Trends in Cognitive Sciences

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Opinion

Human Olfaction at the Intersection of Language, Culture, and Biology

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The human sense of smell can accomplish astonishing feats, yet there remains a prevailing belief that olfactory language is deficient. Numerous studies with English speakers support this view: there are few terms for odors, odor talk is infrequent, and naming odors is difficult. However, this is not true across the world. Many languages have sizeable smell lexicons — smell is even grammaticalized. In addition, for some cultures smell talk is more frequent and odor naming easier. This linguistic variation is as yet unexplained but could be the result of ecological, cultural, or genetic factors or a combination thereof. Different ways of talking about smells may shape aspects of olfactory cognition too. Critically, this variation sheds new light on this important sensory modality.

Highlights

The human sense of smell is far more acute than previously thought, yet it is still commonly believed that there is no language of smell.

In English there are, indeed, few words for smell qualities, smell talk is infrequent, and people find it difficult to name odors in the laboratory. However, the cross-cultural data show a different picture.

There are many languages across the globe that have large smell lexicons (smell can even appear in grammar) in which smell talk is also more frequent and naming odors is easy.

In different cultural and ecological niches odors play a significant role in everyday life.

These differences in smell language can have consequences for how people think about odors.

The Renaissance of Olfactory Cognitive Science

From antiquity to modern times, people have largely viewed olfaction as a vestigial sense. This view is prevalent in both scientific and popular thought. For example, evolutionary biologists suggest there was a trade-off between vision and olfaction reflected in bodily and brain anatomy. This led to the classification of humans as 'microsomatic' (i.e., with a poor sense of smell) in contrast to 'macrosomatic' animals who have a keen sense of smell [1] and such anatomical evidence continues to be used to conclude that olfaction has been downgraded in humans [2]. Similarly, the public underestimates the importance of human olfaction. British adults consistently rank smell as the least important of the traditional five senses [3] and a survey of 7000 teenagers and young adults found that 1 in 2 would rather give up their sense of smell than be without their phone or laptop [4].

The past years have witnessed several developments that present a new perspective on human olfaction. Previously, the study of olfaction relied heavily on biological over behavioral evidence to make claims about function, since there were so few behavioral studies to draw from. Moreover, the biological evidence often did not come directly from humans but from rodents, and although there are homologies between the two there are also critical differences [5]. Some now challenge longstanding interpretations of the biological data [1,6] and basic assumptions are being questioned. For example, a recent study found that normal odor perception is possible without olfactory bulbs [7], a finding tantamount to claiming that visual perception is possible without the retina.

Behavioral studies of human olfaction in recent years overturn long-held views about our sense of smell. Olfaction plays an important role in food consumption, danger avoidance, and mate attraction; to this, we can add that humans uniquely use odors for religious [8,9], medicinal [10–12], and aesthetic [8,13,14] purposes too. Studies show that smelling in humans is not just an individual act, but an interactional one [15]. There have been numerous developments in odor biometrics [16], electronic noses [17], and olfactory marketing [14]. Loss of the sense of

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smell presages clinical diseases such as Alzheimer's [18], Parkinson's [19], and COVID-19 [20] and has been linked to depression [21], obesity [22], and a range of other conditions. Contrary to the view that we are microsomatic, humans have higher odor sensitivity – that is, lower odor detection thresholds – than animals traditionally considered to be super smellers, including dogs and pigs. Of the approximately 3300 odorants tested for detection thresholds in humans, 138 have also been tested with nonhuman animals, and people outperform animals for most of these odors [23]. Similarly, until recently it was believed that humans could distinguish only a few thousand odors, although there are billions of molecules with the chemical properties of odors. This is now considered a grievous underestimate. On one count humans can distinguish 10^{90} odors, derived by calculating how many different output combinations a simple model with 300 binary olfactory receptors could generate [24]. An experimental attempt to estimate human odor capacity suggested we can distinguish at least 1 trillion odors [25], but additional analyses suggest that the trillion figure is unreliable since the same data can yield estimates ranging from 5000 to 10^{29} [26,27]. So, while the exact number of odors humans can discriminate remains unknown, it far exceeds previous conjectures.

The emerging data have challenged various dogmas surrounding olfactory cognition, but one persists: that is, there is no language of smell and humans are bad at naming odors [28–30]. Scholars have argued that naming odors is not ecologically relevant for humans because the function of olfactory cognition is not to identify odors; instead, odors are primarily processed incidentally and unconsciously as implicit associations with situations [31,32]. This article presents an alternative perspective, suggesting instead that humans have a far richer capacity for olfactory language than is commonly acknowledged. In the next section, I provide evidence (from English) compatible with the prevailing view, before presenting emerging cross-cultural data from a more diverse set of languages that challenge the established perspective. I then consider various explanations for why this linguistic diversity should exist, before exploring the consequences such linguistic diversity could pose for olfactory cognition more broadly.

Olfactory Language: A Global Perspective

Evidence That Smell Is Ineffable

It is claimed that 'a sizeable inventory of basic smell terms, i.e., one with more than two or three items' is unlikely to be found in the world's languages (https://typo.uni-konstanz.de/rara/intro/index.php) and that smell can never appear as a grammatical category [33,34]. Linguists have also doubted the metaphorical potential of olfaction [35,36]. Various approaches have been taken to test these claims, from computational linguistic methods to naturalistic observation in the field [12,37–51]. Three principle pieces of evidence are used to support the claim that smell is ineffable (i.e., difficult or impossible to put into words) [52].

Lack of Smell Vocabulary

To establish smell vocabulary, two chief approaches have been taken. First, linguists have attempted to establish basic smell words. Basic terms are, among other criteria monolexemic (a single word), not source descriptors nor restricted to a narrow class of objects, and psychologically salient (i.e., known by everyone in a speech community) [53]. In English, candidate basic terms for smell include *stinky*, *fragrant*, and *musty* — these are monolexemic, do not refer to a source and can be used widely across objects (both cheese and armpits can be *stinky*, or *fragrant* for that matter, depending on one's proclivities), and are everyday vocabulary for English speakers [54]. A technical term, such as petrichor ('a pleasant smell that frequently accompanies the first rain after a long period of warm, dry weather'), would be excluded as basic vocabulary since it is not commonly known and is restricted to a specific source.

Similarly, words such as *odorous* and *odoriferous* are not basic smell terms since these only indicate the presence of smell (just as *colorful* and *colorless* are not basic color words). Finally, terms such as *fruity* or *chocolatey* are excluded since they describe the source of an odor (fruit and chocolate, respectively). According to these criteria, then, English has limited basic vocabulary to encode odor qualities.

A different approach to establish smell vocabulary (specifically smell-associated words) is used in the psycholinguistic literature. Speakers are presented with a list of words and asked to indicate on a scale from 0–5 how much they experience the concept using each perceptual modality (e.g., by seeing, smelling, etc.) [55]. These ratings are then used to calculate a 'modality exclusivity score' indicating whether something is experienced through a single perceptual modality. According to these data, English has fewer smell-associated words than words for any other sensory modality [50,55]. In a test of almost 40 000 English words, chosen to represent a full adult vocabulary, 74% of words were dominantly visual and less than 1% were dominantly olfactory [55].

Smell Language Is Infrequent

Compared with other perceptual modalities, reference to smell is infrequent [37,45,50,51]. Winter *et al.* [50] used the modality exclusivity norms described previously to identify the ten verbs, adjectives, and nouns most exclusive by sensory modality and found that, on average, each dominantly visual word was used 13 times more often than each smell word. In the same paper, the authors found that, from a sample of around 1000 words, there were 16 times more distinct vision-associated words than smell-associated words [50]. This would mean that English speakers are exposed to vision-associated words 208 times more often than smell-associated words. A more recent study of 40 000 words suggests there are 136 times more vision-associated than smell-associated words in English [55], which would make the asymmetry even larger, with vision words encountered 1768 times more often than smell words.

Smell words are infrequent compared with other sensory modalities, regardless of register or genre [37,45,50,56]. An analysis of almost 8 million words from 7000 British English texts containing first-person descriptions of the Lake District in England (a UNESCO World Heritage Site) found 28 445 descriptions referring specifically to sight, 1480 to sound, and only 78 to smell [56]. In sum, there are relatively few smell words to begin with in English, and the more a word is associated with smell, the less frequently it is used.

Naming Odors under Experimental Conditions Is Hard

In principle, for every odor a person can perceive, there ought to be a way to convey it through language [52]. When asked to describe odors under experimental conditions, a common strategy is to refer to the source of the odor rather than using basic smell words [39–41]. Experimental studies typically present people with decontextualized odors in opaque jars or bottles and ask people to name the smell. Under these conditions, even familiar, everyday smells (e.g., chocolate, coffee, banana) are frequently named incorrectly [31,39–41,57,58]. Compared with pictures, odors take up to four times longer to name, and responses are less accurate and consistent [31]. Why odor naming is difficult is disputed (Box 1), as is the question of whether the weak link between language and olfaction is symmetrical or asymmetrical (Box 2).

Evidence That Smell Is Effable

The data reviewed in the previous section come from English. The emerging cross-cultural data suggest a radical rethinking on the generalizability of the claim that there is no smell language.

Box 1. Why Are Odors Hard to Name?

The difficulty of naming odors – also called the 'olfactory–verbal gap' [29] – is so well accepted that it has generated myriad explanations. Three broad classes of explanation can be identified.

Perceptual Accounts

In this class of theories, the difficulty of expressing olfactory experiences is explained by limitations in the perception and representation of odor signals. It has been suggested that olfactory representations are 'fuzzy' [107,108] 'like a blurred image that is not clearly perceived' [107]. Others have suggested that olfactory representations distinguish themselves from other perceptual modalities because they display a low degree of embodiment [109], do not have primitives [109], or do not lend themselves to compositionality [110].

Connectivity Accounts

Another class of theory suggests the difficulty in talking about odors is due to a limitation in brain connectivity. Perhaps olfactory and language areas of the brain are poorly connected [111], or are too directly connected such that the primary olfactory cortex interfaces with language regions of the brain while olfactory representations remain coarse and unprocessed at the point of lexical–semantic integration [28]. Others posit that the neural codes for olfactory and linguistic representations interfere with one another [112].

Linguistic Accounts

As described in the main text, if there is a limited vocabulary for odors and odors are infrequently talked about, there are insufficient opportunities for a child to learn how to talk about odors. According to this linguistic account, poor odor naming occurs due to deficient learning (see also [107]). Consistent with this, odors are harder to name correctly when they have low-frequency names (e.g., *cinnamon*) but easier when they have high-frequency names (e.g., *coffee*), even when controlling for odor familiarity [57]. Moreover, providing people with consistent verbal input facilitates odor category learning [113]. The linguistic account uniquely predicts there ought to be cross-cultural differences in odor naming when there are different communicative needs across cultures.

Lexicons with Basic Smell Terms Are Common across Languages

Contrary to the claim that sizable inventories of basic smell terms are unlikely to be found in the world's languages, field studies have documented considerable smell vocabularies across the globe (Figure 1). Jahai (Malaysia), for example, has 12 basic smell terms, which have been characterized as 'abstract', that is, their semantics is not limited to a specific source [8,41]. Smell vocabularies have previously been considered a characteristic of small languages with few speakers [51] (of the existing 6500 languages, the median number of speakers is less than 1000) and particularly likely to appear in hunter-gatherer languages [59,60]. Numerous hunter-gatherer languages have indeed been reported with smell vocabularies [8,12,41,43,59–62], but sizeable smell lexicons have also been reported in various pastoral and horticultural communities [37,42,61,63–72] as well as in major languages of industrialized societies with millions of speakers [51,73]. It could be that smell lexicons are more likely to appear in small languages or hunter-gatherer contexts, but it is premature to conclude so.

Smell Can Be Grammaticalized

Not only are there sizable smell lexicons in the world's languages, smell also appears in grammar. For example, Cha'palaa (Ecuador) has a grammaticalized nominal classifier for smell that combines with a closed set of abstract roots to form the smell lexicon of the language (15 basic smell terms) [37]. This belies the claim that smell lacks cue validity (i.e., does not provide additional information about properties of the referent) and therefore is unlikely to appear in nominal classifier systems [33,34]. More generally, linguists hold that independent words change to (grammatical) affixes when they appear with high frequency in discourse, so it is striking that productive olfactory affixes have been reported in a number of languages, including Tofa [74], Nenets, and Selkup [75] (all spoken in Russia), Nisga'a (Canada) [76], and four Formosan languages (Taiwan) [67].

Box 2. Is the Connection between Olfaction and Language Symmetrical or Asymmetrical?

For most people, naming odors is difficult [31,39–41,57,58], and this is often interpreted to mean that language is poorly connected to olfactory perceptual representations [28,111]. In a wide-ranging review of the literature, Yeshurun and Sobel [30] conclude that the weak connection between language and olfaction is symmetrical: it is as difficult to activate olfactory representations from language as it is to activate language from olfaction.

Contrary to this claim, some studies report that smell words connect directly with perceptual representations of odors [100,101,114–116]. Using fMRI, one study found that reading smell-associated words (e.g., garlic) led to activation of the piriform cortex [114], and an intracranial-electroencephalography (EEG) study confirmed piriform cortex activation 640 ms from the presentation of a smell-associated word [115]. Such findings suggest that the links between language and olfaction are asymmetrical: it may be difficult to access language from olfaction (for naming), but it is easier to access olfactory representations from language (during comprehension) (Figure I).

In fact, the imaging studies do not paint such a clear picture, as many studies fail to find activation of piriform cortex from smell-associated words [117–119] (see [120] for a critical review). Moreover, for those proposing an asymmetrical account, it is unclear what specifically is activated from smell-associated words: is it unique object-templates associated with distinct odors, as suggested by some [115], broader smell categories [46,120], or merely valence [30]? These possibilities can be distinguished using a match/mismatch paradigm. In one study [46], participants were presented with smell-associated words that varied in how closely they matched a target odor (e.g., garlic). Words were an exact match (e.g., *garlic*), a near-match (e.g., *onion*), or a mismatch although still smell associated (e.g., *soap*) or had no smell association (e.g., *water*). Participants were asked to remember words while they smelled a target odor. Later in the experiment, they were tested for their memory of odors. If words activate odor representations then, depending on the granularity of the representation accessed we should see differences in odor memory across conditions. No differences were detected, however, suggesting that the olfactory cortex was not involved in the comprehension of smell-associated words. This contrasts with findings using the same paradigm with auditory stimuli where mismatch memory effects were detected [46]. On balance, then, the data support the symmetry account.

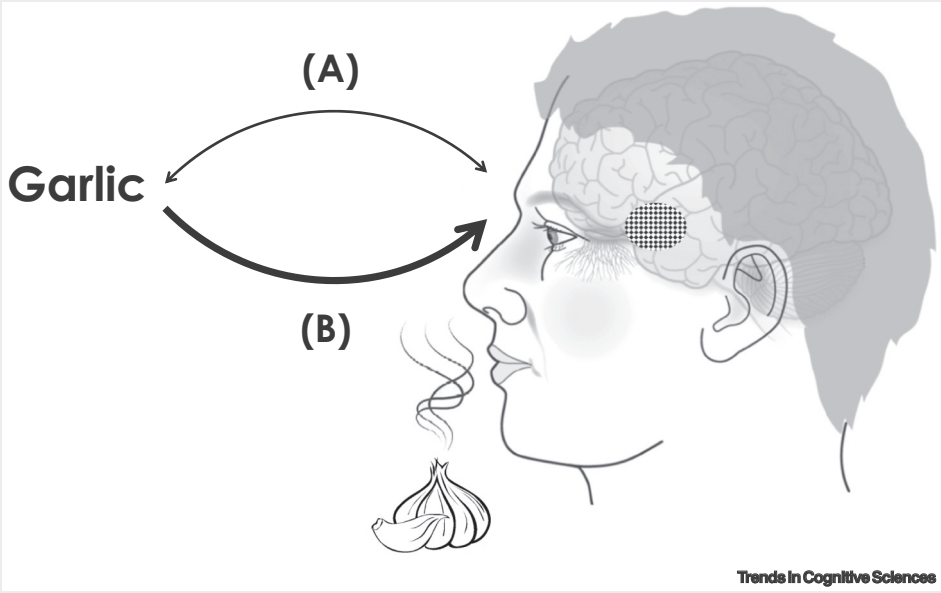

Figure I. Is Language Connected to Olfactory Perceptual Representations Symmetrically or Asymmetrically? According to the symmetrical account (A), it is as difficult to access olfactory representations from language as it is to access language from an olfactory percept. According to the asymmetrical account (B), language strongly activates olfactory perceptual representations, but it is difficult to activate language from a percept.

Smell Can Be the Source of Metaphor

Metaphor typically involves mapping a concrete source domain to an abstract target domain. It has been claimed that semantic extensions from the olfactory domain are limited [35,36], perhaps due to the ambiguity of whether the olfactory domain is abstract or concrete in the first place [39]. Nevertheless, there are a number of olfactory metaphors involving general negative attitude (*this stinks*), suspicion (*smell a rat*), investigation/search (*sniff for clues*) [77,78], and cross-linguistic

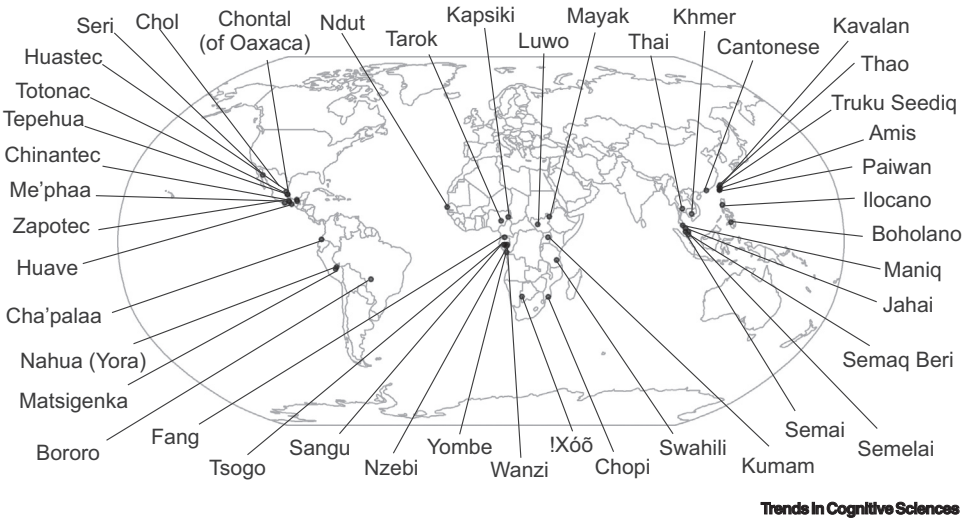

Figure 1. Map of Languages Reported to Have Sizeable Smell Vocabularies. It is unclear whether geographic gaps represent real absence (likely the case in Europe) or lack of dedicated research (e.g., Siberia, Australia).

investigation has revealed more. For example, smell is used metaphorically to refer to knowledge in Luwo (Sudan) [70] and is used to describe the relationship between words as part of an avoidance register in Datooga (Tanzania) [79]. Seri (a hunter-gatherer language of Mexico) has an elaborate smell lexicon and a number of specific olfactory metaphors for emotions (e.g., *being angry*), dreams (e.g., *having a nightmare*), ingestion (e.g., *detesting food*), activities (e.g., *doing something carelessly*), relationships (e.g., *leaving someone without family*), and the weather (e.g., *being bad weather*) [80]. Intriguingly, a recent study found that English smell words are primarily used figuratively, not literally (e.g., *I will not make a stink over it*) [37].

Smell Talk Is More Frequent in Some Cultures

Smell talk is infrequent in English but more frequent elsewhere. The noun 'smell' is three times more common in Thai than in English [51]. A comparison of perception verbs in everyday conversations across 13 diverse languages and cultures showed that smell verbs are overall rare compared with other modalities, but in Semai (Malaysia) and Cha'palaa (Ecuador) smell is ranked much higher [45]. A follow-up study using a 100-times larger conversational sample of Cha'palaa confirmed this higher ranking of the general smell verb and moreover showed that the specific smell lexicon of Cha'palaa is used more frequently than the comparable smell vocabulary of Quechua (an unrelated language in Ecuador) or English [37]. All in all, some languages have more linguistic resources to refer to smell and speakers of those languages talk about smell more frequently.

Odor Naming Is Easier in Some Cultures

The largest cross-cultural study of perceptual language to date compared the naming of perceptual stimuli for colors, shapes, sounds, tactile textures, tastes, and odors in 20 diverse languages and found that, across the board, odor naming had low consensus [40]. However, naming consensus for odors was higher among the hunter-gatherer Umpila (Australia) than in non-hunter-gatherer communities. This difference has been replicated a number of times with different populations [39,41,61]. Majid and Kruspe [61] tested whether odor naming differences were due specifically to subsistence by testing two groups residing in the same ecology (tropical rainforest of Malay Peninsula) and speaking related languages (Southern Aslian, Austroasiatic) but differing in subsistence (hunter-gatherer vs non-hunter-gatherer; i.e., swidden horticulturalist). They found the hunter-gatherer Semaq Beri outperformed the non-hunter-gatherer Semelai in odor naming. A different study

found that not only do the hunter-gatherer Jahai show higher consensus in odor naming than their Dutch counterparts, but they are also six times faster in providing their response [39].

Why Do Smell Languages Differ Across The World?

To the extent that communities differ in their communicative needs, there will be differences in the categories recognized in language. So what drives differences in olfactory language worldwide? There are three major accounts: ecological, cultural, and genetic. A historical perspective can shed further light on which of these is explanations is likely: if, for example, the same population develops and loses smell language then, all else being equal, a biological explanation is less plausible. Let us consider each of these in turn.

Explanations of Cross-Cultural Variation

Ecology

One possibility is that ecology shapes communicative need. Populations living in industrialized environments have poorer olfactory abilities than those not exposed to ambient air pollution [81–84]. If people cannot perceive odors, they may be less likely to communicate about them, just as a blind person may be less likely to remark on colors. Odors may be more relevant in tropical rainforest than temperate environments. Tropical rainforests limit lines of sight, but smells carry over longer distances and are more informative, particularly given the combination of high humidity and greater biodiversity [37,61]. A study comparing the atmospheric chemistry of the Amazon forest with the megacity Beijing found there were more potential odors in the rainforest [85]. This ecological hypothesis would predict that arctic environments are not conducive to smell lexicons. Against this, there is suggestive evidence that Siberian hunter-gatherers may have elaborate smell language [74,86], although this possibility has yet to be explored systematically. A different line of reasoning has led to a distinct ecological proposal that olfactory vocabularies should be highly variable cross-linguistically because olfactory environments are so varied [42]. This would imply that there are no universal principles to be found in the domain of olfactory vocabularies because each language is tied to its specific niche.

Culture

Another possibility is that olfactory language varies because of distinct cultural preoccupations. Anthropologists have divided cultures into those that are odoriphobe (downplay the sense of smell) versus odoriphile (consider odors an important source of knowledge) [87]. Returning to the claim made by some olfactory scientists that odor identification is not relevant for humans [31,32], this would at most characterize odoriphobe societies. City-dwelling urbanites spend little time engaging with their natural environment — the average American, for example, spends 69% of their time indoors [17], and by 12th grade at least 8 h of that is on screen [88]. Compare this with hunter-gatherer communities that are characterized by their high levels of mobility and rich ethnobiological knowledge. Ethnographic data from various odoriphile cultures illustrate how smell is used in animal and plant identification [12,43,89] for use as food and medicine [11,43,62,89,90]. The Kayapó (Brazil), for example, distinguish 56 folk species of bees and can track the odor trails of bee swarms [91]. Intriguingly, olfactory identification abilities correlate with spatial memory in the laboratory, suggesting that navigation may be closely linked to olfaction and olfactory language [92]. More detailed ethnographic accounts of olfactory cultural practices, alongside documentation of basic smell terms, could directly test predictions of the cultural hypothesis, such as the idea that subsistence style is linked to olfactory language.

Genes

Humans carry around 800 olfactory receptors, but only half are functioning: individuals vary in the repertoire and expression of olfactory receptor genes and this affects perception [93,94]. For

example, variation in the expression of OR6A2 that detects aldehydes may explain why some people like coriander leaves while others hate them [95]. A study of more than 11 000 Icelanders found that olfactory receptor expression correlated with odor naming abilities for specific odors [96]. This raises the possibility that genetic differences between groups could explain the cross-cultural variation in smell language reported here. A number of studies have found differences in olfactory receptor genes between populations utilizing broad groupings (e.g., African, Asian) [94,97], but these groupings are too coarse to help explain the diversity of attested smell language. Most likely, if a genetic explanation is to be found it would involve a more complex and detailed scenario of gene–culture coevolution [98].

Explanations of Historical Variation: The Deodorization Hypothesis

According to some, smell was of greater concern in the West in the past and has only recently become marginalized [66]. The deodorization hypothesis appeals to both ecological changes (the industrial revolution and a shift to urbanization) and cultural changes (the introduction of hygiene policies and other modern innovations) to argue that the repression of smell in the West is a modern phenomenon [66,99]. This process is said to have begun in the Enlightenment and by the aftermath of World War I culminated in a radical suppression of smell [66]. If this deodorization hypothesis were true, we would predict that smell language became less common after the 1920s. A study of American English from 1800–2000, however, found no change in the relative frequency of smell-associated words [50]. There are without doubt fascinating linguistic changes in English, but the same strategies for reference to smell have been present since the 1660s [48] and there is no evidence of basic smell vocabulary at earlier stages. This, and the lack of attested basic smell vocabulary in other Indo-European languages, suggests that the paucity of smell language in the West has a far deeper history going back thousands of years, contrary to the deodorization hypothesis.

Do Different Ways of Talking About Smell Affect How We Think About Smell?

What, if any, cognitive consequences are there as a result of these diverse smell vocabularies? The realization of differential linguistic coding of olfaction has only recently been taken seriously by the cognitive science community, so studies of the cognitive consequences are nascent (see also Box 3). The studies to date suggest a mixed picture.

Olfactory Language and Emotion

Within a language, the same odor is experienced as pleasant or unpleasant depending on the label it is given [100,101], raising the question of whether cross-cultural differences in naming strategies may likewise affect the perceived pleasantness of an odor. It appears they do not. Jahai and Dutch speakers use different strategies to talk about odors (abstract basic smell terms vs concrete source-based descriptions) and this may therefore lead to differences in the perceived pleasantness of odors, with some accounts predicting that abstract concepts are more valenced whereas others suggest they are more detached from sensory experience. By comparing facial expressions elicited by monomolecular odors while participants were engaged in an odor-naming task, Majid and colleagues found that both groups had the same initial affective responses to odors, regardless of the odor language they used [39]. These results suggest that the pleasantness of an odor is experienced swiftly and universally, whereas odor identification is slower and cross-culturally diverse. Critically, the role of language in odor perception may differ in important ways depending on whether it is recruited during production or comprehension (Box 2).

Olfactory Language and Cross-Modal Associations

Olfactory and visual information are intimately tied, with connectivity analyses showing that integration happens as early as the primary olfactory cortex [102], and when people are asked to

Box 3. Hunter-Gatherers and Wine Experts: Everyday versus Institutional Language and Cognition

The fact that some cultures have smell lexicons has been interpreted by some as a type of 'expertise' affecting language and thought [28] (Figure I). While lay English speakers show a lack of regard for smell, wine experts, perfumers, and the gourmand have cultivated their noses. So, are the wine experts' and hunter-gatherers' smell knowledge equivalent? The answer appears to be no. Although expertise certainly has relevance for understanding the relationship between olfaction and language, there are important differences between everyday cultural knowledge and institutional expertise.

The trajectory of learning is critically different between everyday and expert knowledge: people acquire cultural categories effortlessly in childhood, via language, and with little explicit instruction; experts, by contrast, acquire categories from institutions effortfully, usually later in life through explicit instruction, and knowledge has to be mapped onto language. In addition, I propose three specific properties that differ between everyday and institutional olfactory language and cognition.

Experts Individuate, Cultures Categorize

Everyday categories generalize over exemplars to capture broad similarities. Jahai, for example, distinguishes *pl eŋ* smells (characteristic of blood, raw meat, fish, etc.) from *cŋɛs* smells (e.g., bat dropping, smoke, petrol, etc.) and *haɛ t* smells (e.g., shrimp paste, sap of rubber tree, rotten meat, etc.), all of which are simply *stinky* in English. By contrast, experts are trained to distinguish very closely related entities, for example, distinguishing fake jasmine from the real thing. This is why when experts develop lexicons, they tend to focus on specifying and identifying an exact odor [121,122].

Specialist Knowledge Is Subdomain Specific, but Cultural Knowledge Is Domain General

The hunter-gatherer Jahai name odors with higher consensus than their Western counterparts and apply their basic smell terms to novel odors they have never previously encountered [39]. Wine experts, too, show high consensus when describing the smell of wine [123–126], but this ability does not generalize beyond their domain of expertise: they are no better than laypeople at describing the smell of coffee or naming other everyday odors [123,125]. Similarly, wine experts have better memory [123] and imagery [127] only for odors in their domain of expertise (see also [122]).

Specialist Olfactory Cognition Is Language Independent, but Cultural Cognition Is Language Dependent

There is a strong link between language and memory for odors in everyday cognition: odors named correctly are remembered more accurately [128,129]. However, specialists do not show this relationship between odor naming and odor memory for their domain of expertise and inhibiting the use of language during encoding does not impair odor memory [123]. In sum, the evidence to date suggests that everyday but not specialist olfactory memory relies on language in the moment.

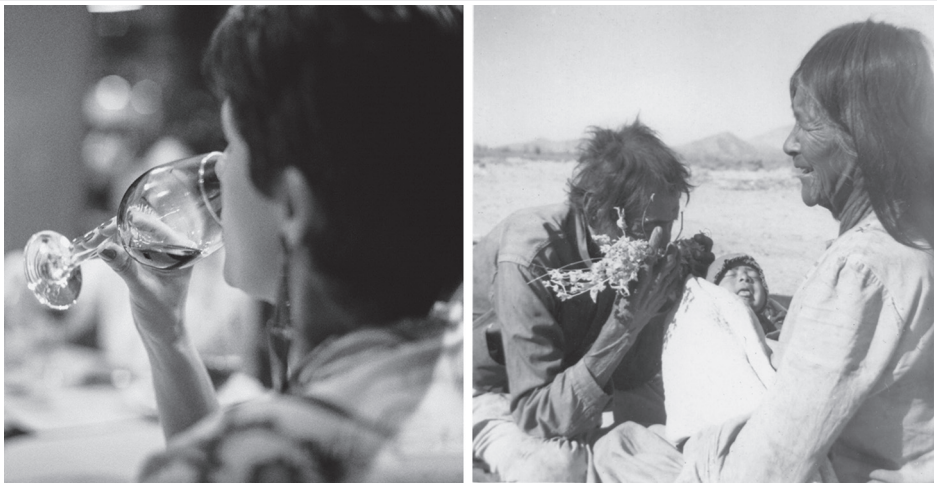

Figure I. Everyday Olfactory Cognition Differs in Key Ways from Olfactory Cognition in Specialist Expert Contexts. American woman at a wine tasting (left); ritual healing of Seri infant by shaman using desert lavender (right).

associate odors with colors they do so in systematic ways [58,103–106]. This could happen in at least two ways: odor perceptual representations could link directly to color due to statistical co-occurrences in the environment or the association between odors and colors could be mediated

by language. According to the language-mediated account of odor–color associations, if people use basic smell words to name abstract odor qualities (e.g., *musty*) they should show weaker odor–color associations than those who refer to their source (e.g., *smells like banana*). To test this, one study compared urban-dwelling Thai and hunter-gatherer Maniq (who both have basic smell vocabulary) with urban-dwelling Dutch participants (who overwhelmingly use source-based odor naming) and found that odor–color associations were mediated by language [103]. People had weaker odor–color associations when they used basic smell vocabulary, but when source-based vocabulary was used, color choices more accurately reflected their source. By the time a child is 6 years old, odor–color associations are culture specific, and odor naming plays an important role in their development [104].

Concluding Remarks

Human olfaction serves diverse functions some of which are shared across species. But humans also uniquely use olfaction deliberatively for religious, medicinal, and aesthetic purposes — and language plays a critical role in coordinating these activities. Despite the prevailing view that there is no olfactory language, this review highlights diverse communities worldwide that have basic smell vocabularies and where smell talk is more frequent. Rather than focusing on constrained experimental tasks, olfactory researchers could benefit from considering human olfaction in all of its contexts to study how people across the globe use, manipulate, and talk about odors in their day-to-day contexts (see Outstanding Questions).

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Outstanding Questions

Are smell words more likely to lexicalize some odors than others? Is there a predictable order of lexicalization or is each odor vocabulary uniquely fitted to its ecological and cultural niche?

Do languages with basic smell terms also have more smell-associated words? Modality exclusivity norms from English reveal a set of smell-associated words, although these are fewer in number than for the other senses. Studies have confirmed the same trend in several European languages (Dutch [130], Italian [131,132], Russian [133], Serbian [134]) and in Mandarin [135]. Critically, no norms have yet been collected from languages with attested smell vocabularies.

Non-literal metaphorical use of smell language appears in some languages (e.g., Seri [80]) but not others (e.g., Jahai). What smell metaphors are used across languages and how common are they?

Before abandoning the deodorization hypothesis, it is worth considering some complications. Words and meanings change over time: words currently with a smell meaning may not have had that meaning in the past and vice versa. Historical comparison is reliant on text written in a standardized, formal register. Smell may be less frequent there because of taboos surrounding smelliness [136]; conversely, smell may be more evident in slang. Intriguingly, there is a large slang lexicon for the 'nose' [137], but no systematic study of smell itself.

Language plays a critical role in odor–color associations but perhaps not in odor–temperature [138] or odor–music [139] associations. Which cross-modal odor associations are mediated by language and culture?

Is the relationship between language and olfaction symmetrical or asymmetrical? Evidence from Western languages suggests it may be symmetrical (Box 2); is the same true for languages with basic smell terms?

Does the trajectory of learning olfactory language differ between children and adults (Box 3)? What conditions give rise to domain-general versus domain-specific olfactory abilities?

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