.967	2.057	1.083	-3.403	0.001
Clove	82/44	2.073	1.669	0.386	1.956	-4.852	<0.001	3.159	1.048	2.114	1.224	-4.797	<0.001
Thyme	66/60	2.348	1.398	0.983	1.672	-4.945	<0.001	2.970	0.960	1.817	0.948	-6.778	<0.001
Caraway	64/62	0.641	1.930	0.129	2.012	-1.456	0.148	2.234	1.269	1.097	0.987	-5.626	<0.001
Rosemary	62/64	1.984	1.920	0.344	1.711	-5.056	<0.001	2.887	1.073	1.406	1.019	-7.939	<0.001
Sage	42/84	1.167	2.305	0.369	1.755	-1.975	0.053	2.286	1.175	1.250	0.834	-5.107	<0.001
Marjoram	39/87	1.385	1.444	0.425	1.821	-3.170	0.002	1.821	0.997	0.931	0.938	-4.716	<0.001
Fennel	36/90	2.167	1.612	1.722	1.914	-1.323	0.190	2.028	0.910	1.833	1.124	-1.010	0.315

[1] The odors are listed in descending order of the proportion of participants who identified the odor correctly.
[2] Total n = 126 (number of participants in the laboratory study).
[3] Independent samples *t*-test (2-tailed, equal variances not assumed).

Supplementary Table 5. Mean odor pleasantness and familiarity ratings by users and non-users of the respective spices.

Spice[1]	n (users/non-users)[2]	Odor pleasantness						Odor familiarity					
		Users		Non-users		Difference[3]		Users		Non-users		Difference[3]	
		Mean	SD	Mean	SD	*t*	p	Mean	SD	Mean	SD	*t*	p
Oregano	109/9	2.706	1.227	2.111	1.269	-1.396	0.207	3.450	0.726	3.000	0.866	-1.514	0.165
Garlic	106/12	1.151	2.366	-2.417	1.311	-8.056	<0.001	3.774	0.540	3.417	0.900	-1.346	0.203
Cinnamon	102/15	3.314	0.717	2.667	1.345	-1.825	0.088	3.961	0.195	3.533	0.915	-1.802	0.093
Thyme	83/35	2.012	1.589	1.000	1.609	-3.133	0.003	2.602	1.059	2.029	1.071	-2.668	0.010
Rosemary	70/48	1.571	2.110	0.583	1.773	-2.751	0.007	2.557	1.235	1.521	1.111	-4.755	<0.001
Mint	53/65	3.057	0.989	2.585	1.286	-2.253	0.026	3.113	1.121	2.585	1.130	-2.538	0.013
Clove	52/66	2.269	1.510	0.985	2.087	-3.876	<0.001	3.115	1.041	2.576	1.313	-2.489	0.014
Marjoram	50/67	1.220	1.741	0.343	1.702	-2.720	0.008	1.600	1.107	0.940	0.919	-3.425	0.001
Caraway	34/84	1.294	2.154	0.071	1.789	-2.927	0.005	1.971	1.467	1.583	1.164	-1.375	0.175
Sage	31/87	1.581	1.766	0.310	2.025	-3.305	0.002	2.258	1.182	1.414	0.959	-3.578	0.001
Fennel	25/91	2.400	1.500	1.670	1.967	-2.005	0.051	2.360	1.036	1.714	1.057	-2.748	0.009
Anise	13/105	2.615	1.660	2.314	1.476	-0.624	0.542	2.692	1.251	2.552	1.019	-0.388	0.704

[1] The odors are listed in descending order of the proportion of users of the respective spice.
[2] Total n = 116–118 (depending on missing values), classified into users and non-users according to the online survey.
[3] Independent samples *t*-test (2-tailed, equal variances not assumed).