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Exploration of olfactory aptitude

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Forty-six subjects participated in eight relatively easy tests of olfactory discrimination and information processing: quality discrimination, recognition memory, odor-visual matching, odor-tactile matching, and various types of verbal identification. In half of 28 comparisons, performance on one test correlated significantly with that on another. The results emphasized the underlying importance of discrimination for performance in the tasks of matching and identification. The ease of the tasks produced a ceiling effect. Nevertheless, an effect of age emerged rather clearly in six of the eight tests. In four tests, a quadratic relation between performance and age proved more appropriate than a linear one. In all four cases and in composite functioning across tasks, the quadratic relation implied peak performance between the ages of 32 and 36 years.

Interest in the clinical evaluation of olfaction has stimulated the development of short, readily administered tests (Cain & Krause, 1979). The primary tests include tests of absolute sensitivity (threshold) and identification of familiar odors (Doty, Shaman, Krefetz, & Dann, 1981; Douek, 1974). These two tests serve to distinguish normosmics (i.e., persons with normal olfaction) from hyposmics or anosmics (i.e., persons with diminished or absent olfaction; Cain, 1982; Cain, Gent, Catalanotto, & Goodspeed, 1983).

The range of olfactory disorders, however, includes more than hyposmia and anosmia. It also includes parosmia, or dysosmia, a distorted sense of smell. Some varieties of parosmia, such as cacosmia, manifest themselves as persistent unpleasant olfactory sensations (Doty, 1979). Other distortions, particularly those of central neural origin, may lead to no such subjective complaints, and potential patients with these distortions may never present themselves for diagnosis. We have explored olfactory functioning of patients with a reasonably well-circumscribed neurological lesion, unilateral temporal lobectomy. Those patients voice virtually no complaints of olfactory dysfunction but seem at the very least to have altered quality discrimination (Eskenazi, Cain, Novelly, & Friend, 1983).

In order to gather normative data on possibly useful tests of dysfunction in neurological patients and others, we have begun to assess normosmics on a variety of tasks. The tasks include quality discrimination, odor memory, odor identification, and cross-modality comparisons. The set of tasks covers various types of olfactory processing common in everyday situations. We generally designed tasks that would yield almost, but not quite, perfect performance in normosmics. Administration of most tasks to the same people enabled us to determine whether performance on one task correlated with that on others.

METHOD

Participants

Participants included 46 nonsmokers (24 males, 22 females) with an average age of 35 years (range: 19-68 years) and an average educational level of 13.8 years (range: 9 to 20 years). Occasionally, a participant was not given all tests.

Procedure

The tests, administered in the following order, were:

Quality discrimination. On each of 20 trials, the participant sought to determine which two of three vials contained the same odorant. The odorants consisted of a 1.6% solution (v/v) of 1-carvone, 0.5% ethyl-n-butylamine, 0.01% 2,3-pentanedione, 1% benzaldehyde, and 1% pyridine, diluted to their respective concentrations with odorless-grade diethyl phthalate. The odorants differed considerably in character but had approximately the same perceived intensity.

Odor-recognition memory. Participants attempted to recognize, with one sniff per odorant, which member of a pair of odorants had appeared in the discrimination test. Ten trials occurred almost immediately after the discrimination test (task A) and another 10 trials 30 min later (task B).

Each *old* odor appeared twice in each test, paired randomly with one of 20 distractors or *new* odors of matched perceived intensity: 1% 1-octanol, 1% methyl butyrate, 1% 2-butanone, 1% isopentyl acetate, 1% lavandin, 1% 1-propanol, 0.8% d-p-mentha,6-8-dien,2-one, 1% linalool, 0.8% benzyl acetate, 1% geraniol, 0.8% p-mentha,3-one, 1% d-limonene, 1% linalyl acetate, 1% eugenol, 100% dodecyl alcohol, 100% hexane, 0.8% phenethyl alcohol, 1.6% acetophenone, 1.6% turpentine, and 0.8% anethole.

Odor-visual matching. (This test was given between recognition memory tasks A and B.) The participant sought to point to stimulus-objects that matched odors. The stimuli comprised 15 familiar odorants and their corresponding stimulus-objects. The odorants (stimulus-objects) included: mustard (jar of mustard), tobacco (pipe), black pepper (canister of pepper), maraschino cherry (actual cherry), green olive (actual olive), Band-aid (actual Band-aid), shredded coconut (whole coconut), garlic powder (garlic bulb), bubble gum (bubble gum with wrapper), popcorn (popped kernels), pencil shavings (actual pencil), orange juice concentrate (actual orange),

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and fresh apple (actual apple). The objects sat in a fixed 3×5 array on a table in front of the participant. The odorants, covered by gauze in opaque plastic jars, were presented three times each. The first two presentations of an odorant could occur on any 2 of the first 30 trials, except adjacent trials. The third presentation occurred only after the first two presentations of all odorants. If the participant chose an object incorrectly, the experimenter pointed to the appropriate object.

Odor-tactile matching. Participants were asked to choose by touch the stimulus-objects that corresponded to 10 common odorants. The odorants (stimulus-objects) consisted of tea leaves (tea bag), Ivory soap (bar of soap), wood shavings (block of wood), onion powder (onion bulb), peanut butter (peanuts), newspaper (actual newspaper), banana (actual banana), egg (hard-boiled egg), lemon seasoning (actual lemon), and rubber (segment of garden hose). Each odorant appeared three times, randomized in the same manner as in the visual matching task. Participants wore blindfolds. If the participant chose incorrectly, the experimenter guided the person's hand to the correct object.

Verbal identification I. Participants attempted to identify odorants verbally, choosing from a printed list that contained 10 target odors (baby powder, chewing gum, chocolate, cinnamon, coffee, mothballs, peanut butter, potato chips, soap [bar], and wintergreen) and 10 distractors (burnt paper, garlic, ketchup, pepper [black], rubber, sardines, spoiled meat, tobacco, turpentine, and wood shavings). The 10 target odorants occurred three times, once in each of three blocks of trials. The experimenter provided corrective feedback. For the first 15 participants, testing ended after only one or two presentations if the participant had successfully identified all the odorants.

Verbal identification II. Participants sought to identify 20 stimuli: silver polish, sauerkraut, graham crackers, shoe polish, paprika, baby shampoo, witch hazel, cloves, Brut aftershave, clay, Lysol, beer, oregano, ginger, soy sauce, nutmeg, steak sauce, Playdough, prunes, and cork. Each appeared once. These odorants were chosen because they seemed from pilot experiments relatively difficult to identify in a free recall situation (i.e., without a list of choices).

After attempting to identify the odorant without the benefit of a list of names or an array of stimuli, the participant was given four printed choices and asked to choose the correct one. The choices provided were similar to the test odorant in quality and, thereby, made even this aspect of the task relatively challenging.

RESULTS AND DISCUSSION

Overall Performance

On the average, participants scored above 85% on quality discrimination, recognition memory, odor-visual matching, odor-tactile matching, and verbal identification I. Performance on the discrimination task equalled 87.3%±1.5% (SE). Performance on the matching tasks and on identification I also approached 90% on average and actually exceeded 90% by the third presentation within each task. Performance on recognition memory task A (shorter retention interval) equaled 96%±1.4% (SE) and decreased to only 94%±1.8% (SE) on task B (longer retention interval). This result conforms to previous findings that recognition memory for odors decays quite slowly (Engen, Kuisma, & Eimas, 1973; Lawless & Cain, 1975; Rabin & Cain, 1984). In verbal identification II, participants found it very difficult to identify an odor without choice, scoring only 22%±2.0% (SE). Performance improved considerably, however, when four choices were given: 66%±2.2% (SE).

Correlations Between Tasks

Average performance on the various tasks exhibited some degree of intercorrelation (see Table 1). Of 28 possible comparisons, 14 proved significant. The highest correlation coefficient equaled 0.64, and the average of the significant correlation coefficients equalled 0.46±0.08. Presumably, the strength of correlation would have risen for more challenging tasks.

Discrimination correlated significantly with both matching tasks and with two of the three tests of identification. This outcome seems reasonable on the grounds that ability to discriminate must underlie ability to identify and match. That is, discrimination forms a necessary, though obviously not sufficient, basis for identification. Viewed generically, identification includes matching. Discrimination and identification would not be expected to correlate perfectly, even if the ease of the tasks had not depressed the values.

Visual and tactile matching displayed the highest intercorrelation (r=0.64). Both correlated significantly with verbal identification I and verbal identification II without choice. The pattern of intercorrelations among these various "identification" tasks implies some commonality among them. Nevertheless, possible ceiling effects engendered by the ease of the tasks make it difficult to assess the true degree to which they provide redundant information.

Recognition memory A (shorter interval) correlated significantly with recognition memory B (longer interval); however, each correlated significantly with only one other

Table 1
Correlations Between the Olfactory Tests

	Recognition Memory		Visual Matching	Tactile Matching	Verbal Identification I	Verbal Identification II	
	A	B				Without Choice	With Choice
Discrimination	.11	.19	.41†	.43†	.48†	.46†	.10
Recognition Memory A (Shorter Interval)		.44†	.36*	.29	.01	.23	.02
Recognition Memory B (Longer Interval)			.22	.21	.04	.42†	.10
Visual Matching				.60†	.56†	.53†	.29
Tactile Matching					.32*	.40†	.18
Verbal Identification I						.48†	.27
Verbal Identification II: Without Choice							.46†

*$p < .05$. †$p < .01$.

test: recognition memory A with visual matching and recognition memory B with identification II without choice. Neither memory task correlated significantly with discrimination. The pattern of intercorrelations between memory and the other tasks seems at first to suggest that this process may operate basically independently of other abilities, although it could hardly operate entirely independently of discrimination. Upon closer scrutiny, it seems that a ceiling effect operated more strongly for recognition memory than for other tasks. More than half the time, participants achieved perfect recognition scores, an outcome that would undoubtedly depress correlations with other tasks.

Olfactory Performance and Age

There exists little doubt that aging ultimately impairs olfactory ability (e.g., Schemper, Voss, & Cain, 1981; Schiffman & Leffingwell, 1981; Stevens, Plantinga, & Cain, 1982). Although most studies have compared only young versus elderly participants, some data imply that age takes its toll on olfaction gradually throughout adulthood. In an authoritative adult life-span study, Venström and Amoore (1968) found that absolute sensitivity declined slowly, by a factor of two with each decade of life, in the range 20-70 years. This actually represents a rather small net change per decade in view of the dynamic range of olfaction. The present investigation, which employed stimuli of supraliminal intensity, also implied a gradual change of functioning but sometimes a slightly nonmonotonic one.

Table 2 shows correlation coefficients for performance versus age (see also Figure 1). In the cases of odor-visual matching, verbal identification I, verbal identification II without choice, and recognition memory B, there was a significant negative linear correlation between performance and age. In two instances, odor-visual matching and verbal identification I, a curvilinear (quadratic) equation gave a significantly higher correlation coefficient. In two other instances, discrimination and odor-tactile matching, only the curvilinear equation gave significant coefficients. Only verbal identification II with choice and recognition memory A failed to correlate significantly with age.

For all the significant curvilinear fits, the equations reached a maximum at an age between 24 and 36. For those curvilinear fits that improved significantly on linear fits, the equations reached a maximum at an age between 32 and 36. Despite this outcome, the curvilinear functions in Figure 1 seem more impressive in the flatness than the sharpness of their peaks. Over the range of ages studied here, the decline of performance after about age 40 certainly seems more important than any increase in performance through the 20s and early 30s. An age distribution that included younger ages would presumably reveal whether performance does indeed peak during adulthood. For such tasks as odor matching and identification of real-world odors, a peak in adulthood seems quite conceivable (Cain, 1980).

At least some of the scatter seen in Figure 1 may have occurred because each task tapped only a small sample of olfactory aptitude. Hence, a composite index across tasks might reduce the scatter and give a clearer picture of the relation between aptitude and age. Figure 2 depicts such an index, namely, average performance for each participant across the following tasks: (1) discrimination, (2) recognition memory (average of scores for A and B), (3) odor-visual matching, (4) odor-tactile matching, (5) odor identification I, and (6) odor identification II (average of scores for with and without choice). The internal averaging of recognition memory A and B and of odor identification II with and without choice was done in order to give proper weight in the composite index to performance on the six different sets of odorants used in the investigation.

The composite results in Figure 2 do indeed show less scatter than do the task-by-task results in Figure 1. A quadratic equation provided a significantly better fit [$r = -0.67$ (peak age: 33)] than did a linear equation [$r = -0.57$; $F(1,34) = 8.13$; $p < .01$]. Despite the better fit of the curvilinear equation over a single linear equation, we can reasonably entertain the notion that performance bears no relation to age between ages 20 and 40 but declines thereafter. To illustrate this possibility, we can note that a linear correlation between age and composite performance equaled +0.08 for persons under age 40 and −0.89 for persons over age 40. Neither the curvilinear relation nor the dual-linear relation conforms to expectations derived from Venström and Amoore's (1968) finding of a progressive decline in sensitivity after age 20. As mentioned above, the relation between absolute sensitivity and suprathreshold functioning remains murky. Recently, Doty et al. (1984) found a gradual and nonmonotonic change with age in a clinical scratch and sniff test. Hence, it would

Table 2
Correlation of Olfactory Performance with Age

	Linear Function		Curvilinear Function		Peak Age	Change in Correlation
Olfactory Tests	*r*	*p*	*r*	*p*	years	*p**
Discrimination	−0.20	n.s.	−0.52	0.002	32	0.01
Recognition Memory A	+0.10	n.s.	+0.19	n.s.		n.s.
Recognition Memory B	−0.45	0.01	−0.51	0.002	29	n.s.
Visual Matching	−0.42	0.01	−0.59	0.002	33	0.01
Tactile Matching	−0.19	n.s.	−0.46	0.002	36	0.01
Verbal Identification I	−0.46	0.01	−0.59	0.002	33	0.01
Verbal Identification II:						
Without Choice	−0.42	0.002	−0.51	0.002	24	n.s.
With Choice	−0.08	n.s.	−0.09	n.s.		n.s.

**p* values calculated to determine significance of the difference between linear and curvilinear fits.

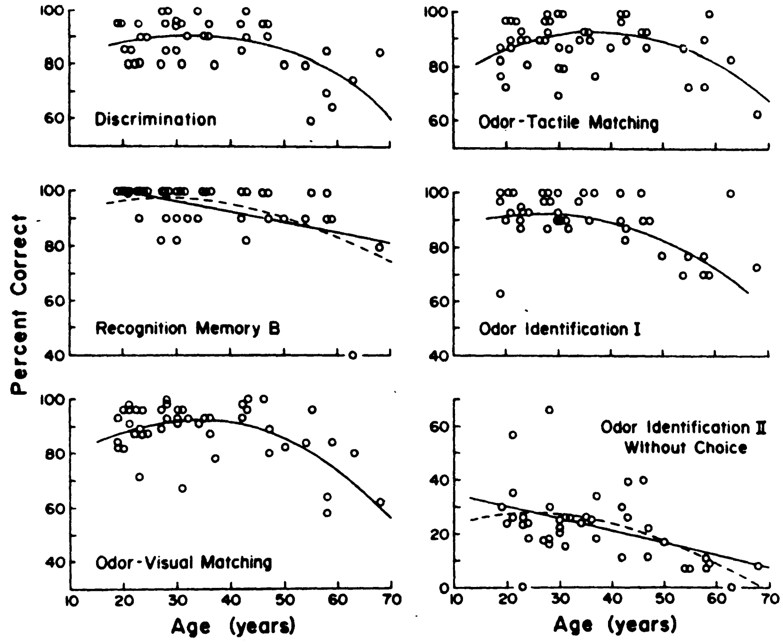

Figure 1. Scatterplots of performance versus age for those cases in which a significant correlation occurred. In the cases of discrimination, odor-visual matching, odor-tactile matching, and odor identification I, curvilinear functions yielded significantly better correlations than did linear correlations. In the cases of recognition memory B (longer interval) and odor identification II without choice, curvilinear functions (dashed lines), although significant, did not improve significantly on linear functions (solid lines).

appear that the relation between age and olfaction may depend on the type of tests employed.

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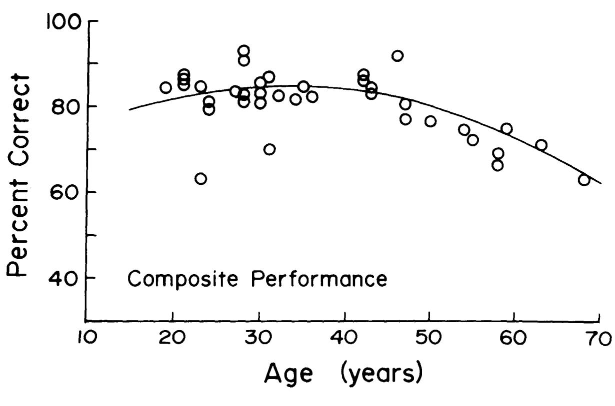

Figure 2. Composite performance on all tasks versus age.

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