Medical Hypotheses

Medical Hypotheses (1993) 41, 118-122

Oscillators in the Human Body and Circular-Muscle Gymnastics

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Abstract—There is a growing body of literature about the role of oscillators in the living body, and about the interactions between different oscillators. Considering the importance of endogenous oscillators in regulating the body's functions, and the existence of 'dynamical diseases', diseases of control systems which involve oscillators in the body, a way to mend disfunctioning oscillators seems to be needed. Circular-muscle gymnastics, a method of physical activity which has been developed in Israel, reveals some phenomena which may point in a promising direction. Some of these phenomena call to mind known facts and theories about oscillators and their effects.

Introduction

Oscillators in the living organism

As early as 1914, Graham Brown suggested that some of the movements of a dog's limb, like scratching and walking, were controlled by oscillators lodged in its spine. Later, the ethologist von Holst (1) suggested that behaviours such as eating, drinking, swimming, grooming and molting were all controlled by oscillators in the spine. In fish for example, fin movements were shown to be generated by spinal oscillators. Some movements were shown to be the result of the 'superposition' of oscillators or of the so called 'magnet effect'. In 'superposition' the outputs of different oscillators were algebraically summated to form a new pattern of movement, more complex than a simple sinusoidal one. An example of the result of superposition was shown in an experiment in which people were asked to move both their arms in different rhythms, with a 1:2 ratio. When the movements were plotted, the patterns showed reciprocal influence and were not sinusoidal. The 'magnet effect' is the effect one oscillator exerts on another in order to maintain coordination between the two, in order that is, to maintain a common tempo and a fixed phase difference. For example, in a fish there is a time coordination between the fin and tail movements, as well as between those and the breathing rate. It has been shown (1) that by superposing and coordinating a small number of sinusoidal systems of oscillators with different amplitudes and different phase relations, it is possible to get complex patterns of movement. Extensive research has been done during the last 20 years on oscillators and on coordination between oscillators, in the human body too. Prime examples are the cardiac cycle and its entrainment to the breathing system (2), oscillations within the brain, and the fact that certain brain areas oscillate to the period of the heart (3). The living organism

Date received 4 August 1992
Date accepted 30 November 1992

has been described as a collection of oscillators, from the biochemical and cellular level up to the entire organism (4, 5, 6). Period time ranges from 0.1–0.3 s to days, months and even years. Attempts have been made at explaining oscillatory phenomena, by proposing physical (6) and mathematical (7) models and by using computer simulation (7). Von Holst formed the idea of a 'compromise' reached among oscillators in the spine. This 'compromise' has often been described as the non-linear result of a multi-variant system. This system, when it is analyzed mathematically, can afford an understanding by dynamic patterns in the body at several levels: behavioural patterns, neural network and individual neuron action (8, 9, 10).

Dynamical diseases

Because systems in the body function rhythmically, abnormalities in rhythm are of major clinical importance. The concept of a dynamical disease has been introduced by Glass and Mackey (11). A dynamical disease is defined as a disease that occurs in an intact physiological control system and leads to abnormal dynamics. Such abnormal dynamics can be of three types: 1) systems that normally oscillate stop oscillating or 2) change their periodicity and 3) systems that do not oscillate, begin oscillating. Examples for loss of rhythmicity include atrial or ventricular fibrillations (12). Cardiac arrest is a dramatic example of a system that stopped oscillating. Abnormalities in cardiac (12) and respiratory (13) cycles consist of new periodicities that appear in a normally oscillating systems and tremors, ankle clonus and hiccups occur in systems that do not usually oscillate (14).

Mackey and Milton (15) express the hope that eventually, therapeutic strategies for dynamical diseases could be devised to re-adjust altered control parameters and reposition the control system in a range of parameter space associated with 'healthy' dynamical behaviour. Some of the relevant literature seems to offer an approach to a possible solution.

A physical model for re-adjusting oscillators

In the seventeenth century, Christian Huygens (16) noticed that pendulum clocks placed against a wall came to swing in perfect synchrony. He explained the phenomenon by claiming that coordination had been reached by vibrations transmitted through the wall. Thus, each of the individual pendulums was affecting the others while at the same time it was getting their effect. After a while, a compromise was reached and all the rhythms became synchronized.

Starting oscillations in vitro

Glass and his colleagues (17) placed tiny aggregates of heart cells from chicken embryos in a dish. When the dish was shaken rhythmically, these aggregates began to beat spontaneously in unison. Unlike the clocks, the heart cells had not been ticking at the beginning, but they were affected by the rhythm of the shaken medium until a heartbeat appeared. The rhythm which appeared was synchronous because of medium and cells mutual effect.

If, as Turvey (6) assumes, we regard living systems as complex physical ones, we can deduce something from these experiments: if a method for activating certain oscillators in the body could be devised, disfunctioning ones might be entrained and readjusted. Is there a method for manipulating oscillators within the body? How can that be done without harm? Circular-muscle gymnastics could offer an answer to these questions.

Circular-muscle gymnastics

By the term 'circular-muscles' we refer in this paper to voluntary contractile muscular rings which encircle orifices of the body: the eyes, nostrils, mouth, anus and the urethral orifice (18).

The method of circular-muscle gymnastics was developed in Israel by Paula Garbourg (19). While practicing circular-muscle gymnastics, one contracts and relaxes circular muscles repeatedly for a long time (this should not be attempted without proper supervision!) and this sometimes causes reactions in other parts of the body. Practice of this method has led us to believe that in fact by activating sphincters repeatedly one can affect oscillators in the body. In the following examples we present some observations which seem to illustrate the effect of this kind of gymnastics on body oscillators.

Observations

Specific phenomena

a) Contracting and relaxing a circular muscle repeatedly for a long time sometimes causes a resonance somewhere in the body. Resonance might occur in a weak, damaged or disfunctioning spot, or in another circular muscle. For example, contracting and relaxing the circular muscles around the eyes will sometimes cause inversions of the feet or contractions of the sphincter urethra in synchrony with the eyes. When one dilates and relaxes the nostrils repeatedly, the anal sphincter might join, or aversion movements of the feet resonate. To use a metaphor, when the first pendulum out of a row of pendulums, suspended from a bar and touching one another, is swung, the last one will get the momentum and move. The energy which is put into the first pendulum travels through the whole system, and an explicit effect is observed in the last one. Interestingly, in the body too, resonance typically does not start in an adjacent muscle, but far away.

b) Lying for some time with the palms covering the eyes will often generate some rhythmic behaviour. For example, the abdominal muscles will start to contract and relax regularly. This phenomenon brings to mind the following experiment (20): The diameter of the pupils of a sleepy narcoleptic patient in complete darkness was measured. The result showed that as the patient became less alert, regular oscillations in pupil diameter appeared. It might be interesting to examine whether, while the eyes of a person who practices circular-muscle gymnastics are covered, his pupils diameter start to oscillate, and whether these pupil oscillations cause another oscillator to resonate, etc.

c) When people practicing circular-muscle gymnastics cover their eyes, this often starts a rhythmic response, which is followed by a whole sequence of spontaneous activity. The spontaneous sequence is characteristic for the same individual, and appears across sessions. The observed variability could be explained in terms of Bernstein's problem of motor coordination cited by Turvey: 'The kinematic (spatiotemporal) details of any coordinated state are not determined at the outset, in a single step by a single subsystem. The details are contributed gradually, by many subsystems working together' (6).

d) When a person is instructed to contract and relax a circular muscle repeatedly, the resulting frequency of oscillations is individual. Each person constitutes a different system and variability is extensive (15). The variability in the body is the result of adding together the outputs of so many oscillators, that only the boundaries which define the state of 'life' are common to organisms. Even among organisms of the same species, say humans, variations within these boundaries are numerous and the natural rhythm is individual.

e) Doing the same exercise in different ways (i.e. quickly or slowly, lying, sitting or standing, forcefully or gently) by the same person may elicit different responses. Different ways cause different oscillators to react. For example, when one works slowly, a resonance does not always occur in the same oscillator which reacts to a quick motion.

f) Yamanishi and his colleagues investigated the coordination of finger tapping by both hands. Their results showed that when subjects tried to tap by both hands with a constant phase difference, the performance of synchronous rhythm pattern and of alternate rhythm pattern were much better than that of others. This means that these phase relationships are more stable than others (21).

Schoner and Kelso describe an experiment in which subjects oscillate their index fingers bilaterally in the transverse plane, that is, abduction-adduction. Initially this was done in 'antiphase' pattern but as frequency increased, a sudden spontaneous switch to 'in phase' pattern emerged. Such a switch does not occur from 'in phase' to 'anti phase' pattern (10).

Using Schoner and Kelso's terms to describe circular-muscle gymnastics we can say that when one oscillator is activated long enough, another one will start to perform, and at some stage oscillations show a locked phase pattern. Sometimes the coordination pattern is 'in phase' and on other times 'anti phase'. In these latter cases, changing the frequency of the activating oscillator alone, or even just keeping the same frequency for a long time, might cause a switching to the 'in phase' coordination. For example, when a subject performs the exercise which has been described above (a), in which he or she contracts and relaxes the circular muscles around the eyes, if inversions of the feet occur they might appear in a locked phase with the contractions of the sphincters around the eyes. When this happens, inversions sometimes show an 'anti phase' pattern of coordination with the sphincters of the eyes. Then, if the contractions of the sphincters are repeated for a long time or if they become more and more frequent, a switch might occur to an 'in phase' pattern.

A case description

A description of how the movements of one man in his fifties developed with time and exercise would give some idea of the effect of circular-muscle gymnastics. On the first session, the man was asked to lie down on his back and cover his eyes by the palms of the hands. His breathing was very shallow, the nostrils frozen in a dilated position and the stomach protruding. After 10–15 min he was instructed to take his palms off the eyes and to contract and relax the eyelids repeatedly. When after a while this tired him, he was allowed to stop, cover his eyes again and rest. During the 1 h session, this pattern of activating the circular muscles around the eyes by various exercises and then resting with the palms covering the eyes was repeated several times. Another four or five sessions were spent exercising the circular muscles of the eyes and mouth, alternating with one eye covering. Then came the time when suddenly while lying with covered eyes, the man's abdominal muscles began to respond: his stomach started to oscillate regularly between a pushed out and a relaxed state. The man reported that it was as though he had learned to enable his body to perform contractions under its own control but he could stop the contractions at will. Some of the contractions, which came every 1.5–2 seconds, were so forceful that they came with a cry. At times, when a contraction reached its peak, a quicker, smaller contraction was added before total relaxation. It looked as if two oscillators were in action, sometimes competing with each other.

This pattern of movement came again during the following sessions. At first, some coaxing by circular-muscle exercise was needed in order to bring spontaneous movement, but later on, covering the eyes was enough to trigger the action of the abdominal muscles. Nothing seemed to be moving in other parts of the body, but the man reported that he was feeling some reaction in the anal sphincter. He was worked very hard by his body, one might observe, sometimes even sweating, but he felt good and stood up refreshed at the end of the hour.

After several sessions of spontaneous motions, the trainee was instructed to do other circular-muscle exercises, including for example contractions of the nostrils. This time, the response showed in the legs and the feet: at first, tiny inversions of the feet were observed, in a rhythm which was identical to the rhythm of the circular muscle the man was exercising. But, whenever he tried to rest with his palms covering the eyes, his abdominal muscles took over and kept the rhythm. Gradually, the response of the feet gained momentum and the amplitude of their inversions grew. At that time, the oscillators of the abdominal muscles seemed to have reached a compromise and coordinated their action so that only one rhythm was seen. The stomach stopped its protruding movements and this was replaced by tightening and lifting the abdomen towards the diaphragm. Breathing became more intensive, sometimes in various frequencies during one session.

Exercising the anal sphincter caused the knees to bend and move apart at each contraction of the sphincter and after a while the shoulders joined. It began with the right shoulder which moved toward the knees when they bent, then the left shoulder reacted and they both moved in unison. Next, the torso was lifted from the bed, with the head still resting on the mattress, to meet the knees whenever they bent to the rhythm of the contracting anal sphincter. Later on, the head was lifted too. At that stage, the anal sphincter kept contracting on its own accord, affecting the pattern of the spontaneous motion. To the expert's eye it was obvious from the pattern of movement that this man should keep exercising, so that his body could reach better coordination. This is one out of many examples but it provides some idea of how exercising circular muscles might form oscillations in the body and how they spread to cause reactions in different areas.

The therapeutic value of circular-muscle gymnastics

This method of physical exercise has been practiced in Israel for several decades. During this period, more and more of the people who practiced it reported improvements in health. People suffering from conditions like arthritis, prolapse of bladder and rectum, back aches, incontinence, asthma, cerebral palsy and many other conditions have been helped by circular-muscle gymnastics (19). While some physicians prescribe a course of circular-muscle exercise for certain patients, others are reluctant to do so, claiming that there is as yet no specific proof of its therapeutic value.

The model proposed in this paper provides a key to understanding many of the phenomena observed during circular-muscle gymnastics and to its therapeutic effects. It does not escape us however, that other, complementary explanations, are called for. These might relate to the interaction between voluntary and autonomic systems, to the interaction between striate and smooth muscles, to the activation of allied reflexes, etc. It seems, therefore, that research into the nature and therapeutics effects of circular-muscle gymnastics might both provide a wealth of data concerning the nature of spontaneous oscillations in the human body, and a means of affecting and readjusting their coordination.

Conclusion

The living body might be described as an aggregate of coupled oscillators whose coupling can vary from zero to very strong. The modes of coupling may be physical, like the vibrations of the pendulum clocks that travel through the wall, biochemical, hormonal or neuronal. It is conceivable that circular-muscle gymnastics might improve the functioning of endogenous oscillators in one of several ways. A disfunctioning oscillator which cannot be activated directly, could be activated indirectly by an oscillator coupled to it. A weak oscillator could be strengthened through extended activation, in the appropriate frequency, of a normally functioning oscillator coupled with it. Finally, the extended and intensive activation of an oscillator could perhaps reopen a blocked neuronal channel which connects two oscillators, thereby improving transmission capacity of this channel.

Acknowledgements

SYT is grateful to P. Garbourg and her pupil N. Eilat for their guidance and teaching of sphincter gymnastics and to Yoram Yom-Tov for his help and support. The authors are grateful to P. Garbourg, N. Kafkafi, M. Shik and H. Ur for critical comments on the manuscript. IG was supported by the Basic Research Foundation administered by the Israeli Academy of Science and Humanities.

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