# Conditions That Appear to Favor Extrasensory Interactions Between Homo Sapiens and Microbes

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Abstract — We report laser Doppler studies of the possibility of extrasensory interactions between Homo sapiens and isolated unicellular microbes, and unattended computer-controlled studies of the response of cultures of microbes to the distant sacrifice of clones.

From the first series of experiments we find evidence that the focussed attention and intention of a person in nominal physical isolation from a culture of *Dunaliella tertiolecta* can influence their activity. Averaging of all data from a total of 251 trials strongly suggested the rejection of the null hypothesis. However, a subset of 118 formal trials conducted with more restrictive protocols were only marginally significant.

A second series of experiments used the sacrifice of clones as a distant stimulus. The data appear to show that the marine alga *Tetraselmis suecica* reacts dramatically to the sacrifice of cells in a physically isolated aliquot of the same culture if the experimenters are aware of the moment of sacrifice, and excited by the novelty of the experiment. In sharp contrast, only marginally significant results were obtained when the same experiment was run entirely automatically, with the time of the sacrifice defined by random number selection, and the experiment activated by computer command in an empty laboratory.

A third series appears to illustrate a difference between the effect of the attention of experimenters and participants in a formal series, and the more highly developed states of excitement and interest which normally characterize pilot trials.

In conclusion, we draw attention to the support which our observations provide for an "experimenter effect." Our present working hypothesis is that the result of any experiment is a form of environmental feedback, a complex manifestation of the conscious and subconscious expectations of the experimenter and the participants.

## Introduction

As background to the general question of interactions within and between living organisms, we should recognize the emerging new field of psychoneuroimmunology (Ader, 1981; Lock, Ader, & Besedovsky et al., 1985). At some level, we are all aware that human consciousness is interactive with the body. We are now finding experimental evidence that myriad cells interact within tissue, vast microbial populations maintain symbiotic relationships, and to paraphrase an old English drinking song, "the whole . . . is driven by (thought)."

There is clear evidence that the psyche and the immune system are interactive, although we are obliged to admit that only a few of the system vari-

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ables are well defined. As is the normal practice in our times, investigators have progressed by applying the scientific method to nominally isolated parts of the whole system such as electrical activity in the neural network. Most recognize that there is a limit to the information that science can give us about living systems, set by its own protocol: the need to define the variables influencing an experimental sequence and replicate the results. Living systems are open systems, characterized by the ongoing exchange of water, minerals, organic substances, and electromagnetic radiation with the environment; they are all different, and constantly changing.

To a generalist, the differences between a single cell, a person, and the world that they live in are trivial when viewed against the background of common features. Many people including Thomas (1975) and Lovelock (1979) have drawn our attention to this. We have tried to assume this perspective when designing our experiments, to illuminate the central question of the nature of the interaction of consciousness with its environment and clarify our reasoning. The work reported here spanned five years, 1984–1989, with a two year break, 1986–1988, between different experiments.

Using cultures of the unicellular marine algae *Dunaliella* and *Tetraselmis,* and opto-electronic systems for characterizing the He/Ne laser light scattered from a very small measuring volume, we have been able to monitor changes in the activity of large numbers of individual cells in response to psi stimulus. The single cell is the simplest living entity whose behavior can be studied, and to make behavioral changes visible, we have worked with cells that can swim. In the first series of experiments the psi stimulus was conventional, involving the focussed attention and intention of a participant. In later experiments the psi stimulus was the sacrifice of a distant and nominally isolated culture of microalgal clones, following Backster (1968).

There are relatively few previous studies of the effect of psi stimulus on single-celled organisms. However, Rauscher (1980) studied the effect of a psychic subject on the growth rate of *Salmonella typhirmurium.* Nash has also attempted psychokinetic control of bacterial growth (Nash, 1982) and mutation (Nash, 1984). Randall (1970) made an attempt to detect psi effects with protozoa. Many experiments have been conducted with small laboratory animals; however, these lack the cogency of the experiments with cultures of unicellular microbes, since the number of subject organisms in any given trial is necessarily quite limited.

Research in the domain of macroscopic plants relates directly to research with marine microalgae which are, in effect, unicellular swimming plants. There are many reports of psi effects on large plants, ranging in scientific quality from the anecdotal to instrumentated studies. Backster's seminal paper (Backster, 1968) describing the use of a polygraph to monitor the resistance of the leaves of plants during periods of psi stimulus attracted the interest of many scientists, the media, and the general public. It is most interesting to note that despite this widespread interest and the evident possibility of replicating Backster's experiments, there has been no convincing

scientific follow-through. Tompkins and Bird (1973) have described several attempts to replicate, and much other relevant research. However, in every case, as far as we can ascertain, no other publications ever appeared in refereed scientific journals. In some cases we note claims that papers were turned down by journals, but it seems unlikely that this is the whole story; a much more parsimonious explanation would be that in general the effect is not replicable. Indeed our own work is only replicable in the stochastic sense.

Considerations of this kind support the hypothesis that the magnitude of psi effects might be complex functions of the conscious and subconscious attitudes of the participants and the experimenter. If this were the case, each new datum would be dependent to some extent on its predecessor, and the only valid analytical techniques would be nonparametric.

The second series of experiments described in this paper were therefore specifically designed to allow the experimenter and the participant to vary the level of their involvement. In summary, our objectives (which were developed sequentially) were to search for empirical evidence that:

1. Individual microbes in a culture respond to human attention and intention.
2. Microalgae respond to the violent death of physically isolated clones.
3. The results obtained were primarily influenced by the people involved.


## Apparatus, Method, and Protocol

The generic apparatus is illustrated schematically in Figure 1. It is a light scattering spectrometer, which translates Doppler shifts caused by microbial motion into time series data representing velocity and vector. The patterns exhibited by the time series data strings are analyzed statistically to evaluate the probability of a change in activity during the experimental periods. The variable may be the mean velocity during the period of interest or some higher moment of the distribution of observed velocities such as the variance. The apparatus was set to monitor the vertical axis since most marine microbes show a tendency to migrate vertically with more or less pronounced circadian rhythms. References and detailed descriptions can be found in Pleass and Dey (1985, 1986).

In all experiments the method was to study changes in microbial activity during periods of psi stimulus. The "activity" measured is exocellular; the Doppler shifts corresponding to swimming speed and secondary motions like flagellum beat are recorded in the data sets obtained in adjacent "control" and "stimulus" periods. In the first series of experiments stimulus means the attention and intention of an isolated "operator" or participant, and the initiation and termination of the period is marked by pressing a preprogrammed key at intervals chosen by the participant. A control data block of equal size is developed from the time series immediately before the
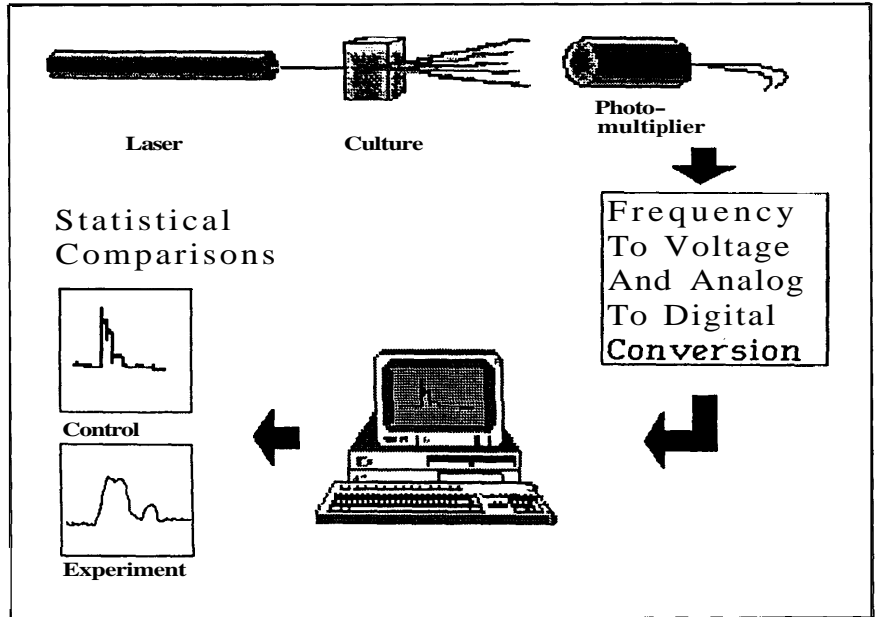
Fig. 1. Experimental set-up: PK86. A 5-milliwatt He-Ne laser (Hughes model 3225-PC) is beam-split in a custom Dantec Electronics, Inc. single axis Laser Doppler Velocimeter (LDV). One beam is passed through a Bragg cell, which imposes a 40 khz frequency shift. The two beams are then focused to cross at the beam waist at an 18.60" intersection angle. The crossover is normally located within a 1 cm X 4 cm capped polycarbonate spectrophotometer cuvette or a polycarbonate tissue culture flask. Individual bursts of Doppler-shifted light from the 0.6 nanoliter crossover, representing particle passages through the crossover volume, are collected by an 80-mm focal-length lens, and passed through a narrow band-pass filter and a pinhole into a photomultiplier (Model # RCA 4526). The resulting signal is passed to a Dantec model N55 frequency tracker, which matches the incoming frequency with a voltage controlled oscillator. The analog voltage is passed to a Scientific Solutions LabMaster 12-bit analog to digital converter mounted in an IBMPC-I computer. The velocity and vector of each particle and the statistical moments of distributions of data are calculated by a custom program, which also governs the (random) timing of control and experimental periods, and the collection of any environmental control data. Time series data is stored on hard disk for later analysis by custom programs, Lotus[B], or Statgraphics®.

onset of the stimulus period, after the stimulus period has been defined. The second series of experiments involving the sacrifice of clones was computer-controlled throughout, with a random start to the stimulus period within each hour.
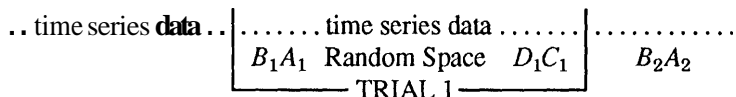
A "tripolar" protocol similar to that developed by Jahn and Dunne (1987) is optimal under any circumstance where an "operator" is given the tasks "go high" and "go low." We are unable to adopt it since our instruction to the participant is to "be with the algae" during the stimulus period. This is not an arbitrary decision: consideration of early data from the period 1982–1984 showed that natural changes in the vectors of the microbes due to

endogenous rhythms were sufficiently pronounced to make the result of a command such as "go high" or "swim faster" ambiguous. Expressed differently, the algae should not be expected to respond in the same way to exogenous stimuli which are separated in time by a substantial fraction of a day.

## Sampling and Statistical Treatment

*Series 1: 1986 Data*

Data for the entire year representing 251 trials were analyzed by a somewhat severe statistical procedure known as double-differencing. A further level of "global" control was applied by running otherwise identical experiments in the absence of any "real" stimulus. The double-differencing procedure has been described in detail in Pleass and Dey (1986). However, in outline it can be illustrated in this way:

$$.. \text{time series } \textbf{data} ..\left|\begin{array}{c} \dots\dots \text{ time series data } \dots\dots \\ B_1A_1 \quad \text{Random Space} \quad D_1C_1 \\ \hline \text{TRIAL 1} \end{array}\right| \dots\dots\dots \\ B_2A_2$$

Where:

Period $A$ = the stimulus period, defined by key-press.

Period B = a control period of equal duration, defined subsequent to the completion of period $A$.

$\dfrac{\text{Period C}}{\text{(Global control)}}$ = period between $A$, and $B_2$, equal in duration to $A$, and B, and selected by the data processing computer *after the trial,* using an internal random number generator.

$\dfrac{\text{Period } D}{\text{(Global control)}}$ = "control" for C

If the baseline time series consists of normally distributed data the differences between the mean values of the velocities in each period should tend to zero as the number of trials n increases:

$$\Delta V = \sum_{n}^{1} (\bar{X}A_n - \bar{X}B_n) - (\bar{X}C_n - \bar{X}D_n).$$

Only the first term of the algorithm, $(\bar{X}A_n - \bar{X}B_n)$ would normally be examined in a system which was expected to give a time-invariant baseline. The second term has been introduced to compensate for trends in the data due to circadian rhythms, and toughen up the test for significance.

Note that one substantial difference between the pilot trials and the formal series was that in the latter case the global control was taken from another completely independent time series data string, matching the circadian phase angle by superimposing the clock times of the real trials. This is a more demanding technique with the merit of cleanly separating the global control

period from any residual effects due to the previous stimulus period. However, it is not necessarily superior: the culture giving rise to the time series data string for the global controls is a derivative of that used in the experiment, since the cells divide once a day.

## Results and Discussion

### *Part 1: Experiments with Dunaliella tertiolecta*

Figures 2 and 3 represent a metaanalysis of the 1986 data describing the interaction' of various participants with cultures of the marine microalgae *Dunaliella tertiolecta.* Since the distributions of the "scores" from the real trials and the global controls (the unattended computer-generated data, taken when there was no "real" stimulus) are both zero centered, the two-sample $\chi^2$ statistical test is appropriate.

Figure 2 illustrates the distributions of data from all the trials conducted using this protocol. The 251 global controls are normally distributed with p = .501. This is reasonable. The distribution of experimental scores is visually different and certainly nonnormal with $p = 5.341E-9$. Comparing control and experiment gave $p = 2.35E-10$. These results strongly suggest that algal behavior, manifest by the motions of individual cells, changed on a significant number of occasions when the participant followed the instruction to "identify with" or "be with" the cells in the measuring volume. Summary statistics are given in Table 1.

Cogent results, which began to appear in late 1985, attracted the attention of many colleagues and scientists from other laboratories. We hosted a substantial number of visitors through 1986, and toward the end of the year had a small portfolio of comments from them suggesting changes in our control procedures which might help to persuade the community of science to accept the result. Typical suggestions included radio frequency shielding, increased control over temperature variations in the room, improved physical isolation of the vessel holding the culture of microbes, and global control data taken from uninterrupted time series data acquired on a different occasion.

We took all these comments into account in the last part of 1986. The University of Delaware was kind enough to cooperate by building a quiet temperature control system for our lab with a dedicated heat pump outside the building.[2] Within it we assembled a walk-in environmental chamber, with grounded metal walls, and inside this we set up the experiments. Through ports in the wall, we were able to take data to a computer outside the enclosure. With all this done, we had high expectation of a fine series of experiments. We called these our "gold" trials. The results are presented in Figure 3, and the summary statistics in Table 2. Somewhat to our chagrin, the probabilities against chance were not significant, with $p = 0.059$.

An unbiased scientist has to conclude from the results of these experi-

**Distribution of Experimentel Results and Global Controls from 251 Trials**
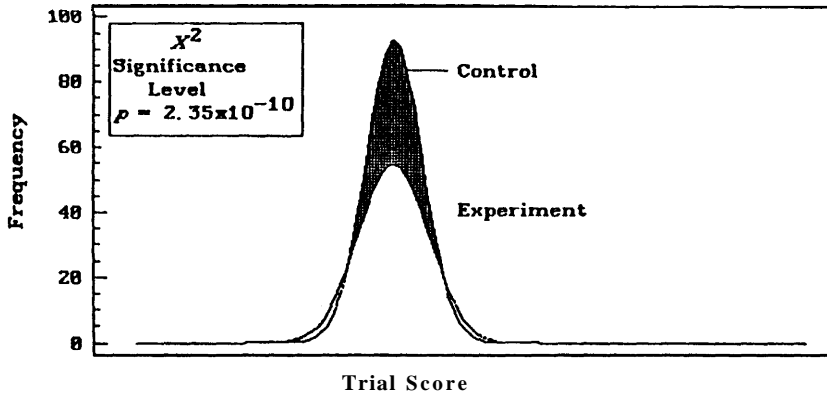
Trial Score

Fig. 2. Interaction between Homo sapiens and *Dunaliella.* 251 trials were conducted by 18 participants during 1986. Significance level is derived from a two-sample $\chi^2$ test of the distribution of control and the trial data. The control data are essentially normally distribited ( p = .0501) while the trial data show Pareto–Levy tails, and deviate strongly from normality (p = 5.341E-9). Raw data (the Doppler shift representing the velocity of the cell in the measuring volume) was acquired at a rate of approximately 70 datums $sec^{-1}$. Variation in rate is due to occasions when no cells are present. $1.87 \times 10^6$ raw data points form the database.

Breakdown of Contributions to the Database

| Participant # | # of Sets | Total Trials | % of Trials | % of Data |
|---|---|---|---|---|
| 5 | 11 | 59 | 23.5% | 20.1% |
| 6 | 2 | 13 | 5.2% | 2.7% |
| 7 | 5 | 36 | 14.3% | 4.2% |
| 8 | 1 | 7 | 2.8% | 2.1% |
| 9 | 1 | 7 | 2.8% | 3.2% |
| 11 | 1 | 4 | 1.6% | 2.5% |
| 17 | 1 | 7 | 2.8% | 4.9% |
| 22 | 1 | 8 | 3.2% | 1.3% |
| 29 | 3 | 15 | 6.0% | 12.6% |
| 31 | 1 | 5 | 2.0% | 2.7% |
| 33 | 1 | 3 | 1.2% | 4.7% |
| 34 | 1 | 4 | 1.6% | 4.6% |
| 35 | 1 | 5 | 2.0% | 6.3% |
| 36 | 1 | 3 | 1.2% | 2.8% |
| 37 | 2 | 7 | 2.8% | 0.7% |
| 38 | 4 | 37 | 14.7% | 16.1% |
| 39 | 1 | 8 | 3.2% | 2.9% |
| 40 | 3 | 23 | 9.2% | 5.6% |

ments that the apparent difference between the "psi" and "control" periods is likely to disappear as the experiment becomes more and more precisely defined.

At first this seemed like a good reason for giving up this research. Our best effort, tightly controlled by any standards, utilizing a mass of data from
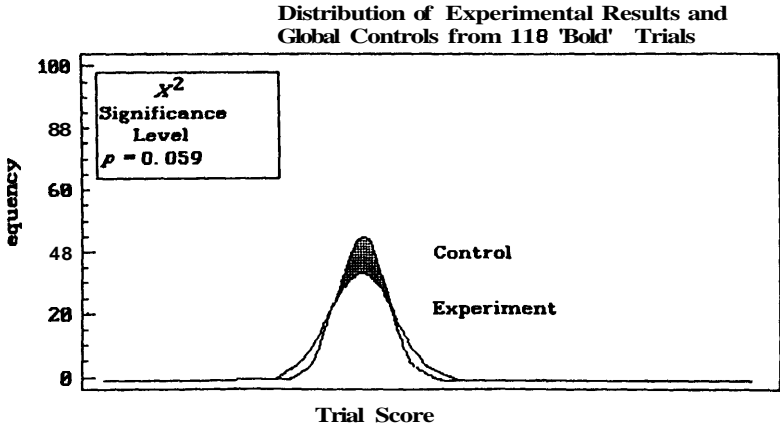
**Distribution of Experimental Results and Global Controls from 118 'Bold' Trials**



Fig. *3*. Interactions between Homo sapiens and Dunaliella. 118 " gold trials were conducted by 14 participants during 1986. Significance level is derived from a two-sample $\chi^2$ test of the distribution of control and trial data. Both control and trial distributions are effectively normal: significance levels of .403 and .643' respectively. This is a subset of the data presented in Figure 2. Data acquisition rates are similar. $1.08 \times 10^6$ raw data points form the database.

Breakdown of Contributions to the Database

| Particpant # | # of Sets | Total Trials | % of Trials | % of Data |
|---|---|---|---|---|
| 5 | 3 | 10 | 8.5% | 8.2% |
| 23 | 2 | 14 | 11.9% | 6.3% |
| 25 | 1 | 12 | 10.2% | 1.8% |
| 29 | 1 | 6 | 5.1% | 4.3% |
| 30 | 1 | 10 | 8.5% | 4.1% |
| 38 | 1 | 6 | 5.1% | 6.9% |
| 39 | 1 | 7 | 5.9% | 7.9% |
| 40 | 1 | 7 | 5.9% | 4.5% |
| 41 | 3 | 15 | 12.7% | 20.9% |
| 42 | 2 | 5 | 4.2% | 7.2% |
| 43 | 1 | 1 | 0.8% | 1.4% |
| 44 | 2 | 7 | 5.9% | 10.0% |
| 45 | 2 | 16 | 13.6% | 9.8% |
| 46 | 1 | 2 | 1.7% | 6.7% |

many millions of observations, seemed to have led us to the same marginally significant result that has characterized much of the last few decades of scientific consciousness research.

It was not until we had pondered the results for about a year (while earning our keep with more conventional laser Doppler studies) that we began to appreciate a more subtle hypothesis. Switch perspectives, and think like a bright young scientist; if he or she has not recognized any prior experiences which suggest the possibility of so-called "extrasensory" interactions, it is reasonable for them to declare that only data from the gold series are **valid**

TABLE 1
Summary statistics for all 1986 trials

| Variable | Control | Psi |
|---|---|---|
| Sample size | 251 | 251 |
| Average velocity | 0.214914 | 0.0268669 |
| Median velocity | −0.0626707 | −0.0467433 |
| Mode | −0.0787449 | −1.2613 |
| Variance | 37.913 | 58.4067 |
| Standard deviation | 6.15735 | 7.64243 |
| Standard error | 0.388649 | 0.482386 |
| Minimum | −24.9731 | −50.1647 |
| Maximum | 20.5917 | 49.5457 |
| Range | 45.5648 | 99.7104 |
| Lower quartile | −3.41318 | −3.1802 |
| Upper quartile | 3.78367 | 3.11628 |
| Interquartile range | 7.19685 | 6.29647 |
| Skewness | 0.0742012 | −0.538967 |
| Standardized skewness | 0.479923 | −3.48597 |
| Kurtosis | 1.5576 | 16.6134 |
| Standardized kurtosis | 5.03718 | 53.7268 |

evidence. However, it does not follow that by constraining the experiment (the gold series) we are approaching the true result. *We suspect that we may be approaching the result that a perfect scientific experiment would obtain.* Our current hypothesis is that a "perfect" scientific experiment is limited in that it must totally exclude human activity and therefore by definition, all psi effects.

TABLE 2
Summary statistics from the "gold" trials

| Variable | Gold Control | Gold Psi |
|---|---|---|
| Sample size | 118 | 118 |
| Average velocity | 0.136849 | 0.0428034 |
| Median velocity | −0.110172 | 0.19604 |
| Mode | −0.145843 | −0.0983624 |
| Variance | 33.5796 | 57.6133 |
| Standard deviation | 5.79479 | 7.59035 |
| Standard error | 0.533454 | 0.698748 |
| Minimum | −18.6734 | −40.697 |
| Maximum | 17.3044 | 17.2879 |
| Range | 35.9778 | 57.9848 |
| Lower quartile | −3.55412 | −3.1802 |
| Upper quartile | 3.80811 | 3.82702 |
| Interquartile range | 7.36223 | 7.00722 |
| Skewness | 0.0613546 | −1.39725 |
| Standardized skewness | 0.27209 | −6.19641 |
| Kurtosis | 0.819328 | 6.73379 |
| Standardized kurtosis | 1.81674 | 14.9312 |

*Part 2: Experiments with the Sacrifice of Clones of Tetraselmis suecica*

One of the factors which prompted this research was data from Backster *(1968).* He described strip chart records which showed that the resistivity of the leaves of a plant changed dramatically when brine shrimp were tipped into boiling water at a distant location. The experiment was automated, in the sense that the act of dumping the brine shrimp into the water was carried out in the absence of the experimenter. The scientific community paid relatively little attention to this intriguing experiment, and after one or two attempts to replicate the result had proved inconclusive, there was a general loss of interest.

Backster remains an active researcher today, and is quite convinced that the effects which he was able to demonstrate are viable, though not consistently replicable (Backster, personal communication, *1989).* In this sense, his observations are quite similar to our *1986* studies.

We reasoned that a psi stimulus could be applied to our algae without involving a human participant, and in fact, without involving an experimenter beyond the point of initiation of the experiment. The experimental concept can best be described with reference to Figure 4. We had learned how to turn our experiments over to our computers, and there was no reason why we should not start them and go home. If we kept doing this, we would tend toward a point where no one was acutely conscious of the ongoing experiment, and that result promised to be most interesting. As an added advantage, computer control and the exclusion of Homo sapiens promised to make the data quite acceptable, at least in biology journals.

It seemed appropriate to use the death of algal clones as the source of the stimulus, and we therefore designed a microcomputer program with an analog/digital interface which would dump a small aliquot of our sea water algae *Tetraselmis* into a large volume of fresh water. Since the osmotic pressure difference across the cellular membrane is then enormous, the effect on the cells could be likened to the effect of placing Homo sapiens in a vacuum. There is good reason to suppose that this would be a very painful way to die. In effect, this was a programmable natural event.

The single-celled motile algae *(Tetraselmis suecica)* were prepared in 500 milliliter flasks in an incubator; the seed culture placed in the flask initially was prepared from a single spot removed from an agar plate. These are classical techniques for preparing cultures of a single strain. Under normal growth conditions cells will divide once a day. When the concentrations in the large flask reached approximately 500,000 per milliliter the particular culture was examined microscopically for vigor and divided into two parts, one of which was set up in the laser Doppler system, and the other above the sacrificial vessel.

At a random time within each hour the computer sent a signal through a digital to analog converter which opened the solenoid valve (shown schematically in Figure 4). This allowed the seawater culture of *Tetraselmis* to flow
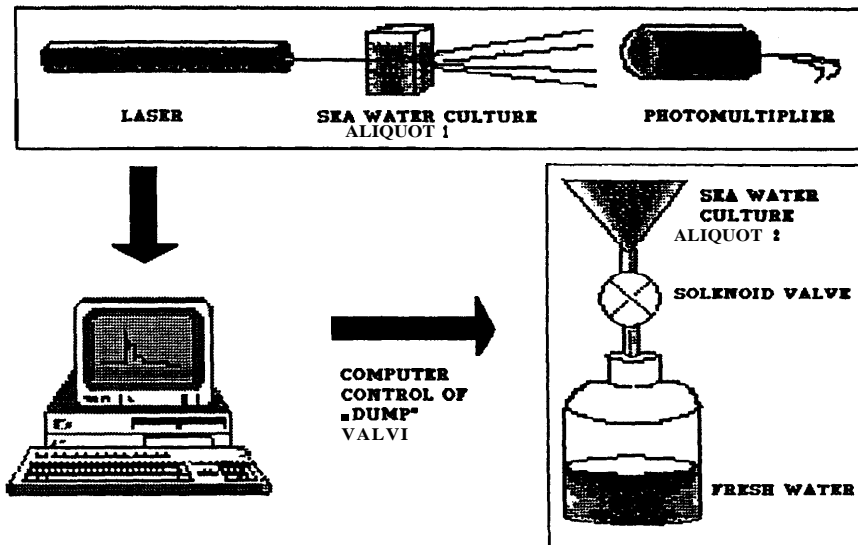
Fig. 4. Experimental set-up for "Scream" and "AutoScream" experiments. The laser and data collection systems are as described in Figure I. A custom program randomly selects an algal dump period in each hour. The only connection between the observed cuvette and the sacrificial culture is in the computer or via the sound of the solenoid valve snapping open, which is also present in the control set involving water into water. After *the first control data have been collected,* the Scientific Solutions Lab Master A/D is instructed by the custom program to activate a Magnecraft relay (model W49REICIVG-5DC-sil, normally open) connected to one of the A/D board's auxiliary parallel ports. This relay closes, completing an AC electrical connection to a solenoid valve (ITT model S301AFO2V3BE1, normally closed). The opened solenoid valve allows an algal culture to flow through silicone tubing into fresh water in a 20-liter bottle. After 120 velocity samples have been obtained from the "isolated" cuvette (circa 2 minutes), the computer stops the flow by opening the relay and thus closing the solenoid. The fresh water reservoir has a constant flow of fresh water through it. The level of the reservoir is controlled by a Dyna-Sense Electronic Liquid Level Controller, Model 7186.

into the fresh water. Experimental periods were two minutes in the hour, and the whole system was geared to weekend operation. Control data were taken from the time series record immediately prior to the sacrifice. It was possible to initiate the trial just before leaving on Friday night and stop it on Monday morning. The experiment became known as "AutoScream."

In any series of consciousness experiments the development of a protocol is normally brought to closure with a set of trials that confirm the viability of the particular combination of software and hardware. If the experimenters are feeling good about the experimental design and an interesting result seems likely, these are "salad days." In an optimal case, bright, happy, and attentive people watch these "pilot trials" closely. Over the years we have come to realize that these are prime conditions for the manifestations of psi effects. As the protocols are subsequently formalized in an attempt to make the overall experiment more scientific, and the compilation of statistics from

a large number of trials becomes the most obvious task, the result always seems to become less and less persuasive.

We chose to do the first complete pilot trials for AutoScream on a day when we were entertaining a relatively skeptical but open-minded visitor. This decision was spontaneous; made only a few days before the visit. The intent was light and bright: what better way could there be to describe our work than to actively involve our visitor in something that we had never attempted before? A modification to the computer program enabled us to bypass the random start to the stimulus period, and substituted a computer keyboard button press.[3] This created the required atmosphere of involvement for our visitor and guaranteed that all those in the lab would be aware of the period in which the *Tetraselmis* were being torn apart.

Four of us stood together around the computer keyboard, outside the shielded environmental chamber in which the experiment was set up. Our guest had responded warmly to the opportunity to be actively involved, and the group watched while he pushed the F1 key to sacrifice approximately 20 million *Tetraselmis* and create a computer record reporting the behavioral parameters of 120 *distant* clones. (To be sure of statistical independence, with sequential data from different cells, we limited the sample rate to one per second.) For the record, the group conversed quietly during trials 1 & 2. Trials 3, 4, and 5 were slightly different; although all of the group were aware that a trial was ongoing, only one participant was present at the keyboard. The others continued their discussions in an adjacent room. It is interesting to note that although no statistical tests were applied at that time, the raw time series data from trials 1 and 2 were displayed prior to trials 3–5, and the visible drop-outs in the stimulus period (Figure 5) served to enhance the general feeling of excitement.[4]

Our null hypothesis was that there would be no significant change in behavior manifest by the clones which were being examined by the laser Doppler system, during the period of the sacrifice. Time series data reporting the activity of microalgae very rarely show visually identifiable "quiet" periods like that in trial 2 (Figure 5). It was, therefore, no surprise to find that the result of applying statistical tests for significant differences between the distributions of mean velocities in the experimental and control periods suggested the rejection of the null hypothesis, with a very low probability of a chance result. Table 3 reports the Kolmogorov–Smirnov (K&S) and $\chi^2$ scores[5] for the five pilot trials carried out on that day. The K&S test is most sensitive to differences in the means of two populations. The $\chi^2$ test is complementary; it is most sensitive to extended tails. Normally in computer controlled series we would ensemble average these data before performing a statistical test. In this case, where the stimulus period varies in duration, the analysis was modified.

We chose to use two different analytical techniques; ensemble averaging at the period of the shortest trial, and individual treatment of each data set. Our
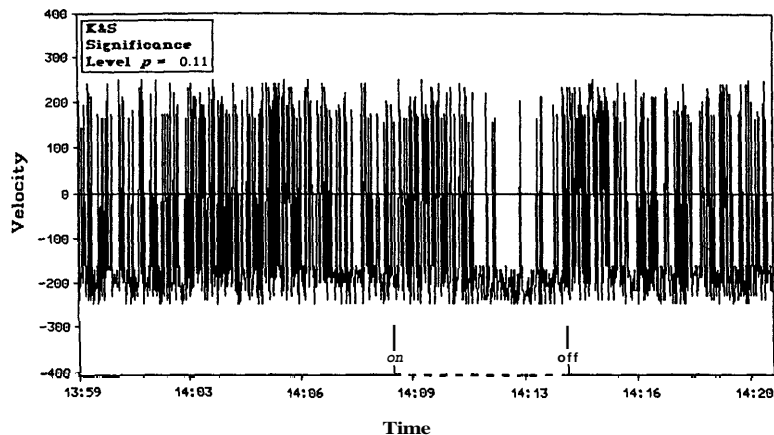
Fig. 5. Pilot experiment: Scream series. Time series data from pilot trial of the "Scream" series. Data are recorded continuously. The four participants stood outside the shielded environmental chamber in which the apparatus was set up. One participant pushed a preprogrammed key on the computer keyboard (at the "ON" marker), opening a solenoid that allowed ca. 20 million *Tetraselmis* to flow into fresh water, lysing them by osmotic pressure. After an interval of his choosing, the participant then pushed the key again (indicated by the "OFF" marker), terminating the algal flow into the fresh water. The K & S test was used to compare the distribution of data in the preceding control period to the experimental "ON" period.

reward was to observe several instances where the probability that the data sets from the control and stimulus periods came from the same distribution exceeded the low limit built into the statistical package!

In the subsequent series of computer-controlled experiments in which the experimenter left the lab immediately after turning on the computer we used

TABLE 3
Statistical comparisons of set I data: Probabilities of a correct null hypothesis
(no significant difference between stimulus and control periods)

| Trials # | Time of Exp. Period Sec. | $\chi^2$ Test Ensemble Av. Control vs. Experiment[a] | $\chi^2$ Test Raw Data Distributions | K&S Test Raw Data Distributions |
|---|---|---|---|---|
| 1 | 363 | | $9.72 \times 10^{-6}$ | 0.0014 |
| 2 | 349 | | $3.4 \times 10^{-10}$ | 0.1112 |
| 3 | 368 | $< 10E\text{-}11$ | $<10E\text{-}11$ | $4.28 \times 10^{-7}$ |
| 4 | 374 | | $<10E\text{-}11$ | $<10E\text{-}11$ |
| 5 | 316 | | $<10E\text{-}11$ | $1.2 \times 10^{-8}$ |

[a] To ensemble average this early data, where the period of the sacrifice was at the discretion of the participant it was necessary to chop the data strings from the longer experimental periods to be equal in length to the shortest. This does not affect the validity of the subsequent test.

*Note:* The statistics were developed using Statgraphics[R] software, which will report probabilities down to 10E-11.

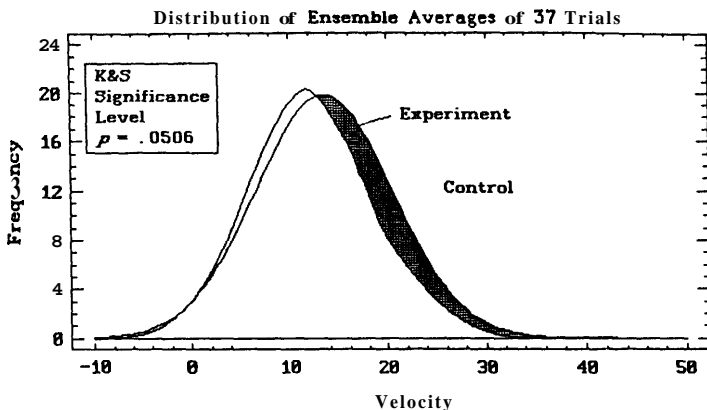**Distribution of Ensemble Averages of 37 Trials**



Fig. 6. AutoScream: *Tetraselmis.* The alga *Tetraselmis,* served as both the target and sacrificial subject. Each experimental period was 2 minutes. One velocity record was collected per second. The control data were taken from the time series record immediately preceding the experimental stimulus. Each curve, therefore, derives from 4,440 data points. A comparison of the control and experimental periods using the two-sample K & S test produced a probability of $p = 0.0506$.

Summary Statistics

| Variable | Control | Stimulus |
|---|---|---|
| Sample size | 20 | 120 |
| Average | 11.717 | 13.4909 |
| Median | 10.8634 | 13.3207 |
| Mode | 9.05282 | 12.9327 |
| Geometric mean | | |
| Variance | 35.9194 | 47.6285 |
| Standard deviation | 5.99328 | 6.90134 |
| Standard error | 0.547109 | 0.630004 |
| Minimum | −8.01855 | −4.91466 |
| Maximum | 24.3135 | 32.332 |
| Range | 32.3321 | 37.2466 |
| Lower quartile | 7.63021 | 9.05282 |
| Upper quartile | 15.5192 | 17.8472 |
| Interquartile range | 7.88904 | 8.79434 |
| Skewness | −0.102187 | 0.0788196 |
| Standardized skewness | −0.456992 | 0.352492 |
| Kurtosis | 0.15026 | 0.170979 |
| Standardized kurtosis | 0.335991 | 0.38232 |

ensemble averaging of the 37 trials to bring the relatively weak signal out of the noise. It appeared possible that the culture monitored by the laser Doppler system may have reacted to the demise of the distant culture of clones (Figure 6 should be compared to the global control, Figure 7), but the magnitude of the effect was dramatically reduced to the level which we jokingly call "normal"; a probability level $p = 0.051$ which we regard as "marginally significant."
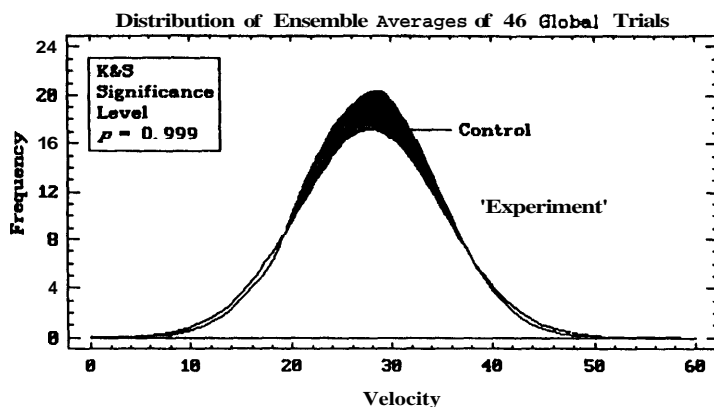
**Distribution of Ensemble Averages of 46 Global Trials**



Fig. 7. AutoScream global control. The alga, *Tetraselmis* served as a target and distilled water was used in the sacrificial vessel. Two-sample K & S comparisons of the periods produced a nonsignificant probability of $p = 0.999$. Data acquisitions and sampling were identical to that described for Figure 6.

Summary Statistics

| Variable | Control | Stimulus |
|---|---|---|
| Sample size | 120 | 120 |
| Average | 27.8816 | 27.8514 |
| Median | 27.1567 | 26.7314 |
| Mode | 27.0504 | 26.4123 |
| Geometric mean | 27.1257 | 27.0006 |
| Variance | 44.1461 | 52.7973 |
| Standard deviation | 6.64426 | 7.26618 |
| Standard error | 0.606534 | 0.663308 |
| Minimum | 14.928 | 15.9913 |
| Maximum | 51.9332 | 51.0825 |
| Range | 37.0052 | 35.0911 |
| Lower quartile | 22.9032 | 23.4349 |
| Upper quartile | 32.1545 | 30.6658 |
| Interquartile range | 9.2513 | 7.2309 |
| Skewness | 0.665393 | 1.11191 |
| Standardized skewness | 2.97574 | 4.9726 |
| Kurtosis | 0.574194 | 1.59852 |
| Standardized kurtosis | 1.28394 | 3.5744 |

These experiments were triple blind; the paired control and stimulus periods were initiated randomly (the control precedes the stimulus, because one must anticipate the possibility of prolonged effects) and the distribution of the data was compared to that from a global control sequence, which differed only in the substitution of water for the distant culture of clones (Figure 7). All clicks, creaks, electrical noise, and other building and environmental variables therefore had similar long-term averages. It was pleasing to note that the probability that the global control data from 46 trials were all from the same distribution was $p = 0.999$ (Figure 7).
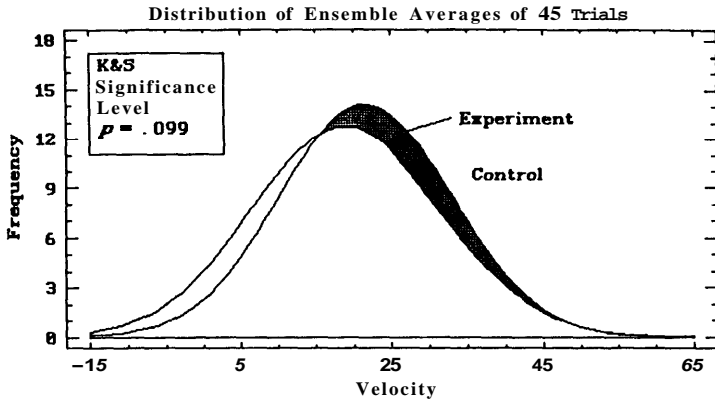
**Distribution of Ensemble Averages of 45 Trials**



Fig. 8. AutoScream: *Tetraselmis.* The alga *Tetraselmis* served as the target and the sacrificial subject. This was a precise replication of the experiments whose results were illustrated in Figure 6. The global controls described by Figure 7 serve both sets since they have quite adequate statistical power and give an unambiguous result. Two-sample K & S comparisons of the periods produced a nonsignificant probability of p = 0.099.

Summary Statistics

| Variable | Control | Stimulus |
|----------|---------|----------|
| Sample size | 120 | 120 |
| Average | 18.9908 | 21.5394 |
| Median | 18.3652 | 21.8743 |
| Mode | 18.3652 | 21.5553 |
| Geometric mean | | |
| Variance | 156.498 | 128.142 |
| Standard deviation | 12.5099 | 11.32 |
| Standard error | 1.14199 | 1.03337 |
| Minimum | −26.5089 | −5.6669 |
| Maximum | 53.2437 | 49.2029 |
| Range | 79.7526 | 54.8698 |
| Lower quartile | 11.4533 | 14.0054 |
| Upper quartile | 26.8722 | 30.0623 |
| Interquartile range | 15.4188 | 16.0569 |
| Skewness | −0.0491128 | −0.237949 |
| Standardized skewness | −0.219639 | −1.06414 |
| Kurtosis | 0.961031 | −0.391417 |
| Standardized kurtosis | 2.14893 | −0.875235 |

At first glance, these data seemed to suggest that natural modalities exist for distant real-time communication between algae clones. In effect, we had used expensive apparatus to demonstrate something that Grandmother knew: identical twins can sense each other's well-being. But, as Figure 8 illustrates, the effect continued to weaken in the next set of 45 trials. The probability that the null hypothesis was incorrect was not significant, with $p$ = 0.099. Where was all the fire and excitement that our early pilot trials had promised?

Backtracking to examine the possibility that direct involvement by a participant would enhance the effect, we conducted 42 trials with participants

from inside and outside our laboratory. All had participated in our previous trials in 1984–1986. The participant pushed the F1 key of a computer keyboard to initiate a two-minute sacrificial period, and data was then recorded automatically. Control data was taken from the period immediately prior to the key-press. The experimenter sat in an adjacent room, continuing with other work.

Data from all 42 trials were ensemble averaged to eliminate random noise and bring out any signal associated with the experimental period. The averaged data were tested for significant differences between the two-minute control and experimental periods using the two-sample test ($p = 0.627$) and the K&S test ($p = 0.999$). It was necessary to accept the null hypothesis (no difference). It is important to appreciate the structure of the experiment in the context of the research; the trials were a formal series modelled after the pilot trials which had given such exciting results, differing only in that the stimulus period was set at two minutes to allow us to ensemble average all the data and directly compare the results with the AutoScream series. The experimenters had no vested interest in either a positive or negative result, since at the onset, both were fascinating possibilities.

Overall, the implication of the four formal AutoScream series is clear: the algae, per se, are not significantly perturbed by the death of their clones. Since the statistics from the group of 42 attended formal trials showed that the physical presence of Homo sapiens and awareness of the period of the "kill" are not a sufficient condition for a significant result, and the result of the set of pilot trials was so robust, one can argue that some property of the overall system (the algae, the participant, and the experimenter) changes as we pass from pilot trials to formal trials. This is, indeed, the point we wish to make.

## Conclusions

None of the formal series reported in this paper were statistically significant at the $p < 0.05$ level and we must therefore accept the null hypothesis and clearly state that we have no scientifically viable evidence for extrasensory interactions between Homo sapiens and the unicellular algae *Tetraselmis suecica* and *Dunaliella tertiolecta,* or between clones of *Tetraselmis suecica.*

In sharp contrast, data from the pilot experiments, which preceded the formal series, require the rejection of the null hypothesis. This conclusion is robust. As naturalists interested in phenomena which attend living systems, we must report this, and see if we can conceive a simple hypothesis which will embrace all data sets.

The pilot trials and exploratory series spoken of in this paper all met our own very high laboratory standards for viable scientific experiments. They use the same elegant laser Doppler monitoring techniques, data processing,

and very conservative statistical methods as the formal trials. In every case global controls are taken from the time series data string which accumulates between trials, using random sampling of the string.

As trained observers we therefore have to conclude that anomalous extra-sensory information transmission does take place under certain as yet unde-fined conditions. Although the factors are not susceptible to quantitative definition we suspect that it is a sense of the "importance" of a formal series which damps performance. By definition, the formal series is intended to produce data which persuades others. The ego-involvement of the experi-menter(~)would be expected to increase: emotions might vary from fear of failure to anticipation of enhanced stature in the scientific community. Our experience with participants from outside our laboratory is that for the most part, individuals wish to test their ability to create an impressive result, even if they choose what might be called a mystical approach.

Speaking as experimenters, *and* as individuals who have played a substan-tial role as participants, there seem to be certain rare occasions when an individual or a group resonate with an experiment, bonding to it in the sense of an exclusive awareness, free from peripheral thoughts. The data from periods like this often calls for rejection of the null hypothesis (no significant effect due to the stimulus).

Biologists and behavioral scientists use the methods of science: replication normally precedes the presentation of data. However, work with living sys-tems should not be presented as pure science, since many of the variables show a complex time dependance which makes complete definition impossi-ble. We cannot reasonably expect to define a set of conditions which cause the resonance which we occasionally observe, and use this definition to structure a scientific proof of an effect.

We, therefore, expect to find that anomalous phenomena will continue to be most meaningful to the individuals involved. In this context the experi-menter stands out clearly: if unbiased curiosity prompted them and sus-tained their experimental work, our experience suggests that they will de-velop an enhanced awareness of their personal ability to influence other physical systems. The secondary act of persuading other people that this may be generally true appears to be much more difficult, since the expectations of the experimenters are then generally modified by ego-involvement.

Our work with interspecific communication between clones of *Tetraseli-mis suecica* is negative, in a strictly scientific sense. However, the quite strik-ing behavioral changes observed in the preliminary trials reinforce the idea that data often correlate with the expectations of the experimenter(s), if they are free from any artificial sense of the importance of their work. In a larger context, this suggests that the environment which an individual perceives may be a manifestation of their conscious and subconscious expectations. In engineering terminology, the individual and their environment may form an interactive feedback system.

## Endnotes

[1] Interactions are referred to as follows:
Set: A group of trials carried out during one session by one participant.
Trial: One stimulus period, marked by key-press or computer generated start.

[2] We must have made the request at exactly the right moment: perhaps this in itself is the best evidence we can produce of a verifiable anomaly!

[3] This modification is identified as "Scream."

[4] Readers interested in the integrity of this set of experiments, or the prevailing atmosphere of excitement and expectation may speak with the guest who participated, whose formal responsibility was to evaluate our program. The author will be pleased to provide details.

[5] These standard tests were applied using the statistical software package Statgraphics®, version 2.6.

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