Homeopathy (2005) 94, 241–247

doi:10.1016/j.homp.2005.07.003, available online at http://www.sciencedirect.com

ORIGINAL PAPER

A new approach to the memory of water

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We investigated whether water has a 'memory' for succussion compared to unsuccussed controls. The method is based on a bioassay using dinoflagellates. The duration of memory measured by this method is at least 10 min, and may be longer. The effect may be based upon solitons. A hypothesis about the mode of action of homeopathy may be experimentally investigated by this method. *Homeopathy* (2005) 94, 241–247.

Keywords: succussion; memory; hypothesis of action; solitons

Introduction

'Memory' refers to a long decay time of information within a structure. Specifically, the 'memory of water', is the relaxation time of previous specific excited states. This pattern or structure may be spatial or temporal (dynamic), or both. A detector can be used to register the memory time in such a way that it starts to react to the corresponding emitted signals when the information is first stored and stops after irreversible damping of the signals. The measurement of the memory time is not only dependent on the properties of the information carrier but also on the sensitivity of the detector system. An insensitive detector will register a shorter memory time than a sensitive one.

A crucial problem in homeopathy is the question of whether the succussion is a decisive process in preparing the remedy. If an indicator that registered a significant difference between succussed and unsuccussed fluid could be found, it would be an important insight into an essential mechanism of homeopathy. Any difference would need to persist for a relatively long period, say, minutes to months, in order to gain serious attention.

The damping of vibrations in water is expressed in terms of a frequency $\nu = 1/\tau_0$, where τ_0 characterizes the lifetime of a stable mean position of a water molecule. The potential W must be exceeded by a molecule in order to jump over the barrier that stabilizes this resting position in such a way that $\tau = \tau_0 \exp(W/(kT))$, where kT is the mean thermal energy. With increasing W, τ increases exponentially and τ is taken as a measure of the 'viscosity' of the fluid, or, more generally, of the memory time on the molecular level. At room temperature, water displays a time τ of about 10^{-11} s. For water below 0°C, and for glasses, τ may be hours or days. If one finds at room temperature a time interval $\tau_x \gg 10^{-11}$ s, after which it is possible to detect previous succussion, one has to look for an explanation, which may at the same time provide a tool for understanding the action of homeopathic ultramolecular dilutions.

We report here the repetition of an experiment using a bioindicator in succussed and unsuccussed water[1] based on a hypothesis of the mode of action of homeopathy[2]. These experiments suggested a memory time of at least some minutes for succussion. We used the occasion of recent financial support to repeat this experiment. We used the same bioindicators, dinoflagellates that react sensitively in their bioluminescence and biophoton emission to changes in their environment.

Materials and Methods

Dinoflagellates are marine organisms that display a puzzling bioluminescence. In contrast to the more common bioluminescence type of luminescence displayed by fireflies, etc the photon emission from dinoflagellates changes its intensity following distinct biological rhythms. Dinoflagellate photon emission is characterized by sequences of relatively strong peaks

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Received 29 March 2005; revised 1 July 2005; accepted 25 July 2005

and a much lower continuous 'ultraweak luminescence' background. This weak emission has been identified as biophotons that provide the regulatory activity of the biochemical amplification (chemoluminescence), resulting in the luminescence bursts (Figure 1). A suitable species of dinoflagellate is *Gonyaulax polyedra*. They were cultivated as previously described[3]. For measurement, a detector system based on a single photon counting technique was used. The method has been described several times.[4-6]

The measurements were always performed between 10.00 and 14.00 h, after the animals had been adapted in an incubator with an artificial lamp to reverse the day night rhythm. This provides for the highest bioluminescence activity during the measurement time. The medium consisted of 1000 ml natural sea water, 15 mg $NaNO_3$, 5 mg NaH_2PO_4, 0.25 ml Metal-Mix, and 0.125 ml Vitamin-Mix. The sea water was collected by the Biologische Anstalt Helgoland, Germany, from the North Sea. The Metal-Mix was composed of 8.68 g/l Na_2-EDTA, 0.71 g/l $FeCl_3 \cdot 6H_2O$, 360 mg/l $MnCl_2 \cdot 4H_2O$, 44 mg/l $ZnSO_4 \cdot 7H_2O$, 22 mg/l $CoCl_2 \cdot 6H_2O$, 19.6 mg/l $CuSO_4 \cdot 5H_2O$, and 12.6 mg/l $NaMoO_4 \cdot 2H_2O$. The Vitamin-Mix was composed of 600 mg/l

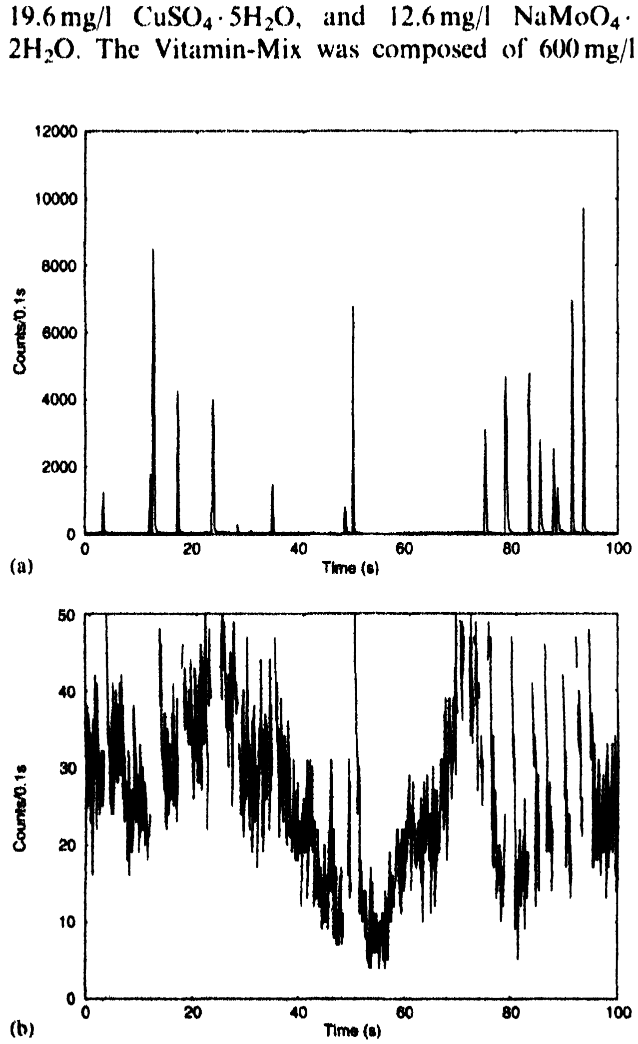

Figure 1. Typical record of bioluminescence of *G. polyedra* with two different components: (a) Chemoluminescence; (b) biophotons (corresponding to the invisible background of (a). Note the different amplitudes of photon emission measured in units of [counts/(0.1 s)].

thiamine · Cl, 100 mg/l pyridoxamine · 2HCl, 40 mg/l riboflavin, 300 mg/l Ca-panthothenate, 400 mg/l nicotinic acid, 1 mg/l biotin, 0.1 mg/l vitamin B_{12}, 1 mg/l *p*-aminobenzoic acid, and 1 g myo-inositol. The medium was sterilized through a 0.2 μm filter before use. The resulting medium is a completely clear solution.

One hundred milli liter of the medium was divided into two equal parts of 50 ml and put into two tubes covered by gastight tops. One of these tubes was succussed manually, the other remained untreated. The succussions were at about 1 Hz with an amplitude of about 30 cm. We used different numbers of succussions to see whether the result is dependent on the number of successions, we succussed 20, 36, 64, and 13 times. Thirteen attempts were added in view of the claim that this number is particularly successful. The number of succussions remained the same in each experiment. Ten milli liter of the unsuccussed, or 10 ml of the succussed medium were put into quartz cuvettes (2.5 × 2.5 × 4 cm). In order to keep the number of *G. polyedra* for every experiment constant (6500/ml), 1 ml of the medium containing the *G. polyedra* was always put into the cuvette under investigation. The experiments were performed under the same conditions, i.e. by alternation of succussed and unsuccussed medium such that the time between filling the cuvette with *Gonyaulax* and the measuring remained independent of whether the animals were put into succussed or unsuccussed seawater solvent. Photon emission was measured in terms of the number of emitted photons per 0.1 s. The bioluminescence intensity and its variance (standard deviation) was the main parameter measured in a measurement time of 100 or 200 s. The high number of measurement points (in the order of 10^3) per experiment enables significant results even if the standard deviation is very large. The *F*-test was used to confirm the significance of the measured differences between the measured photon intensities of succussed and unsuccused samples. The experimental procedure is schematically shown in Figure 2.

Results

The medium itself displayed no photon emission at all; the emission of about 0.4 photons/0.1 s is not different from the background noise. No difference in photon emission was detected between succussed and unsuccused media.

Table 1a displays the details of all measurements, including statistical analysis. In view of the large number of values per measurement, the *z*-test instead of the *t*-test is appropriate. In most cases, the differences between mean values and standard deviations of the luminescence from succussed and unsuccussed samples are highly significant. According to these results, there is a clear difference between succussed and unsuccused water.

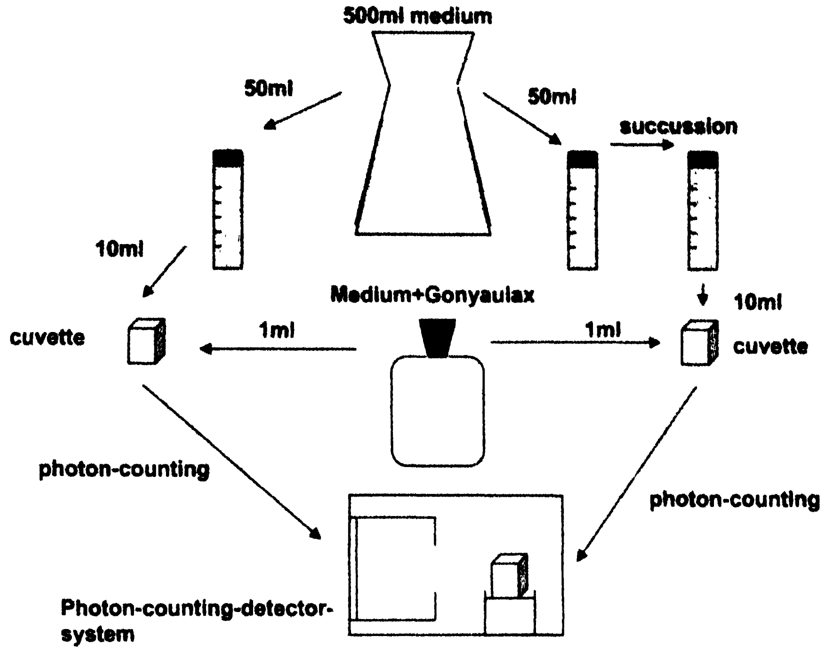

Figure 2. Experimental set-up.

Figure 3a and b shows typical examples of photon emission of *G. polyedra* within succussed and unsuccused media, respectively.

Despite a clear significance of the effects even including the 'bursts' of bioluminescence, our main analysis was confined to the underlying biophoton emission and we cancelled all the values that were higher than about 10 times the standard deviation σ. The cut-off intensity chosen was 50 counts/(0.1 s). This is reasonable according to the 4σ rule.[7] The result of this correction can be seen, for example, in Figure 4a and b. The corrections are shown in Table 1b.

Figures 5a–f shows examples of the data.

The results can be summarized as follows:

- There is a highly significant difference between the photon emission of *G. polyedra* in medium that is succussed *vs* medium that is unsuccussed.
- The radiation intensity and its fluctuations are much higher in succussed than in unsuccussed medium.
- The difference increases when bursts of bioluminescence are eliminated.
- The difference is independent of the number of succussions between 13 and up to 64.
- The difference is independent of rest time in both the succussed and unsuccussed media, at least between 5 and 10 mins.

The time between the addition of the *G. polyedra* to the sample and the measurement of its photon emission was always the same, independent of whether it is succussed or unsuccused. It is also not possible to trace the effect back to different absorption rates of molecules (like oxygen) in the succussed and unsuccussed seawater, since succussion took place under gastight conditions.

Discussion

G. polyedra expresses, in its biophoton emission, differences between succussed and unsuccussed samples of its medium. Viscosity effects can be excluded because the samples had the same temperature and the same distribution of their contents. There was no difference in photon emission between a 5 or a 10 min interval between succussion and measurement. We did not perform experiments with longer time intervals because uncertainties in rhythms and other biological factors would compromise the reliability of the results.

A possible explanation for this effect, in line with other results,[1] is based on the hypothesis[2] that solitons are created by succussions and that they are modulated by the 'information' of the effective substance. The persistence of the solitons then provides the 'memory' of the homeopathic medicine.

Solitons were discovered in water more than hundred years ago. They are non-linear coherent oscillations of matter.[8,9] There is no doubt that mechanical shaking of water will create solitons, and that they persist without dissipation in the fluid where they are formed. They provide optimal properties as information carriers. For a more detailed description of solitons, see the specialist literature.[9] These results do not prove the hypothesis of soliton-information transfer in Homoeopathy. However, they do explain the surprising observation that succussed dilutions have a long memory. This is a necessary, but certainly not sufficient, condition for homeopathic

Table 1 Dates, modalities, and results of the measurements

Date	Modality	No. of data	No. of cuvettes	Mean	St.Dev	*z*-Value	Sign.	*F*-ratio	Sign.
(a) Bursts included									
02.09.05	Successed(5 min)	1000	10	21.20	249.53	5.41	h.s.	3.96	h.s.
20 ×	Unsuccussed(5 min)	1000	10	6.10	125.39				
	Successed(10 min)	1000	10	36.38	476.13	6.92	h.s.	424.12	h.s.
	Unsuccussed(10 min)	1000	10	3.38	23.12				
02.11.05	Successed(5 min)	1000	10	3.02	14.84	−0.60	n.s.	17.87	h.s.
36 ×	Unsuccussed(5 min)	1000	10	3.15	3.51				
	Successed(10 min)	1000	10	21.66	468.65	2.02	s.	7.74	h.s.
	Unsuccussed(10 min)	1000	10	7.44	168.49				
02.14.05	Successed(5 min)	1000	10	50.70	511.38	4.71	h.s.	2.62	h.s.
36 ×	Unsuccussed(5 min)	1000	10	20.84	316.07				
	Successed(10 min)	1000	10	23.43	287.03	−1.04	n.s.	1.09	h.s.
	Unsuccussed(10 min)	1000	10	27.73	299.90				
02.22.05	Successed(5 min)	2000	5	11.71	169.81	2.16	s.	5.52	h.s.
64 ×	Unsuccussed(5 min)	2000	5	8.89	72.30				
	Successed(10 min)	2000	5	10.21	85.35	−2.11	s.	5.28	h.s.
	Unsuccussed(10 min)	2000	5	13.58	196.16				
02.25.05	Successed(5 min)	2000	5	2.40	46.70	2.13	s.	6.59	h.s.
64 ×	Unsuccussed(5 min)	2000	5	1.22	18.19				
	Successed(10 min)	2000	5	3.19	53.66	−0.53	n.s.	3.67	h.s.
	Unsuccussed(10 min)	2000	5	3.82	102.79				
02.26.05	Successed(5 min)	2000	5	1.95	2.72	12.18	h.s.	1.83	h.s.
13 ×	Unsuccussed(5 min)	2000	5	1.46	2.01				
	Successed(10 min)	2000	5	1.17	1.69	0.71	n.s.	1.30	h.s.
	Unsuccussed(10 min)	2000	5	1.15	1.48				
02.27.05	Successed(5 min)	2000	5	1.94	2.24	−0.86	n.s.	42.54	h.s.
13 ×	Unsuccussed(5 min)	2000	5	2.07	14.64				
	Successed(10 min)	2000	5	1.82	1.72	9.80	h.s.	2.25	h.s.
	Unsuccussed(10 min)	2000	5	1.52	2.59				
(b) Bursts eliminated with cut-off intensities higher than 50 counts/(0.1 s)									
02.09.05	Successed(5 min)	1000	10	4.47	6.92	22.62	h.s.	6.19	h.s.
20 ×	Unsuccussed(5 min)	1000	10	2.78	2.78				
	Successed(10 min)	1000	10	5.04	7.69	24.45	h.s.	6.55	h.s.
	Unsuccussed(10 min)	1000	10	3.02	3.00				
02.11.05	Successed(5 min)	1000	10	3.15	3.51	6.69	h.s.	1.52	h.s.
36 ×	Unsuccussed(5 min)	1000	10	2.72	2.84				
	Successed(10 min)	1000	10	4.48	4.85	14.49	h.s.	1.73	h.s.
	Unsuccussed(10 min)	1000	10	3.23	3.68				
02.14.05	Successed(5 min)	1000	10	1.27	3.48	7.29	h.s.	2.24	h.s.
36 ×	Unsuccussed(5 min)	1000	10	0.95	2.33				
	Successed(10 min)	1000	10	1.45	2.69	2.90	h.s.	1.16	h.s.
	Unsuccussed(10 min)	1000	10	1.34	2.90				
02.22.05	Successed(5 min)	2000	5	7.86	8.90	11.31	h.s.	1.54	h.s.
64 ×	Unsuccussed(5 min)	2000	5	6.94	7.18				
	Successed(10 min)	2000	5	7.19	9.42	5.98	h.s.	1.62	h.s.
	Unsuccussed(10 min)	2000	5	6.65	7.40				
02.25.05	Successed(5 min)	2000	5	7.86	8.90	11.31	h.s.	1.54	h.s.
64 ×	Unsuccussed(5 min)	2000	5	6.94	7.18				
	Successed(10 min)	2000	5	1.71	2.03	18.96	h.s.	1.22	h.s.
	Unsuccussed(10 min)	2000	5	1.16	1.84				
02.26.05	Successed(5 min)	2000	5	1.95	2.72	12.18	h.s.	1.83	h.s.
13 ×	Unsuccussed(5 min)	2000	5	1.46	2.01				
	Successed(10 min)	2000	5	1.17	1.69	0.71	n.s.	1.30	h.s.
	Unsuccussed(10 min)	2000	5	1.15	1.48				
02.27.05	Successed(5 min)	2000	5	1.94	2.24	7.74	h.s.	1.10	h.s.
13 ×	Unsuccussed(5 min)	2000	5	1.70	2.14				
	Successed(10 min)	2000	5	1.82	1.72	14.02	h.s.	1.17	h.s.
	Unsuccussed(10 min)	2000	5	1.50	1.60				

From left to right, the tables display (1) date of measurement, (2) modality (successed or unsuccussed), (3) number of measurement values, (4) the number of cuvettes measured, (5) the mean value of the measured photon emission from the samples (in counts per 0.1 s), (6) the standard deviation of the measured photon emission, (7) the *z*-value for the difference of the corresponding mean values of successed and unsuccussed samples, (8) the significance level of the difference, (9) the *F*-ratio of the corresponding variances, and (10) the significance level of the *F*-value. n.s. = not significant; s = significance > 95%; h.s. = significance > 99%.

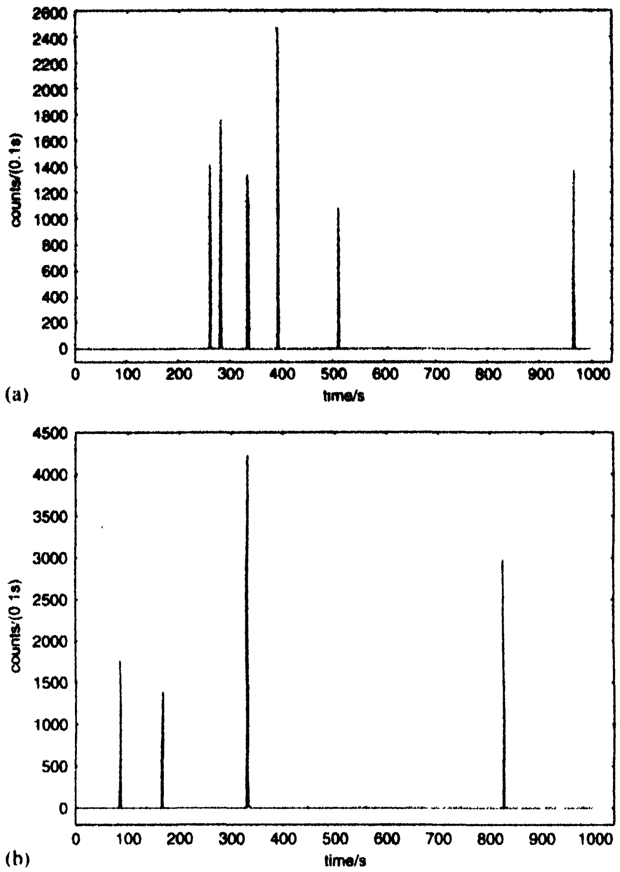

Figure 3. (a) The bursts of bioluminescence of *G. polyedra* in successed medium (36 succussions). The peaks are so high that the background biophoton emission disappears in the scaling. (b): Bioluminescence bursts of *G. polyedra* in unsuccussed medium (10 succussions). Again the biophoton 'background' is so low that it disappears in the scaling.

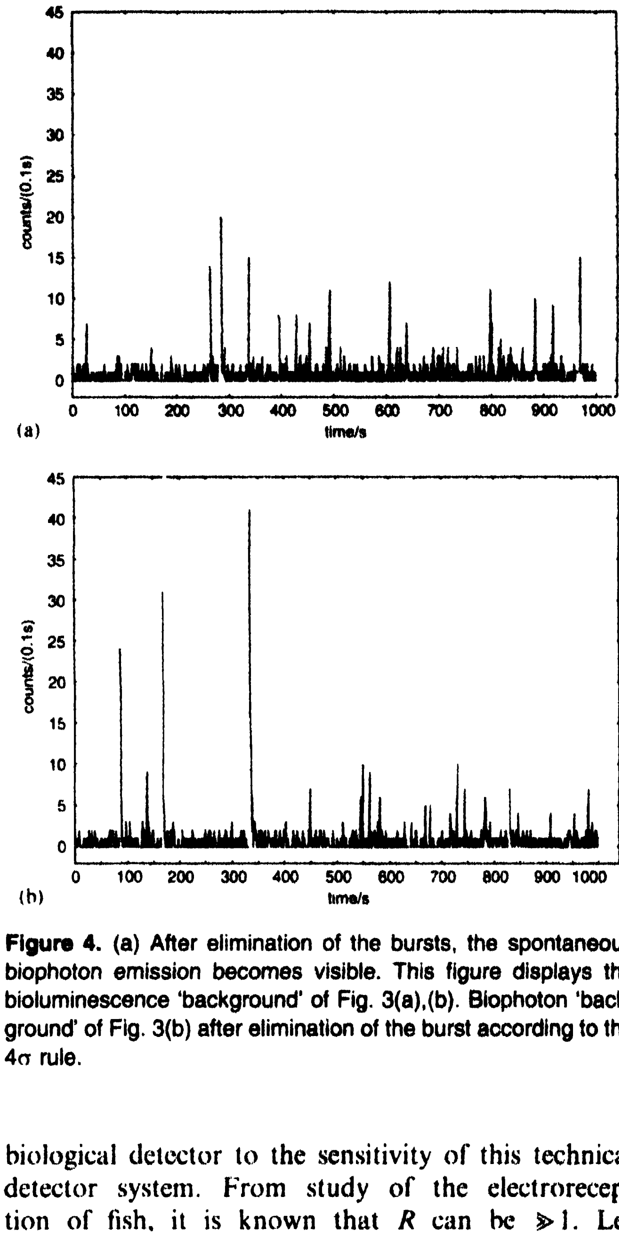

Figure 4. (a) After elimination of the bursts, the spontaneous biophoton emission becomes visible. This figure displays the bioluminescence 'background' of Fig. 3(a),(b). Biophoton 'background' of Fig. 3(b) after elimination of the burst according to the 4σ rule.

ultramolecualr dilutions to be effective. However, the results are in agreement with an original hypothesis of the action of modes of homeopathy.[2] This hypothesis has never been the subject of systematic research. Because of the extremely high sensitivity of the detector system, it requires the inclusion of bioindicators.

But now the time seems to be ripe to investigate this approach to high dilutions. The hypothesis has general validity, including the fact that it does not provide for interactions of its contents on the molecular level. The inclusion of seawater was necessary because the bioindicators cannot live without it.

Among the numerous attempts to explain the modes of action of homeopathy, this rather biophysical hypothesis originates from the field of 'Biophotons and Biophotonics'.[10,11] It has been shown[12] that instead of the normal memory time

$$T = \tau(1 + \ln R), \qquad (1)$$

solitons have a memory time

$$T = \tau(2R - 1), \qquad (2)$$

where τ is the memory time of an artificial detector, and R is the ratio of the sensitivity of a 'subjective' biological detector to the sensitivity of this technical detector system. From study of the electroreception of fish, it is known that R can be $\gg 1$. Let us consider a realistic example. τ of collective states in water may take at most a time of 10^{-1} s, which is on the order of the lifetime of excited vibrational collective modes. Electro-reception shows that it is reasonable to include values of about $R = 10^9$: the biological system may be 10^9 times more sensitive than exisiting detector systems. Ordinarily, chaotic excitations of water would be damped out according to Eq. (1) after $T = 2.172$ s ($\ln 10^9 = 20.72$). This is irrelevant for practical purposes. According to Eq. (2), solitons could persist for more than 2×10^8 s, or more than 5 years.

Homeopathy could then be explained in terms of the remedy-specific modulation of the solitons in succussions. They may work then as the information carriers of the substance-specific modulations of the soliton interactions induced by shaking. The mechanism could then be described in terms of the medicines' resonance absorption of the similar, but 'wrong' and long-lasting, vibrations that were induced by the original disease state.

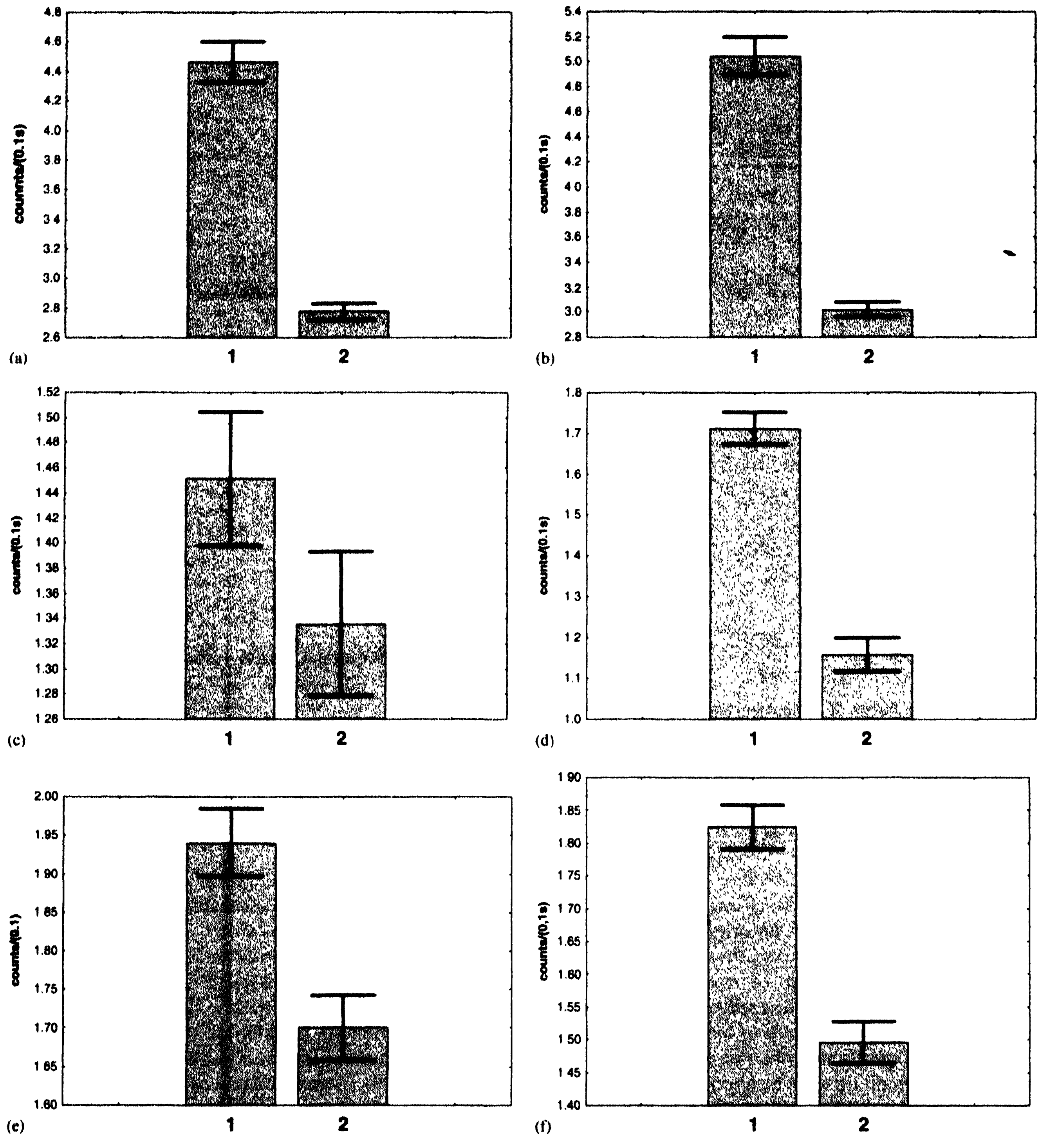

Figure 5. (a) Mean values and error bars of 20 times succussed medium (1) compared with unsuccussed medium (2), 5 min after adding *Gonyaulax* into the cuvette. (b) Mean values and error bars of 20 times succussed medium (1) compared with unsuccussed medium (2), 10 min after adding *Gonyaulax* into the cuvette. (c) Mean values and error bars of 64 times succussed medium (1) compared with unsuccussed medium (2), 5 min after adding *Gonyaulax* into the cuvette. (d) Mean values and error bars of 64 times succussed medium (1) compared with unsuccussed medium (2), 10 min after adding *Gonyaulax* into the cuvette. (e) Mean values and error bars of 13 times succussed medium (1) compared with unsuccussed medium (2), 5 min after adding *Gonyaulax* into the cuvette. (f) Mean values and error bars of 20 times succussed medium (1) compared with unsuccussed medium (2), 10 min after adding *Gonyaulax* into the cuvette.

The next step in the continuation of this research is independent reproduction of the results, including an extension of the duration. The time between succussions and the measurement of the difference of photon emission from dinoflagellates in succussed and unsuccussed water solutions can be prolonged, provided one can exclude further possible influences on the system during this time.

If these results are positive, the system could be used to examine other aspects of homeopathic medicines, including specific remedies. The bioindicators could also be treated by poisons at low concentrations with and without succussion.

Acknowledgements

We thank the Karl and Veronika Carstens Foundation for financial support. We thank Prof. Fritz-Albert Popp for assistance and discussion.

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