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HUMAN OLFACTORY COMMUNICATION OF EMOTION [1,2,3]

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Summary.—Nonhuman animals communicate their emotional states through changes in body odor. The study reported here suggests that this may be the same for humans. We collected underarm odors on gauze pads from 25 young women and men on two different occasions. On one occasion the donors were induced to feel happy by viewing an excerpt from a funny movie whereas on the other, separated by a day, they were induced to feel afraid by watching an excerpt from a frightening movie. One week later, 40 women and 37 men were asked to smell several different bottles, some of which contained underarm odor pads collected during the happy movie, some contained underarm odor pads collected during the frightening movie, whereas others contained unused pads (control odor). Each odor was identified on two separate tasks that involved identifying the odor from among three odors and identifying it again from among six odors. Data were the number of women and men who identified an odor correctly on both tasks. When asked to select which bottles contained "the odor of people when they are happy," women chose the correct bottles for both tasks significantly more often than chance. Men chose the bottle which contained the body odors collected when women (but not men) viewed the happy movie more often than would be expected by chance. When asked to select which bottles contained "the odor of people when they are afraid," women and men both chose the bottle that contained the body odors collected when men (but not women) viewed the frightening movie more often than would be expected by chance. The finding suggests that there is information in human body odors indicative of emotional state. This finding introduces new complexity in how humans perceive and interact.

Scientists have known for decades that animals from invertebrates (sea anemones, ants, aphids, honeybees, earthworms) to fish (minnows, yellow bullheads) to mammals (rats and mice) can communicate fear and alarm through changes in their body odor (e.g., Todd, Atema, & Bardach, 1967; Wilson, 1975; Nault, Montgomery, & Bowers, 1976; Agosta, 1992). A chemical substance released by an animal under stress, e.g., electric shock, injury,

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impending danger, can either alert other animals (usually of the same species) to escape or gather them together to attack a predator. For example, rats can distinguish between the air from stressed and nonstressed rats; they can learn to press a bar for the former and interrupt bar pressing when the latter is introduced (Valenta & Rigby, 1968). Odors from stressed rats can lower the immune response in nonstressed rats (e.g., Cocke, Moynihan, Cohen, Grota, & Ader, 1993) and, like other stressors, activate the endogenous mechanism that inhibits pain (e.g., Fanselow, 1985) and produce avoidant behavior (e.g., Rottman & Snowdon, 1972). Because the avoidant behavior is not observed in recipient animals whose olfactory mucosae have been surgically removed, the information is assumed to be conveyed by olfactory cues (e.g., Rottman & Snowdon, 1972). The present study was designed to assess whether natural human body odors may also carry emotional information about the odor donors which can be detected by others.

METHOD

Participants

Volunteers participated as Donors and Observers. Donors were 14 nonsmoking women ($M=20$ yr., $SEM=1$) and 11 nonsmoking men ($M=20$ yr., $SEM=1$). Observers were 40 women ($M=24$ yr., $SEM=1$) and 37 men ($M=26$ yr., $SEM=2$). All but one of the Donors also participated as an Observer. All participants were students or staff members at a university in New Jersey. Their ethnic composition is presented in Table 1. This ethnic distribution is identical across female and male Donors. It is comparable across female and male Observers [60% vs 51%, respectively, for the Euro-Americans ($z=.57$, $p>.05$) and 15% vs 27%, respectively, for the Asians ($z=1.01$, $p>.05$)]. College students received research credits for their participation.

Induction of Mood

The Donors' emotional state was manipulated by viewing two emotion-

TABLE 1

ETHNIC COMPOSITION OF ODOR DONORS AND OBSERVERS

	Donors				Observers			
	Men ($n=11$)		Women ($n=14$)		Men ($n=37$)		Women ($n=40$)	
	n	%	n	%	n	%	n	%
Ethnicity								
Euro-American	5	46	6	43	19	51	24	60
Asian	4	36	5	36	10	27	6	15
African American	1	9	1	7	6	16	4	10
Hispanic	1	9	1	7	2	5	5	13
Other	0	0	1	7	0	0	1	3
Age: *M*; *SEM*	20; 1		20; 1		26; 2		24; 1	

inducing movie excerpts separated by a day. The happy mood was induced by a 13-min. excerpt from a comedy and the fearful mood was induced by a 13-min. excerpt from a film of snakes, bugs, and crocodiles menacing people. Twelve women and 10 men watched both excerpts whereas 2 women and 1 man watched only one. The viewing order of the excerpts was counterbalanced across Donors. Some researchers who study emotion have proposed that facial feedback can influence subjective experience of an emotion such that the exaggeration of a facial expression will lead to greater emotional reactions (Izard, 1971; Tomkins, 1979; Zuckerman, Klorman, Larrance, & Spiegel, 1981). Accordingly, to ensure active viewing, Donors were instructed to act out facially the emotions during each excerpt, so that people watching them would be able to guess the nature of the excerpts based on their facial expressions alone. At the end of each excerpt, they rated how happy or afraid they felt during the movie on a 7-point scale using anchors of 1 = not at all, 7 = very much.

Donors reported feeling happy during the comedy ($M=5.5$, $SEM=0.2$; $M=6.1$, $SEM=0.3$, for women and men, respectively). They also reported experiencing moderate fear during the frightening excerpt ($M=3.9$, SEM, 0.3; $M=3.9$, $SEM=0.5$, for women and men, respectively).

Collection of Odor Stimuli

Odor donors had been instructed to shower the night before the session during which odors were collected and to refrain from bathing or using antiperspirant, deodorant, or fragrance on the day of the session. Donors kept a 4-in. × 3-in. gauze pad in each armpit while viewing the video excerpts. At the end of each excerpt, the cotton pads containing the sweat were grouped by movie and sex of the Donors, placed in glass bottles, and stored at −80°C. The unused control pads were also placed in two separate jars and stored in the same freezer.

Odor Stimuli

Odor stimuli represented six groups of odors, each contained in a separate glass jar. These were (1) underarm odors collected from women while they watched the comedy excerpt (hence Happy odor of women) and (2) odors from the same women while they watched the frightening excerpt (hence Fearful odor of women), (3) underarm odors collected from men while they watched the comedy excerpt (hence Happy odors of men), and from (4) the same men when they watched the frightening excerpt (hence Fearful odor of men); (5) 10 and (6) 12 unused, crumbled cotton pads as controls, to match the number of pads in the odor samples constituted the control sample. Each jar was labeled with a randomly assigned letter on the bottom.

Judgment of Odors

One week later, 40 women and 37 men (including all but one of the Donors) were tested in a session during which they were exposed to the odor pads and asked to identify a Happy or Fearful odor in a double-blind fashion. Subjects were asked to identify each type of odor twice, first on a 3-choice task and then again on a 6-choice task. The sex of the Donors was not mentioned at any time. No feedback about success was provided for any of the tasks.

On two trials, subjects were given three bottles containing odors of female Donors obtained during their viewing the two video excerpts and odors of the unused pads. They were asked to choose a bottle that contained "odors of people when they are happy." The bottle was then returned to the pile where they were thoroughly mixed and scrambled to randomize the order. Subjects were then asked to pick the bottle containing "odors of people when they are afraid." On two other tasks, the procedure was the same except that the three bottles contained odors from the male donors and the unused pads. On the final two tasks, subjects were presented all six bottles and asked to first pick two Happy odors, followed by two Fearful odors. On this last task, some subjects returned the two Happy odors before they identified the two Fearful odors and some did not.

Probability Calculations

The probability of identifying a female Happy odor on both the 3-choice and the 6-choice tasks is $1/3 \times \{1/6 + (5/6 \times 1/5)\}$ or 1/9. The reasoning is the following: 1/3 is the probability to identify it on a 3-choice task, and $\{1/6 + (5/6 \times 1/5)\}$ or 1/3 is the probability to identify it on a 6-choice task. The reasoning for the calculation on the 6-choice task is the following: 1/6 is probability that the first picked bottle contains the female Happy odor, and $5/6 \times 1/5$ is the probability that the second picked bottle contains the female Happy odor, i.e., 5/6 is the probability that the first pick does not contain the female Happy odor, and 1/5 is the probability that the second pick does. In the same fashion, the probability to identify a male Happy odor on both tasks is 1/9.

On the final task, some subjects did not return the two Happy odors from the previous task and picked the two Fearful odors from the remaining four bottles whereas others returned the Happy odors and picked the two Fearful odors from six bottles. The experimenter did not keep a record of how many subjects sampled without replacement. Consequently, the 6-choice task on which subjects identified two Fearful odors was conservatively treated as a 4-choice task that consisted of the two unused control odors, and the two Fearful odors. The probability of identifying a female Fearful odor on both the 3-choice and the 4-choice task is thus: $1/3 \times \{1/4 + (3/4 \times 1/3)\}$ or 1/6 where 1/3 is the probability to identify it on a 3-choice task, and $\{1/4 + (3/4 \times 1/3)\}$ or 1/2 is the probability to identify it on a 4-choice task. Similarly, the probability of identifying a male Fearful odor on both tasks is also 1/6.

Some people may argue that the 6- or 4-choice tasks contain two control odors that are identical, and therefore the two controls should be combined, namely, the 6-choice task should be treated as a 5-choice task, and the 4-choice task a 3-choice task. This suggestion, however, is not appropriate statistically because there is the possibility that both selections chose the control odors, and we need to distinguish them.

Statistical Analyses

Data were analyzed based on the number of women and men who correctly identified a target odor on *both* the 3-choice and 6-choice tasks. Normal approximation to binomial tests (Fleiss, 1981, p. 13), a type of chi-square test, was used to compare the proportion of subjects who identified the same target odor correctly on both tasks with that expected by chance. Tests of equality between two proportions (Fleiss, 1981, p. 23) were performed to compare proportional differences between two independent samples. The effect size was estimated by r (Rosenthal, 1991) which equals z divided by $\sqrt{N}$ when a single proportion is tested, and equals z divided by $\sqrt{(N1+N2)/2}$, when two proportions are tested. According to Cohen (1988), a small effect size for r is .10, a medium effect size is .30, and a large effect size is .50. Chi-squared tests were performed to investigate whether, within each sex, Donors and Nondonors performed differently on each task.

Results

The number of women and men who correctly identified the same target emotion on both the 3-choice and the 6-choice tasks and their percentages are presented in Table 2.

Happiness

As is shown in Table 2, when asked to pick which bottle contained "the odor of people when they are happy," women chose above chance the bottle that contained the body odors collected when the women were Happy (30% vs 11% chance; $z=3.59$, $p \leq .0003$, 2-tailed, $r=.57$). Women also chose above chance the bottle that contained the body odors collected when men were Happy (33% vs 11% chance; $z=4.19$, $p<.0001$, 2-tailed, $r=.66$). Men chose above chance the bottle that contained the body odors collected when women (but not men) were Happy (24% vs 11% chance; $z=2.26$, $p \leq .02$, 2-tailed, $r=.37$). Women were more accurate than men at identifying the Happy odor of men (33% vs 11%; $z=2.05$, $p \leq .05$, 2-tailed, $r=.33$).

TABLE 2

FREQUENCIES AND PERCENTAGES OF FEMALE AND MALE OBSERVERS WHO CORRECTLY IDENTIFIED HAPPY AND FEARFUL ODORS ON BOTH 3- AND 6-CHOICE TASKS

Target Odor	Chance for Tasks		Women ($n=40$)		Men ($n=37$)	
	%	Tasks	*f*	%	*f*	%
Female Happy Odor	11	1 and 5	12	30‡	9	24†
Male Happy Odor	11	3 and 5	13	33‡	4	11
Female Fearful Odor	17	2 and 6	3	8	2	5
Male Fearful Odor	17	4 and 6	18	45‡	11	30*

*$p=.057$. †$p\leq.02$. ‡$p<.001$.

Fear

When asked to pick which bottle contained "the odor of people when they are afraid," both women and men chose above chance (45% of women and 30% of men vs 17% chance) the bottle that contained the body odors collected when men (but not women) viewed the frightening movie ($zs=4.50$ and 1.90, respectively, $p<.0001$ and $p=.057$, 2-tailed, $rs=.71$ and .31). Neither women nor men chose the female Fearful odor above chance.

Donors versus Nondonors

No significant difference in performance was found between male Donors and Nondonors or between female Donors and Nondonors in identifying the female Happy odor, the male Happy odor, the female Fearful odor, and the male Fearful odor, on both tasks ($\chi_1^2=1.97$, .88, .78, and 0, for male Observers, and $\chi_1^2=.44$, 2.57, .03, and .08 for female Observers, $p>.05$). This may be because the odor from each donor constituted only less than 10% of the odors in each bottle.

Some people may question whether the unused cotton control pads had an odor and argue that statistical tests should exclude the control responses. We disagree for the following reasons. First, the unused pads were not odorless but smelled of cotton. Subjects interviewed after the experiment indicated that none of the odors, control or body odors, were strong. The cotton pads used to collect body odors were in contact with the skin for only 13 minutes, a very short period of time compared with a minimum of 8 hours used in other studies (e.g., Russell, 1976; Doty, Orndorff, Leyden, & Kligman, 1978; Chen & Haviland-Jones, 1999). Second, odor-identification patterns on individual tasks (Tables 3 and 4) further suggest that subjects did not perceive the unused cotton pads as odorless; they were not able to discriminate between the control and the body odor on any single task ($p>.05$).

Note that, when asked to identify a Happy odor (female) among three choices (Table 3, Task 1), there was no significant difference in the percentages of women who chose the Fearful odor (23%) or the control (30%)

TABLE 3

FEMALE AND MALE OBSERVERS' IDENTIFICATIONS OF HAPPY AND FEARFUL ODORS ON 3-CHOICE TASKS

Observer's Choice	Target Odor							
	Female Happy Odor Chance=33% Task 1				Female Fearful Odor Chance=33% Task 2			
	Women*		Men		Women		Men	
	f	%	*f*	%	*f*	%	*f*	%
Female Happy Odor	19	48†	12	32	12	30	16	43
Female Fearful Odor	9	23	9	24	12	30	13	35
Control	12	30	16	43	16	40	8	22
	Male Happy Odor Chance=33% Task 3				Male Fearful Odor Chance=33% Task 4			
	Women		Men		Women		Men	
	f	%	*f*	%	*f*	%	*f*	%
Male Happy Odor	18	45	11	30	9	23	10	27
Male Fearful Odor	5	13	4	11	21	53‡	20	54‡
Control	17	43	22	59	10	25	7	19

*Women, $n=40$; Men, $n=37$. †$p=.06$. ‡$p\leq.012$.

as the correct odor ($z=.79$, $p>.05$). Nor was there a significant difference in the percentages of men who chose the correct odor (32%) or the control (43%; $z=1.26$, $p>.05$). When asked to identify a Happy odor (male) among three choices (Table 3, Task 3), there was no significant difference in the percentages of women who selected the control (45%) versus the correct odor (43%), whereas there was a difference in the percentage of men who chose the control (59%) versus the correct odor (30%; $z=3.67$, $p<.0002$). These, however, are not to be confused with subjects' identification of a target odor on a single task. Women identified the female Happy odor on Task

TABLE 4

FEMALE AND MALE OBSERVERS' IDENTIFICATIONS OF HAPPY AND FEARFUL ODORS ON 6-CHOICE TASKS

Observer's Choice	Target Odor							
	Happy Odor Chance=33% Task 5				Fearful Odor Chance=50% Task 6			
	Women*		Men		Women		Men	
	f	%	*f*	%	*f*	%	*f*	%
Female Happy Odor	16	40	15	41	15	38	11	30
Male Happy Odor	21	53†	9	24	8	20	17	46
Female Fearful Odor	16	40	14	38	8	20	9	24
Male Fearful Odor	7	18	10	27	31	78‡	19	51
Control 1	10	25	13	35	9	23	9	24
Control 2	10	25	13	35	9	23	9	24

*Women, $n=40$; Men, $n=37$. †$p\leq.01$. ‡$p<.001$.

1 (48% vs 33% chance; $z=1.85$, $p=.06$, $r=.29$), the male Happy odor on Task 5 (53% vs 33% chance; $z=2.52$, $p \leq .012$, $r=.40$) and Task 6 (78% vs 50% chance; $z=3.38$, $p \leq .0007$, $r=.53$). Men identified the male Fearful odor on Task 4 (54% vs 33% chance; $z=2.54$, $p \leq .01$, $r=.42$).

Discussion

To summarize, the results indicate that (1) human emotional states were accompanied by changes in body odors and (2) women identified the odors better than did men. In particular, women identified above chance the Happy odors of women and men and the Fearful odor of men (but not women) whereas men identified above chance the Happy odor of women (but not men) and the Fearful odor of men (but not women). These findings suggest that the women were better at olfactory identification of emotions in men than the men were themselves. This is consistent with previous findings that women outperformed men at making fine discriminations between hand odors of two individuals of the same sex (Wallace, 1977), at identifying the sex of the donors based on differences in intensity of breath odors (Doty, Green, Ram, & Yankell, 1982), and at identifying their own t-shirt odors from those of others (Lord & Kasprzak, 1989). Moreover, women were better than men at recognizing and identifying synthetic commercial odors and have lower thresholds for some (e.g., Koelega, 1970; Koelega & Koster, 1974; also see review by Doty, 1981). Aside from olfactory sensitivity, women have also outperformed men at deciphering visual and auditory emotional signals in others (e.g., Brody & Hall, 1993). Together with previous research, our findings further suggest that women may be better able to perceive differences associated with emotionally and sociobiologically significant signals.

Research (e.g., Kirk-Smith, Van Toller, & Dodd, 1983; Epple & Herz, 1999) suggests that an odor previously present when subjects completed a stressful task could later activate the stress and fear in the same subjects in the absence of the task. Although many aspects of olfactory recognition and identification may come from learning and conditioning, evidence from animal literature (e.g., Dell'Ome, Fiore, & Alleva, 1994; Fluck, Hogg, Mabbutt, & File, 1996) shows that the detection of and behavioral reaction to certain biologically significant signals, e.g., avoidance of the odor of certain predators, can be inborn. Research also shows that both humans (e.g., see reviews by Ohman, 1993; Ohman, Flysk, & Lundqvist, 2000) and animals (e.g., LeDoux, 1990) are predisposed to attend to certain danger signals quickly and automatically with or without conscious awareness. For example, Globisch, Hamm, Esteves, and Ohman (1999) showed that subjects displayed increased heart rate, blood pressure, and other signs of fear to pictures that contained animals of which they were afraid but not to pictures of flowers and mushrooms, even though the content of both was masked and blocked from subjects' conscious awareness. Our present study, however, did not show that subjects identified the Fearful odors more readily than they did the Happy ones. Although both men and women identified above chance the Fearful odor in men, both also identified the Happy odor in women. This could in part be due to the fact that Donors reported their fear as only moderate, and so it may be that the motivational value of the olfactory cue in the Fearful odors was low.

Individual differences aside, research suggests that, in general, breath and underarm odors of young adult women are less intense than are those of young adult men (e.g., Doty, *et al.*, 1978; Doty, *et al.*, 1982; Chen & Haviland-Jones, 1999). Our finding that women's Fearful odor was not readily identified but men's was, despite identical estimates of self-reported fear, may also suggest that they reacted to the fearful stimuli differently under the circumstance of the experiment. Young adult men under stress might have released a stronger body odor than when they were cheerful and relaxed. By contrast, young adult women under stress might have suppressed their production of body odor.

It is possible that odors were identified by differences in their intensities and pleasantness. Just as stronger and less pleasant odors are more likely to be attributed to men and older people as opposed to women and younger people (Doty, *et al.*, 1978; Doty, 1981; Doty, *et al.*, 1982; Chen & Haviland-Jones, 1999), stronger and less pleasant odors may also be more likely to be assigned as fear. It is possible that odors from men reporting fear were in fact stronger than those from men reporting being happy. If the identifications made by subjects were guided by intensity of odor cues, such guidance appears to have been more salient for the male than for the female subjects. Although intensity of odor was not directly measured in this study, we think intensity alone is not sufficient to explain our finding that female subjects identified not only the Fearful odor in men but also the Happy odors in men and women.

The idea that humans communicate emotions through olfactory signals has long existed in folklore and anecdotes (e.g., Bedichek, 1960; Corbin, 1986). People are said to give off foul odors in their underarms when afraid and sweet odors when happy (e.g., Hearn, 1921, p. 216). We do not claim that our subjects identified the specific Happy and Fearful emotions *per se*. In a real life situation, inferences of happy or fearful feelings in other people based on their behavior alone often have to be validated against the cultural and situational context and against self-report and output from other sensory channels. Our study is, however, the first to indicate that human body odors may change with the emotional states of the odor donors and that such changes can be identified olfactorily. Moreover, we believe that changes in body odor that accompany an emotion, although not to be mistaken for the emotion itself, should be considered associated with that emotion. If the findings of this study hold true in additional studies, they will introduce a new level of complexity in how humans perceive and interact.

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