

# Effects of taste stimulation on gastric myoelectrical activity and autonomic balance

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## Abstract

**Background/Aim:** Sham feeding, reproducing the cephalic phase of digestion, and involving combined visual, olfactory, and taste stimulation affects gastrointestinal motility and secretory functions of the digestive system, as well as the sympathetic/parasympathetic balance (SPB). In this study, we aimed to check if taste stimulation with a single flavor affects the gastric myoelectrical activity (GMA) and/or SPB.

**Materials and Methods:** Eighteen healthy volunteers underwent, on four separate days, 30-min electrogastrographic and electrocardiographic recordings: basal, with stimulation – while keeping in the mouth an agar cube with taste-delivering substance, and postexposure. Concentrations of saccharose, NaCl, citric acid, and quinine hydrochloride within the cubes were adjusted to 100-fold the individual taste recognition thresholds. SPB was determined from the heart rate variability (HRV) analysis of the recorded electrocardiograms.

**Results:** A moderate but statistically significant increase in tachygastria and bradygastria percentage time share was observed, regardless of the type of taste applied. Bitter taste elicited a considerable decrease in the normogastria time share (from  $82.8 \pm 2.5\%$  to  $73.5 \pm 3.5\%$ ,  $P = 0.00076$ ) and a diminution of the dominant frequency (from  $3.07 \pm 0.08$  to  $2.90 \pm 0.10$  cycles per minute (cpm) postexposure,  $P = 0.01$ ). Sour taste brought about a drop of the dominant power (from  $42.5 \pm 1.1$  to  $40.1 \pm 1.4$  dB,  $P = 0.0015$ ). Two tastes hindered propagation of the gastric slow waves – the average percentage of slow wave coupling decreased from  $77.9 \pm 3.1\%$  to  $69.5 \pm 3.1\%$  ( $P = 0.0078$ ) and from  $74.6 \pm 2.5\%$  to  $68.2 \pm 2.8\%$  ( $P = 0.0054$ ) with the bitter and the salty taste, respectively. Stimulation with sweet, salty, or sour taste evoked a significant decrease in the high frequency component of the HRV, whereas bitter taste did not affect the SPB.

**Conclusions:** Oral stimulation with tastes subjectively perceived as unpleasant brings about disturbances of the interdigestive GMA. This, however, does not coincide with its effect upon SPB.

**Keywords:** Bitter taste, gastric myoelectrical activity, heart rate variability, salty taste, sour taste, sweet taste

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## INTRODUCTION

Taste, in combination with the other four senses (smell, hearing, touch, vision), permits the individual to

orient himself within the surrounding environment. In the past taste helped our ancestors to differentiate between edible and inedible foods, with sour and bitter taste

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warnings performing a particularly vital role.<sup>[1,2]</sup> Nowadays, the sense of taste plays a much more complex role. In a hedonistic sense, it enables gourmets to revel in the sophisticated cuisines of different nations and cultures.<sup>[3,4]</sup> More specifically, to carefully target and indulge the tastes of consumers, food manufacturers are greatly interested in research on taste. From this perspective of the food industry, so-called fast food is a good example of spot on manipulation of artificial taste-delivering chemical compounds.<sup>[5,6]</sup> Sadly, addiction to the pleasures delivered by these tastes has led to threatening incidences of obesity in Western societies. Finally, one should not overlook the fact that disturbance of taste may be a symptom of disease.<sup>[7]</sup>

The sense of taste accounts for food consumption, and therefore it is indirectly related to the control of appetite.<sup>[8,9]</sup> Intuitively, taste stimulation should affect the physiology of the gastrointestinal tract. The experiments of the famous Russian physiologist Pawlow<sup>[10]</sup> demonstrated the existence of cephalic phase of digestion consisting of stimulation of saliva and/or gastric acid secretion to visual, olfactory, and taste stimulation. Since then it was proven in numerous experiments that sham feeding, a procedure consisting of chewing of food without swallowing it, causes activation of gastrointestinal motility, gastric acid, and pancreatic enzyme secretion, as well as release of the gastrointestinal hormones: gastrin and pancreatic polypeptide.<sup>[11]</sup>

The mechanical phase of digestion within the stomach consists of grinding down solid food to particles of <1–2 mm in size, which can then be passed through the pylorus. This task is accomplished by functional coupling of the gastric myoelectrical and motor activity.<sup>[12]</sup> Several research groups independently demonstrated that sham feeding elicits a short-term (limited almost to its duration) stimulation of the gastric myoelectrical activity (GMA), reflected by an increase in the dominant power and/or dominant frequency of the gastric slow waves.<sup>[13–15]</sup> Pharmacological experiments<sup>[16]</sup> as well as examinations performed in subjects who underwent highly selective vagotomy<sup>[17]</sup> indicate that the GMA is dependent on the parasympathetic constituent of the autonomic nervous system, namely the vagal nerve. By means of heart rate variability (HRV) analysis, it was shown that sham feeding also alters the sympathetic/parasympathetic balance (SPB) – bringing about a transient increase in the sympathetic activity<sup>[18]</sup> – similar to that observed after a meal intake.<sup>[19]</sup> One can infer therefore that sham feeding affects both the SPB and the GMA. It remains, however, unclear whether the latter effect is causally related to the former one, or if they remain unrelated to each other.

As was already mentioned above, sham feeding provides parasympathetic, vagally-mediated, boost of several secretory and motor functions of the digestive tract. One should, however, be aware that on the input side this is rather an imprecise research tool. Namely, it summarizes stimulation through visual, olfactory, and taste receptors. Regarding the latter, no distinction can be made among contribution of particular tastes because for a sham feeding procedure composite appetizing food is usually applied, for example cooked frankfurters,<sup>[20]</sup> or a beef steak.<sup>[15,18]</sup>

We conceived, therefore, a new method enabling controlled, selective, and at the same time prolonged taste delivery into the mouth. Making use of this research tool, we endeavored to check if taste stimulation with just a single flavor, as opposed to the complex nature of arousal elicited by sham feeding, may affect the GMA and/or SPB.

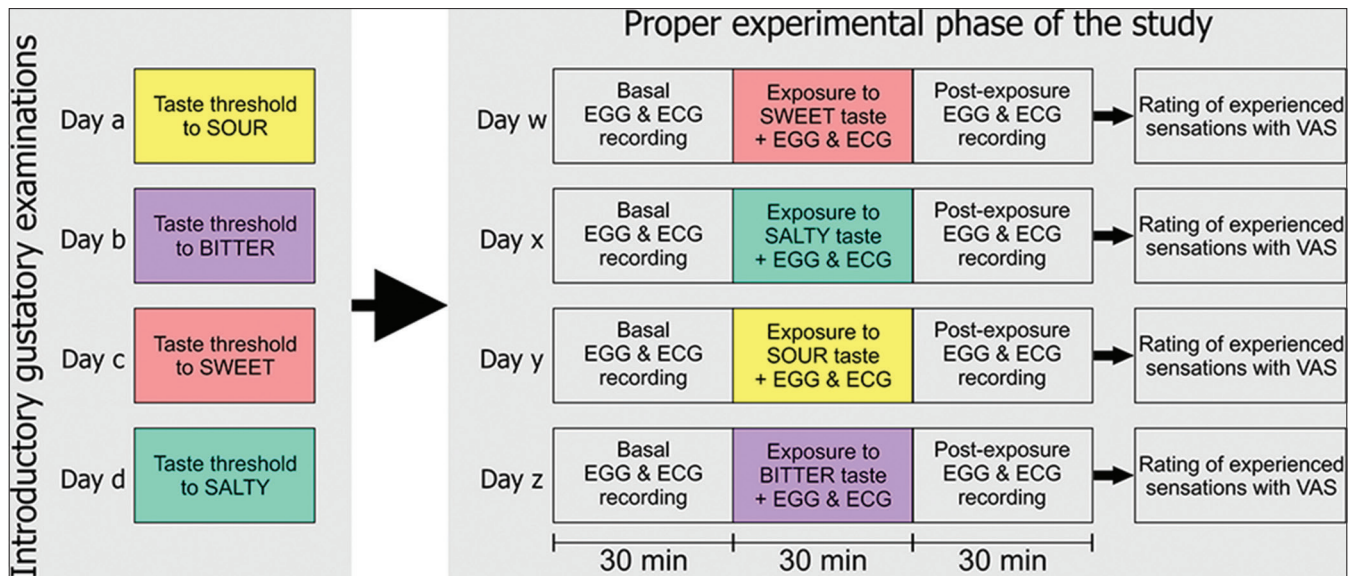
## MATERIALS AND METHODS

The study was conducted in 18 nonsmoking volunteers who responded to an advertisement posted on a bulletin board of the Department of Basic Biomedical Science and agreed to participate without remuneration. Among them there were 10 women and 8 men (age:  $24.8 \pm 0.7$  years, body mass index:  $22.26 \pm 0.87$  kg/m<sup>2</sup>) fulfilling the World Health Organization criteria of good health.<sup>[21]</sup> Each subject had a negative result of a <sup>13</sup>C-urea breath test for *Helicobacter pylori* infection. Exclusion conditions included current use of any medication, a history of surgery affecting the anatomy of the digestive tract (except for an appendectomy), and pregnancy. Every volunteer was provided with detailed information concerning the aim of the study, as well as its protocol and methodology. Written consent was obtained from all subjects and the study was performed in accordance with the Declaration of Helsinki. The project was approved by the Bioethics Committee of the Medical University of Silesia.

### Introductory gustatory examinations

This initial stage of the study was devoted to determination of the individual taste recognition thresholds and every volunteer accomplished it before participation in the proper examination sessions [Figure 1].

Individual taste recognition thresholds of the sweet, bitter, sour, and salty taste were determined following the sip and spit approach described in detail in the International Standard ISO3972,<sup>[22]</sup> with one modification which consisted of the replacement of caffeine with quinine hydrochloride as a bitter taste standard. In the latter case, a set of eight concentrations was used: 0.0656; 0.1166; 0.2075; 0.369; 0.628; 1.146; 2.071; 3.699 mg/L.



**Figure 1:** Exemplary flow diagram of the study. At first individual test recognitions thresholds to the four tastes were determined in random order in a subject on four separate days (a–d). Then the volunteer entered the experimental phase of the study, where on four separate days (w–z) EGG and ECG recordings were performed in the interdigestive state during a 30-min basal period, a 30-min stimulation with one of the four tastes applied in random order, a 30-min postexposure period. After completion of the recordings, the volunteer rated the stimulation-related sensations in three categories: displeasure/pleasure (score ranging from –10 to 10 points), intensity (0 to 10 points), and nausea feeling (0 to 10 points) with the use of VAS

Accordingly, every volunteer was asked to come to the laboratory on four separate days, because on one occasion the taste recognition threshold of one taste only was determined. The procedure was performed always in the morning, after an overnight fast. In a single-blind manner and in random order as to selection of one from among the four tastes, a subject was presented an array of aqueous solutions of a taste-delivering compound arranged in a series from the smallest to the largest concentration. After taking into the mouth 10 mL of the first solution, the subject kept it there for 30 s and subsequently spat into a spittoon. Subsequently, the subject rinsed the mouth with distilled water for 30 s and thereafter spat it. The next test solution was taken into the mouth after a break of at least 45 s. The procedure was continued until correct identification of the taste, and the concentration of the taste-delivering compound within that solution was taken as the taste recognition threshold.

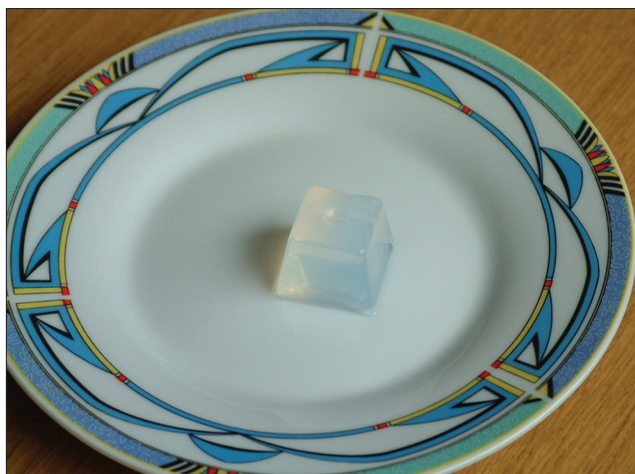
#### Preparation of agar cubes for taste stimulation

One hundred milliliter of an aqueous solution of saccharose, NaCl, citric acid, or quinine hydrochloride was prepared *ex tempore* at a concentration of 100-fold the individual taste recognition threshold. It was heated until boiling and then 2 g of agar (Arche Naturprodukte GmbH, Hilden, Germany) was added while stirring intensely. When the solution was ready, it was poured into a form, cooled steadily and finally put into a refrigerator so that solid cubes could be obtained. The cubes were colorless (transparent) and odorless [Figure 2].

#### Placement of electrodes

The subjects came to the laboratory in the morning after a 12-h overnight fast. For electrogastrographic (EGG) recording, six Red Dot class Ag/AgCl electrodes (type 2222, 3M Canada, London, Ontario, Canada) were placed on the abdomen following a standard preparatory procedure, which involved shaving of the skin, if necessary, and a careful abrasion until pink with the use of Every Paste (Sorimex, Toruń, Poland)<sup>[23]</sup> [Figure 3]. Four of them were active electrodes: the third active (A3) electrode was fixed in the midline half way between the xyphoid process and the umbilicus (which is a standard position for a single-channel electrogastrography), the fourth (A4) electrode was attached 4–6 cm to the right – in line horizontally with A3 electrode, whereas the second (A2) and the first (A1) electrodes were placed with an interval of 4–6 cm on a line leading up from A3 at a 45° angle toward the left costal margin. The reference electrode (R) was fixed at the interception of a horizontal line passing through A1 and a vertical line stretching from A3. The grounding electrode (G) was put on the interception of the left midclavicular line with a horizontal line passing through A3. In every volunteer a sketch of the exact positions of the electrodes, as well as of the anatomical landmarks such as the costal margins and the umbilicus, was done on a transparent foil so that they could be exactly reproduced on repeat examination sessions. A quality control was performed by measurement of the electrical resistance between every active electrode and either the reference





**Figure 2:** Appearance of the agar cube containing the taste-delivering substance

electrode (pairs: A1-R, A2-R, A3-R, A4-R) or the grounding electrode (pairs: A1-G, A2-G, A3-G, A4-G) with the use of a digital ohmmeter (type M3850D, Metex, Seoul, Korea).<sup>[24]</sup> In case it exceeded 5 k ohms, the respective electrodes were removed and the whole preparatory procedure was started from the beginning. Finally, the electrodes were connected to Polygraph ID recording device (Synectics Medical, Denmark).<sup>[23]</sup> The measurement of the electrical resistance between the electrode pairs specified was taken again at the end of the registration session.

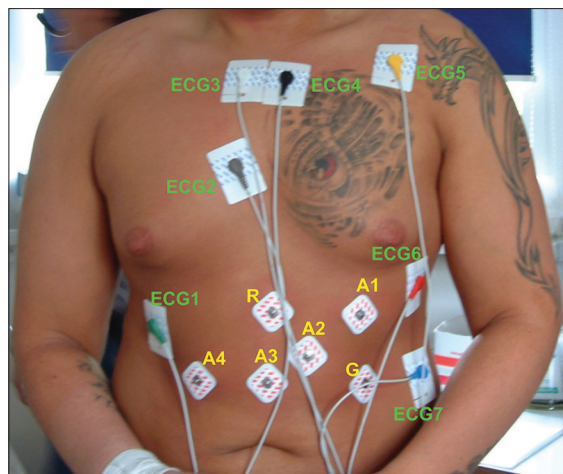
For continuous electrocardiographic (ECG) recording, seven Ag/AgCl electrodes (type R-LLL-510, Bio Lead-Lok, Józefów, Poland) were fixed to the thorax. The placement of the ECG electrodes was accomplished in conformity with the manufacturer's recommendations of the flash memory recorder AsPEKT 702 (Aspel, Zabierzów, Poland)<sup>[25]</sup> [Figure 3].

### Study protocol

Every subject participated in a set of four examination sessions, each executed on a separate day. The median interval separating two consecutive sessions amounted to 7 days (interquartile range: 3.25–10 days).

For purpose of randomization, a set of numbered unique combinations of exposure to the four examined tastes was prepared before commencement of the investigations. Those predefined combinations were allotted by the laboratory staff to subjects consecutively entering the study.

According to the flowchart sketched in Figure 1, an examination started with a basal 30-min record of GMA and ECG, completed in a sitting position.<sup>[26]</sup> During the next 30 min, taste stimulation was accomplished. For this



**Figure 3:** Placement of electrodes for multichannel electrogastrography (A1–A4 = active electrodes, R = reference electrode, G = grounding electrode) and continuous electrocardiographic recording (ECG1–ECG7)

purpose, a subject was given an agar cube containing a taste-delivering substance and placed it in the oral cavity between the tongue and the palate. Instruction was provided not to swallow the saliva but to spit it into a provided container. A disintegrated/melted agar cube was spat and immediately replaced by another one. Finally, a 30-min postexposure GMA and ECG recording was done.

After the completion of each of the four sessions described above, the volunteers rated the sensations experienced during the stimulation in three categories: displeasure/pleasure (score ranging from – 10 to 10 points), intensity (0 to 10 points), and nausea feeling (0 to 10 points) with the use of visual analog scales (VAS) [Figure 1].

### Analysis of the recordings

The primary EGG signal was sampled at 105 Hz, filtered through a 15 cpm low pass and 1.8 cpm high pass filter, and subsequently down-sampled to 1 Hz and stored in a database on a laptop computer. The obtained electrogastrograms were analyzed offline with the use of Polygram Net™ EGG 311224 software (Medtronic A/S, Skovlunde, Denmark). The experimental conditions linked to each data set were concealed from the researcher performing the analysis. After visual inspection of the tracings performed in order to identify and remove any fragments containing motion artifacts, the following analytical algorithms were applied:<sup>[23,27]</sup>

- (i) A running spectrum analysis involved an autoregressive moving average approach executed on consecutive 60 s data sets. For each of the four registration channels, this stage of analysis yielded the percentage time share of: bradygastria (0.50–2.00 cpm), normogastria (2.01–4.00 cpm), and tachygastria (4.01–9.00 cpm), as

well as arrhythmia, i.e., an entity when no dominant frequency could be discerned at the default classification threshold of 2.5 dB

- (ii) For the overall spectrum analysis, a fast-Fourier transformation, using a Hamming window was run on consecutive 256 s data sets with a 128 s overlap. The result of this procedure is a two-dimensional vector of power density within frequency domain, usually referred to as a “frame.” Within it, the maximum power and corresponding frequency are discerned. The procedure is iterated until a given time interval has been analyzed. As a result, a set of numerical data consisting of maximum power and corresponding frequency for each frame is obtained. Finally, the overall dominant power (DP) is calculated as a geometric mean of the set of maximum power values, and the overall dominant frequency (DF) is computed as a median of the corresponding set of frequencies. These parameters were derived by default from the third channel tracing
- (iii) A cross-channel analysis was achieved with the use of the VAIVA Propalyzer module in order to derive the percentage of slow-wave coupling defined as the percentage time within a given period during which the difference in DF between two channels is <0.2 cpm. Averaging the results pertaining to six possible channels pairs yielded the averaged percentage of slow-wave coupling (APSWC).

The analysis outlined was performed for the 30-min basal fasted period, the 30-min taste stimulation period, and the 30-min postexposure period. In order to determine the SPB, the recorded electrocardiograms were subjected to a spectral analysis within the frequency domain performed with the HolCARD 24W v5.10 software (Aspel S.A., Zabierzów, Poland). The powers within the low frequency (LF: 0.04–0.15 Hz) and high frequency (HF: 0.15–0.40 Hz) band were expressed as a percentage of the total power of the whole frequency range. The LF/HF ratio was also calculated.<sup>[25]</sup> The above analyses comprised the 30-min basal fasted period, the 30-min stimulation period, and the 30-min postexposure period.

The efferent vagal (parasympathetic) activity is a major contributor to the HF component. The LF component was considered in the past as a marker of sympathetic modulation, but nowadays it is accepted that it includes both sympathetic and vagal influences.<sup>[28]</sup>

#### Power of the measurement methods and statistical analysis

According to our former research on the medium-term reproducibility (with examinations separated by a two-

three-week gap) of EGG parameters,<sup>[27,29]</sup> a within-subject study protocol involving 18 paired examinations permits to attain the smallest detectable difference (at  $P = 0.05$  level, two-tailed) of 7.5% for percent time share of normogastria, 0.10 cpm for DF, 1.53 dB for DP, and 3.4% for APSWC.

The results obtained were subjected to repeated measures analysis of variance (R-ANOVA).<sup>[30]</sup> In the case of percentage time share of normo-, brady-, and tachygastria, as well as arrhythmia, the R-ANOVA involved two main factors: Intervention with three levels (basal observation, stimulation period, and postexposure period) and Registration channel with four levels (channel #1 to #4), as well as their interaction. For the remaining EGG parameters (DF, DP, APSWC) and the indices of sympathetic/parasympathetic activity balance (HF, LF, LF/HF), R-ANOVA was performed to test the effect of Intervention with three levels (basal observation, stimulation period, and postexposure period).

In case a statistical significance of the main factor(s) or their interaction was detected, differences between means were checked *post hoc* for statistical significance with the Tukey’s honest significant difference test.<sup>[30]</sup>

Data obtained from VAS were subjected to Friedman’s ANOVA to test the effect of taste (four levels: sweet, salty, sour, and bitter) followed, in case of detection of statistical significance, by a Wilcoxon signed rank test.<sup>[30]</sup>

Statistical significance was set at the  $P < 0.05$  level, and was two-tailed. Depending on the distribution of data, the results are presented as means  $\pm$  standard error (SE) or as medians with interquartile ranges.<sup>[30]</sup>

## RESULTS

### Perception of taste

The individual taste recognition thresholds are assembled in Table 1. When compared to the sweet taste, stimulation with salty, sour, and bitter taste was clearly perceived as unpleasant [Table 2]. The perceived intensity was rated lower in the case of the sour and bitter taste than in the case of the sweet and salty taste; almost all subjects rated nausea with a zero score [Table 2].

### Effect of taste stimulation on the interdigestive gastric myoelectrical activity

With regard to the percentage time share of particular GMA rhythms (normo-, brady-, tachygastria, and arrhythmia), R-ANOVA repeatedly revealed a significant main effect of the Intervention (represented by three levels: basal observation, stimulation period, and

**Table 1: Taste recognition thresholds determined in 18 healthy volunteers**

Subject code	Sweet	Salty	Sour	Bitter
	Saccharose g/L	NaCl g/L	Citric acid (g/L)	Quinine HCl (mg/L)
SM 01	7.20	0.16	0.13	0.37
SM 02	4.32	0.34	0.20	1.15
SM 03	2.59	0.24	0.16	0.37
SM 04	4.32	0.24	0.20	0.37
SM 05	4.32	0.34	0.16	2.07
SM 06	2.59	0.16	0.20	1.15
SM 07	7.20	0.34	0.25	2.07
SM 08	2.59	0.24	0.25	1.15
SM 09	4.32	0.34	0.13	2.07
SM 10	4.32	0.16	0.13	0.63
SM 11	4.32	0.24	0.20	0.63
SM 12	4.32	0.48	0.13	1.15
SM 13	4.32	0.24	0.13	1.15
SM 14	1.56	0.16	0.20	1.15
SM 15	7.20	0.16	0.13	0.63
SM 16	4.32	0.24	0.20	0.37
SM 17	1.56	0.16	0.16	0.37
SM 18	4.32	0.16	0.13	0.37
Median	4.32	0.24	0.16	0.89
(interquartile range):	(3.02; 4.32)	(0.16; 0.32)	(0.13; 0.20)	(0.37; 1.15)

**Table 2: Subjective ratings of sensations experienced by the volunteers during taste stimulation in the interdigestive state**

	Sweet	Salty	Sour	Bitter
Pleasure (score range: -10 to 10)	5(4; 6.75)	-1 <sup>a</sup> (-3; 3)	1 <sup>b</sup> (-2.75; 2.75)	-3 <sup>c</sup> (-5.75; 1.75)
Intensity (score range: 0 to 10)	7(5.5; 8)	7(6; 7)	5.5 <sup>d</sup> (4; 7)	5.5 <sup>e</sup> (3; 8)
Nausea (score range: 0 to 10)	0(0; 0)	0(0; 0)	0(0; 0)	0(0; 0)

Data in the table are medians with interquartile ranges (in brackets)

Statistical significance of differences: <sup>a</sup> $P=0.0039$ , <sup>b</sup> $P=0.0036$ ,

<sup>c</sup> $P=0.0031$ , <sup>d</sup> $P=0.0031$ , and <sup>e</sup> $P=0.046$  vs "Sweet"

postexposure period), whereas in every instance the interaction of the factors, Intervention  $\times$  Registration channel, appeared to be statistically not significant. The results of *post hoc* comparisons among the means, pertaining to the main effect of intervention, are assembled in Table 3. During the stimulation period and, in most instances, during the recovery period also, a moderate but statistically significant increase in tachygastria and bradygastria percentage time share was observed regardless of the type of the taste applied. Interestingly, in case of the sweet taste, the increase in the tachy- and bradygastria time share occurred at the cost of a diminished arrhythmia time share, whereas in the case of the bitter taste a considerable and statistically significant decrease in the normogastria time share was observed. The other findings comprise a statistically significant decrease in the DP observed during and after the exposure to the sour taste, and a decrease in the DF elicited by stimulation with the bitter taste. In addition,

stimulation with either the salty or the bitter taste brought about a significant decrease in the APSWC [Table 3].

### Effect of taste stimulation on the sympathetic/parasympathetic balance

Stimulation with three tastes (sweet, salty, and sour) produced a significant decrease in the HF component of the HRV, but the SPB was affected only in the case of the salty taste. On the contrary, stimulation with the bitter taste did not affect any of the HRV indices of the SPB [Table 4].

## DISCUSSION

While designing the study protocol, we faced a serious methodological challenge; namely, a reliable taste-delivery system had to be developed. Approaches used formerly by other authors have included: rinsing the mouth for 5 s with a solution of a taste-delivering compound,<sup>[31]</sup> chewing and spitting of appetizing or unappetizing frankfurter/tofu sausages for at least 5 min,<sup>[20]</sup> or intermittent 15 s chewing and spitting of modified Slim-Fast bars.<sup>[32]</sup>

The approach adopted in this study is unique for two reasons. Firstly, the use of agar cubes with incorporated taste-delivering substances allowed for a continuous, prolonged stimulation with a single taste. Secondly, it should be pointed out that our experiment differed fundamentally from what is referred to as "classical" sham feeding, i.e., chewing and spitting of an appetizing food. Contrary to this procedure, in our volunteers the stimulation was always performed with just one, strictly defined taste, at a level comparable among the volunteers. To achieve this, the concentrations of the taste-delivering substances within the cubes were individually adjusted according to the taste recognition thresholds determined in every subject. It is also important that because the cubes were both odorless and colorless, the stimulation did not involve either the sense of smell or vision.

Electrogastrography is a validated research tool enabling the registration and analysis of the gastric slow waves.<sup>[33]</sup> Disturbances in an electrogram were proven to be indicative of pathologic conditions connected with gastric dysmotility.<sup>[34]</sup> However, recent methodological progression pertaining to the concept and implementation of multichannel electrogastrography allows researchers to gain insight into the propagation of the gastric slow waves.<sup>[35]</sup>

In this study three tastes were rated subjectively as definitely unpleasant in contrast to the sweet, and the ranking of distaste was: bitter > salty > sour. Regarding the GMA, one of the findings showed a moderate increase



**Table 3: Effect of taste stimulation on the interdigestive GMA**

	Sweet taste					
	Basal		Stimulation		Postexposure	
	Mean	SE	Mean	SE	Mean	SE
Normogastria (%)	76.3	2.3	76.5	2.9	77.3	3.4
Bradygastria (%)	2.0	0.4	5.1***	0.7	3.9*	0.7
Tachygastria (%)	2.2	0.4	4.9*	0.8	4.9*	1.0
Arrhythmia (%)	19.5	2.0	13.5**	1.8	13.9**	2.3
DF (cpm)	2.95	0.05	2.91	0.06	2.93	0.07
DP (dB)	40.7	1.8	39.6	1.7	40.9	1.8
APSWC (%)	71.4	2.4	73.2	3.3	72.1	3.0

	Salty taste					
	Basal		Stimulation		Postexposure	
	Mean	SE	Mean	SE	Mean	SE
Normogastria (%)	78.0	2.4	73.8	3.1	76.1	3.7
Bradygastria (%)	1.6	0.3	3.5*	0.7	3.7*	0.8
Tachygastria (%)	2.2	0.6	5.9***	0.7	4.3**	0.7
Arrhythmia (%)	18.3	2.2	16.9	2.3	15.9	2.8
DF (cpm)	3.01	0.06	3.02	0.05	2.98	0.06
DP (dB)	41.1	1.9	40.7	1.7	41.2	1.6
APSWC (%)	74.6	2.5	70.8	3.6	68.2**	2.8

	Sour taste					
	Basal		Stimulation		Postexposure	
	Mean	SE	Mean	SE	Mean	SE
Normogastria (%)	76.0	3.8	74.1	4.1	75.7	3.0
Bradygastria (%)	2.5	0.6	4.9	1.0	4.3	0.8
Tachygastria (%)	2.3	0.5	5.5**	0.8	4.7*	0.4
Arrhythmia (%)	19.3	3.5	15.5	2.7	15.3	2.5
DF (cpm)	2.91	0.07	2.96	0.04	2.94	0.07
DP (dB)	42.5	1.1	41.0*	1.1	40.1**	1.4
APSWC (%)	73.8	3.7	72.6	3.0	70.2	3.7

	Bitter taste					
	Basal		Stimulation		Postexposure	
	Mean	SE	Mean	SE	Mean	SE
Normogastria (%)	82.8	2.5	73.5***	3.5	79.7*	2.9
Bradygastria (%)	1.5	0.5	3.9**	0.7	3.9**	0.7
Tachygastria (%)	1.3	0.3	4.8**	0.7	4.6**	1.0
Arrhythmia (%)	14.5	2.3	17.9	2.9	11.9	1.8
DF (cpm)	3.07	0.08	3.01	0.07	2.90**	0.1
DP (dB)	41	1.4	39.4	1.7	39.7	1.6
APSWC (%)	77.9	3.1	73.4	3.4	69.5**	3.1

DF=Dominant frequency, DP=Dominant power of the gastric slow waves; APSWC=Average percentage of slow wave coupling reflecting the propagation of the gastric slow waves. Statistical significance of differences vs the basal situation: \* $P<0.05$ , \*\* $P<0.01$ , \*\*\* $P<0.001$

in the percentage time share of tachy- and bradygastria during the stimulation period and also within the postexposure period. Because this change in the GMA was common for each of the four tastes examined, it can be considered a nonspecific phenomenon attributable to the act of taste stimulation *per se*. Other findings appeared to be taste-specific. In the case of the bitter taste, which was ranked by the subjects as the most unpleasant, the stimulation also brought about the most profound disturbances of the GMA, which consisted of the diminution of the percentage time share of normogastria, a negative chronotropic effect manifested by a diminished DF, and uncoupling of the gastric slow waves reflected by the decreased APSWC. Exposure to the salty taste

**Table 4: Effect of taste stimulation in the interdigestive state upon the sympathetic/parasympathetic activity balance assessed by means of the HRV analysis**

	Sweet						Salty						Sour						Bitter					
	Basal		Stimulation		Postexposure		Basal		Stimulation		Postexposure		Basal		Stimulation		Postexposure		Basal		Stimulation		Postexposure	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE		
HF (%)	45.1±1.6		46.1±1.5		43.6±1.5		45.7±1.2		46.6±1.1		44.6±1.1		45.9±1.2		46.4±1.3		46.4±1.3		44.6±0.9		44.7±1.7		44.0±1.1	
LF (%)	37.0±1.5		36.5±1.2		38.0±1.2		36.9±1.0		36.3±0.9		38.0±0.9		37.3±1.0		36.4±1.2		36.6±1.3		38.5±1.3		36.8±1.2		38.4±0.9	
LF/HF (%/%)	0.88±0.06		0.81±0.05		0.90±0.05		0.82±0.04		0.79±0.03		0.86±0.04		0.82±0.04		0.80±0.05		0.86±0.06		0.87±0.05		0.85±0.06		0.88±0.03	

HF=normalized high frequency (0.15-0.40 Hz) power, LF=normalized low frequency (0.04-0.15 Hz) power; Statistical significance of differences: \* $P=0.034$  vs \*\**Stimulation*†; † $P=0.025$  vs \*\**Stimulation*†; † $P=0.031$  vs \*\**Basal*† and † $P=0.0071$  vs \*\**Stimulation*†; † $P=0.033$  vs \*\**Stimulation*†

resulted solely in a significant disturbance of the slow wave propagation. Stimulation with the sour taste elicited a significant decrease in the DP of the gastric slow waves. Only the sweet taste did not evoke any specific negative changes in the GMA. The diversity of observed effects of taste stimulation on the GMA is not surprising when one recalls the complexity of the structure and mechanisms of stimulation of receptors that account for the sensation of the four tastes.<sup>[36,37]</sup>

The effect of taste stimulation upon the HRV has not been examined before. It is well known that ingestion of a meal brings about a decline in the HF power and a rise in the LF power and consequently the LF/HF ratio increases postprandially. Such pattern of the shifts in the HRV parameters is consistent with a meal-induced blunting of the parasympathetic activity and a relative predominance of the sympathetic component.<sup>[19,25]</sup> Sham feeding with an appetizing meal (hamburger) elicited similar shifts in HRV parameters, namely an increase in the LF/HF ratio resulting from a decrease in HF power with unchanged LF power. Contrary to a real feeding situation, however, the shift in the autonomic equilibrium was observed solely during sham feeding and not during the recovery period.<sup>[38]</sup> As was already outlined above, at odds with a “classical” sham feeding, our experiment consisted of exposure to just a single taste. Several rather unexpected findings were obtained. Firstly, a minor and statistically insignificant increase in HF power occurred during the stimulation phase, whereas during the postexposure period a marked decrease was observed. Secondly, the result of taste stimulation upon the HRV, at odds with what was observed with the GMA, did not coincide with the ranking of the subjectively perceived distaste. Similar shifts of the HF power were observed in the case of stimulation with the sweet, salty, and sour taste, although in the case of the salty taste alone there was a significant increase in the LF/HF ratio. Quite strikingly, stimulation with the bitter taste did not elicit any changes in the autonomic balance reflected by the HRV parameters.

## CONCLUSION

The results of this study suggest that oral stimulation arising from tastes subjectively perceived as unpleasant brings about disturbances of the interdigestive GMA which, however, does not coincide with its effect upon the autonomic balance.

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## Conflicts of interest

There are no conflicts of interest.

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