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The influence of sensory training on taste sensitivity

Effects on sweet and bitter perception over a half-year period

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Summary

The sensory abilities of test persons must be regularly tested and trained. However, there are no basic data available on the effect of training on the perception and recognition of the basic tastes. The present controlled study examines whether the perception of the basic tastes sweet and bitter can be influenced by sensory training and whether this effect extends over a study break of 29 weeks. The intervention group (n = 41) received intensive sensory training over the course of a week. The results from a matching test and threshold tests were compared with a control group (n = 35). It was found that the perception and recognition of both groups improved during the study. Thus, experience and habituation could influence this just as much as sensory training. Moreover, the "sensory break" of 29 weeks had hardly any influence on the training and experience effect.

Keywords: sensory analysis, training, experience, thresholds, basic tastes

Introduction

Over a period of decades, the sensory testing of foods has been established and has proven its worth in product development and in guaranteeing defined product quality. This mainly employs analytical procedures under controlled test conditions and with selected and trained test persons (TPs) (◆ Figure 1). To save money and time, analytical tests are mostly only performed in larger companies that can manage the difficult development of a specified panel. Smaller companies may use service providers or often totally dispense with sensory analysis [2]. Many people have therefore asked how sensory methods, recruitment, and training can be simplified and abbreviated. It has been generally accepted that about five or six times as many people must be recruited than are actually needed [3]. For example, people are excluded from the start if

OVERVIEW 1: FACTORS INFLUENCING SENSORY EVALUATION

References [4] and [5] provide a good overview of the physiological basis of taste perception.

- Age: Taste and odor thresholds increase with age [6, 7].
- State of health: Dental health (e.g. dentures [8]), drug intake [5, 9] and hormonal status (e.g. pregnancy) influence sensory evaluation.
- Psychological factors: Taste perception is influenced by the state of mind or mood [10].
- Genetic disposition: The sensitivity of TPs depends on the rate of salivary flow (low flow vs. high flow, [11]), the density of the fungiform taste papillae (33–184 papillae/cm^2 [12]), as well as the ability or inability to perceive bitter-tasting compounds with isothiocyanate or thioamide groups (e.g. phenylthiocarbamide [PTC] or propylthiouracil [PROP] [4, 5, 13]).

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they are not willing or available, or if their sensory or cognitive abilities (e.g. the ability to express themselves) do not meet the demands. It would be simple to generate knowledge on individual differences in the sensitivity of the test personnel (cf. ◆ Overview 1) and thus their suitability for sensory tests; this might shorten the process. Another possibility to save time and money would be to shorten the difficult training process. However, there have been few studies on these issues. In particular, there are little or no fundamental data on sensitivity to basic tastes and how this is influenced by sensory training. The present article concentrates on solutions of sweet and bitter tastes and investigates whether and to what extent untrained TPs differ with respect to their sensitivity to these basic tastes. It is also investigated whether and to what extent sensory training influences taste sensitivity and whether any training effects can last over an extended period (29 weeks) without further intervention.

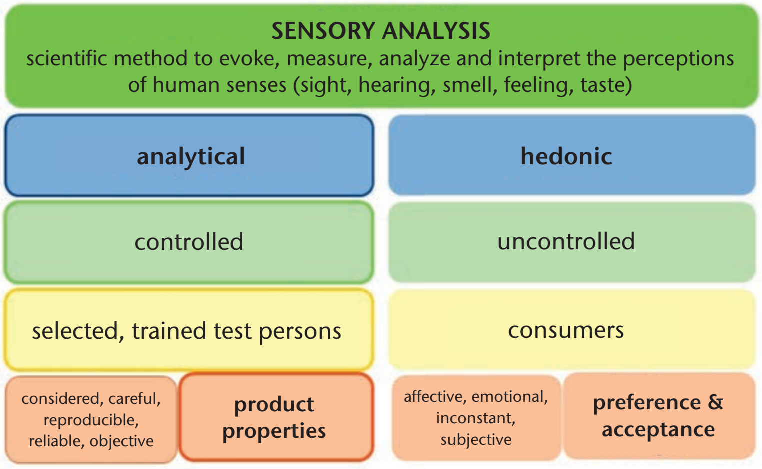

Fig. 1: **Definition of sensory analysis** (based on [1])
Under controlled test conditions with selected and trained test persons, sensory analysis leads to statements on objective product properties (e.g. "The new product A has the same creaminess as the old product B, even though the fat content was reduced"). Test persons (TPs) make their assessments in a considered, careful, reproducible, reliable and objective manner. Hedonic tests are performed at different locations with consumers who make affective and subjective assessments. These can lead to statements about preferences (e.g. "Product A tastes better than product B") and acceptance ("I would prefer the new product A to the old product B").

Material & methods

Study design and test persons

The study was performed as part of the cooperation between the Faculty of Life Sciences, Hamburg University of Applied Science (HAW), and the Dr. Rainer Wild Foundation, Heidelberg, and was financed by the Dr. Rainer Wild Foundation. The taste tests were performed in the HAW Sensory Analysis Laboratory (conceived in accordance with DIN EN ISO 8589 [14]) and approved in advance by the University Ethics Committee. 82 female students (mean age = 22.3 years, standard deviation [σ] = 2.5) were recruited from the HAW Faculty of Life Sciences. The selection criteria included the following aspects: age under 30 years, not pregnant or breast feeding and without training in sensory analysis ("naive"). The test persons gave their written consent and were reimbursed for their expenditure at the end of the study.

The study plan is shown in ◆ Figure 2. After time point t_0, the TPs were randomly assigned to the control or intervention groups, allowing for their PROP-(6-Propyl-2-thiouracil) status[1], so that the different types were balanced in the control and intervention groups. In the third week of the study, the intervention group took part in a 5-day training session on sensory analysis.

Taste samples and determination of taste sensitivity

The aqueous solutions of sucrose and caffeine were prepared in 1 L graduated flasks with deionized water (◆ Table 1). The taste samples (20 mL) were presented in 40 mL plastic beakers labelled with a 3-figure random code. The samples were tasted with the "whole mouth sip-and-spit method" (taste and spit out). Between the individual samples, the TPs were instructed to neutralize the taste with deionized water and/or matzo bread and to wait for at least 30 seconds. The matching test used the highest concentration in the serial dilution (D1). This deviates from the instructions in ISO 3972 [15], which recommend lower concentrations for the test. In this way, it was ensured that the majority of the TPs could perceive the actual taste. The test was performed in two parts:

1. Openly presented samples of test substances for each taste (sweet, sour, salty, bitter, metallic[2]);
2. Tray with twelve randomized and coded taste samples; each taste was

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[1] The methods and results on the PROP status will be covered in a second article. The PROP status designates a receptor variant that influences the ability to perceive the taste of thiourea.

[2] An initial test showed that, for some TPs, the taste quality "umami" "clung on" and sometimes greatly influenced the perception of other taste qualities (cf. [16]). For this reason, "umami" was not included in the matching test. "Metallic" was introduced as a stimulus, even though its perception is not restricted to the taste buds, but probably also involves nasal, retronasal and tactile perception [17].

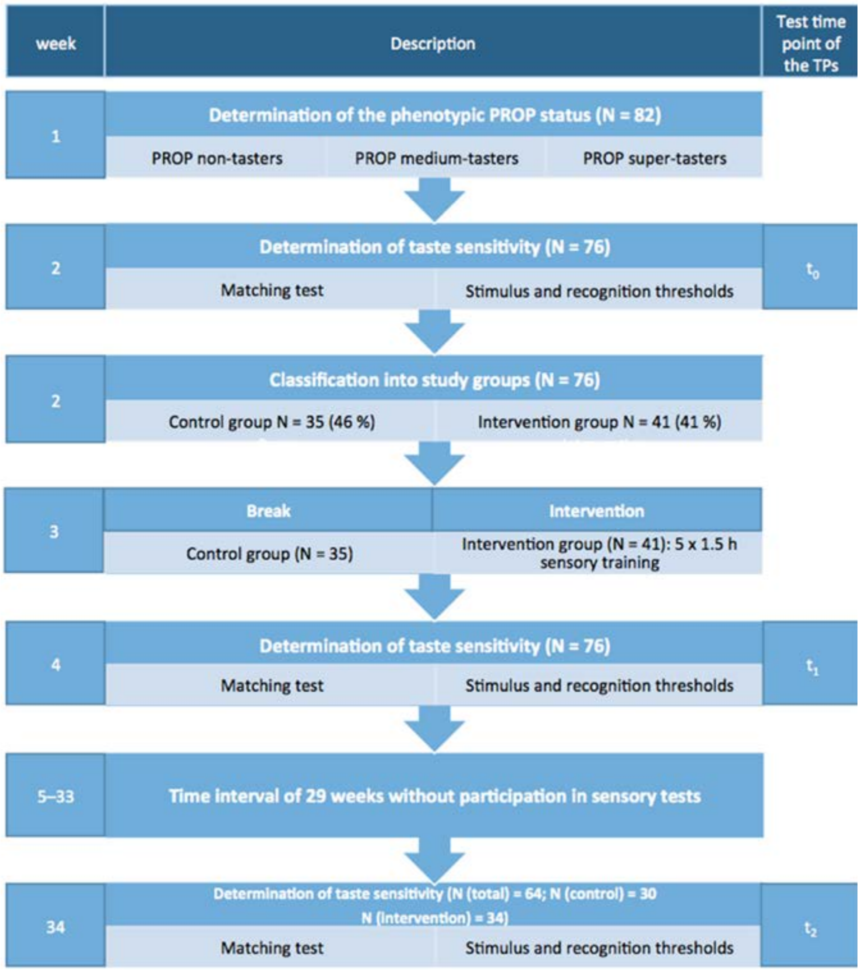


Fig. 2: **Study design**
TP = test person; PROP = 6-propyl-2-thiouracil; PROP status = receptor variant which influences the ability to perceive the bitter taste of thiourea; extends from virtually "taste blind" to extremely sensitive. (The methods and results on the PROP status will be covered in a subsequent article).

duplicated and two water samples were also presented. In the test form, the TPs assigned a taste to each sample.

As laid down in the ISO [15], the **stimulus and recognition thresholds** (◆ Overview 2) for sweet and bitter were specified with a series of eight increasing concentrations; each series started with a water sample. The TPs tasted the samples in ascending sequence; after each sample, they recorded the perceived sensory impression on the test form.

OVERVIEW 2: THRESHOLDS

According to the ISO definition, the **stimulus threshold** is the concentration of a test substance that is capable of producing a sensory impression that differs from water. It is not necessary that the type of taste is recognized. In contrast, the **recognition threshold** is the concentration of a test substance at which the TPs can assign the sensory impression to the correct taste.

Sensory training

The content and structure of sensory training in the third study week was based on ISO Standard 8586 [3]. Each of the five training units consisted of one hour of practical exercises, including training of the optical, haptic, olfactory and taste perception of aqueous solutions and complex foods, as well as half an hour on the theoretical principles of sensory testing (e.g. explanation of the correct procedures for tasting and neutralization, use of scales, structure and use of various test procedures).

Statistics

The data were evaluated with the program SPSS Statistics 21. To calculate the means and standard deviations, logarithms were taken of the concentrations of the test substances in μmol/L. However, the results are transformed back to the original units. This aids comprehensibility and comparison with the results of other groups. Group differences were calculated with single factor variance analysis (ANOVA). Study time points within a single group were compared with the paired t test. When the probability of error was $\alpha = 5$ % ($p \leq 0.05$), significance was assumed. In addition, some results are presented which only approached significance ($p \leq 0.1$; [18]).

Results and discussion

◆ Figures 3–5 present the results of the taste sensitivity tests over a period of 31 weeks, both as a block diagram and as a table (t_0–t_2).
◆ Table 2 gives an overview of the results, but is restricted to the "positive" findings – the findings that show that the TPs have improved their taste sensitivity.

Matching test

Untrained TPs could correctly assign a mean of 10.2 (85 %) of 12 samples. Sweet was correctly classified in a mean of 95 % samples and bitter in 80 % (t_0, ◆ Figure 3). The minimum ISO requirements [3] are that TPs who correctly assign more than 80 % of samples fulfil the criteria for selection. With 12 samples, this corresponds to 10 correctly recognized samples (≈ 83 %). With the higher concentrations selected here, this would have been reached on average by all TPs. On the other hand, the range was between 5 and 12 correctly recognized samples. Only 67 % of the TPs ($n = 51$) actually fulfilled the ISO requirements, i.e. correctly assigned at least 10 samples to the correct taste. It would also be expected that the number of untrained TPs who spontaneously reached the ISO reference would have been even lower if the lower concentrations recommended in the standard had been used. In an earlier study [19] with the test design and concentrations as in ISO 3972 [15], the TPs reached the reference value for sweet (≈ 80 %), but not for bitter (< 60 %). In the present study too, the TPs assigned the sweet samples better than they did the bitter samples.

After the intervention (t_1), the trained TPs ($n = 41$) tended to have a higher rate of taste recognition ($p = 0.07$; $t = -1.86$) and recognized significantly more bitter samples ($p = 0.04$; $t = -2.08$) than at t_0 (◆ Figure 3, ◆ Table 2). On the other hand, the rates of taste recognition in the control group did not change. More intervention TPs reached the ISO minimum requirements of 80 % correct assignments than was managed by the control TPs ($n = 34$; 82.9 % and $n = 26$; 74.2 %, respectively).

Threshold test for sweet

In the untrained "naive" condition, the mean value of the stimulus threshold for sweet for all TPs was 1.7 mmol/L (◆ Figure 4), which was just under D7. Thus the present value is lower than in other studies, in which the TPs had mean stimulus thresholds of 5.5 mmol/L and 5.8 mmol/L, respectively [19, 20].

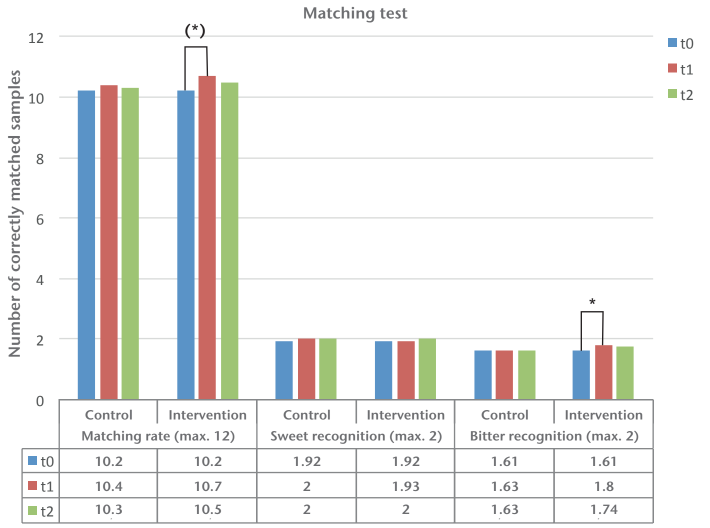
In the present study, the mean recognition threshold for sweet was 12.9 mmol/L (just under D3), which was above the value of 9.5 mmol/L found by Gomez et al. [20]. The differences in these results may be linked to differences in test conditions (e.g. different serial dilutions or test design). The mean recognition threshold for sweet in the present study (4.4 g/L) was below the value of 5.76 g/L given in the ISO references for trained TPs [15]. However, it appears that threshold values are generally imprecise and are highly variable, as they are influenced by the physical and psychological status of the TPs [21]. Moreover, the studies use different concentrations and methods – such as the filter paper method [22] and the "triangle-forced-choice" test with increasing concentrations [23]). For example, Keast and Roper [23] do refer to ISO 3972 [15], but then use a different caffeine concentration, without giving the reason for this. Fukunga et al. [22] also determined thresholds of basic tastes. However, their dilution series for sucrose exceeded the ISO

Taste	Concentration series*		
sweet (sucrose[a]; $C_{12}H_{22}O_{11}$; 342.30 g/mol)	Stock solution: 24 g/L		
	Dilution	g/L	mmol/L
	D1	12.00	35.06
	D2	7.20	21.03
	D3	4.32	12.62
	D4	2.59	7.57
	D5	1.56	4.56
	D6	0.94	2.73
	D7	0.55	1.61
	D8	0.34	0.98
bitter (caffeine[b]; $C_8H_{10}N_4O_2$; 194.19 g/mol)	Stock solution: 0.54 g/L		
	Dilution	g/L	mmol/L
	D1	0.27	1.39
	D2	0.22	1.11
	D3	0.17	0.89
	D4	0.14	0.71
	D5	0.11	0.57
	D6	0.09	0.46
	D7	0.07	0.36
	D8	0.06	0.29

Tab. 1: **Concentrations of test substances**
* prepared by dilution of the stock solution (eight logarithmic dilution steps)
[a] Riedel-de Haën, Sigma-Aldrich Laborchemikalien GmbH, Seelze;
[b] Fluka, Sigma-Aldrich Chemie GmbH, Steinheim

	Matching test			Threshold test			
				sweet		bitter	
	Matching rate (total of 12 samples)	Sweet recognition (total of 2 samples)	Bitter recognition (total of 2 samples)	Stimulus threshold	Recognition threshold	Stimulus threshold	Recognition threshold
t_1 vs. t_0	Intervention (*)	–	Intervention*	Intervention**	Intervention* Control**	Intervention (*)	Intervention* Control***
t_2 vs. t_0	–	–	–	Intervention**	Intervention** Control**	–	Intervention*

Tab. 2: **Overview of positive effects on the taste sensitivity by sensory training (intervention TPs) and by habituation-experience (control TPs)** (significant improvements in the matching test are presented, together with reduced taste thresholds for "sweet" and "bitter")
(*) = trend ($p \leq 0.10$); *–*** = significant: *$p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

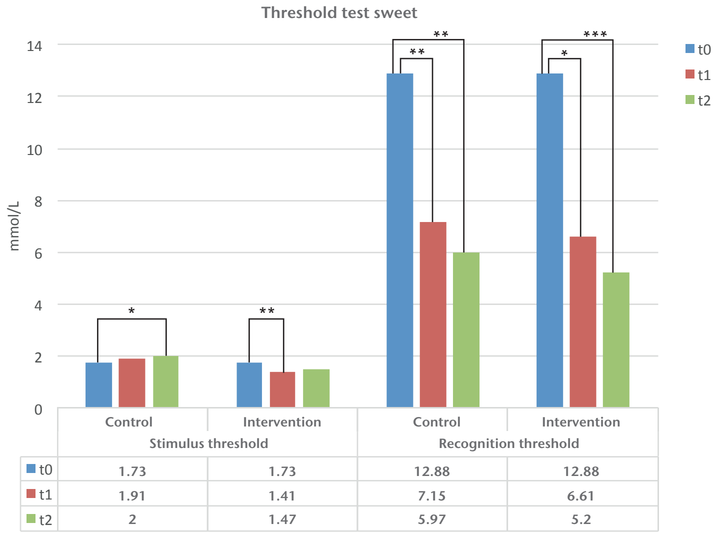


	Control	Intervention	Control	Intervention	Control	Intervention
	Matching rate (max. 12)		Sweet recognition (max. 2)		Bitter recognition (max. 2)	
t0	10.2	10.2	1.92	1.92	1.61	1.61
t1	10.4	10.7	2	1.93	1.63	1.8
t2	10.3	10.5	2	2	1.63	1.74

Fig. 3: **Number of correctly matched samples (overall matching rate; recognition of sweet samples and recognition of bitter samples) in the matching test**
Number of test persons (TPs) per group and study time point: control TPs (t_0 and t_1) = 35; control TPs (t_2) = 30; intervention TPs (t_0 and t_1) = 41; intervention TPs (t_2) = 34
(*) = trend (p ≤ 0.10)
* = significant (p ≤ 0.05)

values by large factors: the lowest concentration was 1.7 g sucrose/L and the greatest 342 g/L, instead of the concentrations of 0.34–12 g/L as given in ◆ Table 1.

After the intervention (t_1), the trained TPs had significantly reduced both their stimulus threshold (p = 0.01; t = 3.01; to a value between D7 and D8) and their recognition threshold for sweet (p = 0.01; t = 2.67; to a value between D4 and D5) (◆ Figure 4; ◆ Table 2). Thus they improved both the perception and recognition of sweet. In contrast, the control TPs only significantly improved the recognition of sweet – to a value just under D4 (p = 0.003; t = 3.18). Some earlier studies [24–26] have already addressed the hypothesis that sensitivity to taste test substances increases with repeated contact (experience or habituation); this is the so-called “taste induction hypothesis”. This hypothesis has been confirmed for some test substances for taste or smell (e.g. glucose, monosodium glutamate [MSG], 1,5-pentandial). Moreover, functional magnetic resonance tomography (MRT) has demonstrated increasing activation of specific regions of the brain after repeated contact with previously unknown taste components (e.g. aspartame, quinine hydrochloride, threonine etc.) [27].



	Control	Intervention	Control	Intervention
	Stimulus threshold		Recognition threshold	
t0	1.73	1.73	12.88	12.88
t1	1.91	1.41	7.15	6.61
t2	2	1.47	5.97	5.2

Fig. 4: **Results of threshold test for the taste “sweet” (sucrose) in mmol/L**
Number of test persons (TPs) per group and study time point: control TPs (t_0 and t_1) = 35; control TPs (t_2) = 30; intervention TPs (t_0 and t_1) = 41; intervention TPs (t2) = 34
*–*** = significant: * p ≤ 0.05; ** p ≤ 0.01; *** p ≤ 0.001

Threshold test for bitter

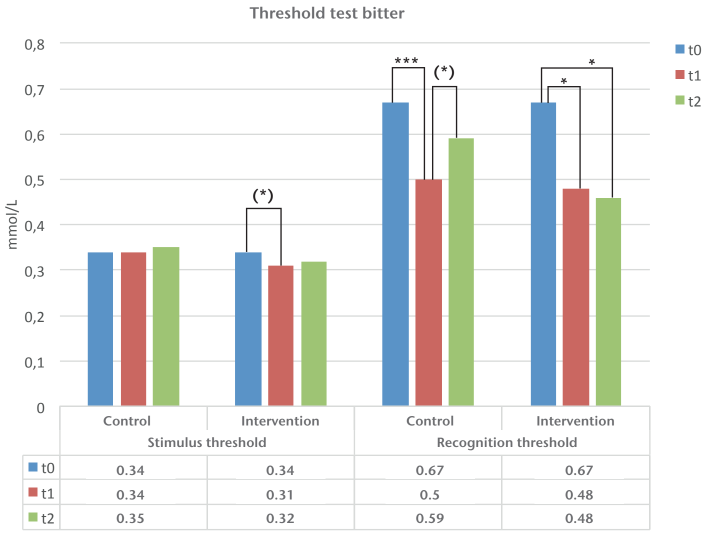
Just as with the sweet recognition threshold, the bitter recognition threshold for bitter for the untrained TPs at t_0 (0.67 mmol/L; between D4 and D5; ◆ Figure 5) was below the ISO reference value [4] for trained 0.13 g/L TPs (0.205 g/L). In the present study, the corresponding stimulus threshold was 0.34 mmol/L (below D7). For both threshold tests (“sweet” and “bitter”), a taste that was different from water was perceived at a mean value near to the second lowest concentration.

In two other studies [23, 28], TPs exhibited mean stimulus thresholds of 1.2 mmol/L and 1.83 mmol/L, respectively, and DSAMOU et al. [28] classified six volunteers as hypersensitive who had exhibited caffeine stimulus thresholds below 0.5 mmol/L. However, the mean stimulus thresholds for untrained TPs in the present study are consistent with two other studies [19, 29], which found mean values of 0.5 mmol/L and 0.52 mmol/L

(Mattes [29] did not differentiate between stimulus and recognition thresholds).

After the sensory training, the intervention TPs exhibited a trend to a reduced bitter stimulus threshold. The value was just under D8 (lowest concentration; ◆ Figure 5; $p = 0.10$; $t = 1.69$). At t_1, both study groups (intervention and control) exhibited significantly lower recognition thresholds in comparison to t_0 (intervention: $p = 0.03$; $t = 2.27$; control: $p = 0.001$; $t = 3.54$). There was thus both an effect of sensory training in the intervention group and an effect of experience and habituation in the control group.

An older study also compared the threshold values of trained and untrained TPs [30]. The authors reported the group differences for sweet, sour and salty solutions, but not for bitter solutions. The trained TPs had significantly lower thresholds for the three tastes.



	Control (Stimulus threshold)	Intervention (Stimulus threshold)	Control (Recognition threshold)	Intervention (Recognition threshold)
🟦 t0	0.34	0.34	0.67	0.67
🟥 t1	0.34	0.31	0.5	0.48
🟩 t2	0.35	0.32	0.59	0.48

Fig. 5: **Results of the threshold test for the taste “bitter” (caffeine) in mmol/L**
Number of test persons (TPs) per group and study time point: control TPs (t_0 and t_1) = 35; control TPs (t_2) = 30; intervention TPs (t_0 and t_1) = 41; intervention TPs (t_2) = 34
(*) = trend ($p \leq 0.10$)
*, *** = significant: * $p \leq 0.05$; *** $p \leq 0.001$

Effects of a sensory break (29 weeks) on taste sensitivity

The sensory break of 29 weeks did not influence the results from the matching test: The matching rates or the recognition of sweet or bitter did not change in either the control or the intervention groups. In a long-term study, Bitnes et al. [31] concluded that TPs continuously improved their taste recognition rates for “sweet”, “sour”, “salty” and “bitter”. For TPs who had been members of the panel for longer periods (and were therefore older) and who had carried out more tests, the number of mistaken identifications of basic tastes gradually decreased. In the current study, the break had an unfavorable effect on the control TPs’ stimulus thresholds for sweet and bitter. After the relatively long sensory break, this group only perceived “sweet” and “bitter” at higher concentrations than at the start of the study (t_0). On the other hand, the control and intervention groups maintained their improved recognition of the sweet taste (t_0 vs. t_1) even at t_2 after the break. Thus, at t_2 the intervention TPs recognized the sweet taste at a mean concentration of 5.2 mmol/L ($p = 0.001$; $t = 3.75$[3]) and control TPs at a mean concentration of 5.97 mmol/L ($p = 0.002$; $t = 3.39$). This is in disagreement with the study of Kobayashi et al. [32], in which the experience and habituation effect for the recognition of monosodium glutamate (MSG) was reversible after the relatively short break of 11 days.

Limitations

This analytical and basic research study on taste sensitivity provides information on two basic tastes (“sweet” and “bitter”). It is unclear whether the results would also apply to the other basic tastes (“sour”, “salty” and “umami”), other types of sensory perception (e.g. “metallic”, “fatty” or “hot”) or to complex foods with other sensory perceptions. Moreover, the study group was deliberately homogenous (female students of European origin, not older than 30 years), so that sociodemographic factors were excluded. It would have to be tested whether our results also apply to older test persons and/or to male subjects. As some very different methods have been used to determine taste sensitivity, additional studies are needed to determine optimal procedures and concentrations.

Conclusion and outlook

One important conclusion from the data presented is that TPs improved their taste sensitivity for “sweet” and “bitter” during the study as a result of training and/or experience and habituation. The results were independent of the group (control or intervention). These results extend

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[5] The p values are for the comparison between t_0 and t_2, and were calculated using a pair difference test.

our knowledge of "experience-induced taste modulation" ("the taste induction hypothesis") and confirms that the results of previous studies [24–26] also apply to sucrose and caffeine.

As regards the selection process of sensory TPs, this is a confirmation of the ISO recommendation [3] that the final panel should only be formed after the training phase. Thus, even TPs whose initial taste sensitivity was outside the reference values could be trained and their performance might then be just as good. This is also supported by a study that showed that TPs who initially exhibited low taste sensitivity for glucose could be given sensory training and might then achieve the same sensitivity as TPs whose performance was originally average [24]. It is also possible that excessively high demands on the sensory abilities might lead to excessive loss of TPs, and thus to smaller panels [33]. In the present study, the favorable training and experience effects were maintained over the relatively long period of 29 weeks without participation in sensory tests. This result is confirmed in other studies [34, 35]. The performance of the sensory TPs appears to be stable and reproducible over a relatively long period.

Our results also suggest possible new projects of practical relevance. Perhaps training courses for the senses could help to bring about long-term changes in nutritional and health behavior. Such courses have been used in nutritional education for many years. For example, it would be interesting to find out whether training and experience can reduce sweet thresholds in such a way that foods are selected or preferred that contain less sugar.

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Conflict of Interest

The authors declare no conflict of interest according to the guidelines of the International Committee of Medical Journal Editors.

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