Anxiety emotion affects health in view of system science

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Abstract

In this paper we discussed the affect of anxiety emotion in view of system science. With the help of limit cycle model and non-equilibrium thermodynamics, it shows that the affect caused by anxiety emotion is different from person to person. Using synthesis and metabolism frequency as the basis to category the affects, we found that the affect will cause some kind of population over weighted while some kind of population will become thinner and thinner. This depends on whether synthesis and metabolism frequency decreases or increases. We gave some suggestion about getting rid of the affect caused by such kind of emotion according to different kind of population.

KEYWORDS: Anxiety emotion, synthesis and metabolism frequency, non-equilibrium thermodynamics

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1 Introduction

Emotion can affect our health, which is seriously researched by scientists[1–5]. Even though the scientific research is based on the statistical method through experiment and observation. The way of study is like epidemiological survey. This method does give us information which shows the relation between the emotion and health. In recent years, the researchers give us ”emotion map” of the body[6], by experimental study, the researchers points out that under certain emotion apart from neutral emotion, there are some specific areas in our body are activated or deactivated, regardless of our sex, age or race.

In this paper we follow the research result in reference [6], and choose the emotion called anxiety which we are often bothered by in our daily life. Our study only focuses on the healthy population: how this emotion affect the health, when we are healthy. Scientific research has already shown that this emotion does affect our health[7–9] by statistic method. The statistic method shows us the relation between the anxiety and health. The experiment study might reveal the mechanism that how anxiety emotion affects our circulation system or how the biochemical reactions are affected, but the results are limited, because the human body is a complex system. Simple mechanism is not able to reveal all the fact. Because of this, we suggest using system dynamics a new way to study how this emotion affect our health.

The organization of this paper is like this: in section 2 we give a brief introduction of the method we use, in section 3 we use this method to study how the anxiety emotion affect our health, and give some suggestion of getting rid of the affect caused by such emotion. In section 4 we give a conclusion and out look of this method.

2 A brief introduction of the method we use

As the human life is sustained by synthesis and metabolism, we use a limit cycle model to construct this process. The parameters in the limit cycle model correspond to the organ systems of our body. The behaviour of the organ groups are related to the basal metabolism. Readers can consult the paper in archive version (http://vixra.org/abs/1603.0195).

In view of non-equilibrium thermodynamics, it corresponds to the stable energy dissipation of a certain self-organised system, which has the minimum entropy production rate[10–13]. More exactly

$$\frac{d_i s}{dt} = -\kappa \bigtriangledown T(T_b^{-1} - T_{en}^{-1}) \tag{1}$$

is a constant. T_{en} is the temperature of the environment and T_b is the body temperature. κ is the thermal conductivity. The minimum energy dissipation is related to the basal metabolic rate, which sustains the stability of life. The basal metabolic rate is related to body mass, gender, age etc[14].

Taking the stability and periodic property of the human body system into consideration, we have established a limit cycle model, which is like the Van der Pol model[15]

$$\begin{aligned} \frac{d}{dt'}q_1 &= -q_2 \\ \frac{d}{dt'}q_2 &= q_1 + \frac{\mu}{\omega}(a - q_1^2)q_2 \end{aligned} \tag{2}$$

This mathematical model consists of 2 fast variable and 3 parameters (slow variables), since the parameters is in fact changeable (imagine that the life will end at last). $\frac{\mu}{\omega}$ reveals the "distance" from equilibrium (death). The solution to the first order approximation $O(\frac{\mu}{\omega})$ is[16, 17]

$$\sqrt{q_1^2 + q_2^2} = 2a - 8\frac{\mu}{\omega}\cos\theta\sin^3\theta \tag{3}$$

in which $q_1 \equiv \sqrt{q_1^2 + q_2^2}\cos\theta$ and $q_2 \equiv \sqrt{q_1^2 + q_2^2}\sin\theta$. This solution is a limit cycle represented by polar coordinates in phase space. We can figure out the energy dissipation rate when the individual is at stationary state by the mathematical model (2) to the first order approximation

$$\beta\sum_{T_b} T_b\frac{d_i s}{dt}\sigma(T_b) = \frac{k_B < T_b > \mu}{4}[3(\frac{\mu}{\omega})^2 + 8a^2 - 4a] \tag{4}$$

where $\sigma(T_b)$ is the body surface area where the temperature is. And β is a dimensionless parameter which builds the bridge between microscopic world and macroscopic world. $< T_b >$ is the average body temperature.

The parameter ω represents the frequency of synthesis and metabolism. In a short period of time, the basal metabolic rate remains constant, the constraint relation of these parameters is

$$\frac{\mu}{4}[3(\frac{\mu}{\omega})^2 + 8a^2 - 4a] = \frac{\beta c}{k_B < T_b >} \tag{5}$$

in which we use c to represent the total energy dissipation of human body.

If the individual is healthy, for instance, a young healthy college student, the basal metabolism is estimated by the oxygen demand[18] using metabolic equivalent (MET) task in calculation.

$$1MET = 1kcal.kg^{-1}.h^{-1} = \frac{4.2\times 10^3}{3600}J.kg^{-1}.s^{-1} = 3.5\dot{V}_{O_2} \tag{6}$$

in which the dimension of $\dot{V}_{O_2}$ is $ml.kg^{-1}.min^{-1}$[18]. When the individual is at stationary state, $\dot{V}_{O_2}$ corresponds to the basal metabolic rate. We can simplify the energy dissipation by the oxygen demand:

$$\frac{k_B < T_b > \mu}{4\beta}[3(\frac{\mu}{\omega})^2 + 8a^2 - 4a] = \frac{4.2\times 10^3}{3600}m \tag{7}$$

m is the mass with dimension kg. This simplified version of the basal metabolic rate makes it possible to study the perturbation, such as daily exercise, emotion apart from neutral, some curable sickness so on and so forth.

Readers can consult the paper in archive version (http://vixra.org/abs/1603.0195) for details.

3 How anxiety emotion affect our health

3.1 The affects from the system science study

The emotion of anxiety is a kind of perturbation to healthy individuals. Most often, the anxiety emotion will disappear when the items which gives us heavy pressure are handled. This popular case is what we will study in this paper. The study [6] shows that when people are under such emotion, they feel their heart area is most activated. Even though we are not sure which parameter is related to the heart area, we can turn to (5). The basal metabolic rate is increased, because of the activated feeling. Those who are anxious will suffer heart rate variability and higher systolic blood pressure[19–22]. Even though the heart rate almost does not change, the blood pressure definitely increases. This will change the basal metabolic rate. As what we consider is the healthy individuals, the interval of basal metabolic rate change is in $\pm 10\%$. Then we can write the metabolism and synthesis frequency that

$$\omega^2 = \frac{3\mu^2}{\frac{4\beta c'}{\mu k_B < T_b >} + 4a - 8a^2} \tag{8}$$

in which $c \leq c' \leq 1.1c$. $\frac{\mu}{\omega}$ is the "distance" from equilibrium (death). For a healthy individual the distance is often invariant. So the the parameter μ is changed into μ' and satisfy

$$\frac{4\beta c'}{\mu' k_B < T_b >} + 4a - 8a^2 = \frac{4\beta c}{\mu k_B < T_b >} + 4a - 8a^2 \tag{9}$$

which means that $\mu' = \frac{c'}{c}\mu$. Then the synthesis and metabolism frequency ω increases. So it is not surprising that higher basal metabolic rate causes marasmus. If the individual still belongs to the healthy population, then the decreasing of body mass causes the basal metabolic rate decreasing. This means that the parameter $\mu' = \frac{c'}{c}\mu$ will tend to μ, with the systolic blood pressure being higher than relaxed case. This means that the "distance" from equilibrium $\frac{\mu}{\omega}$ decreases. In order to keep the distance from equilibrium invariant, ω also decreases. This explains why part of the population who suffers anxiety for a long time becomes thinner and thinner.

The discussion in section 6 it shows a is not a totally "free" parameter. The constraint works when $\mu \to 0$. Before $\mu = 0$, there is a competition between μ and a.

If the "speed" of $\mu \to 0$ and $a \to \frac{1}{4} + \sqrt{\frac{1}{16} + \frac{1}{8}\frac{4\beta c}{k_B < T_b > \mu}}$ are the same, this corresponds to the case that anxiety that makes this kind of population weaker and weaker.

If the "speed" of $\mu \to 0$ is slower than $a \to \frac{1}{4} + \sqrt{\frac{1}{16} + \frac{1}{8}\frac{4\beta c}{k_B < T_b > \mu}}$, then ω increases. The metabolic and synthesis frequency increases, this kind of anxiety might caused by some kind of sickness such as thyroid dysfunction [7, 23].

If the "speed" of $\mu \to 0$ is faster than $a \to \frac{1}{4} + \sqrt{\frac{1}{16} + \frac{1}{8}\frac{4\beta c}{k_B < T_b > \mu}}$, then ω decreases. The synthesis and metabolism frequency decreases. $\frac{\mu}{\omega}$ can either increase or decrease. If $\frac{\mu}{\omega}$ increases, this drives the system "farther" from equilibrium. But the cost is that the digesting system is affected. And if $\frac{\mu}{\omega}$ remains invariant or decreases, this kind of population both over weighted and weaker. In conclusion, this kind of case is related to dyspepsia. Reference [24] reported that anxiety but not depression is related to dyspepsia in clinical observation. From our study and discussion, it is not difficult to understand why some of those who are often in anxious emotion are over weighted.

3.2 How to get rid of the affect

In section 3.1, we analyzed the affects from the anxiety emotion. It can either make an individual thinner and thinner, or cause him (or her) over weighted. Different cases needs different approach to eliminate the affect, according to our analysis in 3.1. Roughly speaking, whether ω increases or decreases is a good way to category the cases.

For the case ω decreases, the metabolic rate decreases. This is the main cause of being over weighted. The exercise prescription may be effective, since exercise can improve the circulation so as to increase the metabolic rate. For this kind of population proper exercise is helpful.

For the case ω increases, the blood pressure remains in a higher level, and the metabolism frequency is increased. Exercise might cause more energy consumption, however this kind of population is often weaker than they were healthy. So exercise prescription is not the prior option, even though exercising is helpful to discharge adrenaline by sweating. For this kind of population, having a good rest is more helpful.

4 Conclusion and remarks

In view of system science, with the help of limit cycle model and non-equilibrium thermodynamics, we roughly gave the picture how anxiety emotion affects our health, and gave some suggestion of getting rid of the affect from such emotion. Even though we have only discuss one kind of emotion, the result from our discussion shows that the affect caused by such kind of emotion is different from person to person. So for clinical doctors, they could not use a simple prescription to handle the symptoms. This stems from the fact that human body system is complex. Although by the method of system science, there still remains parameters such as μ and a which are not totally determined. The emotion caused by environment extends the signal to nervous system that makes the individual feel his (or her) heart area activated. However we are not sure whether this kind of activation acts on the parameter μ or a. In this paper we just follow the mathematical constraint and the physical rules, to determine the relation of a and μ. So finding out the direct action on the parameters would be much more exciting and interesting. But just depending on thermodynamics, the information may be limited.

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6 Appendix

Perhaps readers might have already noticed a paradox: by using (5), it might leads to $\mu \to 0$ then $\frac{\mu}{\omega} \to \infty$. We are to eliminate this paradox in this appendix. In (5), it will leads to:

$$\omega^2 = \frac{3\mu^2}{\frac{4\beta c}{\mu k_B < T_b >} + 4a - 8a^2} \tag{10}$$

a and μ must be positive or the model is not a limit cycle. The denominator must be positive definite, since $\omega^2 \geq 0$ and $\mu > 0$. We can figure out the root of a for the denominator, so as to get the interval of a:

$$a = \frac{1}{4} \mp \sqrt{\frac{1}{16} + \frac{1}{8} \frac{4\beta c}{k_B < T_b > \mu}} \tag{11}$$

So $a \in (0, \frac{1}{4} + \sqrt{\frac{1}{16} + \frac{1}{8} \frac{4\beta c}{k_B < T_b > \mu}})$, and ω reaches its minimum when $a = \frac{1}{4}$, without changing μ.

We must emphasize the case that $\frac{\mu}{\omega}$ is positive definite. When $\mu \to 0$ then the system tends to equilibrium. However, the case in this calculation leads to the result that

$$3\frac{\mu^2}{\omega^2} = \frac{4\beta c}{\mu k_B < T_b >} + 4a - 8a^2 \tag{12}$$

Naively from this relation we get if $\mu \to 0$ then $\frac{\mu}{\omega} \to \infty$. So their must be a constraint between a and μ. When $\mu \to 0$

$$a \to \frac{1}{4} + \sqrt{\frac{1}{16} + \frac{1}{8} \frac{4\beta c}{k_B < T_b > \mu}} \tag{13}$$

when $\mu > 0$, then $0 < a < \frac{1}{4} + \sqrt{\frac{1}{16} + \frac{1}{8} \frac{4\beta c}{k_B < T_b > \mu}}$.

References

[1] HS Sullivan. The interpersonal theory of psychiatry (vol. 5), 1953.

[2] Craig A Smith and Lois K Pope. Appraisal and emotion: The interactional contributions of dispositional and situational factors. 1992.

[3] DJ Kiesler. Wiley series in clinical psychology and personality. contemporary interpersonal theory and research: Personality, psychopathology, and psychotherapy, 1996.

[4] Laura Smart Richman, Laura Kubzansky, Joanna Maselko, Ichiro Kawachi, Peter Choo, and Mark Bauer. Positive emotion and health: going beyond the negative. *Health psychology*, 24(4):422, 2005.

[5] Timothy W Smith, Kelly Glazer, John M Ruiz, and Linda C Gallo. Hostility, anger, aggressiveness, and coronary heart disease: An interpersonal perspective on personality, emotion, and health. *Journal of personality*, 72(6):1217–1270, 2004.

[6] Lauri Nummenmaa, Enrico Glerean, Riitta Hari, and Jari K Hietanen. Bodily maps of emotions. *Proceedings of the National Academy of Sciences*, 111(2):646–651, 2014.

[7] Seref Gulseren, Leyla Gulseren, Zeliha Hekimsoy, Pinar Cetinay, Cigdem Ozen, and Basak Tokatlioglu. Depression, anxiety, health-related quality of life, and disability in patients with overt and subclinical thyroid dysfunction. *Archives of medical research*, 37(1):133–139, 2006.

[8] Lise Gormsen, Raben Rosenberg, Flemming W Bach, and Troels S Jensen. Depression, anxiety, health-related quality of life and pain in patients with chronic fibromyalgia and neuropathic pain. *European Journal of Pain*, 14(2):127–e1, 2010.

[9] Kurt Kroenke, Samantha Outcalt, Erin Krebs, Matthew J Bair, Jingwei Wu, Neale Chumbler, and Zhangsheng Yu. Association between anxiety, health-related quality of life and functional impairment in primary care patients with chronic pain. *General hospital psychiatry*, 35(4):359–365, 2013.

[10] Sybren Ruurds De Groot and Peter Mazur. *Non-equilibrium thermodynamics*. Courier Dover Publications, 2013.

[11] Gregoire Nicolis and Ilya Prigogine. *Self-organization in nonequilibrium systems*, volume 191977. Wiley, New York, 1977.

[12] P Glansdorff and Ilya Prigogine. Structure, stability and fluctuations. *New York, NY: Interscience*, 1971.

[13] Ilya Prigogine. Introduction to thermodynamics of irreversible processes. *New York: Interscience, 1967, 3rd ed.*, 1, 1967.

[14] Mark D Mifflin, Sachiko T St Jeor, Lisa A Hill, Barbara J Scott, Sandra A Daugherty, and YO Koh. A new predictive equation for resting energy expenditure in healthy individuals. *The American journal of clinical nutrition*, 51(2):241–247, 1990.

[15] Balth Van der Pol. Lxxxviii. on relaxation-oscillations. *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, 2(11):978–992, 1926.

[16] Hector Giacomini, Jaume Llibre, and Mireille Viano. On the shape of limit cycles that bifurcate from hamiltonian centers. *Nonlinear Analysis: Theory, Methods & Applications*, 41(3):523–537, 2000.

[17] H Giacomini, J Llibre, and M Viano. On the nonexistence, existence and uniqueness of limit cycles. *Nonlinearity*, 9(2):501, 1996.

[18] American College of Sports Medicine et al. *ACSM's guidelines for exercise testing and prescription.* Lippincott Williams & Wilkins, 2013.

[19] Gary D James, LS Yee, Gregory A Harshfield, Seymour G Blank, and Thomas G Pickering. The influence of happiness, anger, and anxiety on the blood pressure of borderline hypertensives. *Psychosomatic Medicine*, 48(7):502–508, 1986.

[20] Bruce S Jonas, Peter Franks, and Deborah D Ingram. Are symptoms of anxiety and depression risk factors for hypertension? longitudinal evidence from the national health and nutrition examination survey i epidemiologic follow-up study. *Archives of family medicine*, 6(1):43–49, 1996.

[21] Ichiro Kawachi, David Sparrow, Pantel S Vokonas, and Scott T Weiss. Decreased heart rate variability in men with phobic anxiety (data from the normative aging study). *The American journal of cardiology*, 75(14):882–885, 1995.

[22] Jack M Gorman and Richard P Sloan. Heart rate variability in depressive and anxiety disorders. *American heart journal*, 140(4):S77–S83, 2000.

[23] RG Kathol and JW Delahunt. The relationship of anxiety and depression to symptoms of hyperthyroidism using operational criteria. *General hospital psychiatry*, 8(1):23–28, 1986.

[24] Pertti Aro, Nicholas J Talley, Jukka Ronkainen, Tom Storskrubb, Michael Vieth, Sven-Erik Johansson, Elisabeth Bolling-Sternevald, and Lars Agréus. Anxiety is associated with uninvestigated and functional dyspepsia (rome iii criteria) in a swedish population-based study. *Gastroenterology*, 137(1):94–100, 2009.