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A Cue to the Relationship between Brain Asymmetry and Long-term Memory

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Experimental observation shows that long-term memory is related to brain asymmetry in fruitful Drosophila. A mathematical model to describe this phenomenon is established. There could be important implications for future developments in fugue or hypomnesia therapy.

Keywords: long-term memory, allometric scaling, mathematical model, fruitfly *Drosophila*

1. INTRODUCTION

Pascual *et al.* (2004) found that brain asymmetry is important in formation or retrieval of long-term memory in fruitfly *Drosophila.* No theory exists to date to explain the intriguing and this enduring phenomenon. There could be important implications for future developments in fugue or hypomnesia therapy if its precise function is clear. We give a possible explanation by taking into account the metabolic activity in memory-related asymmetrical body.

2. AN ALLOMETRIC MODEL

Many characteristics of organisms vary with body size, as described by allometric equation of the form(West et al. 1997; Kuikka 2002; Kuikka 2003; He and Chen 2003; He 2004): $Y \sim M^b$, where Y is the dependent variable, M is the body mass, b is a power exponent. A similar allometry holds for brain in the form(He 2004; He and Huang 2004)

$$B_{brain} \sim T_{brain}^{(3+N/6)/4} \tag{1}$$

where B_{brain} is the metabolic rate of brain , T_{brain} its mass, N is cell's degree of freedom of motion in the brain. For active brain, the cell's degree of freedom is close to 3. Therefore, the prediction (1) yields

$$B_{brain} \sim T_{brain}^{0.87} \tag{2}$$

Wang *et al.*'s observation (Wang *et al.* 2001) illustrated that

$$B_{brain} = 20.5M^{0.62} \text{ (kJ/d)} \tag{3}$$

and

$$T_{brain} = 0.011M^{0.76} \tag{4}$$

where M is the body mass. From the above two scaling relations, we obtain:

$$B_{brain} \sim T_{brain}^{0.81} \tag{5}$$

So our prediction (2) is in good agreement with experiment data(5).

To verify the suggested allometric scaling (1) for brain, we consider a person in the condition of slow wave sleep. Under such a condition, the cell's degree of freedom of motion in brain reduces up to zero, i.e. $N \to 0$.

We assume that M=70 kg for man, the decrease in brain metabolism for slow wave sleep (N=0) is calculated as

$$\frac{T_{brain}^{0.87} - T_{brain}^{0.75}}{T_{brain}^{0.87}} = \frac{M^{0.6612} - M^{0.57}}{M^{0.6612}} = 32.1\%$$

Our prediction shows a 32% decrease in the global cerebral metabolism, while the observed data show a 44% decrease (Laureys et al. 2002; Buchsbaum et al.1989; Maque et al. 1996).

For better explanation of memory in asymmetrical body in *Drosophila,* we consider regional allometric scaling for memory-related area:

$$B_{memory} \sim T_{memory}^{(3+N/6)/4} \tag{6}$$

where B_{memory} is the metabolic rate of the memory-related area, T_{memory} is its mass. Memory scales isometrically with respect to the cell population density, ρ, in the memory-related area. Studies of animals suggest that many variables scale with quarter-powers of the whole-body mass, for example, $b \approx 3/4$ for metabolic rate, $-3/4$ for population density and 1/4 for lifespan(Enquist *et al.* 1998; Marquet 2000; Schmid et al. 2000). We write the scaling relation between the cell population density and its mass in the form:

$$\rho \sim T_{memory}^{-(3+N/6)/4} \tag{7}$$

When N = 0, the allometry (7) is consistent with that for population density in ecological communities(Enquist et al.1998; Marquet 2000; Schmid et al.2000) , and can explain why big is beautiful but lonely(Marquet 2000).

Consequently the memory score can be expressed as

$$\text{memory score} \sim T_{memory}^{-(3+N/6)/4} \tag{8}$$

Let T_{asym} be mass of the asymmetrical body in fruitfly's brain, T_{sym} mass of the symmetrical body (Pascual *et al.* 1997), and assume $T_{asym} = 0.5T_{sym}$, and all cells in asymmetrical body or symmetrical body are activated, we have N=3, and the following result:

$$\frac{\text{Memory score for asymmetrical body}}{\text{Memory score for symmetrical body}} = (\frac{T_{asym}}{T_{sym}})^{-(3+3/N)/4} = 2^{7/8} = 1.8 .$$

It is obvious that memory score for asymmetrical brain is almost twice higher than that with symmetrical brain. We, therefore, give a possible explanation why brain asymmetry in Drosophia leads to long-term memory.

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4. CONCLUSION

A mathematical model is presented which describe experienced and empathic pain. Although the model (8) makes few simplifying assumptions, its power rests on the fundamental physical and biological principles as well as a realistic feature of biomechanics. There could be important implications for future developments in fugue or hypomnesia therapy.

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