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A cross-cultural study on odor-elicited life stage-associations

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ABSTRACT

Associative conceptualization plays an important role in how we perceive and interact with our environment. Particularly odor associations can be highly vivid and often long-lasting due to their close connection with our episodic memory and emotions. Based on the findings of a study conducted in Austria in 2017, this work was carried out to investigate odor-elicited life stage-associations (OELSA) in seven nations and to identify potential similarities and differences in conceptualizing odor impressions across these nations.

A total of 1144 adults (aged 21–60) from Austria, Australia, Germany, Switzerland, Thailand, USA, and Vietnam participated in this study. Nine odors (*vanilla*, *orange*, *lemon*, *mint*, *coconut*, *basil*, *rose*, *anise*, and *hay*) were presented to the participants, and they were asked to answer questions about their spontaneous associations with life stages.

The results indicate the existence of OELSA in all investigated nations. For example, *vanilla* was predominantly assigned to children in all nations, while *hay* was primarily assigned to elder people. While most of the investigated odors were most frequently associated with adults, some significant differences in OELSA were observed between the different nationalities. For instance, *mint* was more frequently associated with children by Australian participants compared to participants from all other nations, while *coconut* was more strongly associated with children by the Vietnamese participants compared to all other participants.

The results of this study demonstrate the existence of consistent life stage-related associations elicited by certain odors across different nations and cultures and, at the same time points to differences in life stage-related association with certain odors between the nations. Since this work was not designed to identify the reasons for these differences, we can only make assumptions about the potential underlying causes for these behaviors.

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1. Introduction

This study was inspired by a conceptualization study carried out in the European country of Austria (Danner et al., 2017), in which approximately 400 non-trained, naïve individuals associated seven odors from different odor groups (*fruity-citrus, vanilla, floral, spicy-brown, confectionery, green* and *nutty*) with four distinct stages of life (children, adolescents, adults, and seniors). This prior study demonstrated that six out of seven odors were significantly associated with a specific life-stage. The majority of the participants associated the odors *confectionery* and *vanilla* with children, *floral* and *spicy-brown* with adults and *green* and *nutty* with seniors. We hypothesized that the idea of an odor is more or less closely associated with concepts which in turn constitute its meaning. In this previous work, we investigated associations between the perceived odor and different life-stages, as life stages are experienced by every living human and, therefore, have a basic meaning. These odor-elicited life stage-associations (OELSA) are thought to consciously or non-consciously influence how individuals experience odors and subsequently, how they behave towards the odor. For example, vanilla-odor, which is often closely associated with childhood (Spahn et al., 2019), might allow the individual to re-experience childhood and the associated positive feelings while consuming a vanilla-flavored product.

Such results support the efforts of food, pharmaceutical, perfume and cosmetic manufacturers, to align their products with the desires of specific consumer groups. In aging societies such as those in 'wealthy industrialized nations' (e.g., Europe, China and Japan), it might be of high interest to specifically target the population over 50 years of age and consider their needs and desires when changing a brand or product, as the willingness to accept such changes generally decreases with age (Helm & Landschütze, 2013). Thus, age-related research and product development is of high interest. Consumers' associative assignments of life stages to specific odors might provide additional opportunities for customized, age-related product development by exploring the age-focused selection of foods or product flavorings.

Associative conceptualizations also play an important role in contemporary marketing, since assigning a distinct identity to a product is an important aspect of marketing. This identity should fit into already existing associations and the intuitive conceptualization of the product. Especially in the case of odors, associative conceptualization can be highly vivid and effective in influencing behavior; they are also mostly long-lasting due to their close connection with episodic memory (Herz & Engen 1996; Saive et al. 2013; Herz, 2016).

Associations are important parts of conceptualization, which is the process of giving meaning to perceptions supported by memory. The result of the conceptualization process is the consideration of a certain content, which enables the recognition of objects, experiences, or perceptions and the selection of adequate behavioral options (Gärdenfors, 2019). The framework for this work is the fundamental model of perception which was characterized by Smythies (1956) as a 'causal chain of perception and action'. The individual process steps between stimulus, behavior and reality described in this model are roughly outlined in Fig. 1. The model is based on the idea that an outer world meets a perceiving individual and describes how stimuli elicit sensory perception, affective reactions, associations, wanting, and liking in a causal chain that finally leads to a specific behavior or action (Smythie, 1956, Carey, 2009). In the case of food, chemical and/or physical stimuli are detected by the human sensory systems, initiating a complex process which results in their evaluation and the decision, whether these stimuli actually derive from food and whether this food can, should, or has to be eaten. The results of this evaluation process clearly influence our nutritional behavior (Bellisle, 2003). Thus, the stimulus ultimately elicits behavior and consequentially influences the food and product choice. This model is not only valid for food commodities and their odors, but for all stimuli emitted by any object like products and consumer goods (Carey, 2009).

Motivation to eat as incentive salience or wanting is a strong behavior-influencing reaction rooted in affective reactions to the

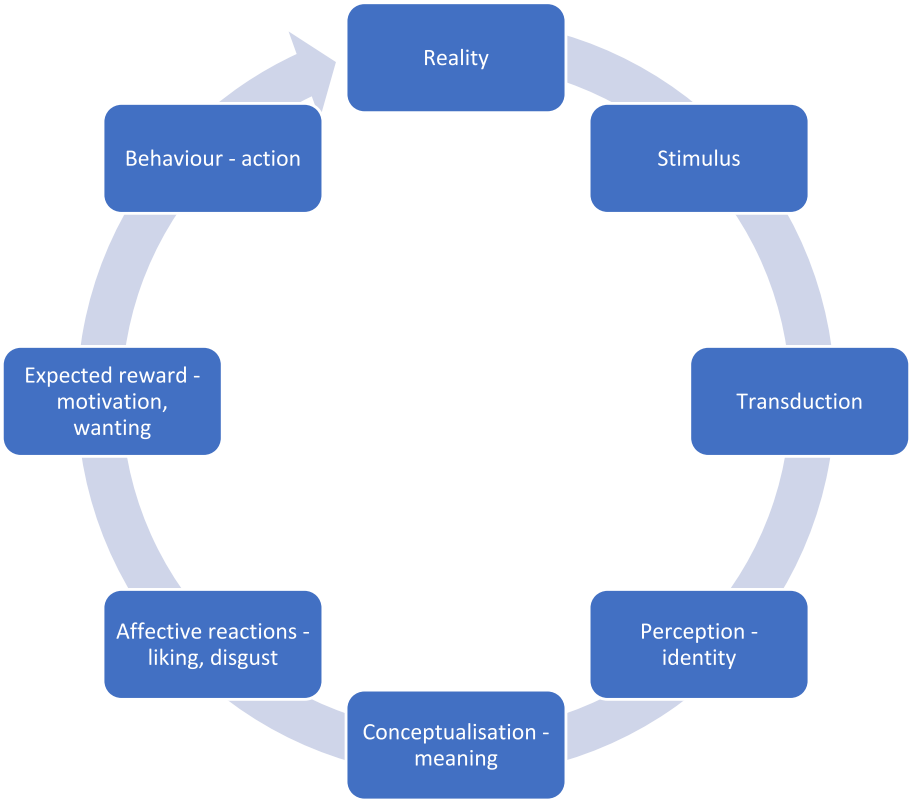

Fig. 1. *Causal chain model from reality to behavior; graphic inspired by Smithey (Smithey, 1956;* Carey, 2009*;* Thomson; 2015).

identity and the meaning of a food/product item (Rolls, 2008; Kringelbach, 2015; Morales & Berridge, 2020). Without conceptualization, motivation is not elicited in the same way. Thus, this model clearly shows why conceptualization is so important and requires further scientific investigation. Conceptualization lends an associated meaning to the product that is also called 'conceptual content' (Carey, 2009). Conceptional contents are not necessarily conscious but may be elicited by automatic and unconscious cognitive processes, that occur without our awareness and that influence our responses to odors such as belief, thoughts, and evaluations (Dijksterhuis, 2004; De Luca & Botelho, 2021). Since our habits of self-learning or learning from others form the basis of conceptional content assignment, these conceptualizations are highly diverse (Thomson & Crocker, 2014). Nevertheless, they can be assigned to three categories: functional (e.g., 'will make me healthier'), emotional (e.g., 'will make me happy') and abstract (e.g., 'is trustworthy'). Thomson (2010) suggested defining only two categories (i.e., emotional, and functional), arguing that abstract conceptualizations usually have emotional and functional connotations. Herz (2005) claimed that the hedonic experience of odors and odor-related behavior results from learned associations between an odor and the emotional context in which that odor was perceived for the first time. Consequently, whether an odor is liked or not is deeply connected to experiences which might differ between individuals, across cultures and geographical sites. Memories can evoke positive or negative emotions related to smell (Herz, 2016) and memory-based familiarity normally increases the affective rating of pleasant odors (Liu et al., 2020). Moreover, cultural background, olfactory knowledge (Ferdenzi et al., 2012) and age (Honnens de Lichtenberg Broge et al., 2021) have been reported to influence affective reactions towards odors. Interestingly, affective reactions to odors do not only depend on the odor quality but also its intensity. The intensity of unpleasant odors, for example, seems to be more important than that of pleasant ones (Liu et al., 2020). Also, the reaction rate on pleasant and unpleasant odors was reported to be different (Jacob & Wang, 2006). The general decrease in sensitivity to odor perception with increasing age modifies perception; thus, it might also impact the conceptualization of the perceived odors. However, results of a recent study indicate that the hedonic rating of odors is specific to individual odors and not generally related to age-induced alterations in intensity perception (Honnens de Lichtenberg Broge et al., 2021).

We chose the conceptualization of life-stages as it is an archetypal construct that forms the basis of all human existence. We all exist in a certain life-stage and obtain knowledge of different life-stages. Biology divides the life cycle of humans into four stages: Embryogenesis, childhood, adolescence and adulthood (Noack, 2007). These life-stages are characterized by the development, ripening and aging of physical, social and mental functions (Erikson, 1973). All possible segmentations of the life cycle appear to some extent arbitrary. We decided to choose the concept of a four staged life cycle, which we consider to be a widespread thinking about life: childhood, adolescence, adulthood and seniors. Already Wackernagel (1862) describes these four steps of human life cycle as the most common way of structuring the life cycle starting from the antique romans to today. The four life stages do of course not cover similar time spans but are distinctly and easily distinguishable stages. The concept of 'stages of life' in general is an abstract construct, but we assume it might also have affective or emotional, mostly ambivalent connotations. We consider that childhood and youth might be associated with both positive feelings of optimism, adventurous starts and good health, as well as negative feelings such as a lack of experience or emotional instability. In contrast, the older life-stage might be associated with depression, illness, and death, but also with wisdom and serenity.

Cross-cultural differences in odor descriptions (Majid et al., 2018), associations between odors and colors (Levitan et al., 2014), and dietary patterns and choices (Rozin et al., 2006; Rodrigues & Parr, 2019) were described in the past. These variations may reflect differences in mental concepts; therefore, these are also assumed to differ across cultures. The term 'culture' is an extraordinarily complex and broad umbrella term that describes the manifestations of human existence. Tourism, migration, globalization, and ethnic blending might further influence the conceptualization of odors (Rodrigues & Parr, 2019).

Since only Austrian individuals were investigated in our previous work (Danner et al., 2017), this follow-up study investigated whether the same conclusions could be reached when using a significantly larger and more heterogeneous population. Consequently, this study was designed to investigate odor-elicited life stage-associations (OELSA) in seven nations located in different geographic regions of the world and to identify potential similarities and differences in odor conceptualization. Based on our previous study we hypothesize that perceiving odors would elicit life stage-related associations, and that the study participants would be able to select the elicited association using a questionnaire. We aimed to find out whether there were differences in life stage-related associations elicited by odors between seven nations, gender and age. Results on OELSA obtained from participants living in different parts of the world would help to better understand the emotional connotations of odors and would deliver valuable information for the targeted development of consumer goods emitting a distinct odor.

2. Material and methods

2.1. Selection of odors

Odors used in this study were selected in a multistep procedure using (a) the results of the previous Austrian study (Danner et al., 2017), (b) the results of a web-based pre-study, and (c) the international relevance of the odors regarding their economic importance in the flavor industry. The web-based pre-study that was carried out prior to this study (results not shown) consisted of an association task where 339 participants (102 males, 237 females, 21–55 years old, primarily from European and Asian cultures), were asked to assign 30 different odors to one life-stage by means of association (i.e., children, adolescents, adults, and seniors). The pre-study findings enabled us to reduce the selection of odors to those for which a preferential assignment to specific age groups was expected. The following nine odors were ultimately selected for this study: *vanilla, orange, lemon, mint, coconut, basil, rose, anise*, and *hay* (green tea) (Table 1).

The raw materials used for this investigation were oils and extracts or pure compounds with a purity of at least 95 %. According to EU Regulation No. 872/2012, all pure compounds were registered in the European Union as flavoring compounds and were authorized to be used in all categories of flavored foods at the time of the investigation. With the exception of the *hay* odor, the odors were diluted in either 1,2-propylene glycol (99.8 % purity, Symrise, Germany) or ethanol (96 % purity, Symrise, Germany). The ready-to-use solutions were kindly provided by Symrise Austria (Vienna, Austria) and distributed as such among the

Table 1
Detailed information about the odors investigated in this study.

Odor name	Raw material	Solvent	Dilution [w/w]	CAS no.	FEMA no.
Vanilla	Vanillin	PG *	1 %	121–33-5	3107
Orange	Orange oil type Valencia	EtOH **	10 %	8008–57-9; 8028–48-6	2824
Lemon	Lemon oil	EtOH **	10 %	8008–56-8; 84929–31-7	2625
Mint	L-Menthol	PG *	1 %	2216–51-5	2665
Coconut	γ octalactone	PG *	1 %	104–50-7	2796
Basil	Sweet Basil oil	PG *	1 %	–	–
Rose	Geraniol	PG *	1 %	106–24-1	2507
Anise	Anethol	PG *	1 %	4180–23-8	2086
Hay	Green tea, CO_2 extract	EtOH **	Pure	–	

* PG propylene glycol.
** EtOH ethaTable_LegendTable_Legendnol.

participating institutions. The solutions were marked with three-digit-random codes. They were suitable for storage at room temperature for the whole testing period of three months. Diluted odor samples, filter paper strips and cellophane sachets were mailed to the participating institutions along with detailed instructions for preparing the sniffing strips. Filter paper strips were to be dipped into the solutions, dried to remove the solvents through evaporation and put into coded cellophane sachets before being presented to the panelists. The average participant perceived the flavor intensity as moderate to slightly strong (3.9 to 4,9 on a 7-point scale (Lawless & Heymann, 2010)).

2.2. Participants

Participants were recruited in eight nations: Austria, Australia, Germany, Singapore, Switzerland, Thailand, USA and Vietnam. A total of 1675 untrained participants was recruited by the institutions listed in Table 2.

We aimed for at least 80 participants per nation with an equal gender split (i.e., female, male, 'other', 'prefer not to say'), an equal portion of three age-groups (i.e., 21–33, 34–47, 48–60 years of age) and a minimum of 60 panelists per investigated group, respectively, to be able to make statements on the effects of nationality, gender or age on OELSA. After data collection, the raw data were processed carefully. According to the following rules, the following data were removed: (i) incomplete data sets; (ii) data of panelists below 21 and above 60 years of age; (iii) persons whose nationality did not match their residency; (iv) individuals with dual citizenship; and (v) gender groups with low numbers of panelists. Only 0.3 % of the panelists selected 'other' or 'prefer not to say'; we considered this number of participants as too low and far from being representative and, consequently, did not analyze this gender group as such. The final dataset included data of 1144 participating persons (Table 3). For Singapore, the overall number of recruited participants was too small (n = 55) and, therefore, these data were not considered in this study. Demographics of the participants reveal some limitations of the dataset with respect to equal distribution of age and gender. As indicated in Table 3 in Austria, Australia and Vietnam, the results on age and gender as well as in Germany on age can only be seen as preliminary.

Table 2
List of participating institutions.

Participating institution	Country
Department of Food Science and Technology, University of Natural Resources and Life Sciences (BOKU), Vienna	Austria
Institute of Analytical Chemistry and Food Chemistry, University of Technology, Graz	Austria
Symrise Vertriebs GmbH, Vienna	Austria
Institute of Dietetics and Nutrition, University of Applied Science FH JOANNEUM, Graz	Austria
Eva Derndorfer Sensory Consultancy, Vienna	Austria
University of Adelaide, School of Agriculture, Food and Wine, Adelaide	Australia
Hamburg University of Applied Sciences	Germany
ttz Bremerhaven	Germany
Symrise AG, Holzminden	Germany
Symrise Asia Pacific Pte ltd, Singapore	Singapore
Zurich University of Applied Sciences, Institute of Food and Beverage Innovation, Food Perception Group	Switzerland
School of Agricultural, Forest and Food Sciences (HAFL)	Switzerland
Wander AG	Switzerland
ETH Zurich, Dept. Health Sciences and Technology, Institute for Environmental Decisions	Switzerland
Agroscope	Switzerland
Department of Food Technology and Nutrition, Mahasarakham University	Thailand
Department of Food Science, The Pennsylvania State University	USA
Department of Food Science. University of Arkansas, Fayetteville	USA
Symrise Inc., New Jersey	USA
School of Biotechnology and Food Technology, Hanoi University of Science and Technology Bach Khoa University, Hanoi	Vietnam

Table 3
Demographics of participants by nation.

Nation	Total	Female/ Male	21–33 years	34–47 years	48–60 years
Austria	107[§]	56/51	67	20	20
Australia	71[§]	41/30	32	25	14
Germany	257[$]	167/90	136	50	71
Switzerland	302	178/124	126	80	96
Thailand	115	84/31	51	27	37
USA	201	131/70	63	63	75
Vietnam	91	50/41	32	30	29
Total	**1 144**	**707/437**	**507**	**295**	**342**

[$] *results on OELSA can be regarded as preliminary with respect to gender.*
[§] *results on OELSA can be regarded as preliminary with respect to age.*

2.3. Test procedure

This study was carried out between October and December 2019. The participating institutions were asked to conduct the investigation on site according to the provided guidelines to guarantee standardized settings at each location. The sensory evaluation was carried out at ambient temperature in sensory laboratories or in open space rooms with neutral conditions with respect to the ambient odor and minimal other distractions. Participation in the study was on a voluntary basis. Individual panelists received their personal and complete set of odors strips, labelled with random three-digit codes, counter-balanced across participants. If no sensory booths were available, the test was carried out on a separate table for each participant. Tap water was provided.

Media devices (tablet or computer) were provided onsite and data were collected using EyeQuestion® software (EyeQuestion®, Version 4.11, Elst, the Netherlands). The questionnaire was translated into site-specific languages by the participating sensory experts (native speakers) from the participating nations to avoid language barriers.

The data acquisition process was completely anonymous, and from all participants sociodemographic data (i.e., age group, gender (female, male, other, 'prefer not to say'), nationality, country of birth, country of residence) were collected prior to the odor task. Participants were asked to take the sniffing strips out of the sachets, sniff the odors and immediately answer all questions before proceeding with the next sample. According to the concept of a four staged life cycle that was chosen for this study, we focused on the following question: 'Which age group comes into your mind first, when you smell this odor? Please choose one option.' (Options: children 6–12 years old, adolescents 13–20 years old, adults 21–60 years old, and seniors 61 + years old).

The testing procedure lasted approximately 12 min and included some additional questions about the odor (intensity, familiarity, liking, flavor description, description of the impression - results are not reported in this paper).

2.4. Ethical approval

In Austria, Germany, Switzerland, Thailand, and Vietnam as well as for Symrise employees (USA and Singapore), the ethical committees confirmed that no full institutional review process was required for the execution of this study. Data collection in Australia was approved by the Human Research Ethics Committee of the University of Adelaide (approval number: H-2019–222). At The Pennsylvania State University (USA), the procedures were reviewed and deemed exempt from full institutional board review by the Penn State Office of Research Protection under the exemptions listed in 45 CFR 46.104 (protocol #13115). At University of Arkansas (USA), the procedures were reviewed by the university's IRB Committee and an exemption was granted (protocol #1909217925). In all participating nations, regardless of whether an

ethical approval was required or not, the study was conducted in accordance with the Declaration of Helsinki. All participants provided their informed consent at the beginning of the test. In most nations the panelists were offered small incentives (e.g., tea samples, candies, chocolate bars) for their participation. Panelists at The Pennsylvania State University were compensated for their time at the IRB approved rate (5 USD).

2.5. Data analysis

To investigate the effect of odor, nationality, age and gender on the odor association, a mixed-effects multinomial logistic regression was carried out in SPSS Statistics (version 25, IBM Corporation, New York, NY, USA). The Akaike Information Criterion (AIC) was used to optimize the model (Burnham & Anderson, 2002). Initially, odor, nationality, age, gender, and their second order interactions were treated as fixed factors, and the panelist ID as a subject combination and a random intercept were included in the model. Next, non-significant interactions (odor*gender, age*gender, and nationality*gender) were excluded, resulting in a substantial decrease in the AIC, which indicates an improvement in the model.

Furthermore, for each odor separately, a multinomial model (the R packages 'nnet', as described by Venables and Ripley (2002), and 'car', as described by Fox and Weisberg (2019)) was fit to the life stage-association data using the statistical software language R (R Core Team, 2021). The factors of nationality, age, and gender as well as all two-way interactions were included in these models. Additionally, post-hoc tests (R package 'emmeans' as described by Lenth (2020)) using all pairwise contrasts were performed for all significant main effects. We note that the resulting homogeneous subgroups cannot be ordered in the usual way, e.g., by ascending or descending group means of the factor levels, as the response variable 'age association' is categorical and not discreet.

Principal component analysis (PCA) was conducted using predicted probabilities to visualize the correlation between odors, nationalities and OELSA using 'FactoMineR' (Le et al., 2008) and 'factoextra' (Kassambara and Mundt, 2020).

3. Results

A detailed statistic evaluation of the large amount of data gathered in this study was required to understand odor-elicited life stage-associations (OELSA). Below, we present the results, starting with a general consideration of all investigated factors and proceeding with a break down on the level of single factors, to enable a deep understanding of the observed effects.

3.1. Do odor, nationality, age, and gender affect OELSA?

A mixed-effect multinomial logistic regression was used to calculate the effects of odor, nationality, age, and gender and their possible interactions on OELSA. The data obtained from the mixed-effect multinomial logistic regression including depictions of predicted probabilities and observed proportions are presented in Table 4.

All influencing factors and their interactions were found to be significant ($p < 0.05$) sources of variation except for the participants' age. Odor has by far the largest effect on life stage-associations ($F = 41.7$), followed by the effects of gender ($F = 5.48$) and nationality ($F = 3.58$). Interestingly, in addition to the significant main effects identified for nationality, a significant interaction between odor and nationality were also observed ($F = 2.37$), indicating that OELSA varies between nations depending on the type of odor.

Table 4
Results of the mixed-effect multinomial logistic regression performed to investigate the effects of odor, nationality, age and gender of respondents on odor-elicited life stage-associations (OELSA)[§].

	F ratio	*df*	*p*-value
Corrected Model	7.283	279	<0.001
aroma	41.721	24	<0.001
nationality	3.584	18	<0.001
age of respondents	1.241	6	0.282
gender	5.484	3	<0.001
odor*age of respondents	2.507	48	<0.001
odor*nationality	2.371	144	<0.001
age of respondents *nationality	1.970	36	<0.001

[§]Other non-significant effects were excluded from the model based on Akaike Information Criterion (AIC) (Burnham and Anderson, 2002).

3.2. Do panelists from different nations differ in odor-elicited life stage-associations?

Fig. 2 shows the predicted probabilities based on the model used for the four life stages in the nations under investigation. To improve the visibility of the mean predicted probabilities and the corresponding confidence intervals, the data are presented as line graphs rather than stacked bar graphs.

Fig. 2(a) and the confidence area reported for each nationality clearly shows considerable differences for the predicted probabilities of the odors associated with children between different odors and nations - especially for *coconut* and *mint*. The *coconut* odor was significantly more frequently associated with children in Vietnam as compared to all other nations. *Mint* is clearly more often associated with children in Australia than in any other nationalities. In Thailand, we observed low percentage levels of association with children for all odors in general, but strikingly low levels of associations for the odors of *hay*, *lemon* and *vanilla*. In Austria, the percentage of participants who associated children with the odors *lemon*, *orange* and *vanilla* was comparably high (Fig. 2(a)).

An analysis of the associations between odors and the adolescent life stage (Fig. 2(b)) also revealed significant nationality-specific differences; however, these were not as pronounced as those observed for the associations with children. The odors of *lemon*, *mint* and *orange* were more frequently associated with adolescents in Vietnam than in other nations. Furthermore, in Australia the odor *hay* was frequently associated with adolescents compared to all other investigated nationalities. *Anise* and *vanilla* seldomly elicited associations with adolescents in Austria, although these associations were observed in other nationalities.

Significant differences between nations were observed regarding the associations between odors and life stage adulthood (Fig. 2(c)); however, the results are not as clear as those for associations between odors and the younger life stages. Odor associations with the adult life stage appear to be less pronounced in Vietnam for the *coconut* and *basil* odors than in other nations. Three groups of OELSA could be tentatively identified: (i) Vietnam with weak adult life stage associations for all odors except *anise* and *rose*, (ii) Austria, Germany, and Switzerland, which are geographically and culturally quite close, and show very similar adult life stage associations except for odor *lemon* and (iii) USA, Thailand and Australia showing a strong association between *coconut* odor and the life stage adulthood. The association between the odor of *vanilla* and the adult life stage was quite low across nations, except for Thailand, which showed a strong association between *vanilla* odor and the adult life stage. Thailand generally shows stronger associations between the investigated odors and the life stage adulthood compared to the other nations.

Odor-elicited associations with the life stage of seniors seem to show the least variability of all life stages except for *anise*, *basil*, *hay*, *mint* and *rose*. The odor *basil* is more strongly associated with seniors in Vietnam than in other nations (Fig. 2(d)). *Hay* is less frequently associated with

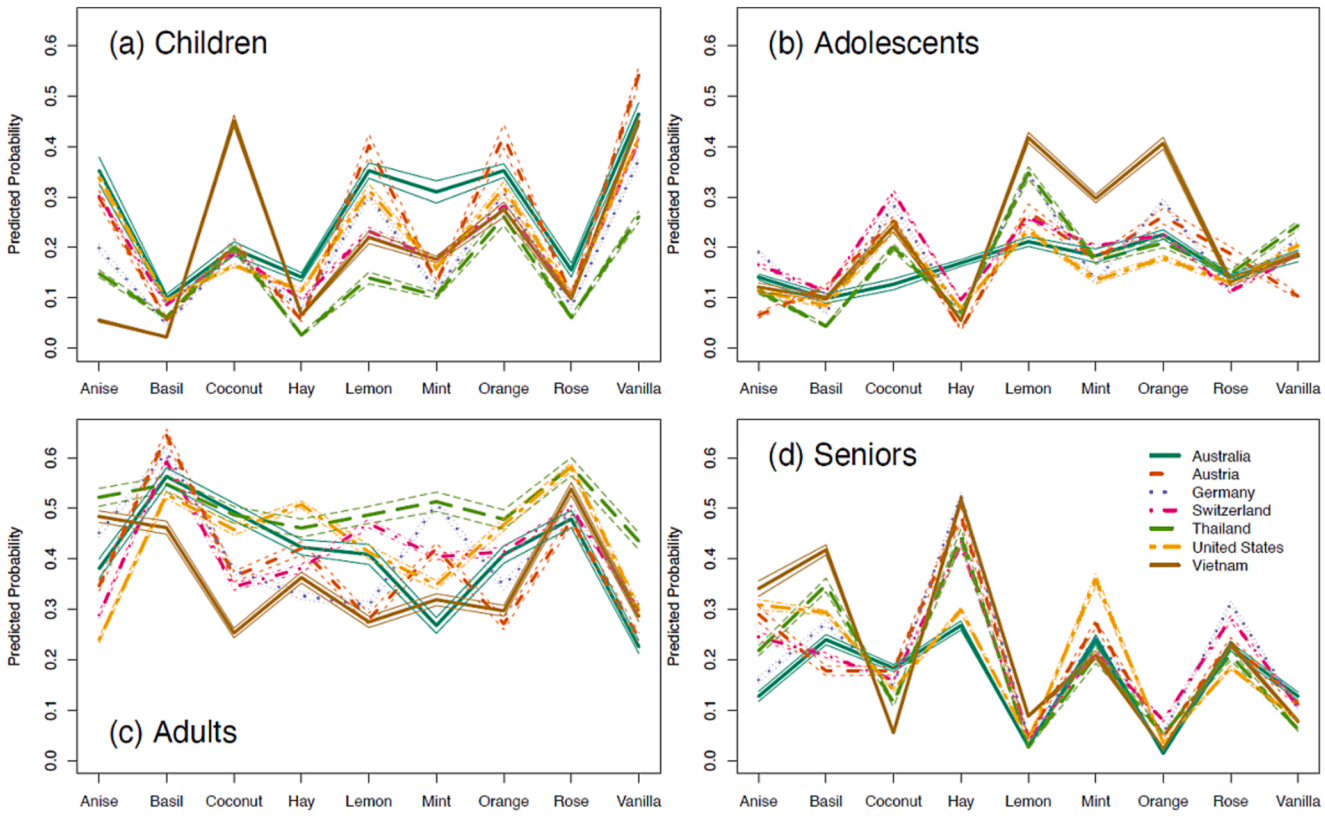

Fig. 2. Interaction plots for the fixed factors odor and nation for all OELSA using the mean predicted probabilities together with the 95% confidence intervals Statistically significant differences were observed when confidence intervals do not overlap.

seniors in Australia and in the USA. *Mint* is more frequently associated with seniors in the USA; the odor *rose* showed the highest levels of associations with seniors in Switzerland and Germany.

Even though we observed OELSA that are specifically associated with certain geographical regions, some more general conclusions can be drawn from this dataset. The biplot resulting from a principal component analysis (PCA) provides an overview of the observed odor-by-nationality interactions (Fig. 3). Dimension 1 of the biplot explains approx. 66 % of variability, and dimension 2 approx. 23 %. The nine different odors evaluated are depicted in different colors for better visibility. Each ellipse of the same color represents the position of an odor in the biplot across all regions. This general overview of the investigated nations and odors shows that four 'young odors' can be identified, i.e., the odors of *vanilla*, *lemon*, *orange,* and *coconut* are mainly associated with the children and adolescent life stages. The *hay* odor is mainly associated with seniors, while *basil* and *rose* are closely associated with adults. *Mint* and *anise* do not appear to show a clear association with any of the four life stages as they are located in the center of the biplot; however, a tendency to associate these odors with adults and seniors can be seen.

3.3. Do persons from different age groups differ in OELSA?

The results of this study show that most odors were associated with different life stages. Subsequently, we wondered if and how much the age of the panelists contributes to differences in OELSA. Fig. 4(a) to 4(d) show the effect of the panelists' age on the life stage-related odor associations using mean predicted probabilities. Several striking effects are clearly visible: Odor associations with children differ significantly among the three age groups for several odors (Fig. 4(a)). Younger participants (21–33 years) associated children less frequently with the odors of *anise* and *coconut*, but more frequently with *lemon* and *orange*. In contrast, older participants (48–60 years) tended to associate *orange* less frequently with children than participants in the other two age groups. The associations between odors and adolescents (Fig. 4(d)) were quite similar for all participants, except for *coconut* and *basil*. Middle-aged participants between 34 and 47 years of age associated *coconut* less frequently and *basil* more frequently with adolescents than younger and older participant groups. For associations between adults and odors, the effect of the participants age is less clear (Fig. 4(c)); several differences could be observed, especially for the young participants, where mean predicted probabilities differed from the two other age groups for all odors except for *anise, rose* and *vanilla*. Odor associations with seniors were again quite similar for all three age groups, although older participants made less frequent associations between *anise* and seniors, and younger participants less frequently associated *mint* with seniors.

3.4. What are the effects of nationality, age, and gender on life stage-associations per odor?

As a next step, each odor was fit separately to the observed OELSA while considering the factors of nationality, age, and gender, as well as all possible two-way interactions using a multinomial model. The results of the model are provided in Table 5, revealing significant effects of nationality on OELSA for eight of the nine odors under investigation; only for the odor *rose* the effect was not significant ($p > 0.05$). The OELSA for the four odors *anise*, *lemon*, *mint,* and *orange* were also significantly influenced by age, i.e., whether participants belonged to the younger, middle-aged or older age group. Gender was significantly associated with life stages for the odors *lemon*, *rose* and *vanilla,* and a significant interaction for nationality-by-age was observed for the odors *lemon* and *vanilla*.

Subsequently, post-hoc tests using all pairwise contrasts were used to study the homogeneity of OELSA for the nine odors in all involved nations (Table 6). No significant differences among the seven nations were observed for the odor *rose*. For *coconut,* all nations grouped together with

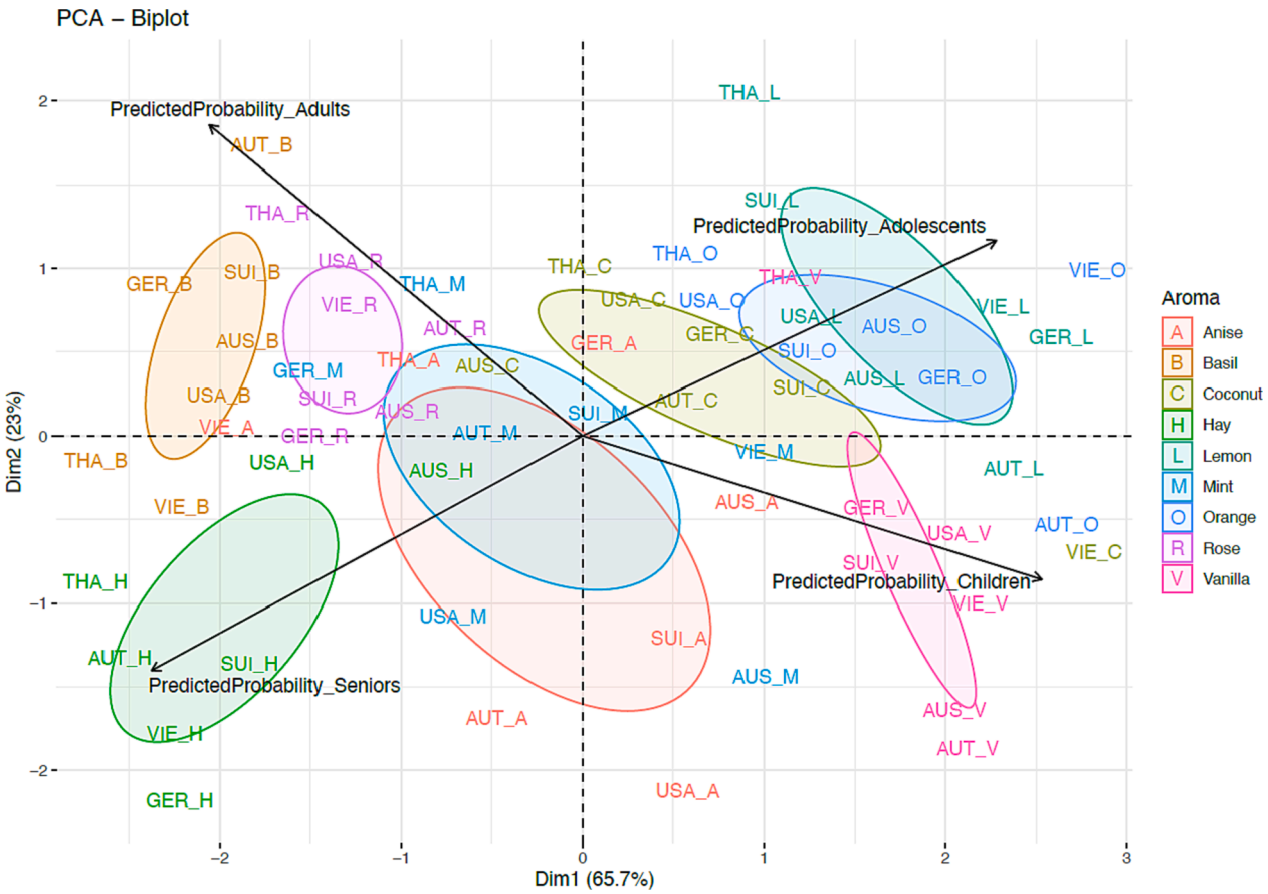

Fig. 3. Biplot of mean predicted probabilities; nationality abbreviations used: AUS Australia, AUT Austria, GER Germany, SUI Switzerland, THA Thailand, USA United States, VIE Vietnam. Different colors depict the different odors.

the exception of Vietnam, which was significantly different from all other nations. The odor with the highest level of OELSA heterogeneity across nations, as measured by the number of different post-hoc groups, was *lemon*; we found five subgroups that were significantly different from each other. For the odors *anise* and *vanilla,* three subgroups were found, and four subgroups were found for *mint*, *orange*, *hay* and *basil*.

When looking deeper into the observed patterns, no obvious structure emerges. We expected that culturally close nationalities, such as Germany, Austria, and Switzerland, would show similar groupings, but this assumption was not supported by the data. For example, Switzerland and the USA are grouped together with respect to their associations for all nine odors (Table 7), while Austria, and Germany, which are quite close geographically and with respect to their culture, group together for only four odors (*coconut, lemon, mint, rose*). Similarly, Thailand and Vietnam, which are also quite close in terms of geography and culture, only show similar OELSA associations for three of the nine odors, namely *mint, rose and anise* (Table 7).

To more clearly understand the data reported in Table 5, multinomial generalized linear/mixed models were calculated. Figs. 5 through 7 show the observed proportions of life stage-associations for all investigated odors. Clear differences can be seen among nations (Fig. 5), less clear differences among the three age groups of the participants (Fig. 6) and weak differences between the gender of the participants (Fig. 7).

4. Discussion

In this study we investigated odor-elicited life stage-associations (OELSA) in different regions of the world. To the best of our knowledge, this is the first time that OELSA have been investigated on a global basis. We consider this life stage-related conceptualization as non-functional since life-stages are an abstract concept with emotional connotations. In general, our results reveal comparable odor-elicited life stage-associations across the investigated seven nations with the exception of odors *mint* and *coconut*. Since this work was not designed to identify the causes for those differences in OELSA, we can only make assumptions about potential cultural roots. For a deep understanding of this topic, a complex interdisciplinary study including scientists from various disciplines (e.g., nutritional psychology, cultural studies, consumer science) has to be designed.

We found heterogeneous responses for OELSA across the participating nations. For instance, Switzerland, and USA were quite homogenous in their life stage associations for all nine odors. On the contrary, Germany, Austria, and Switzerland did not show homogeneity in OELSA even though these countries are neighbors, both geographically and culturally (Table 7). We assumed that countries that display cultural similarities, would form homogenous subgroups; however, this hypothesis was not supported by our results. In a comparable way Levitan (2014) found that German and US-American individuals showed similar patterns in association research on colors and odors, as well as German and Malay participants. Contrary to what was assumed, similarities between German and Dutch participants were not found. Here, it was argued that these differences could be due to differences in eating behavior, role of scents in a society or other social factors such as cooking frequency or travel experience. Even though Levitan's study focused on different associations, its results are in accordance with the OELSA results reported here. Therefore, one could speculate that geographic and cultural similarities do not necessarily imply similar associations of sensory perceptions as previously assumed. Potential social factors have to be taken into consideration in future research.

Although differences in OELSA were found among the seven nations,

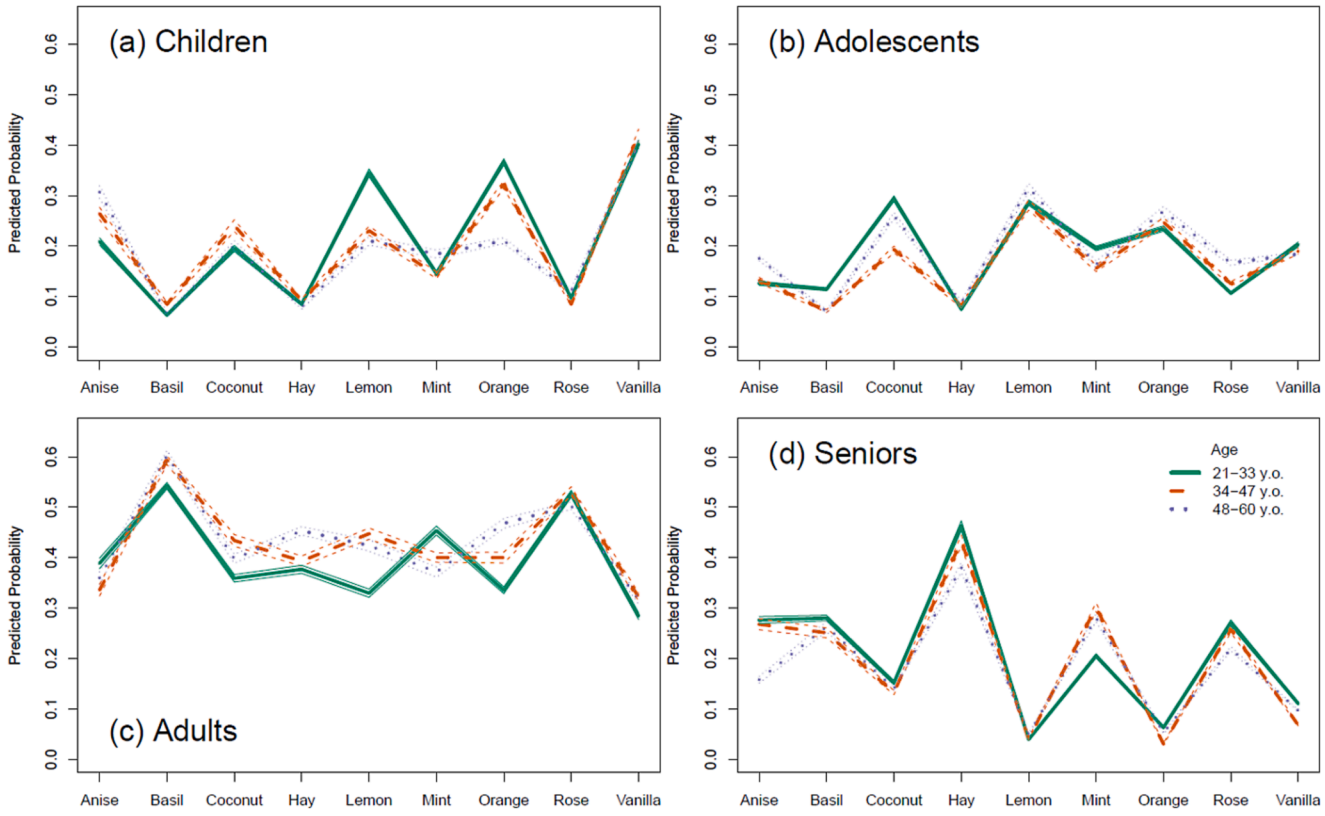

Fig. 4. Interaction plots for the fixed factors odor and age for all four life stage-associations using mean predicted probabilities with 95 % confidence intervals. Participants (n = 1,144) were split into younger (21–33 years of age), middle-age (34–47 years of age), and older (48–60 years of age).

Table 5
Results of the multinomial modelling of each separate odor for contributions of nationality, age, gender, and all two-way interactions, showing p-values. Statistically significant effects ($p < 0.05$) are bolded.

	Anise	Basil	Coconut	Hay	Lemon	Mint	Orange	Rose	Vanilla
Nationality	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	0.204	**0.009**
Age	**0.000**	0.059	0.095	0.480	**0.001**	**0.019**	**0.000**	0.175	0.490
Gender	0.060	0.453	0.402	0.218	**0.009**	0.686	0.495	**0.033**	**0.030**
Nationality*Age[§]	0.119	0.450	0.733	0.083	**0.000**	0.690	0.553	0.573	**0.043**
Nationality*Gender[§]$r	0.080	0.108	0.786	0.062	0.741	0.519	0.971	0.859	0.279
Age*Gender[§]	0.833	0.621	0.801	0.225	0.356	0.071	0.067	0.482	0.482

[§] Preliminary results due to limited number of participants in some nations.

Table 6
Post-hoc tests using all pairwise contrasts. Letters indicate homogeneous groups.

	Australia	Austria	Germany	Switzerland	Thailand	USA	Vietnam
Anise	a	a	b	a	bc	a	c
Basil	a	b	c	c	c	c	d
Coconut	a	a	a	a	a	a	b
Hay	a	b	c	ac	d	a	e
Lemon	a	bc	c	d	b	d	e
Mint	a	bcd	c	abd	bcd	d	ab
Orange	a	b	c	cd	cd	d	b
Rose	a	a	a	a	a	a	a
Vanilla	a	b	c	c	d	c	c

the life-stage associations elicited by many odors are comparable across nations (Fig. 3). Consequently, the odors *vanilla*, *lemon*, *orange,* and *coconut* may be called 'young'; *basil* and *rose* can be referred to as 'adult' odors; and *hay* is a 'senior' odor according to our data. No clear results for *anise* and *mint* could be obtained. It is well known that *vanilla* is an odor that is greatly liked by children and, thus, is used as a flavoring in a broad range of products that are primarily consumed by children (Ward et al., 1999; Yoo et al., 2017; Velázques et al., 2020). In the context of conceptualization and the results of this study, it is also possible to conclude that the association between children (and one's own childhood) with the odor *vanilla* also contributes to the successful application of *vanilla* in these types of products. The association of the life stage of children with the odor *vanilla* was already reported in our previous investigation with Austrian participants (Danner et al., 2017).

Table 7
Number and percentage odors that showed a similar association for the pair of nationalities.

	Australia	Austria	Germany	Switzerland	Thailand	USA	Vietnam
Australia		3 / 33 %	2 / 22 %	5 / 56 %	2 / 22 %	4 / 44 %	2 / 22 %
Austria			4 / 44 %	4 / 44 %	4 / 44 %	4 / 44 %	3 / 33 %
Germany				6 / 67 %	6 / 67 %	4 / 44 %	2 / 22 %
Switzerland					5 / 56 %	9 / 100 %	3 / 33 %
Thailand						5 / 56 %	3 / 33 %
USA							2 / 22 %
Vietnam							

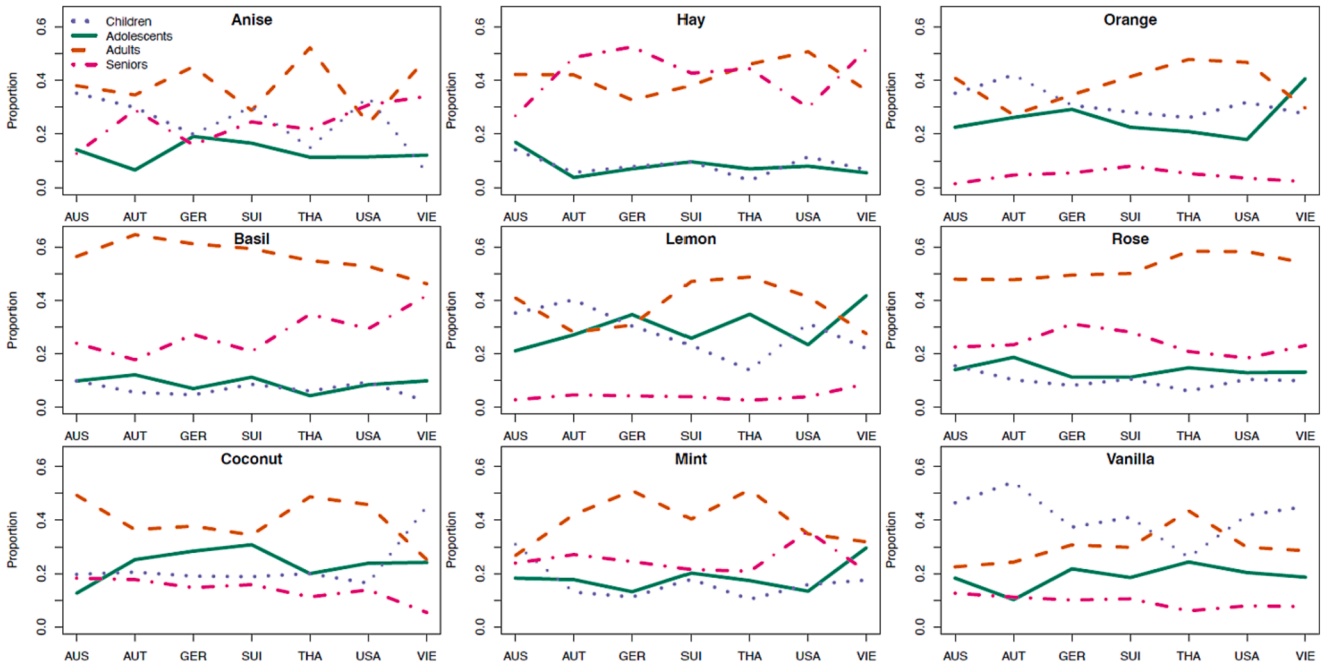

Fig. 5. Observed odor wise proportions for all four life stage-associations by nationality (according to IOC country code).

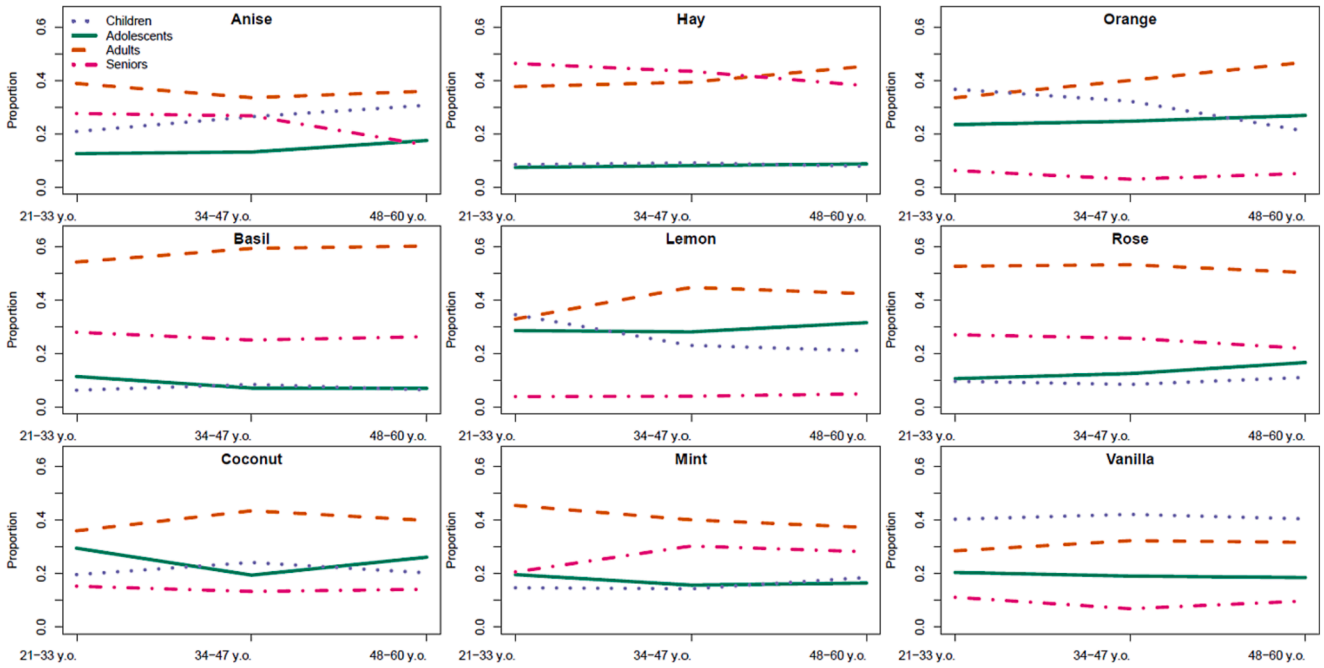

Fig. 6. Observed odor wise proportions for all four life stage-associations by the participants' age.

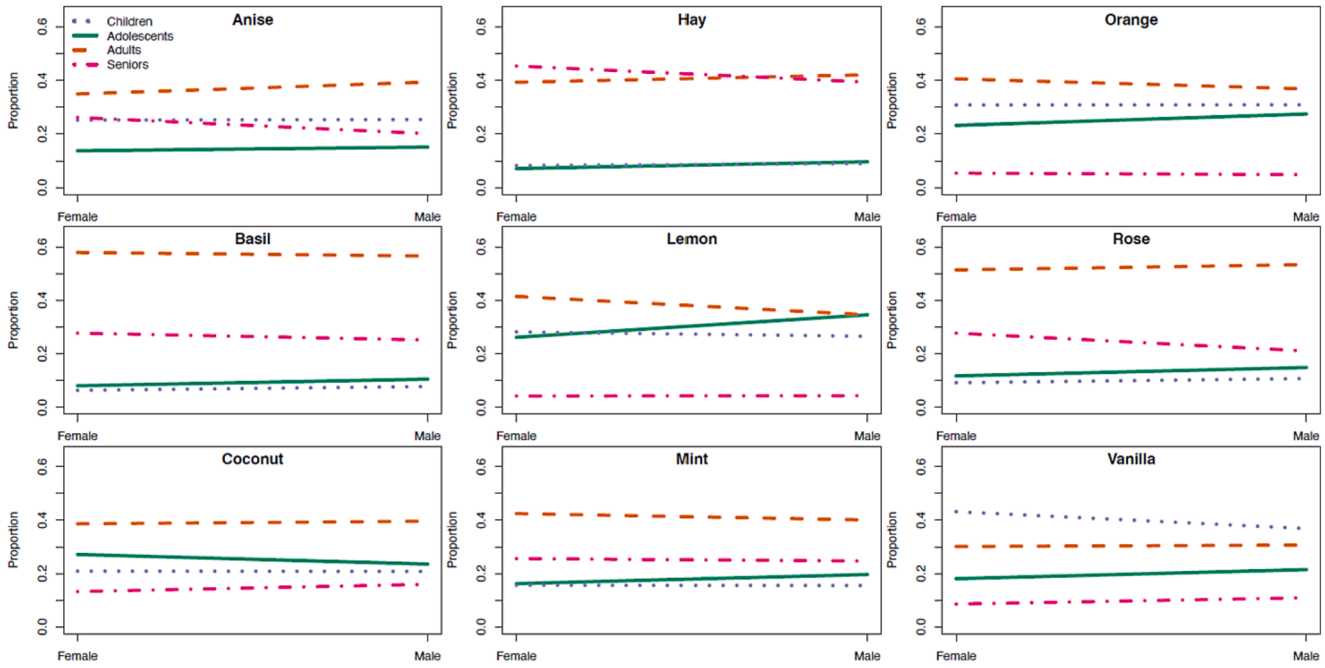

Fig. 7. Observed odor wise proportions for all four life stage-associations by gender.

A recent study by Chang et al. (2016) proposed that ethnicity might also play a role in the conceptualization of foods, which might also be true for individual odors. Within one country, people of different ethnicities live together and might react differently to odors. This aspect could partly explain the diversity of results obtained from nations that are geographically close (e.g., Austria *vs* Germany *vs* Switzerland). In future studies, this aspect should be taken into consideration.

With respect to the age of respondents, no significant overall age effect on OELSA was observed (Table 4). However, a more specific data analysis revealed differences in OELSA among respondents of different age groups (Fig. 4). These age-groups are known to react differently in some cases in sensory and consumer studies. Helm (2013) e.g., found, that younger consumers are more open to trying and to switching to new brands/products than older persons. Such variations in consumer behavior of people differing in age might also be reflected in the spontaneous decisions for OELSA.

Significant effects of gender on OELSA were found for the odors *lemon*, *rose* and *vanilla*. Gender differences have been described in several sensory investigations before. One of these studies showed that women rate odors as more intense and identify them more correctly than men, whereas male participants associate more intense feelings with odors regardless of their nationality (Ferdenzi et al., 2013). Such gender effects might have contributed to the gender differences in OELSA observed in our study.

5. Conclusions

This work can be seen as a specific starting point for exploring the meanings of odors to humans. As has been assumed, the perception of odor stimuli may activate mental concepts and evoke life stage-associations. The results obtained from 1144 participants show the direction of future research which comprises the following aspects: (1) Representative samples of participants have to be investigated to elaborate differences between nations and cultures more effectively. (2) More odors have to be studied. (3) At least several important associations (e.g., gender, health, or emotions) have to be considered for a better understanding of the relative impact of associations on odor experience (4) The meanings of the elicited associations have to be investigated to help with the interpretation of findings. (5) Implicit associations – although difficult to measure and interpret – have to be considered to obtain more cognitively unbiased associations. (6) Different seasons in participating nations while performing the tests should be considered. Considering all these aspects, we strongly believe that such investigations will deliver valuable information for product development, enabling researchers to focus on products designed for specific target groups. Moreover, they will also contribute to a deeper understanding of a basic research question: How are odors conceptualized?

CRediT authorship contribution statement

Martin Wendelin: Project administration, Resources, Investigation, Software, Data curation. **Andrea Bauer:** Investigation. **Elisabeth Buchinger:** . **Lukas Danner:** Investigation, Writing – review & editing. **Eva Derndorfer:** Investigation. **Vu Thi Minh Hang:** Investigation. **Helene Hopfer:** Investigation. **Marlies Wallner:** Investigation, Writing – review & editing. **Srinual Jantathai:** Investigation. **Nina Julius:** Investigation. **Imke Matullat:** Investigation. **Dorota Majchrzak:** . **Barbara Siegmund:** Investigation, Writing – review & editing. **Han-Seok Seo:** Investigation. **Bernhard Spangl:** . **Klaus Duerrschmid:** Investigation, Writing – review & editing.

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.

Data availability

Data will be made available on request.

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