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Taste Thresholds in Twins and Siblings[1, 2]

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Introduction

Taste thresholds for the majority of compounds follow monomodal or approximately ' Gaussian ' distributions. Quinine is a bitter-tasting representative of these ' Gaussian ' compounds, and a positive correlation has been observed between high taste threshold for quinine and high thresholds for a large number of other substances, including sodium chloride, sucrose, urea, phenylalanine, amphetamine, chlorpromazine, methlylene blue, *etc.* (Fischer and Griffin, 1964). Pedigree and population studies of taste thresholds, however, have been largely limited to the bitter-tasting phenylthiourea (' PTC ') type antithyroid compounds containing the characteristic H-N-C = S grouping. Taste thresholds for members of this group, which includes 6-n-propylthiouracil (PROP), 1-methyl-2-mercaptoimidazole, *etc.*, follow bimodal distributions in a population. Fox (1931) characterized the individuals belonging to one mode as " tasters " and those belonging to the other mode as " nontasters " of ' PTC ' (after ' phenylthiocarbamide ', a misnomer for phenylthiourea) and related compounds (Fox, 1932). Blakeslee and Salmon (1931) and, independently, Snyder (1931) observed that inability to taste phenylthiourea appeared to be inherited in

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a simple mendelian recessive manner. These observations were supported by the family studies of Snyder (1932), who tested members of 800 families with phenylthiourea crystals; and by those of Blakeslee (1932), who tested members of 103 families with phenylthiourea solutions.

All the published taste studies of phenylthiourea employed the compound in one of three forms — as crystal, in solution, and as phenylthiourea-impregnated filter paper. Much of the significance of many of the published data has been attenuated by the demonstration of Hartmann (1939) that both the PTC crystal and paper tests were significantly less reliable than the solution test. Procedural improvements for determining taste thresholds with solutions were reported by Harris and Kalmus (1949), who used " a few c.c. in a tumbler " and preliminary as well as final sorting procedures. The most recent and extensive genetical studies based on this improved methodology were those by Merton (1958), Kalmus (1958), and Leguèbe (1960). Additional testing refinements were described by Fischer, Griffin, England, and Pasamanick (1961), which methodology included use of the odorless phenylthiourea-type compound, 6-n-propylthiouracil. Fischer *et al.* also stressed the observation of an optimal taste-testing volume of five ml per cup; the importance of a between-sample mouth rinse; and the use of distilled water instead of tap water. The literature in general has supported the genetic explanation advanced by Snyder (1931) and Blakeslee and Salmon (1931), although pedigree and twin data have not entirely confirmed the classical genetic hypothesis (Ardashnikov, Lichtenstein, Martynova, Soboleva, and Postnikova, 1936; Rife, 1938; Harris and Kalmus, 1951; Das, 1956 and 1957; Kalmus, 1957; Merton, 1958; Dencker, Hauge, and Kaij, 1959; Verkade, Wepster, and Stegerhoek, 1959; Sutton, de LaMadrid, and Esterer, 1962). Some of the discrepancies may be of methodological origin. The use of phenylthiourea, which is an odorous and toxic compound, for example, implies the uncontrolled variable of differential olfactory sensitivities. Furthermore, most of the reported discrepancies have involved subjects whose thresholds occurred at or near the antimode in the curve of population distribution. This observation is in agreement with the hypothesis that the bimodal curve showing a population's distribution of taste thresholds for phenylthiourea type compounds reflects the superimposition of two distinct distribution curves, one curve for insensitive homozygotes (tt) superimposed upon another curve for heterozygotes (Tt) and sensitive homozygotes (TT).

The present study has reexamined taste thresholds in twins and siblings for quinine sulfate and hydrochloric acid, two ' Gaussian ' compounds; and for 6-n-propylthiouracil (PROP), a ' bimodal ' compound. Ancillary taste threshold data were also obtained for relatives who were persuaded to cooperate.

Material and methods

Subjects

Taste thresholds for l-quinine sulfate and 6-n-propylthiouracil have been determined for a total of 145 twin pairs and 78 nontwin sibling pairs. A part of the sample,

comprising 71 of the twin pairs and 45 of the nontwin sibling pairs, were also taste-tested for hydrochloric acid. Contacts with the subjects were established through the Cleveland Area Twin Registry and Mothers-of-Twins Clubs in the greater Cleveland area. The large majority (over 85 percent) of the subjects were between five and 18 years of age, but older twin and sibling pairs were also tested and included in the present analysis. The stated zygosity was corroborated in every case by checking morphological features such as shape of head, ears, nose, and mouth; finger and palm dermatoglyphic patterns; skin, hair, and eye pigment; hair patterns; and relative toe lengths. In addition, the MZ twin diagnoses for 25 pairs of twins were checked by typing for the following blood factors: A, B, M, N, S, C, c, D, E, e, Kell, Fy^a, Jk^a, and P. This group included one pair of allegedly questionable zygosity, which proved to be DZ, and 24 of 76 allegedly MZ pairs (*i.e.*, each third pair whenever possible), one of which proved to be DZ. Blood typing and determinations of MZ-DZ zygosity probabilities for all the twin subjects would have been preferable, but this was not possible. The effect on our results of any undetermined discrepancy regarding zygosity would have been to decrease evidence for genetic involvement.

Procedure

Taste thresholds were determined according to the modified version of the procedure described by Harris and Kalmus (1949) involving double-blind placebos and final sorting technique. The procedure has proved to be the most reliable of the published methods for determining taste thresholds. Serial dilutions of the compounds were prepared by dissolving each substance in distilled water, in concentrations ranging from 7.32×10^{-7} M to 6.00×10^{-3} M. Each solution number represents twice the concentration of the preceeding solution number, as shown in Tab. 1. The highest

Tab. 1. Molar concentrations of all taste test solutions

Solution N.	Molarity	Solution N.	Molarity
1	7.32×10^{-7}	9	1.88×10^{-4}
2	1.46×10^{-6}	10	3.75×10^{-4}
3	2.93×10^{-6}	11	7.50×10^{-4}
4	5.86×10^{-6}	12	1.50×10^{-3}
5	1.17×10^{-5}	13	3.00×10^{-3}
6	2.34×10^{-5}	14	6.00×10^{-3}
7	4.69×10^{-5}	15	1.20×10^{-2}
8	9.38×10^{-5}		

solution number of PROP (6-n-propylthiouracil, U.S.P.), 14, is prepared by dissolving 1.0212 gm of the compound in 1.0 liter of distilled water. The highest solution number of quinine (l-quinine sulfate, U.S.P.), 13, is prepared by dissolving 1.1744 gm of the compound in 1.0 liter of distilled water. The highest concentration of

hydrochloric acid is a 0.012 M solution, corresponding to solution number 15. A subject's threshold, expressed as a solution number, is defined as the lowest concentration correctly differentiated from placebos. Estimation of the threshold at room temperature is first accomplished by offering the subject cups containing solutions of progressively doubled concentrations of a compound together with cups containing distilled water, in a double-blind manner, until he experiences a difference in taste between solution and placebo. Next, the threshold is determined by presenting the subject four cups of the solution which was clearly differentiated (5 ml per cup) and four cups of placebo (5 ml distilled water per cup) in a double-blind manner. The subject is then expected (with this " forced choice ") to accurately sort the cups into two groups, solutions and placebos. During the whole procedure, he is required to rinse his mouth with distilled water prior to and after tasting the contents of each cup. Due to the strong affinity of phenylthiourea type compounds for taste receptor cells, which results in an increase of threshold for certain subsequently-tasted compounds, the testing was performed in the following sequence: hydrochloric acid, quinine, and 6-n-propylthiouracil. If a subject was tested only for the latter two compounds, the threshold for quinine was determined first. The testing of a subject for all three compounds required about 45 minutes. Data regarding age and smoking habits were obtained from questionnaires completed by the subjects. Reproducibility of threshold was determined by retesting all available subjects after intervals ranging from two weeks to 14 months.

Data Treatment [8]

A preliminary factorial analysis of variance was performed on the threshold values from the first testing sessions for each compound using all the subjects in each group. The dual factors tested were genetic kinship and sex. No significant variations between different groups were found regarding taste thresholds for quinine or for PROP. There was a significant variation in intrapair differences between the sexes regarding thresholds for hydrochloric acid, statistically significant at less than .001 (F (1/224) = 18.84). Tab. 2 presents the mean thresholds and variances for each compound and the numbers of subjects involved.

Intrapair differences in taste thresholds obtained during the subjects' initial testing sessions were obtained for monozygotic twin (MZ), dizygotic twin (DZ) and sibling (SIB) pairs of the same and of opposite sex. A summary of these data is presented in Tab. 3. The within-pair variances of the MZ and DZ groups were obtained, the difference values for male and female like-sex pairs being combined (the values indicated in Tab. 3). Comparisons of these variances with each other were

[8] The variances of the means of the raw differences were not independent of the sizes of their means. The differences were therefore transformed into their reciprocals, which made them independent (which would not have been accomplished by a logarithmic transformation). Analyses parallel to those reported in the text were performed with the transformed values, and comparable results were obtained in all instances. For this reason, only the raw data are reported.

Tab. 2. Means and variances (σ^2) of taste thresholds for hydrochloric acid (HCl), 1-quinine sulfate (Quinine), and 6-n-propylthiouracil (PROP)

	HCl* ♀♀	HCl* ♂♂	Quinine (all groups combined)	PROP** (all groups combined)
N. of subjects	124	108	446	446
Mean	9.85	10.55	5.28	9.55
σ^2	1.51	1.65	3.24	5.95

* Significant difference in thresholds between females and males at $p < .001$
** No significant difference in thresholds among groups at $p < .20$

Tab. 3. Mean ($\bar{x}$), variance (σ^2), within-pair variance (σ^2_w), and number of pairs (N) of intrapair differences in thresholds for HCl, quinine, and PROP

	MZ		DZ			SIB		
	♀♀	♂♂	♀♀	♂♂	♀♂	♀♀	♀♂	♀♂
HCl								
$\bar{x}$	1.29	.44	.87	1.27	1.68	1.00	1.32	1.00
σ^2	1.02	.30	.41	.83	1.72	1.18	2.13	1.50
σ^2_w	1.29	.22	.57	1.18	2.21	.88	2.12	1.93
$*\sigma^2_w$	.92		.83			1.47		
N	17	9	15	11	19	18	22	5
Quinine								
$\bar{x}$	1.31	1.26	1.70	1.65	1.84	1.53	1.28	1.68
σ^2	1.68	2.46	2.32	2.57	1.40	1.84	1.64	1.67
σ^2_w	1.62	1.93	2.56	2.53	2.34	2.00	1.46	3.96
$*\sigma^2_w$	1.71		2.55			1.77		
N	52	23	34	17	19	30	29	19
PROP								
$\bar{x}$	.88	.74	2.62	2.88	1.68	2.50	2.86	1.63
σ^2	1.22	.62	5.88	5.17	2.32	4.46	5.48	2.58
σ^2_w	.96	.54	6.22	6.56	2.53	4.63	5.23	4.57
$*\sigma^2_w$	.83		6.33			4.88		
N	52	23	34	17	19	30	29	19

* Like-sex pairs combined.

made for each compound, with DZ variance as numerator in each case. This statistical procedure has been described in detail and recommended by Kempthorne and Osborne (1961). More detailed comparisons of the within-pair variance among the three kinship categories and the two sexes were also considered important for evalu-

ating the data with regard to genetic influence. Therefore, two factorial analyses of variance were made of the various comparisons for each compound. The first analysis compared the three kinship pairings, MZ, DZ, and SIB, and two same-sex pairings, DZ and SIB, and the three sex pairings, female, male, and opposite sex. An unweighted-means solution was used because the unequal sample sizes did not reflect the proportions of the groups found in the population. Whenever significant F ratios were found, a statistical comparison between the DZ and SIB groups was made. If the DZ and SIB groups were not significantly different from each other, they were combined and compared to the MZ group. A full explanation of these statistical methods has been detailed by Winer (1962).

The differences observed between results obtained in the first and second test sessions are shown in Tab. 4. These data were obtained from 44 subjects retested for hydrochloric acid, 221 for quinine, and 225 for PROP. There was no marked tendency for thresholds determined during the second test to be either higher or lower than the initial thresholds. When the thresholds of males and females were considered together, the proportions of the subjects with taste thresholds stable within a

Tab. 4. Comparisons of taste thresholds determined at initial and at second testing sessions for hydrochloric acid (HCl), l-quinine sulfate (Quinine), and 6-n-propylthiouracil (PROP). The second tests were performed two weeks to 14 months after the initial tests

Solution		N. of subjects retested	Threshold difference at retest														
			+7	+6	+5	+4	+3	+2	+1	0	−1	−2	−3	−4	−5	−6	−7
HCl	♀	14						1	1	5	4	3					
	♂	30					2	2	6	10	6	2	2				
Quinine	♀	144				1	1	10	27	58	33	9	2	2			1
	♂	77	1		1	3	3	7	22	21	9	7	2		1		
PROP	♀	145		1			4	10	29	59	28	7	4	2	1		
	♂	80					5	6	18	24	13	5	4	3	1		1

range of ± 1 threshold were 72.9% for hydrochloric acid, 76.9% for quinine, and 76% for PROP.

The PROP threshold distribution curve in our population sample shows the expected bimodality, with the antimode at solution number 10. The concentration in molarity of this particular PROP solution corresponds most closely to solution number 5 in the phenylthiourea series of Harris and Kalmus (1949), as tabulated by Fischer and Griffin (1964). Subjects whose thresholds occur within the low-threshold mode of the bimodal PROP distribution curve were classified as " tasters ", whereas those with thresholds within the other mode were classified as " nontasters ". We then determined the various intrapair concordance-discordance proportions for PROP, basing the dichotomy on the location of the antimode.

Results

DZ/MZ WITHIN-PAIR VARIANCE

For each compound, the DZ within-pair variance was compared to the MZ within-pair variance, in which the male and female same sex pairs were combined for each genetic group. The obtained ratio (*i.e.*, DZ σ_w^2/MZ σ_w^2) is an F ratio associated with particular probability values. For hydrochloric acid, F (25/25) = .90, $p > .10$. For quinine, F (50/74) = 1.49, $p > .05$. For PROP F (50/74) = 7.63, $p < .001$.

ANALYSIS OF VARIANCE, FACTORIAL DESIGN FOR EACH COMPOUND

The findings described below relate only to the first analysis (*i.e.*, DZ, MZ, and SIB kinship pairings, female and male same-sex pairings). In no instance in the second analysis (*i.e.*, DZ and SIB kinship pairings, male, female, and opposite-sex pairings) was any F ratio statistically significant at $p < .10$.

For hydrochloric acid, the kinship-by-sex interaction was significant at $p < .02$ ($F = 3.91$, $df = 2/86$). Individual comparisons are shown in Tab. 5. The intrapair variance in male MZ twins was significantly less than that in the female MZ twins. The male MZ pairs had significantly smaller intrapair differences than the male DZ

Tab. 5. Grouping of ordered means of differences between pairs for hydrochloric acid. The means underlined with a common line are not different from each other. (MS error of analysis of variance = 1.12)

Sex	DZ	SIB	MZ
♀♀ *	.87	1.00	1.29
	MZ ***	DZ	SIB
♂♂ **	.44	1.27	1.32

* Within ♀♀ group, there is no significant difference between means ($p > .10$)

** Within ♂♂ group, DZ and SIB pairs do not differ significantly from each other ($p > .20$). MZ pairs are significantly different from DZ and SIB pairs combined, at $p < .01$

*** MZ ♂♂ intrapair difference is significantly smaller than MZ ♀♀ intrapair difference, at $p < .02$. Other within-kinship differences are not statistically significant ($p > .10$)

and SIB pairs ($p < .01$). The intrapair differences between the male DZ pairs and male SIB pairs were not significantly different from each other, and these two groups of data were therefore combined.

For quinine, there were no significant differences between any of the main factors or their interaction.

For PROP, the kinship factor was significant at a level of $p < .001$ ($F = 19.12$, $df = 2/179$). Individual comparisons are shown in Tab. 6. The MZ pairs had significantly smaller intrapair differences than the DZ and SIB pairs ($p < .001$). The intrapair differences between the DZ and the SIB pairs were not significantly different from each other, and these two groups of data were therefore combined.

Tab. 6. Grouping of ordered means of differences between pairs for PROP. The means underlined with a common line are not different from each other. (MS error of analysis of variance = 3.48)

Kinship with sexes combined		
MZ	SIB	DZ
.84 *	2.37 **	2.70

* MZ pairs differ significantly from DZ and SIB pairs combined, at $p < .001$
** DZ and SIB pairs do not differ significantly from each other ($p < .20$)

Correlations between thresholds for the three compounds

The PROP thresholds of MZ twins with differing quinine thresholds were examined, to determine whether the co-twins with the higher quinine thresholds also tended to have higher PROP thresholds. The quinine thresholds of 53 pairs of MZ twins differed by one or more thresholds. In 14 of these pairs, the same co-twin manifested the higher threshold for each of the two substances; in 22 of these pairs, both co-twins had the same PROP thresholds despite their differences in quinine thresholds; and in 17 of the 53 pairs, the co-twins with the lower quinine thresholds had the higher PROP thresholds. Apparently, independent factors influence the intrapair taste threshold differences observed in MZ twins for the two bitter-tasting drugs, quinine and PROP.

The thresholds determined for 308 individuals were analyzed, including those subjects whose data were examined above (*i.e.*, in analyses of twin pairs and non-twin sibling pairs) and those of their parents who were tested. Tab. 7 indicates the distribution of thresholds for PROP versus those for quinine. The product-moment correlation coefficient, r, between thresholds for these two compounds = $0.44 \pm .05$, which is significant at the level of $p < .01$. Tab. 8 indicates the distribution of thresholds for quinine versus those for hydrochloric acid. The product-moment correlation coefficient, r, between the raw threshold values for these two compounds = $0.35 \pm .05$, which is also significant at the level of $p < .01$. Tab. 9 indicates the distribution of thresholds for PROP versus those for hydrochloric acid. The correlation coefficient between the two, for which $r = 0.17 \pm .06$, is significant at the level of $p < .05$.

Tab. 7. Distribution of taste thresholds for 6-n-propylthiouracil (PROP) and 1-quinine sulfate (Quinine) in 308 individuals

PROP solution N.	Quinine solution N. 1	2	3	4	5	6	7	8	9	10	>10	Total subjects
>14							4	2	2	1		9
14			2			4	3	2	1	1	1	14
13			3	2	1	5	7	5	2	2		27
12	1	1	2	1	14	8	13	4				44
11		3		4	11	4	5	1	1	1		30
10	1		2	1	9	5	5	2	2			27
9			9	7	11	9	7	3	1			47
8	1	2	11	16	7	12	7					56
7	1	1	4	9	6	8	3	1				33
6			10	1	3	2						16
5			1				:					2
4		1										1
3					1							1
2												
1				1								1
Total	4	8	44	42	63	57	55	20	9	5	1	308

Tab. 8. Distribution of taste thresholds for 1-quinine sulfalte (Quinine) and hydrochloric acid (HCl) in 308 individuals

Quinine solution N.	Hydrochloric acid solution N. 5	6	7	8	9	10	11	12	13	14	Total subjects
>10						1					1
10							1	3	1		5
9				1	1	1	4	2			9
8				1	1	3	8	4	1	2	20
7				2	6	11	20	10	4	2	55
6			1		10	19	19	6	1	1	57
5	1			3	14	26	14	5			63
4				1	7	17	13	4			42
3			1	4	8	19	10	1	1		44
2			1	2	3		2				8
1		1			1	2					4
Total subjects	1	1	3	14	51	99	91	35	8	5	308

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Tab. 9. Distribution of taste thresholds for 6-n-propylthiouracil (PROP) and hydrochloric acid (HCl) in 308 individuals

PROP solution N.	Hydrochloric acid solution N.										Total subjects
	5	6	7	8	9	10	11	12	13	14	
>14					1		5	3			9
14					3	3	2	6			14
13				1	3	6	9	6	2		27
12	1		1	4	4	17	13	1		3	44
11				1	6	11	8	3	1		30
10					4	5	12	6			27
9				2	6	21	15	1	1	1	47
8		1	2	5	6	17	16	6	2	1	56
7					9	13	7	3	1		33
6				1	5	5	4		1		16
5					2						2
4					1						1
3					1						1
2											
1						1					1
Total subjects	1	1	3	14	51	99	91	35	8	5	308

INTRAPAIR CONCORDANCE FOR PROP THRESHOLD PHENOTYPE

With the antimode separating subjects whose PROP thresholds were below 10 from those whose thresholds were 10 or higher, 68 of the 75 MZ twins (90.7%) were concordant. For the DZ twins, 28 of the 51 same-sex pairs (54.9%) were concordant. A χ^2 test performed on these data yielded a value of $\chi^2 = 21.18$, significant at $p < .001$ with two *df*. The percentage of concordant DZ opposite-sex pairs is not significantly different from the DZ same-sex pairs' percentage: $\chi^2 < 1.00$, $p > .50$ with one *df*.

Discussion

Most of the previous genetic and population studies were carried out with phenylthiourea, an odorous and the most toxic representative of its class. PROP is the least toxic of the phenylthiourea type compounds (Eichholtz, 1956) and, as a currently marketed drug, PROP is available in pure form. By contrast, phenylthiourea contains a variety of aromatic impurities even in recrystallized form. Half-saturated aqueous solutions as well as lower concentrations of PROP are odorless, compared to the distinct aromatic odor of phenylthiourea solutions (Skude, 1963) in all testing

concentrations. Furthermore, PROP has been shown to be at least as good a differentiator between " tasters " and " nontasters " as phenylthiourea. Taste thresholds for the two compounds were shown to have a high positive correlation ($r = + 0.873$) in a study on 66 subjects (Fischer, Griffin, and Pasamanick, 1965), and the positive correlation was even higher on second tests.

The intrapair differences observed in our sample of monozygotic twins indicate that nongenetic factors also influence taste thresholds. We have observed, for example, changes in taste thresholds in some subjects associated with such medications as thyroid extract, aspirin, estrogens, and anticholinergic drugs. Another observation showed the occurrence of threshold differences significantly associated with smoking habits: specifically, heavy smoking over a period of years tends to increase taste thresholds, while smoking habits apparently had no significant effects on taste thresholds of subjects 20 years old and under (Kaplan, Glanville, and Fischer, 1965). Since more than 90 percent of our subjects were age 20 or under, and more than 80 percent were nonsmokers, the influence of smoking on taste threshold was excluded in the present study.

Fluctuations in taste sensitivity in relation to the menstrual cycle may have been another factor contributing to twin discordance in taste threshold, since some females have been observed to shift between the " taster " and " nontaster " categories during the cycle (Glanville and Kaplan, 1965). Concordance rates observed in twin pairs may also be affected by the co-twins' exposures to similar taste experiences through dietary routines. Similar environments and routines may confound effects of " the genetic family and the behavioral family " (Rosenthal, 1964). In this regard, Fischer and Griffin (1964) found that taste practice may considerably lower a subject's thresholds for various compounds.

The MZ:DZ ratios of our samples do not reflect the general U. S. proportions (*i.e.*, about 33-40% MZ). Apparently, the Cleveland area families with MZ twins have been more inclined than those with DZ twins to seek affiliations with Mothers-of-Twins Clubs and/or to volunteer cooperation in our research projects.

The relative importance of genetic factors for each of the three compounds may be assessed by comparing intrapair threshold differences of the MZ and the same-sex DZ twin pairs. A preceding study involving smaller numbers of twins (Kaplan and Fischer, 1965), and the present study, have shown that the intrapair differences of raw threshold scores between the two twin categories was greatest for PROP, less for quinine, and least for hydrochloric acid.

Summary

Monozygotic twin (MZ), dizygotic twin (DZ), and sibling (SIB) pairs were taste-tested for hydrochloric acid, l-quinine sulfate, and 6-n-propylthiouracil (PROP). The numbers of pairs involved were 75 MZ, 70 DZ, and 78 SIB, for the latter two compounds; 26, 45, and 45, respectively, for the acid.

There was a significant difference in intrapair variance, between the MZ and the same-sex DZ pairs, in thresholds for bitter-tasting 6-n-propylthiouracil ($p < .001$). The difference in intrapair threshold variance was not significant for bitter-tasting quinine ($p > .05$) or for sour-tasting hydrochloric acid ($p > .10$).

The male MZ pairs had a significantly lower intrapair threshold variance than the male DZ or male SIB pairs for hydrochloric acid ($p < .01$), but the female pairs manifested no such difference. The intrapair variance in hydrochloric acid threshold was significantly less for the nine male MZ pairs than for the 17 female MZ pairs ($p < .02$).

Repeated taste tests on the same subjects reproduced results similar within a single threshold range in a high proportion for each compound: for hydrochloric acid, 72.9% (N = 44); for quinine, 76.9% (N = 221); and for PROP, 76% (N = 225).

Correlations between thresholds for the different substances were positive and significant (N = 308): between PROP and quinine, $r = + 0.44 \pm .05$ ($p < .01$); between quinine and hydrochloric acid, $r = + 0.35 \pm .05$ ($p < .01$); between PROP and hydrochloric acid, $r = + 0.17 \pm .06$ ($p < .05$).

Bibliography

Ardashnikov S. N. *et al.* (1936). The diagnosis of zygosity in twins (Three instances of difference in taste acuity in identical twins). *J. Hered.*, **27**: 465-468.

Blakeslee A. F. (1932). Genetics of sensory thresholds: taste for phenylthiocarbamide. *Proc. Nat. Acad. Sci.*, **18**: 120-130.

— Salmon M. R. (1931). Odor and taste blindness. *Eug. News*, **16**: 105-109.

Das S. R. (1956). A contribution to the heredity of the P.T.C. taste character based on a study of 845 sib-pairs. *Ann. Hum. Genet.*, **20**: 334-343.

— (1957). Inheritance of the P.T.C. taste character in man: An analysis of 126 Rarhi Brahmin families of West Bengal. *Ann. Hum. Genet.*, **22**: 200-212.

Dencker S. J. *et al.* (1959). An investigation of the PTC taste character in monochorionic twin pairs. *Acta Genet.*, **9**: 236-244.

Eichholtz F. (1956). Die toxische Gesamtsituation auf dem Gebiet der menschlichen Ernährung. Springer Verlag, Berlin.

Fischer R., Griffin F. (1964). Pharmacogenetic aspects of gustation. *Drug Research* (Arzneim.-Forsch.) **14**: 673-686.

— *et al.* (1961). Biochemical-genetic factors in taste polymorphism and their relation to salivary thyroid metabolism in health and mental retardation. *Med. Exp.*, **4**: 356-366.

— *et al.* (1965). The perception of taste: some psychophysiological, pathophysiological, and clinical aspects. *In*: Psychopathology of Perception. Hoch P. & Zubin J. Ed. (New York: Grune & Stratton): 129-164.

Fox A. L. (1931). Tasteblindness. *Science* (Suppl.) **73**: 14.

— (1932). The relation between chemical constitution and taste. *Proc. Nat. Acad. Sci.*, **18**: 115-120.

Glanville E. V., Kaplan A. R. (1965). The menstrual cycle and sensitivity of taste perception. *Amer. J. Obst. Gyn.*, **92**: 189-194.

Harris H., Kalmus H. (1949). The measurement of taste sensitivity to phenylthiourea (P.T.C.) *Ann. Eugen.*, **15**: 24-31 and 32-45.

— — (1951). The distribution of taste thresholds for phenylthiourea of 384 sib pairs. *Ann. Eugen.*, **16**: 226-230.

Hartmann G. (1939). Application of individual taste difference towards phenyl-thio-carbamide in genetic investigations. *Ann. Eugen.*, **9**: 123-135.

KALMUS H. (1957). Defective colour vision, P.T.C. tasting, and drepanocytosis in samples from fifteen Brazilian populations. *Ann. Hum. Genet.*, **21**: 313-317.
— (1358). Improvements in the classification of the taster genotype. *Ann. Hum. Genet.*, **22**: 222-230.
— (1958). Improvements in the classification of the taster genotype. *Ann. Hum. Genet.*, **22**: 222-230.
KAPLAN A. R., FISCHER R. (1965). Taste sensitivity for bitterness: some biological and clinical implications. *In*: Recent Advances in Biological Psychiatry, Vol. VII, *Wortis J.* (New York: Plenum Press): 183-196.
— *et al.* (1965). Cumulative effect of age and smoking on taste sensitivity in males and females. *J. Gerontol.*, **20**: 334-337.
KEMPTHORNE O., OSBORNE R. H. (1961). The interpretation of twin data. *Amer J. Hum. Genet.*, **13**: 320-339.
LEGUÉBE A. (1960). Génètique et anthropologie de la sensibilité à la phénylthiocarbamide. *Bull. Inst. Roy. Sci. Nat. Belgique*, **26**: 1-27.
MERTON B. B. (1958). Taste sensitivity to PTC in 60 Norwegian families with 176 children. Confirmation of the hypothesis of single gene inheritance. *Acta Genet.*, **8**: 114-128.
RIFE D. C. (1938). Contributions of the 1937 national twins convention to research. *J. Hered.*, **29**: 83-90.
ROSENTHAL D. (1964). Discussion of Dr. Kallmann's paper. *In*: Recent Research in Schizophrenia. *Solomon P. & Glueck B. C. Jr.*, Psychiatric Research Reports of the Amercian Psychiatric Association, **19**: 146-148.
SKUDE G. (1963). Some factors influencing taste perception for phenylthiourea (P.T.C.). *Hereditas*, **50**: 203-210.
SNYDER L. H. (1931). Inherited taste deficiency. *Science*, **74**: 151-152.
— (1932). Studies in human inheritance. IX. The inheritance of taste deficiency in man. *Ohio J. Sci.*, **32**: 436-440.
SUTTON H. *et al.* (1962). The hereditary abilities study: genetic variation in human biochemical traits. *Amer. J. Hum. Genet.*, **14**: 64-82.
VERKADE P. E. *et al.* (1959). Investigations on taste blindness with thiocarbamides II (I). Intra-pair discrepancy of taste in pairs of identical twins. *A. Ge. Me. Ge.*, **8**: 361-368.
WINER B. J. (1962). Statistical Principles in Experimental Design. McGraw-Hill, New York.

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RIASSUNTO

Sono state esaminate coppie MZ, DZ e SIB per il gusto per l'acido cloridrico, solfato 1-chinino e 6-n-propiltiuracile (PROP). Sono state esaminate 75 coppie MZ, 70 DZ e 78 SIB per gli ultimi due composti, e 26, 45 e 45, rispettivamente, per l'acido. Per il PROP la varianza intracoppia ha presentato una differenza significativa fra MZ e DZ dello stesso sesso ($p<0,001$), mentre non vi era differenza significativa per il chinino ($p>0,005$) e per l'acido cloridrico ($p>0,10$). Le coppie MZ maschili presentavano una varianza intracoppia significativamente minore di quelle DZ o SIB maschili per l'acido cloridrico ($<0,01$), mentre le coppie femminili non presentavano tale differenza. La varianza intracoppia per l'acido cloridrico era significativamente minore per le 9 coppie MZ maschili che non per le 17 coppie MZ femminili ($p<0,02$).

La ripetizione dei test sugli stessi individui ha prodotto risultati simili in alta proporzione per ogni composto: per l'acido cloridrico 72,9% (N=44); per il chinino 76,9% (N=221); per il PROP 76% (N=225).

Le correlazioni fra i valori di soglia per le differenti sostanze sono risultate positive e significative (N=308): fra PROP e chinino $r = + 0,35 \pm 0,05$ ($p<0,01$); fra chinino e acido cloridrico: $r = + 0,35 \pm 0,05$ ($<0,01$); fra PROP e acido cloridrico: $r = + 0,17 \pm 0,06$ ($p<0,05$).

RÉSUMÉ

Des couples MZ, DZ et SIB ont été examinés pour le goût pour l'acide hydroclorique, sulphat 1-quinine et 6-n-propiltiuracile (PROP). 75 couples MZ, 70 DZ et 78 SIB ont été examinés pour les deux dernières substances; et 25, 45 et 45 respectivement pour l'acide. Pour le PROP la variance intra-couple a présenté une différence significative entre MZ et DZ du même sexe ($p<0,001$), tandis qu'il n'y avait pas de différence significative pour la quinine ($p>0,005$), ni pour l'acide hydroclorique ($p>0,10$). Les couples MZ de sexe masculin présentaient une variance intra-couple significativement inférieure vis-à-vis des couples DZ et SIB du même sexe pour l'acide hydroclorique ($p<0,01$), tandis que les couples de sexe féminin ne présentaient pas cette différence. La variance intra-couple pour l'acide hydroclorique était significativement inférieure pour les 9 couples MZ de sexe masculin vis-à-vis des 17 couples MZ de sexe féminin ($p<0,02$). La duplication des tests chez les mêmes individus a produit des résultats semblables en proportion élevée pour chaque substance: pour l'acide hyroclorique 72,9% (N=44), pour la quinine 76,9% (N=221) et pour le PROP 76% (N=225). Les corrélations entre les valeurs de seuil pour les différentes substances sont résultées positives et significatives (N=308): entre PROP et quinine $r = + 4,44 \pm 0,05$ ($p<0,01$); entre quinine et acide hydroclorique $r = + 0,35 \pm 0,05$ ($p<0,01$); entre PROP et acide hydroclorique $r = + 0,17 \pm 0,06$ ($p<0,05$).

ZUSAMMENFASSUNG

EZ—, ZZ— und Geschwisterpaare wurden auf ihre Geschmacksempfindlichkeit für Salzsäure, 1-Chininsulphat und 6-n-Propylthiouracil (PROP) untersucht und zwar für die beiden letzteren Verbindungen 75 EZ—, 70 ZZ— und 78 Geschwisterpaare und für die Salzsäure 26 EZ—, 45 ZZ— und 45 Geschwisterpaare. Die Varianz zwischen den EZ— und den gleichgeschlechtlichen ZZ—Paarlingen ergab eine bedeutende Differenz für das PROP ($p<0{,}001$), die hingegen für das Chinin und die Salzsäure unbedeuten war ($p>0{,}005$) für Chinin und ($p>0{,}10$) für Salzsäure. Bei den männlichen EZ—Paaren war die Varianz zwischen den Paarlingen für Salzsäure bedeutend geringer als bei den männlichen ZZ— und Geschwisterpaaren ($p<0{,}01$); bei den weiblichen Paaren hingegen zeigte sich kein solcher Unterschied. Die Varianz zwischen den Paarlingen war für die Salzsäure bei den 9 männlichen bedeutend geringer als bei den 17 weiblichen EZ—Paaren ($p<0{,}02$). Eine Wiederholung der Tests bei den gleichen Probanden ergab für alle drei Verbindungen bei einem hohen Prozentsatz ähnliche Ergebnisse wie zuvor: für Salzsäure 72,9% (N=44); für Chinin 76,9% (N=221); und für PROP 76% (N=225). Die Korrelationen zwischen den Schwellwerten für die verschiedenen Stoffe waren positiv und bedeutend (N=308): zwischen PROP und Chinin $r = +0{,}44 \pm 0{,}05$ ($p<0{,}01$); zwischen Chinin und Salzsäure $r = +0{,}35 \pm 0{,}05$ ($p.<0{,}01$); zwischen PROP und Salzsäure $r = +0{,}17 \pm 0{,}06$ ($p<0{,}05$).

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