"Taste Strips" - a rapid, lateralized, gustatory bedside identification test based on impregnated filter papers

LANDIS, Basile Nicolas, *et al*.

Abstract

OBJECTIVE: To elaborate normative values for a clinical psychophysical taste test ("Taste Strips"). BACKGROUND: The "Taste Strips" are a psychophysical chemical taste test. So far, no definitive normative data had been published and only a fairly small sample size has been investigated. In light of this shortcoming for this easy, reliable and quick taste testing device, we attempted to provide normative values suitable for the clinical use. SETTING: Normative value acquisition study, multicenter study. METHODS: The investigation involved 537 participants reporting a normal sense of smell and taste (318 female, 219 male, mean age 44 years, age range 18-87 years). The taste test was based on spoon-shaped filter paper strips ("Taste Strips") impregnated with the four (sweet, sour, salty, and bitter) taste qualities in four different concentrations. The strips were placed on the left or right side of the anterior third of the extended tongue, resulting in a total of 32 trials. With their tongue still extended, patients had to identify the taste from a list of four descriptors, i. e., sweet, sour, salty, and bitter (multiple [...]

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Abstract *Objective* To elaborate normative values for a clinical psychophysical taste test ("Taste Strips"). *Background* The "Taste Strips" are a psychophysical chemical taste test. So far, no definitive normative data had been published and only a fairly small sample size has been investigated. In light of this shortcoming for this easy, reliable and quick taste testing device, we attempted to provide normative values suitable for the clinical use. *Setting* Normative value acquisition study, multicenter study. *Methods* The investigation involved 537 participants reporting a normal sense of smell and taste (318 female, 219 male, mean age 44 years, age range 18–87 years). The taste test was based on spoon-shaped filter paper strips ("Taste Strips") impregnated with the four (sweet, sour, salty, and bitter) taste qualities in four different concentrations. The strips were placed on the left or right side of the anterior third of the extended tongue, resulting in a total of 32 trials. With their tongue still extended, patients had to identify the taste from a list of four descriptors, i.e., sweet, sour, salty, and bitter (multiple forced-choice). To obtain an impression of overall gustatory function, the number of correctly identified tastes was summed up for a "taste score". *Results* Taste function decreased significantly with age. Women exhibited significantly higher taste scores than men which was true for all age groups. The taste score at the 10th percentile was selected as a cut-off value to distinguish normogeusia from hypogeusia. Results from a small series of patients with ageusia confirmed the clinical usefulness of the proposed normative values. *Conclusion* The present data provide normative values for the "Taste Strips" based on over 500 subjects tested.

Key words Taste Strips · normative · taste, gustatory · test · lateralization · quantitative · clinical

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Introduction

In contrast to olfaction, which recognizes innumerable odorants, taste, which recognizes only a few basic tastes, has always been considered a less complex sense. Clinically, this has mainly been based on the few cases of gustatory disorders seen in outpatient clinics compared to those presenting with olfactory problems [6]. However, since molecular biology permitted the discovery of a fifth taste [4], which is monosodium glutamate and the decoding of large parts of the taste receptor logic [3], this sense has increasingly drawn the medical community's attention to it [42]. Recent studies even implicate taste receptor variants to influence the risk of alcohol dependence [18] or myocardial infarction [41]. Taken together, taste receptors and their functionality might be relevant for more than only the pleasantness perceived during eating and drinking.

Thus, the necessity of clinical assessment of human chemical gustatory function should not be a matter of debate. However, in contrast to clinical olfactory testing, where numerous validated tests exist (e.g., [11, 23]), most gustatory testing devices are based on liquid dilutions [15, 16, 27], tablets [1] or edible wafers [19], which are either not commercially available or lack available normative data. Furthermore, most test procedures are whole mouth tests and do not allow the assessment of single gustatory nerve afferents such as lateralized testing or testing of the anterior two-thirds of the tongue, innervated by the chorda tympani versus the rear of the tongue innervated by the glossopharyngeal nerve.

A recently proposed test device based on ideas by Kobal, called "Taste Strips", tried to overcome these shortcomings by using filter papers impregnated with tastants (for details see [36]). The spoon-shaped filter papers can be applied selectively to specific areas of the tongue. The shelf life is much longer than that of liquid solutions. Although this test has already resulted in a series of publications [14, 22, 34, 36, 39] and was proven reliable concerning the investigation of tongue side differences [21, 29] and gustatory testing before and after an intervention [30, 37], the initially proposed test procedure had some shortcomings. First, the paper by Mueller et al. [36] was based on solely 69 observations. Second, Mueller et al. [36] did not use a forced choice testing paradigm, but all the authors who consecutively used the "Taste Strips" did so.

The aim of the present study was thus to provide normative data for the "Taste Strips" for both, lateralized and whole mouth testing based on a forced choice paradigm and on a larger number of observations. To this end, we investigated 537 healthy subjects using different concentrations of the four basic tastes (sweet, sour, salty, and bitter). Umami was not included, because this taste concept has been found to be difficult to explain to the European population tested.

Material and methods

The current multicenter study was conducted according to the guidelines of the Declaration of Helsinki on Biomedical Research Involving Human Subjects. The investigation involved 537 participants reporting a normal sense of smell and taste (318 female, 219 male, mean age 44 years, age range 18–87 years). One hour prior to testing subjects were asked not to eat or drink anything except water, not to smoke, and not to brush their teeth. Subjects with severe diseases that might affect taste perception (e.g., chronic renal failure or middle ear affections) were not included in the investigation.

The taste test was based on filter paper strips [36] ("Taste Strips", Burghart, Wedel, Germany), with a length of 8 cm and a tip area of 2 cm^2 being impregnated with tastant (4 concentrations each of the 4 basic taste qualities). The following concentrations were used for the taste strips: sweet: 0.4, 0.2, 0.1, 0.05 g/ml sucrose; sour: 0.3, 0.165, 0.09, 0.05 g/ml citric acid; salty: 0.25, 0.1, 0.04, 0.016 g/ml sodium chloride; bitter: 0.006, 0.0024, 0.0009, 0.0004 g/ml quinine hydrochloride. Distilled water was used as solvent; taste solutions were prepared freshly in regular intervals.

The strips were placed on the left or right side of the anterior third of the extended tongue, resulting in a total of 32 trials (Fig. 1). Before each administration of a strip, the mouth was rinsed with water. The tastes were presented in increasing concentrations. Taste qualities were applied in a randomized fashion at each of the four levels of concentration and alternating the side of presentation. With their tongue still extended, patients had to identify the taste from a list of

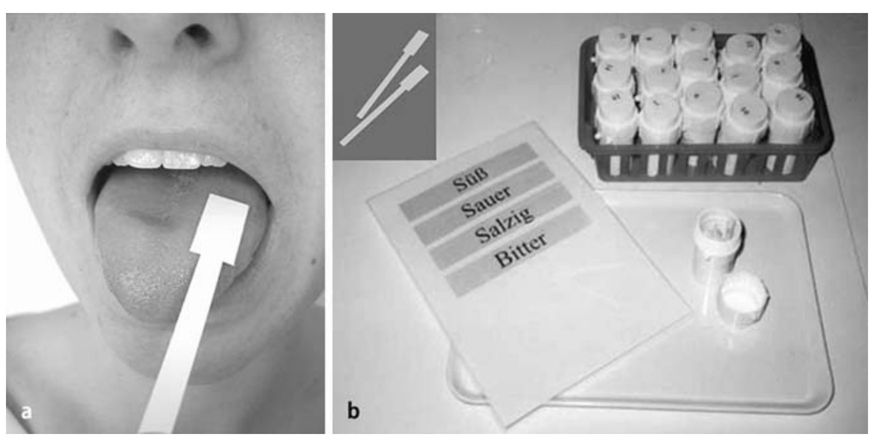

Fig. 1 **A** Testing procedure of the Taste Strips, with the subject being tested with the tongue kept outside while choosing the presented taste quality from a descriptor list. **B** Example of the Taste Strips kept in different boxes separately for the different concentrations used, with a picture of the taste strips in the left corner

four descriptors, i.e., sweet, sour, salty, and bitter (multiple forced-choice). To obtain an impression of overall gustatory function, the number of correctly identified tastes per side was added up to a "taste score" [36]. Both, scores of the left and right side yielded the total number identified tastants. The whole testing procedure for the 4 tastants typically required approximately 20 minutes for lateralized (right and left side separately) testing. Details of the individual taste qualities can easily be obtained when the data are analyzed by the proposed "Taste Strip" software (http://www.tu-dresden.de/medkhno/riechen_schmecken/download.htm), which can be downloaded for free.

Statistical analysis

SPSS 12.0 (SPSS Inc., Chicago, IL., USA) was employed for statistical evaluation. Age-related differences were investigated for three groups: (18–40 years (n = 225, 141 f, 84 m), 41–60 years (n = 206, 122 f, 84 m), older than 60 years (n = 106, 55 f, 51 m)). An analyses of variance for repeated measures (rm-ANOVA) was used with between subjects factors "side of stimulation" (left, right), and between subject factors "sex" (female (f; n = 318), male (m; n = 219)) and "age group" (18–40 years, 41–60 years, > 60 years). Bonferroni tests were used for post hoc comparisons. Correlational analyses were performed using Pearson statistics. The alpha level was set at 0.05.

Results

The distribution of taste scores across the investigated subjects is shown in Fig. 2. Taste function decreased with age ($F(2, 531) = 45.3, p < 0.001$) which was also confirmed by a significant correlation between the subjects' age and overall taste scores ($r_{537} = -0.39, p < 0.001$). In addition, women exhibited higher taste scores than men ($F(1, 531) = 26.9, p < 0.001$) which was true for all age groups as indicated by the missing interaction between factors "age group" and "sex" ($p = 0.20$) (Tables 1 and 2; Fig. 3). There were no significant differences with regard to results obtained on the left and the right side of the tongue.

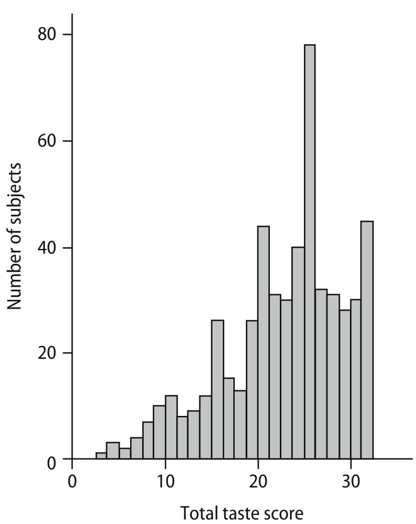

Fig. 2 Distribution of taste scores in the investigated population. Thirty-nine of the 537 subjects (7.3 %) had scores of 11 or less indicating severely compromised gustatory function although subjects rated their sense of taste as normal

Table 1 Distribution of taste scores separately for scores obtained for the left and right side, plus results for the total score in relation to the three age groups (means, standard deviation)

		left side	right side	total score
Age: 18–40 years (n = 225)				
mean		12.7	12.8	25.5
SD		2.8	2.9	5.2
Minimum		1	2	3
Maximum		16	16	32
Percentile	**10th**	9	9	19
	25th	11	11	22
	50th	13	13	26
	75th	15	15	29
	90th	16	16	32
Age: 41–60 years (n = 206)				
mean		10.7	11.0	21.4
SD		3.4	3.3	6.6
Minimum		1	2	4
Maximum		16	16	32
Percentile	**10th**	6	6	11.7
	25th	8	9	17
	50th	11	12	23
	75th	13	13.5	26
	90th	15	15	29
Age: > 60 years (n = 106)				
mean		9.7	9.8	19.4
SD		3.3	3.5	6.3
Minimum		2	2	4
Maximum		15	16	31
Percentile	**10th**	5	5	9
	25th	8	8	15
	50th	10	10	20
	75th	12	12	24
	90th	14	14	27

In terms of the definition of hypogeusia the 10th percentile from subjects aged between 18 and 40 years was used to separate normogeusic from hypogeusic subjects (compare [10, 23]). Thus, women with a score of 19 and higher can be regarded as normogeusic, while this score is 17 in men. The scores for the other age groups and for gender differences are detailed in Tables 1 and 2.

With regard to differences between the left and right side of the tongue, the 90th percentile in subjects aged 18–40 years was 3.3, indicating that pathological differences can be suspected from a score difference of more than 3 between the left and right side of the tongue (Fig. 4).

During clinical testing we also encountered ten patients with ageusia due to various reasons (Table 3). These patients claimed not to be able to taste any of the four basic tastes. This was ascertained by administration

Table 2 Distribution of total taste scores (left and right side together) separately for men and women in relation to the three age groups (means, standard errors of means, minima, maxima, percentiles)

		Women	Men
Age: 18–40 years		*n* = *141*	*n* =*84*
mean		26.3	24.3
SD		5.1	5.3
Minimum		8	3
Maximum		32	32
Percentile	**10th**	19	17
	25th	23	21
	50th	27	25
	75th	30	28
	90th	32	30
Age: 41–60 years		*n* = *122*	*n* = *84*
mean		23.0	19.1
SD		5.7	7.1
Minimum		4	4
Maximum		32	32
Percentile	**10th**	15	9
	25th	19	13
	50th	24	21
	75th	27	24.75
	90th	30	27
Age: > 60 years		*n* = *55*	*n* = *51*
mean		20.6	18.2
SD		6.5	5.9
Minimum		6	4
Maximum		31	26
Percentile	**10th**	10.2	9
	25th	16	13
	50th	22	19
	75th	26	24
	90th	28.4	25

of a screening test for the four basic tastes presented at suprathreshold concentrations as proposed by the Working Group on Taste and Smell of the German ENT Society (http://www.uni-duesseldorf.de/awmf//ll/017–052.htm). When the taste strips were administered the average total taste score was 7.4 (range 4–11) which was well below the scores established to separate normogeusia from hypogeusia/ageusia (see above).

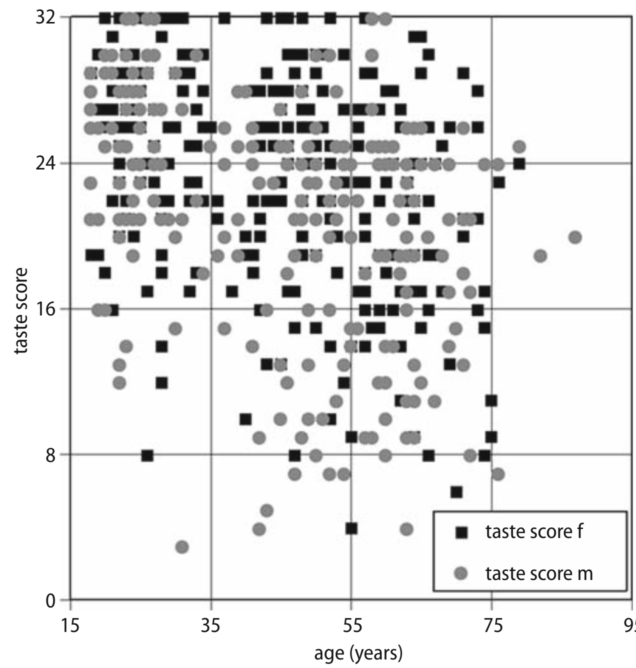

Fig. 3 Results obtained with the Taste Strips in relation to age, separately for men (black squares) and women (grey dots)

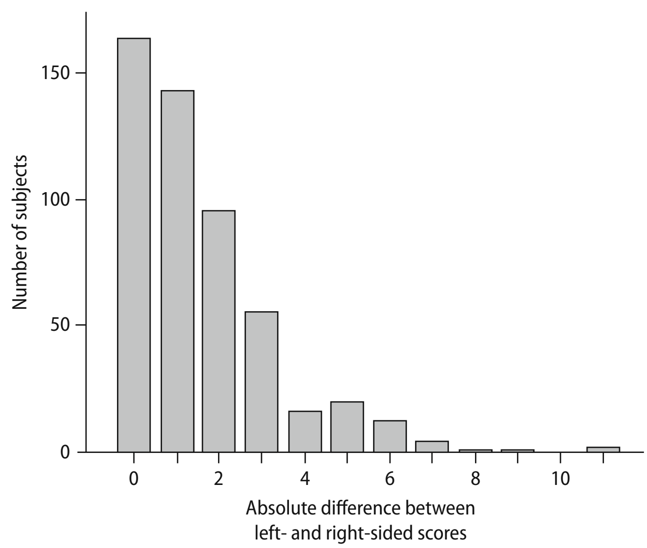

Fig. 4 Distribution of absolute taste score differences between the left and right anterior tongue side. A total side difference of more than three points lies outside of the range of the 90th percentile and is regarded to indicate lateralized taste dysfunction

Discussion

The present study provides normative data for a rapid gustatory identification test. This psychophysical bedside test further allows easy and quick lateralized taste testing as well as whole mouth assessment. Since tastants are presented on impregnated filter paper ("Taste Strips"), shelf life is longer than that of liquid taste solutions. Major findings of this study were that taste function (1) decreases with age and (2) is higher in women compared to men. Further, the postulated cut-off values separating normal gustatory function from altered gustatory function could successfully confirm ageusia or hypogeusia in the included patients (n = 10). Finally, the

Table 3 Characteristics of patients with ageusia

Patient Number	Age (years)	Sex	Cause	Taste strip score (total)
1	43	Female	Idiopathic	11
2	57	Female	Stroke	8
3	67	Female	Dental surgery	8
4	63	Male	General surgery	6
5	53	Male	Idiopathic	6
6	48	Male	Postviral	5
7	64	Female	Lichen Ruber	8
8	52	Male	Idiopathic	4
9	56	Male	Ear surgery	9
10	55	female	Idiopathic	9

present results give normative taste data and define a range of gustatory differences between each side of the tongue.

The present normative data for the "Taste Strips" are based on a high number of tested subjects (n = 548). This is by far the largest series published for this test, and to the best of our knowledge also one of the largest series of psychophysical taste testing [12, 16, 25, 44, 45]. In contrast to a previous report [36] on the "Taste Strips", these values have been acquired with a forced choice testing procedure. Although this seems to be a minor detail, the forced choice testing procedure has the clinical advantage to potentially detect subjects who aggravate or pretend to suffer from ageusia as they are not unlikely to give more wrong answers on purpose, thus ending up with a taste score below chance level. For the same reason, a forced choice paradigm has also been the standard for odor identification tests for over 20 years [11]. The major advantage of forced choice testing, however, is the control of the subjects' response bias. This means that some patients would never give an answer other than "no taste detected" if they were allowed to respond so. If these patients are forced to select a response it is frequently possible to detect some remnants of gustatory function.

The presented normative values refer solely to the anterior two-thirds of the tongue (the area innervated by the chorda tympani). In contrast to the rear of the tongue, the anterior parts can be stimulated easily in most subjects without triggering major gag reflexes. Thus, we restricted the present study to the anterior two-thirds of the tongue because it has the highest density of taste buds [3], is easily accessible and is most often implicated in taste dysfunction [32, 33]. Nevertheless, posterior lingual taste testing is feasible with the taste strips [37] but not all patients tolerate this testing well.

The present application of the "Taste Strips" thus represents a semi-quantitative, accurate, quick and easy tool for chemical taste-specific screening. Previous attempts of easy and quick clinical taste testing have resulted in the creation of electrogustometry [25], which has been used frequently [40, 43, 47]. Electrogustometry has proven useful to monitor changes before and after oral surgery and to detect side differences of the tongue's taste function. However, this method has the limitation that the elicited "taste" is described as metallic or in best case as "sour", as electric stimulation does not convincingly produce perceptions such as sweet, salty, umami, or bitter [46]. Although this is not a major shortcoming, it makes future investigations on the particular taste qualities difficult. This was one of the main reasons why we emphasized chemical taste testing. An isolated loss of sweet taste [17] could, thus, be overlooked by electrogustometry. Therefore, in a clinical context chemical and, thus, specific gustatory stimulation including all four taste qualities seem preferable as opposed to electrogustometry. Investigating the individual taste qualities with an identification tool also has difficulties, since some individuals constantly mistake sour for bitter and vice versa [36]. Thus, individual taste blindness may have to be considered with caution when interpreting taste test scores. In fact, it appears useful to do a screening test for the four basic tastes presented at suprathreshold concentrations as was proposed by the Working Group on Taste and Smell of the German ENT Society (http://www.uni-duesseldorf.de/awmf/ll/017-052.htm).

The presently proposed normal values are defined as "Taste Strip" scores above the 10^{th} percentile of a group of healthy subjects. Further differentiation between ageusia and hypogeusia is not possible based solely on the ten patients investigated. For this purpose a larger number of patients with documented ageusia (e.g., bilateral chorda severing during ear surgery) would have to be studied albeit such cases are rare. It was interesting to note that 42 of the 528 subjects (7.95 %) had Taste Strip scores of 11 or less which was in the range of scores produced by patients with ageusia. These taste scores indicated severely compromised gustatory function although subjects rated their sense of taste as normal. This confirms the observation by Soter and colleagues that taste self ratings do not reflect the measured taste function [44]. Because testing was performed in the anterior portion of the extended tongue, one explanation may relate to the idea that taste receptors in other areas of the oral cavity may allow for a normal taste function [35]. Consequently, clinical testing should not only rely on the localized testing of gustatory function, but should also include, in cases of doubt, whole mouth testing, e.g., using liquids [13].

Our study further confirmed previous findings on a decrease of gustatory function with increasing age. This could be demonstrated by a wide variety of approaches to gustatory function [1, 12, 19, 36, 38, 45]. Accordingly, the presented normative values are presented in an age-related manner.

Results from the present study also suggested that women exhibit higher gustatory sensitivity than men which has also already been described [1, 5, 8, 12, 19, 20, 36, 38, 45]. In contrast to what Fikentscher et al. [12] found, this gender-related effect was found in all age groups. Similar findings have been reported for the other chemical sense, olfaction, where women also outperform men [9, 48]. The exact reason of female superiority in olfaction and taste remains unexplained. One possible explanation relates to a hormonal influence on the chemical senses and their postulated protective effect on at least the sense of smell [2, 7, 31]. In contrast to olfactory function, taste function seems be more influenced by hormonal changes as shown during pregnancy [24]. Clinically the better taste function in women is reflected by higher normative values at any age.

Since many clinically encountered taste disorders occur unilaterally, due to surgery [32], tumors [26], strokes [14, 33] or inflammatory diseases [28, 29], the possibility of a lateralized bedside gustatory testing seems diagnostically valuable.

In conclusion, the present data further underline the clinical usefulness of the "Taste Strips" and provide normative data which should facilitate the interpretation of "Taste Strips" scores in routine clinical practice.

Conflict of interest The authors declare no conflict of interest.

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