

# Computerised biofeedback games: a new method for teaching stress management and its use in irritable bowel syndrome

**ABSTRACT** – **Objectives:** To develop and test a computer biofeedback game designed to teach deep relaxation to patients with a stress related disorder and to assess whether relaxation can improve symptomatic episodes.

■ **Study design and setting:** An open, prospective, single centre study. Department of Gastroenterology, Royal Free Hospital, London.

■ **Subjects:** Forty patients with irritable bowel syndrome refractory to conventional medical treatment.

■ **Main outcome measures:** Development of a computer aided biofeedback apparatus directed at the gut for teaching relaxation to patients with irritable bowel syndrome. The patients' ability to complete a computer game involving biofeedback modulated by a physiological loop that related changes in stress (monitored by electrodermal activity) to animated computer graphics. The degree to which deep relaxation was achieved was measured numerically by a progressive reduction in the sensitivity level of the biofeedback loop. The success of relaxation in ameliorating physical symptoms of irritable bowel syndrome was assessed by daily diaries in which global and weighted bowel symptom scores were entered.

■ **Results:** A computer biofeedback game based on animated gut imagery was successfully developed. Most patients learned to achieve progressively deeper levels of relaxation after four 30 minute biofeedback sessions (mean difference in sensitivity level 2.0 (95% confidence interval 0.96 to 2.93),  $p < 0.001$ ). Use of 'dosed' relaxation when bowel symptoms were troublesome was helpful in 50% of patients. It reduced the global symptom score (mean difference 0.5 (0.02 to 0.32),  $p < 0.04$ ) and the bowel symptom score (mean difference 0.8 (0.04 to 1.58),  $p < 0.04$ ). At long term follow up, 64% of patients who had been helped by dosed relaxation continued to use the technique, although they had had no further contact with the hospital.

■ **Conclusions:** This computer biofeedback game taught deep relaxation rapidly and effectively. Half the patients with refractory irritable bowel syndrome found the technique helpful on most occasions on which it was used. Computer biofeedback games may offer a simple, inexpensive strategy for managing other stress related medical disorders.

Physical symptoms related to stress are common presenting complaints in both general and hospital practice. Many medical conditions have been linked to stress, and these conditions account for a considerable economic cost to society. For most doctors, effective stress management remains a distant goal. There are few readily available methods of providing stress management for the many patients who might benefit from it. Psychological therapies are time consuming and labour intensive, and there are insufficient therapists to meet demand. Stress management is often neglected, therefore, or patients are treated with antidepressant or tranquillising drugs.

Biofeedback is a behavioural therapy technique that can be used to teach relaxation. Stress causes a number of psychophysiological responses, one of which is a change in cutaneous electrical activity (electrodermal activity). This psychophysiological link is called the galvanic skin response and is the basis of the lie detector (polygraph). The instantaneous changes in electrodermal activity in response to stress and relaxation can be monitored from skin electrodes and transformed into a visual or numeric display. This resulting display can then be relayed back to the user to complete the biofeedback loop.

The equipment and expertise for using biofeedback clinically has not been generally available. Personal computer software that allows computer games to be played using mind activation rather than a keyboard or joystick has been developed recently. The game uses changes in electrodermal activity to move animated graphics on a computer screen. The apparatus (Fig 1) consists of two finger electrode sensors connected to a transmission box that relays an infrared signal to the computer. The changing electrodermal activity is then translated by software into an animated game. The tasks required to complete the game are directed by the player's mental state of stress or relaxation. This technology provides a unique way of adapting the mind game strategy to teach patients to relax.

There is strong evidence that stress is a major factor in the pathogenesis of irritable bowel syndrome<sup>1</sup>. The stress of major life events has been recognised as a trigger in many patients, and patients often recognise that stress exacerbates their symptoms<sup>1</sup>. Whilst irritable bowel syndrome is diagnosed on the basis of bowel-related symptoms, most patients have a plethora of other symptoms including nausea, early satiety, fatigue, urinary frequency/urgency and dyspareunia<sup>2</sup>. Several treatments are prescribed, including dietary modification and antispasmodic drugs, but stress management is rarely employed despite evidence that psychological treatments, including hypnotherapy, psychotherapy and behavioural therapy, can be helpful<sup>3-5</sup>.

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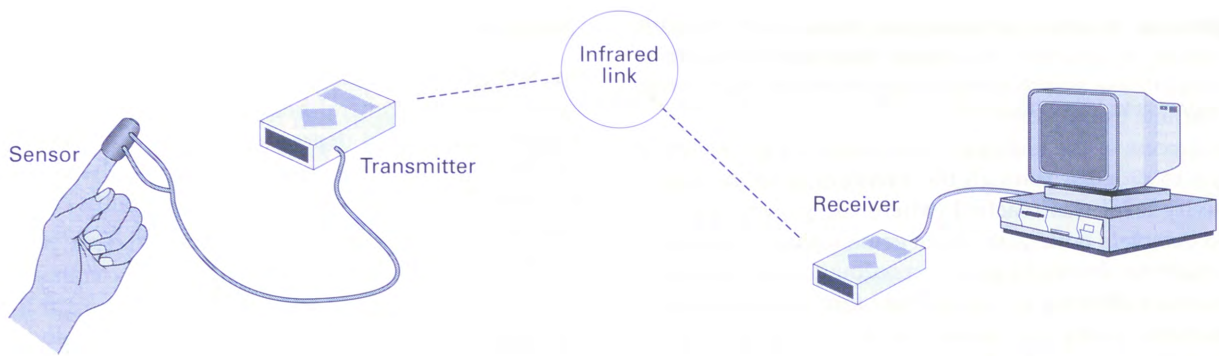
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**Fig 1. Schematic representation of computerised biofeedback games.** Stress and relaxation affects cutaneous electrical activity, which is detected by a finger electrode. This is relayed by an infrared link to a personal computer which displays changing levels of relaxation as animated imagery.

We have used irritable bowel syndrome as a model disorder in which to evaluate computer game biofeedback in teaching stress management. The main aim of the study was to develop and test a computer based biofeedback game designed to teach relaxation to patients with refractory irritable bowel syndrome. In addition to assessing the effectiveness of the method, we also assessed whether relaxation used in 'doses' might influence symptoms. We did not anticipate cure, but aimed to provide a dosed relaxation technique that could help symptoms – analogous to using a dose of antacid to manage an episode of troublesome heartburn.

## Methods

### *Biofeedback game*

The first aim was to design a biofeedback game that created vivid, animated screen imagery but could be played by people with minimum technical knowledge and support. We decided to develop the biofeedback loop using gut imagery. The biofeedback game was adapted from a game called *Evolve* (Ultramind Ltd, UK), which requires sustained mental relaxation to transform a fish swimming in a sea into higher life forms. Animated computer graphics were developed to simulate forward and backward movement through the alimentary tract. The animation provides a stylised image of the bowel as seen through an endoscope.

### *Playing the game*

The game was designed so that mental relaxation caused forward movement through the bowel (positive feedback), while stress was translated into backward movement (negative feedback). The game involved two tasks that could be accomplished only by sustained relaxation. The first task required the patient to travel from the 'stomach' to a distal point in the 'bowel', where their dominant symptom was

symbolised by a red screen (for pain) or bubbles (for bloating). To complete the second task, a further period of sustained relaxation was required to change the screen from its symbolic appearance to a graphic of a stream flowing gently through peaceful countryside (final reward and positive feedback).

A software menu allows the therapist to alter the sensitivity level of the exercise between 10 (highest sensitivity with easy progression) to 1 (lowest sensitivity with extremely difficult progression). This provides a mechanism for making the game progressively more difficult and a numerical score that allows an objective assessment of progress.

### *Study subjects*

Gastroenterology outpatients with refractory irritable bowel syndrome who fulfilled the Rome criteria<sup>6</sup> were recruited consecutively over a period of 36 months into an open study. All patients had repeatedly attended their general practitioners and hospital gastroenterology clinics, and all had failed to respond to antispasmodic drug treatment and dietary manipulation. All patients had had symptoms for a minimum of six months.

### *Study procedure*

All medication for irritable bowel syndrome was stopped at entry to the study. After a two week washout period, patients were invited to attend the first session of the biofeedback programme. Each biofeedback session lasted 30 minutes. The sessions were supervised by a research doctor specialising in gastroenterology (AL), or research nursing sisters with considerable experience in gastroenterology (CC/IM). On the first attempt at completing the exercise, the biofeedback sensitivity was set at 10, and on successful completion the sensitivity was reduced progressively so that deeper levels of sustained relaxation were needed to

complete the exercise. Between each weekly visit, patients were asked to practise visualising the exercises daily at home and to use a dose of relaxation whenever their symptoms became troublesome.

The success of the technique was judged by the ability of patients to progress through the exercises until the lowest sensitivity level was reached (where the patient was just able to complete both tasks of the game within 10 minutes). The sensitivity threshold varies according to individual skin conductance allowing for intrasubject (but not intersubject) comparison. Using the numerical level assigned to the sensitivity for each biofeedback exercise and comparing the level attained during the sessions, it is possible to measure the patient's ability to acquire deeper levels of sustained relaxation.

#### Assessment of symptoms

Symptom assessments were also recorded during the study period. During the washout and trial periods, all patients completed a daily symptom diary. The diary data provided two separate measures of patient response. Patients recorded daily whether or not relaxation helped to control troublesome symptoms when they occurred (recorded as 'yes' or 'no'). A patient was termed a responder if the relaxation technique helped to control symptoms on more than half of the occasions on which it was attempted.

#### Symptom score

The daily diary was also used to score symptoms. Because these patients with refractory irritable bowel syndrome have a plethora of general symptoms in addition to their bowel complaints, each patient recorded a daily global symptom score using a linear visual analogue scale measuring 10cm. Patients indicated on the scale an overall assessment of all of their symptoms. We also developed a bowel score that weighted individually the following: severity, frequency and duration of abdominal pain; severity of abdominal bloating; stool frequency and consistency; and the presence of straining, urgency, tenesmus or mucus. The symptoms were scored according to their presence or severity – for example, for abdominal pain severity, the score for no pain was 0, mild pain was 1, moderate pain was 2 and severe pain was 3. A maximal bowel score of 19 was possible. Mean daily global and bowel scores were calculated for each week before and during the treatment period.

#### Pilot study

As no previous studies had been undertaken with this biofeedback system, an initial study of six biofeedback sessions was conducted to determine the effectiveness of the computer program and the minimum number of biofeedback sessions required to learn the relaxation technique. This information was used to design the biofeedback programme for subsequent patients.

#### Questionnaires

Psychological symptoms were assessed before and after the study using the general health questionnaire 12 and the hospital anxiety and depression scale<sup>28</sup>. A follow up questionnaire was also sent to all patients who had completed the biofeedback programme at least six months earlier. This asked whether visualisation and relaxation techniques were still being used to help control symptoms.

#### Statistical analysis

Data are expressed as mean (SD). Paired and unpaired Student's *t* tests were used for statistical analysis. Statistical significance is taken at the  $p < 0.05$  level, and 95% confidence intervals (95% CI) are included.

### Results

Sixty-two consecutive patients with refractory irritable bowel syndrome were referred for study over the 36 month period. Twenty-two patients either refused to take part or withdrew from the study. The first nine patients completed the six-session pilot study. All nine learned to complete the two tasks of the game during the first biofeedback session and by the end of the fourth session all had reached the lowest sensitivity level. Therefore, the 31 subsequent patients attended only four, weekly biofeedback sessions. All 40 patients who completed the biofeedback programme are included in the analysis.

Eighty percent of patients were able to complete progressively lower sensitivity levels of the biofeedback exercises, and therefore to achieve deeper relaxation throughout the study period. Table 1 indicates that by the end of the first session, patients had learned to complete the exercise to a mean sensitivity level of 6.6. Further progression was achieved during the subsequent sessions, and by the fourth session, patients were completing the relaxation exercises at a lower mean sensitivity level of 4.6 (mean difference 2.0 (95% CI 0.96 to 2.93),  $p < 0.001$ ).

#### Symptom diaries

Analysis of the symptom diaries indicated that 20 patients (termed responders) reported that using doses of relaxation helped to ameliorate troublesome symptoms on more than

**Table 1. Lowest sensitivity level (mean (SD)) of the biofeedback exercise attained during the study period.**

Study week	All patients (n=40)	Responders (n=20)	Non-responders (n=20)
1	6.6 (1.7)	6.2 (2.0)	6.9 (1.4)
4	4.6 (1.9)***	4.3 (2.3)*	4.9 (1.5)**

Mean difference \*1.9 (95% CI 0.12 to 3.67),  $p < 0.05$ ; \*\* 2.0 (0.65 to 3.35),  $p < 0.01$ ; \*\*\*2.0 (0.96 to 2.93),  $p < 0.001$ .

half the occasions the technique was employed. As a group, these responders found the technique helpful for symptom control on an average of 88% of occasions used. The remaining 20 patients (termed non-responders) found the technique helpful on an average of only 16% of occasions. Responders and non-responders did not differ in their ability to learn relaxation in the graded biofeedback exercises (Table 1), and both groups practised visualisation and relaxation exercises equally at home (Table 2). At the onset of the programme there was no significant difference in psychological symptom scores in responders and non-responders (Table 2), nor was there a significant change in anxiety or depression scores following biofeedback.

#### Follow up questionnaires

Thirty patients who had completed the biofeedback programme at least six months previously were sent follow up questionnaires, and 22 replied (11 responders and 11 non-responders). At a mean follow up of 11 months, 7 of 11 responders were still using regularly the relaxation technique for symptom control.

#### Symptom scores

Biofeedback had an important effect on symptom scores (Table 3). When analysed as a whole group, there was an improvement after biofeedback in both the general symptom score (mean difference 0.5 (95% CI 0.02 to 0.32),  $p < 0.04$ ) and the bowel symptom score (mean difference 0.8 (95% CI 0.04 to 1.58),  $p < 0.04$ ). As might be expected the effect of biofeedback on symptom scores differed between responders and non-responders. In responders, but not non-responders, there were appreciable improvements in both the general and bowel symptom scores.

## Discussion

With biofeedback, patients are trained to use visual or audible signals generated and amplified from their bodies to modify organ function. The ability to modify physiological functions in this manner has been used to treat numerous disorders including stress syndromes, migraine, asthma, hypertension, and disordered defaecation<sup>9-13</sup>.

The personal computer, with its ability to store, modify and display a wide range of data, provides a new opportunity to investigate biofeedback. Computer biofeedback games may provide a new method for teaching relaxation. After brief instruction, anyone with access to a home computer can use the program themselves. The vivid, animated colour images displayed on the computer screen can be adapted to any theme. We chose movement along the bowel and symptom imagery as the focus for teaching relaxation to patients with irritable bowel syndrome. The colourful computer screen imagery has a powerful impact and provides an easy reference so that patients can practise visualisation and relaxation without the computer, in much

**Table 2. Characteristics of patients according to their response to the biofeedback programme.**

Characteristics	Responders	Non-responders
- Gender (M/F)	6/14	6/14
- Mean (range) age (years)	36 (21-56)	34 (20-53)
- Mean days biofeedback practised at home (%)	75	69
- Mean occasions that dosed relaxation was effective for symptoms (%)	88	16
- Median general health questionnaire 12 score	0.5	0
- Median hospital anxiety and depression score before and after biofeedback:		
Anxiety	10/12	10/10
Depression	5/7	6/7

the same way as self hypnosis is practised in the absence of a therapist.

The study indicates that the technique is highly effective in teaching patients with refractory irritable bowel syndrome to relax. Most patients showed a steady improvement in their ability to complete the biofeedback exercises at progressively lower sensitivities, and after a cumulative total of two hours' practice, patients had learned to induce a sustained period of profound relaxation.

A secondary aim of the study was to assess the feasibility of using doses of relaxation to control troublesome irritable bowel syndrome symptoms. We recognised the problems of undertaking a randomised, placebo-controlled trial of biofeedback to assess symptom relief. Placebo biofeedback is not feasible as both the patient and therapist would rapidly become aware of the lack of effect. Against this background we made an open assessment of symptom response in the 40 patients with irritable bowel syndrome who were taught the relaxation technique. Most patients

**Table 3. Daily symptom scores (mean (SD)) in relation to the response to biofeedback.**

	All patients	Responders	Non-responders
Global score for symptoms assessed by linear analogue scale:			
Week 0	5.0 (1.6)	5.1 (1.6)	4.9 (1.7)
Week 4	4.5 (2.0)*	3.9 (1.7)****	5.0 (2.4)
Bowel score assessed by multiple response questions:			
Week 0	8.0 (4.4)	8.0 (4.6)	7.9 (4.4)
Week 4	7.2 (5.2)**	6.5 (5.1)***	7.8 (5.4)

Mean difference \*0.5 (95% CI 0.02 to 0.32),  $p < 0.04$ ; \*\*0.8 (0.04 to 1.58),  $p < 0.04$ ; \*\*\*1.5 (CI 0.58 to 2.49),  $p < 0.004$ ; \*\*\*\*1.2 (0.18 to 0.57),  $p < 0.001$ .

learned to change their stress levels and induce relaxation, and half found the technique helpful in controlling their more acute episodic symptoms. The open design of this study does not exclude a placebo effect, but we feel that this is unlikely as all patients had previously failed to respond to antispasmodic drug treatment and dietary manipulation.

Relaxation used in doses seems to have an 'all or none' effect on symptom control. In responders, the technique was almost always helpful (in 88% of occasions used) while in non-responders this was rarely the case (16% of occasions). Failure in non-responders was not due to an inability to learn or practise the relaxation technique, nor was there a difference in anxiety/depression scores when responders were compared with non-responders. Long-term follow up indicates that in the absence of hospital follow up or top up biofeedback exercises, most responders continued to use dosed relaxation for controlling symptoms. The somatic response may be more entrenched in non-responders and other psychological interventions such as hypnotherapy, psychotherapy or psychotropic medication may be more helpful than relaxation alone in these subjects.

This study shows that relaxation can be readily learned using an appropriate biofeedback loop and that this behavioural modification and dosed relaxation may help control symptoms. The computer equipment and software are relatively inexpensive, simple to operate and can be used in hospitals and general practice, as well as in the patient's own home. The simplicity of computer based biofeedback offers a new opportunity for healthcare professionals to explore this treatment in other forms of stress related disorders and provides an inexpensive and labour saving stress management technique.

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