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LETTER TO THE EDITOR

On the Definition and Measurement of Human Scent: Comments on Curran et al.

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A recent article by Curran et al. [*J. Chem. Ecol.* vol. 31(7); 1607–1619, 2005] describes the collection and chemical analysis of "human scent." Contrary to the authors' claims, a great deal is known about the chemical constituents of human scent and its measurement. Here we clarify what is known about human scent and highlight several shortcomings concerning the authors' analysis related to (1) the definition of human scent, (2) chemical analysis of human scent, and (3) conclusions about individual differences.

Human Scent

More than 15 years of research has presented both organoleptic and analytical evidence that a mixture of C_6–C_{11} normal, branched, hydroxy- and unsaturated acids present in axillary sweat constitutes the characteristic axillary odor (Zeng et al., 1991, 1992, 1996a,b; Natsch et al., 2003). In addition to this mixture of major odor constituents are trace amounts of thioalcohols (Hasegawa et al., 2004; Natsch et al., 2004; Troccaz et al., 2004) with high odor impact (low olfactory threshold). The details of the chemical identification, exact structures, and synthesis (of noncommercially available compounds), as well as biogenesis of many of these compounds, have been described in the above cited manuscripts.

Importantly, these characteristic axillary odorants are volatile organic compounds. Thus, we read with dismay the authors' comments that there is "limited understanding of how the body produces the volatile organic compounds present in human odor." Furthermore, their comment on the bottom of page 1608 to the top of 1609, "Although the components of human sweat have been studied extensively, comparatively little work has been carried out

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to determine the volatile organic compounds (VOC's) present in human odor," is also incorrect. The compounds that give the underarm its characteristic odor are volatile organic compounds (VOC's).

We have previously demonstrated that the characteristic odor components are not the most abundant compounds found in underarm extracts (see Figure 2 in Zeng et al., 1991). Hence, their definition of "human scent" as the most abundant VOC's is inconsistent with past studies and unfounded. It also contradicts numerous studies of food, beverages, plants, and malodors that have used the nose as a detector to determine which compounds have the greatest odor impact. The "scent" is often found in the minor constituents of complex mixtures from natural products. Likewise, Zeng et al. (1991) used gas chromatography olfactometry (GC-O) to identify the characteristic "human scent" constituents, which turned out not to be the most abundant compounds.

Analytical Techniques to Measure Scent

To measure scent, Curran et al. used gauze pads to swipe armpits of subjects following exercise, and then used solid phase microextraction (SPME)–gas chromatography/mass spectrometry to sample the headspace above the gauze pads. It is possible that many of the compounds identified by this approach have no relevance to human odor for at least three reasons.

First, and the most serious, the characteristic axillary odorants are predominately a variety of polar, acidic compounds that will bind to the gauze material used for collection. Therefore, SPME headspace analysis over the gauze pads would not be adequate to sample and detect these types of compounds, which offers one possible explanation for their nondetection of 3-methyl-2-hexenoic acid (3M2H). We demonstrated more than 25 years ago (Labows et al., 1979) that the major compounds collected by sweeping and collecting the headspace above either cotton pads worn in the underarm or the underarm itself are not characteristic of axillary odor. In model experiments, we also noted that aliphatic acids were not readily transferable from cotton pads to headspace collection devices. In that study, most compounds observed in the headspace were exogenous constituents because of residual VOCs from cosmetic products. The important odor constituents are polar molecules that tend to bind to pad material. In Curran et al. (2005), dodecanoic and tetradecanoic acid were found only in the axillary volatiles of one subject (out of eight). In a previous study (Zeng et al., 1996a), these acids were found in each gender. The authors do not comment on the sensitivity of their instrumentation, but it is likely that the nondetection of these two compounds is an example of polar compounds remaining on absorbent surfaces.

Second, the sampling procedure of wiping the underarm after exercise is more likely to collect eccrine sweat than apocrine secretions, the well-documented source of axillary odor precursors (Shehadeh and Kligman, 1963; Zeng et al., 1992, 1996b). In an eccrine-enriched sample, odorants derived from the interaction of axillary bacteria and apocrine secretions are not given time to form. To this point, the absence of 3M2H in their analysis, one of the most abundant characteristic axillary odorants, should have been an immediate indication that something was amiss with their measurement technique, and that the measured compounds might not be characteristic of human scent.

Third, prior to sampling, subjects were instructed to discontinue use of deodorants, lotions, and perfumes for at least 48 hr. This "washout" period is likely too short to prevent collection of exogenous compounds, so that many of the compounds detected might actually be artifacts of cosmetic products. Labows et al. (1979) showed that the less volatile components of some

cosmetic products may still be found in axillary headspace analyses 10–14 days after subjects stop using them.

Individual Differences

In their abstract, Curran et al. state, "Qualitative differences noted between the males and females studied, along with differences in chemical ratio patterns among the common compounds, demonstrated the ability to differentiate between the individuals through the examination of VOC's," which is an apparent overgeneralization of their reported data. Any conclusion about differences between individuals needs to account for intrasubject variability, i.e., variability between samples from the same subject collected on different days or conditions. This is illustrated in Figure 2 of the paper, but no data were provided, nor were they factored into statements about individual differences. [The authors cite a previous study in their lab comparing two samples from one subject with one sample from another subject as evidence for repeatable individual differences.] Beyond statistical significance—which is not demonstrated—is the task of accurately discriminating individuals from each other, which is generally more difficult to accomplish, and again not demonstrated by the authors.

For these data, it seems the best we can do is look for qualitative or quantitative differences between *genders*. Four males and four females were used in the study. Table 2 in Curran et al. provides *qualitative* comparisons between the eight subjects, showing which of the 47 compounds were detected for each subject. No compounds show statistically significant qualitative differences between genders.

Table 3 in Curran et al. shows the relative ratios of 22 compounds (relative to decanal) for all eight subjects. Some of these ratios are reported as 0 where the compound was not detected, which can complicate quantitative comparisons: it is possible that the compound is present in trace amounts below detection limit but greater than 0. With this in mind, and using two standard two-sample comparison techniques (*t*-test and Wilcoxon nonparametric test based on ranks), we found only one compound to be marginally significant (nonanoic acid–methyl ester; *t*-test, $P = 0.09$; Wilcoxon, $P = 0.11$), but after adjusting for the large number of hypothesis tests, no compound is significant.

In summary, it is possible, perhaps even likely, that people have distinct genetically determined odor profiles—or *odorprints*. Sweat contains a complex mixture of compounds whose expression is influenced by a person's genetic makeup. The profile of volatile metabolites is also likely to reflect, in part, a person's genotype. Because it is difficult to determine whether a VOC profile is really measuring "scent" without behavioral confirmation (e.g., perception tests using GC-O), the authors may have been a bit overzealous in their definition of "scent." From a forensics perspective, however, it does not really matter whether the VOC profile measures "scent" or something else, as long as it can be used to differentiate individuals. Similarly, it might not matter which secretions the profile of constituents is obtained from, although, again, the "scent" moniker is not justified for all chromatographable constituents.

Whatever the definition, the individuality of human scent as measured by VOC's has yet to be demonstrated.

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