Study Protocol ManyLabs002

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Collaborating research labs: 30+

Project title: *Building a cross-cultural semantic framework for odor vocabularies*

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Background & rationale

The sense of smell appears to be the hardest to verbalize in comparison to the other senses (Majid 2021; Olofsson & Gottfried 2015). Most western languages contain very few basic terms that are used to express olfactory experiences (i.e., they lack dedicated olfactory vocabularies, Majid 2021). At the same time, some "non-western" languages have well-developed olfactory vocabularies, and olfactory experiences are more frequently talked about in those languages (Majid 2021). Recent research suggests a major overlap in the semantic organization of the English smell expressions (e.g. Hörberg et al. 2022) and the dedicated olfactory vocabularies of non-western languages such as Maniq (Wnuk & Majid 2014), Jahai (Majid et al. 2018a) and Thai (Wnuk et al. 2020). The olfactory vocabularies of these languages are semantically organized in a similar way to English (e.g., Hörberg 2022), primarily differentiating between odors in terms of pleasantness, and secondarily in terms of edibility-"dangerousness". Cross-linguistic differences observed in the olfactory domain might thus obscure a shared organization at a deeper level. Even though olfactory vocabularies show cross-linguistic differences at the structural and lexical levels, they might share an underlying universal structure at the semantic level.

We hypothesize that 1) languages differ in terms of their preferred descriptive strategies for describing odors (e.g., in their preference of source-based vs. abstract terms), the specificity of their odor descriptors, and therefore, relatedly, their codability (see Majid et al. 2018b) of odors, but that, despite these differences, 2) the semantic organization of their odor vocabularies will be organized along the same dimensions, primarily distinguishing odors in terms of valence / pleasantness, and secondarily with respect to edibility / dangerousness or toxicity (Haddad et al. 2010).

In order to investigate this, we will use the Global Consortium for Chemosensory Research (GCCR) collaboration to collect cross-linguistic and cross-cultural data of olfactory descriptors and perceptual ratings of a set of selected odors. From this data set, we will derive language-specific olfactory lexicons with the most frequently used olfactory descriptors of each language. This data set will allow us to assess to what extent olfactory vocabularies differ across languages with respect to structural and lexical properties, such as their descriptive strategies (i.e., semantic category, see Hörberg et al. 2022), the specificity of their expressions, and their odor codability (as measured by e.g. Simpsons Index, see Majid et al. 2018b). On the basis of the GCCR collaboration, we will also collect cross-linguistic data of the semantic properties of the selected descriptors of each language. This data set will contain ratings of a number of semantic dimensions (e.g., valence, edibility, modality associations, concreteness) that have been found to be prominent in olfactory vocabularies in previous work (e.g., Hörberg et al. 2022), enabling us to determine to what degree the olfactory vocabularies converge and diverge on these dimensions.

With these two data sets, we will be able to test our hypotheses that 1) odor vocabularies primarily differ in terms of superficial properties, but 2) converge on their underlying semantic dimensions. For each odor × language combination, we will be able to compute the language- and culture-specific profiles of each lexical-semantic dimension. These profiles will together make up the multi-dimensional space of the olfactory vocabularies of each language. We will then be able to assess on which dimensions olfactory vocabularies converge, and on which they diverge. We hypothesize that odor language 1) diverges on dimensions related to lexical and structural properties of the language, such as codability and abstraction, but 2) converges on dimensions related to semantic properties, such as valence, edibility and possibly concreteness. Importantly, the strength of these convergences will align with the strength of these dimensions in the olfactory vocabularies of individual languages, on the one hand, and in the non-linguistic classification of odors, on the other. Olfactory vocabularies will thus primarily converge on the valence dimension and secondarily on the edibility dimension.

Project design

The project consists of three multi-centric studies performed in three separate work packages (WPs). The WP1 study is an experimental study that utilizes a large odor stimulus set. WP2 consists of a survey-based study that is conducted on-line by native speakers of each of the languages included in WP1. WP3 is yet another experimental study that includes the same large-scale odor stimuli as in WP1. In the following, the design of each of the three studies is described.

Work Package 1

Purpose and aim

In WP1, we will establish language-specific odor vocabularies, using the most frequent odor descriptors of each language, and test hypothesis 1—that culturally distinct odor vocabularies differ primarily with respect to abstraction (Majid et al. 2018a) and codability (Majid et al. 2018b). This result would generalize conclusions from research on individual languages and modest odor sets (Majid & Burenhult 2014; Majid et al. 2018a), and provide multi-cultural evidence for the notion that abstraction and codability in odor language are related phenomena. We will collect odor descriptors, perceptual ratings, and odor similarity ratings in the context of the GCCR, a well-established global consortium of over 760 researchers at universities, research institutes, hospitals, and in industry. We will establish a cross-cultural data set from 28 languages of 14 language families, with comprehensive psychophysical and linguistic data of odor descriptors of 60 odors that are “back compatible” with earlier prominent odor-perceptual data sets (Arshamian et al. 2022; Dravnieks 1985; Bierling et al. 2025; Keller & Vosshall 2016). In addition to being used in WP2 and WP3 of the project, this data set will serve as a valuable tool in future work on odor language and odor psychophysics, as well as in the sensory industries, thus helping to unify a growing research field.

Procedure

Participants will freely describe each odor (*Please describe the odor as freely and in as much detail as possible*) (cf. Bierling et al. 2025), provide three words that best describe the odor (*Which three words best describe the odor?*) and will then be asked to name the odor source (*What does the odor smell like?*). We will thus first obtain free descriptors of the odor quality and then assess odor naming. To attain several descriptors from each participant, participants are asked to provide as detailed descriptions as possible.

Their descriptions will be written down by research assistants who will be trained to follow a detailed data collection protocol to ensure reliability. All individual odor descriptors are extracted from the descriptions. Following description and naming, the odor is rated on a visual analog scale of 0–100 (cf. Dravnieks 1985) in terms of valence, edibility, intensity, and familiarity, and regarding its perceptual similarity to another odor from the set. We anticipate that the experiment will take about two hours to complete. To further confirm the cross-cultural stability of odor perception, we will validate the perceptual data against a cross-cultural dataset with odor valence and odor intensity ratings of Westerners and hunter-gatherer groups from Arshamian et al. (2022), and compare the within language-group variability of odor-perceptual features to the between-group variability (cf. Arshamian et al. 2022).

Stimulus materials

To maximize the generalizability and interpretability of our results, we obtained a representative sample of 60 odors from the odor perceptual space, selected from the odors in the DREAM data set (Keller & Vosshall 2016). Sixty-one subjects rated these 480 odors for their perceptual qualities in terms of valence, edibility, familiarity, and intensity, and with regard to their fit with 20 odor descriptors (e.g., *sweet*, *wood*, *fish*). We initially dismissed chemicals that were regarded as odorless in over 25% of all odor exposures or categorized as unknown in over 80% of all exposures. The remaining odors were clustered, based on their odor-descriptor ratings, into eight main clusters, explaining over 50% of the variance in the data (Figure 1; cluster names are the most representative terms of each cluster). To identify the main dimensions along which the odors are distributed, odor-descriptor ratings were analyzed with principal component analysis. For facilitating comparability with previous studies, we also identified, among the 480 odors, those that also are included in either the Dravnieks odor-descriptor ratings data set (Dravnieks 1985), or the data set with perceptual ratings and odor descriptions of Bierling et al. (2025a). The ten odors used by Arshamian et al. (2022) were also identified and included in our selection to enable comparisons and ensure a wide valence range. The remaining 50 odors were selected in the following way. We clustered the 480 odors into 47 clusters, explaining over 75% of the variance in the data. Odors close to the cluster centers, used in the Dravnieks or the Bierling data sets, or highly familiar odors were prioritized. Selected odors were also ensured to be evenly distributed across the main clusters (15-18% of the odors of each main cluster were selected) as well as across the odor-perceptual space as a whole. The odor set thus contains familiar odors representative of the odor-perceptual space, at least for Westerners. We will evaluate if the odors are also familiar to non-Western participants by comparing the across-odor familiarity ratings of each country group to the original familiarity ratings in the DREAM data. The sample is also "back compatible" with previous work (Arshamian et al. 2022; Bierling et al. (2025a; Dravnieks et al. 1985) (Figure 1). Odor stimuli will be delivered in Sniffin' Sticks odorized pens (Hummel et al. 1997), with odors provided by DSM-firmenich (Geneva, Switzerland).

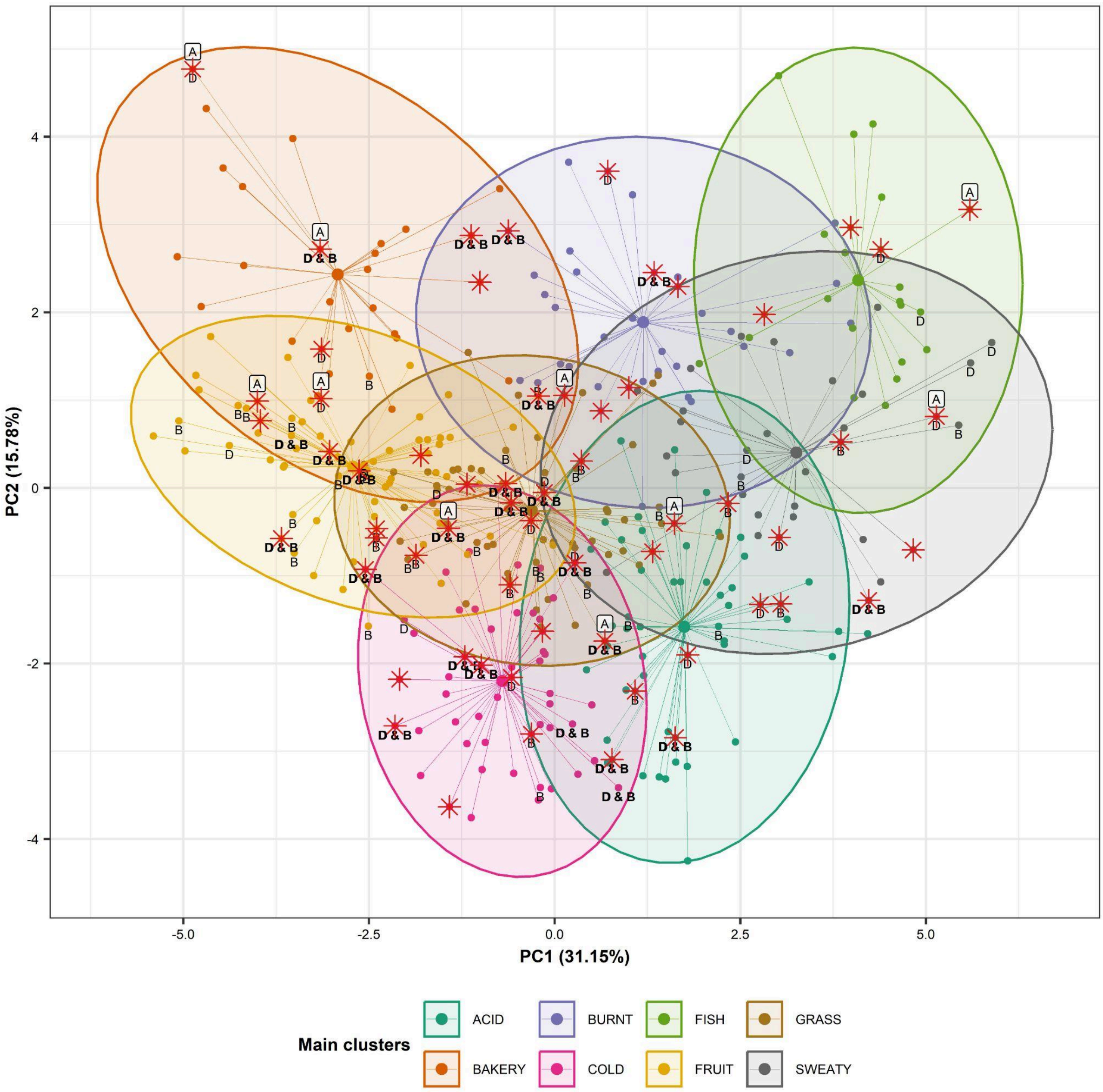

Figure 1. Selected odors (red star) from the DREAM data set. Odors in the Dravnieks (D), Bierling (B) or the Arshamian (A) data sets are shown.

Sample size

The sample size for the WP1 study is 60 participants per language (total N = 1800). Each participant describes and rates 30 of the 60 odors, and gives similarity ratings for 30 odor pairs. If each participant in each country describes 30 odors and provides, on average, 3 odor words per odor (in our previous study, the average was 3.99), this will yield 3 × 60 = 90 odor words per odor and 90 × 60 = 5,400 odor words per language group. This has proven sufficient in previous studies. Since each participant rates 30 odors, we will obtain 30 perceptual ratings per odor per country. Bootstrapping analyses of previously collected perceptual data indicate that 30 ratings per odor are sufficient to provide reliable results (Figure 2; Panel A). Each participant will also provide 30 similarity ratings of odor pairs, drawn from a total set of 1,770 pairs. This ensures that all odor pairs will be rated at least once by participants in each country (60 × 30 = 1,800). Thus, we will collect at least 30 similarity ratings per odor pair. Bootstrapping analyses of previously collected similarity data show that this sample size is sufficient to yield reliable results (ρ > 0.8 compared to benchmarking data, see Figure 2; Panel B).

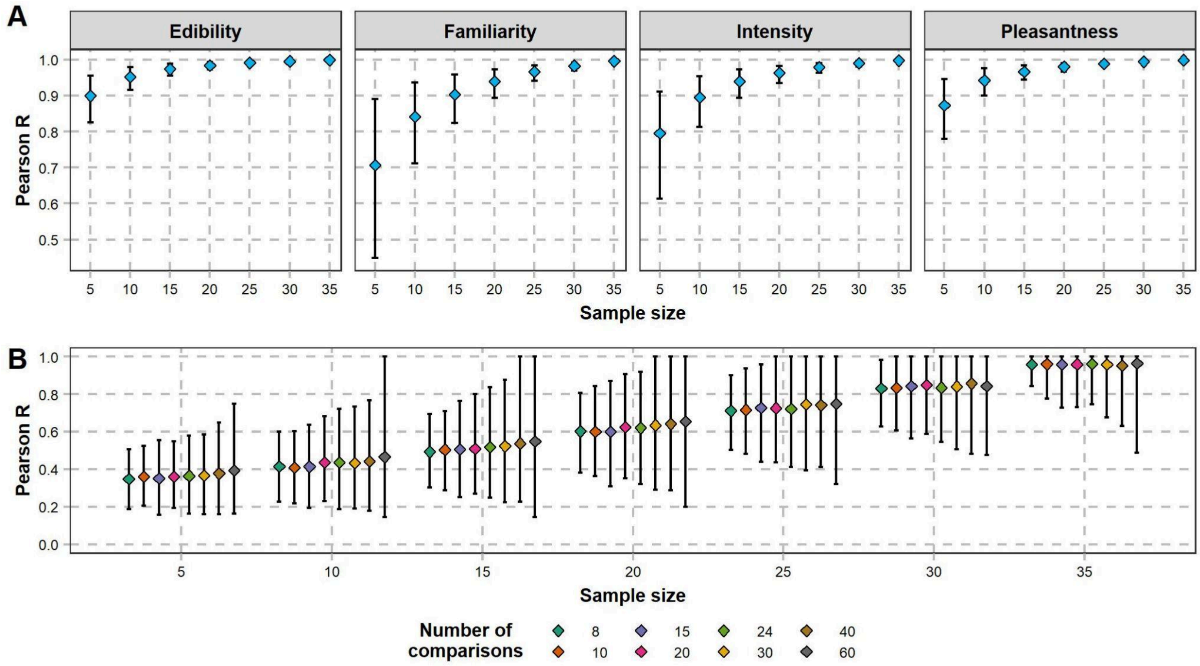

Figure 2. Bootstrapping analysis of odor ratings from Lindroos et al. (2022) and Pierzchajlo et al. (2025). Panel A: Pearson correlations between original data and bootstrapped odor-perceptual ratings of different sample sizes. Panel B: Pearson correlations between original data and bootstrapped odor similarity ratings of different sample sizes and nr of comparisons per subject. Error bars are the 5% and 95% quantiles of bootstrapped R values (n=1000).

Work Package 2

Purpose and aim

In Work Package 2, we will map the semantic organization of the established odor vocabularies and test hypothesis 2 that although culturally distinct odor vocabularies differ in codability and abstraction, they are semantically organized along shared valence and edibility dimensions. Confirming this hypothesis will pave the way to a new theoretical framework for understanding odor language, in which linguistic variability of odor vocabularies is reconciled with an underlying, cross-cultural semantic organization.

Procedure

We will use an online survey panel service (e.g. Warriner et al. 2013) by Qualtrics (Qualtrics, Provo, UT), to collect ratings of odor descriptors emerging from WP1. Descriptors will be rated on semantic properties that are prominent in odor vocabularies of individual languages (Wnuk et al. 2020; Hörberg et al. 2022) and in odor classification tasks (Chrea et al. 2004). First and foremost, these ratings will include associations to valence and edibility, as these properties constitute the main dimensions of odor vocabularies in previous work (e.g. Wnuk et al. 2020; Hörberg et al. 2022; Majid et al. 2018a; Wnuk & Majid 2014; Khan et al. 2007;

Zarzo 2008; Licon et al. 2018). Word valence ratings will be collected similar to Warrnier et al. (2013), who collected valence ratings of 14,000 English words rated online on a 1–9 grade Likert scale. High ratings correspond to feelings of being *happy*, *pleased*, *satisfied*, *contented*, or *hopeful*, and low ratings to feelings of being *unhappy*, *annoyed*, *unsatisfied*, *melancholic*, *despaired*, or *bored*. Previous research on the semantics of odor vocabularies has used associations with taste collected by Lynott et al. (2009; 2013; 2019) as a proxy for edibility (Hörberg et al. 2022; 2023; 2024; 2025; Pellegrino et al. 2021; Winter 2016; 2019). In an online survey, 40,000 words were rated on a 1–5 Likert scale with respect to their association with smell, taste, vision, hearing, interception and touch. Although taste association ratings are related to Edibility, they reflect the association between words and taste in general, rather than edibility (Hörberg et al. 2022). As a case in point, both *eatable* and *uneatable* score high on taste. Here, words will instead be rated with regard to their association with something edible, rather than with taste. The English odor vocabulary is differentiated with respect to the smell associations of words (Hörberg et al. 2022). We will therefore also collect ratings of word-olfaction associations, using the same rating scheme as Lynott et al. (2019). Abstraction of odor language can be measured in terms of the proportion of abstract terms that are used to describe odors. But word abstraction can also be estimated with concreteness—the extent to which a word denotes a perceptual entity (Bryesbaert et al. 2014). Abstract words score low on Concreteness. As previous work has found the concreteness-abstraction distinction (i.e., whether odors are described with concrete terms referring to the odor source, e.g., *lemony*, or with abstract terms describing the odor experience, e.g., *pungent*) to be important in odor vocabularies (Hörberg et al. 2022; 2023; 2024; 2025; Pellegrino et al. 2021), we will also collect word concreteness ratings. We will use a similar method to that of Brysbaert et al. (2014), who collected concreteness ratings of 37,000 words on a 1-5 Likert scale with an online survey. We anticipate that each rating session will take about 30 minutes to complete.

Our survey will be translated from English into each language by two target language native speakers, using the back translation procedure (Beins 2013). The original English text is translated into the target language by one translator and then translated back to English by a second translator. Discrepancies between the original English text and the back translation will be resolved through discussion between translators. For each odor × language combination, we will quantify lexical-semantic dimensions of interest. Codability will be quantified in terms of the odor descriptors' Simpson's Diversity Index (Majid et al. 2018b). Abstraction will be quantified as the proportion of abstract terms used to describe an odor. Semantic ratings of Valence, Edibility, Olfactory modality association, and Concreteness will be averaged across descriptors of each odor (e.g., average valence of the terms describing lemon odor). Concreteness will serve as an additional (inverse) estimate of Abstraction. These lexical semantic dimensions make up a multi-dimensional space of the odor vocabularies of each language. We can then assess dimensions on which vocabularies converge or diverge. This allows us to test hypothesis 2—that although languages diverge on abstraction and codability, they converge on valence and edibility, in parallel to how odors are perceptually distinguished. This will be statistically tested by comparing the dimensions on their between- vs. within language group variance difference (cf. Arshamian et al. 2022).

Sample size

The sample size for the WP2 study is 50 participants of each language (total N = 1500), resulting in a much higher number of ratings per word than in previous studies, which included between 10-20 individual ratings (Warriner et al. 2013; Lynott et al. 2019). As the data from these prior studies were thoroughly evaluated, a sample size of 50 should be more than adequate.

Work Package 3

Purpose and aim

In Work Package 3, we will use the data from WP1 and WP2 to construct a cross-cultural odor lexicon consisting of unique descriptors that 1) are translatable across languages, 2) cover the main dimensions of the odor-perceptual space, and 3) do not contain redundant terms. The lexicon will contain meta-descriptors that encompass terms that describe a specific part of the odor-perceptual space. It may provide a universal descriptive system for odors that will be useful in future research on physicochemical-odor perceptual relationships and in related industries. We will also validate our lexicon using additional empirical data collected in a subsample of languages from different language families.

Bierling et al. (2025b) proposed a standardized lexicon of body odor words, based on a sample of body odor descriptors in thirteen languages. Using an on-line survey, they collected body odor descriptors of imagined body odors and selected the 42 most frequent descriptors of each language. These descriptors were translated to English and included in a final list of 25 terms that were selected on the basis of their within- and across-language frequencies. A descriptor was included if it was 1) among the top 5 words of at least one language and in the full final lists of at least 5 languages or 2) among the top 10 words of at least one language and in the full final lists of at least 10 languages.

This procedure might not be optimal, because it assumes a one-to-one across-language mapping between word forms and word meanings. Meanings are ultimately language dependent: an odor experience that is lexicalized in one language might not be represented in the lexicon of another language. Hence, many of the 25 terms in the final lexicon of Bierling and colleagues are not represented in the lexicons of the individual languages, and thus are not “crosslinguistically valid”. Descriptors, we believe, should instead be selected based on their convergence in the odor space: if a set of descriptors maps out a specific area of odor space in terms of being applicable to a specific odor or a cluster of highly similar odors, that set could potentially be included in the cross-linguistic lexicon. Here, a meta-label would correspond to the words of the individual languages (e.g. **FRUITY** corresponding to English *fruity*, Swedish *fruktig*, German *fruchtig* and so forth). This is the approach we will take.

Procedure

We will identify cross-linguistically valid meta descriptors based on the overlap of individual language descriptors in the odor perceptual space. First, the most frequently used descriptors of each language are selected. Second, the olfactory meanings of the selected descriptors are determined based on the odors they apply to: their frequency of use across the 60 odors constitutes vectors that represent their meanings. Third, meta-descriptors, encompassing individual language descriptors, will be selected based on the overlap between descriptor vectors. Vague (e.g. evaluative terms such as *pleasant*) and overspecific (e.g., source-based terms of specific odors such as *lavender*) descriptors will be discarded due to their redundancy. Individual language descriptor clusters will then be selected based on their degree of overlap in a cross-culturally valid odor-perceptual space. Thus, the creation of the cross-cultural odor lexicon will be data-driven and based on the coverage and degree of overlap of the individual descriptor vectors. This work will result in a novel lexical tool that can be used to categorize odors in an objective and domain-general way and that can be used transparently across languages. To ensure that the odor-perceptual space is 1) language-independent (e.g., compared to the space in Figure 1) and 2) cross-culturally valid, it will be derived from the odor similarity ratings obtained during data collection in WP1.

To evaluate the convergence of the lexicon within and across languages, we will collect descriptor-odor ratings (Bierling et al. 2025a; Dravnieks 1985; Keller & Vosshall 2016) in a subsample of languages from different language families. Participants will rate descriptor-odor applicability on a visual analog scale from 0 to 100 (cf. Bierling et al. 2025a). Each participant rates 10 descriptors, translated into their language, on how well they apply to 60 odors, thereby providing ratings of 600 descriptor-odor pairs. We aim to obtain around 25 ratings for each descriptor-odor pair and anticipate that the experiment will take about an hour to complete. This data set will be used to evaluate the within language consistency of the lexicon, in terms of inter-rater reliability (e.g., Cohens' κ, see Cohen 1960), and the between-language convergence for the fit between descriptor similarity matrices of individual languages.

Sample size

Motivated by our goal to obtain 25 ratings for each word–odor pair in each language, the sample size for the WP3 study is 75 participants (total N = 1500). Assuming the odor lexicon contains 30 words, the total number of word–odor pairs will be 30 × 60 = 1,800. Each participant will rate 10 × 60 = 600 word–odor pairs. To achieve 25 ratings per pair, we therefore need (1,800 ÷ 600) × 25 = 75 participants per language.

Study population

The study population consists of native speakers of a set of as linguistically diverse languages as possible. This sample of languages is, however, in essence be convenience-based, as it is limited by the GCCR community and the labs that can be reached through our networks and the willingness of those labs to participate in the project. A total of 30 labs from Europe, North and South America, Asia and Africa have to date signed up for participating. These labs will collect data from 27 languages of 14 different language families (see Table 1).

Inclusion and exclusion criteria

Participants will be selected to ensure a representative distribution of age (age range: 18-55 years) and gender. Participants with impaired olfactory function or other health issues affecting their ability to participate will be excluded. Individuals who are not native speakers of the target language will also be excluded.

Ethical considerations

Personal information collected from participants includes age, gender, ethnicity, native and spoken languages, education level, current country/city of residence, self-perceived ability to

Table 1. Language families and languages included in the study.

Language family	Languages
Germanic	English, German, Swedish, Danish
Slavic	Polish, Russian
Romance	French, Spanish, Italian, Portuguese
Indo-iranian	Urdu, Hindi, Bengali, Punjabi
Turkic	Turkish
Koreanic	Korean
Sino-Tibetian	Mandarin
Austroasiatic	Vietnamese
Austronesian	Malay
Niger-Congo	Swahili, Luanda, Yoruba
Isolate	Japanese
Hellenic	Greek
Afroasiatic	Arabic, Hebrew
Dravidian	Tamil

taste and smell, tobacco use, and smell-related health conditions. Other personal data such as name, phone number, and/or email address will be collected only for scheduling purposes and will not be stored after participation is complete.

There are no known risks associated with the procedures in this study. It involves no invasive procedures, medical interventions, or potentially harmful stimuli. Some odors may be experienced as unpleasant by some participants, potentially causing mild dizziness or, in rare cases, nausea. Participants will be informed that they have the right to withdraw at any time if they feel discomfort or for any other reason.

Participants may withdraw at any time and can take short breaks between odor presentations. Drinking water is available. Participants are informed about the procedure and the possibility of encountering unpleasant odors. They may ask clarifying questions and must give written consent before participating. The research team can be contacted via email or phone for support. The study design also maximally protects participants' privacy: all data are encrypted, stored securely, and pseudo-anonymized. All reported results will be presented at the group level, with no individual results disclosed.

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