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Short communication

Fractal dimensions: A new paradigm to assess spatial memory and learning using Morris water maze

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HIGHLIGHTS

- Track plots of animals using Morris water maze were generated using a MATLAB script.
- Fractal dimensions of track plots were calculated and compared with escape latency and distance travelled.
- Fractal dimension is a reliable parameter to assess spatial memory and learning.

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ABSTRACT

Morris water maze has been widely used for analysis of cognitive functions and relies on the time taken by animal to find the platform i.e. escape latency as a parameter to quantify spatial memory and learning. However, escape latency is confounded by swimming speed which is not necessarily a cognitive factor. Rather, path length may be a more appropriate and reliable parameter to assess spatial learning. This paper presents fractal dimension as a new paradigm to assess spatial memory and learning in animals. Male wistar rats were administrated with pentylenetetrazole and scopolamine to induce chronic epilepsy and dementia respectively. Fractal dimension of the random path followed by the animals on Morris water maze was analyzed and statistically compared among different experimental groups; the results suggest that fractal dimension is more reliable and accurate parameter to assess cognitive deficits compared to escape latency. Thus, the present study suggests that fractal dimensions could be used as an independent parameter to assess spatial memory and learning in animals using Morris water maze.

1. Introduction

Cognition testing is an extremely important parameter to assess changes in memory and learning abilities. A large range of behavioral tasks such as two compartment shuttle boxes, mazes such as Y-maze, T-maze, radial arm, elevated plus maze and Morris water maze have been developed for testing cognitive abilities in rodents. These tasks are used with different behavioral paradigms including avoidance learning, reversal learning, consolidated memory and long term memory in experimental studies [1]. Among these, Morris water maze (MWM) developed by Richard Morris in 1981 and is generally used to assess the spatial learning in rodents, which relies on distal cues to navigate from start locations around the perimeter of an open swimming arena to locate a submerged escape platform [2]. Spatial learning in the water maze is commonly used and is a reliable method to assess hippocampal-dependent cognitive function in rodents, this is probably because the water maze does not require food or water restriction, which may place differential physiological stress on rodents, and because learning in the water maze proceeds rapidly and efficiently. Previously, it has been observed that hippocampal and septo-hippocampal lesions in rats induces hyperactivity and the animals show deficits in the MWM [2]. In various models, MWM has been successfully used for evaluation of anti-dementia and anti-amnestic drugs. Primarily, this method is based upon the escape latency of animals which is calculated on the basis of time taken by animal to locate the hidden platform and hence this test relies on the time variable. Many a times, behavioral tests fail to provide the expected sensitivity and specificity [3]. The MWM has proven to be a robust and reliable test that is strongly correlated with hippocampal synaptic plasticity and NMDA receptor function [4,5].

In this paper, the concept of random fractals to assess learning and memory functions in animals has been introduced. Fractals

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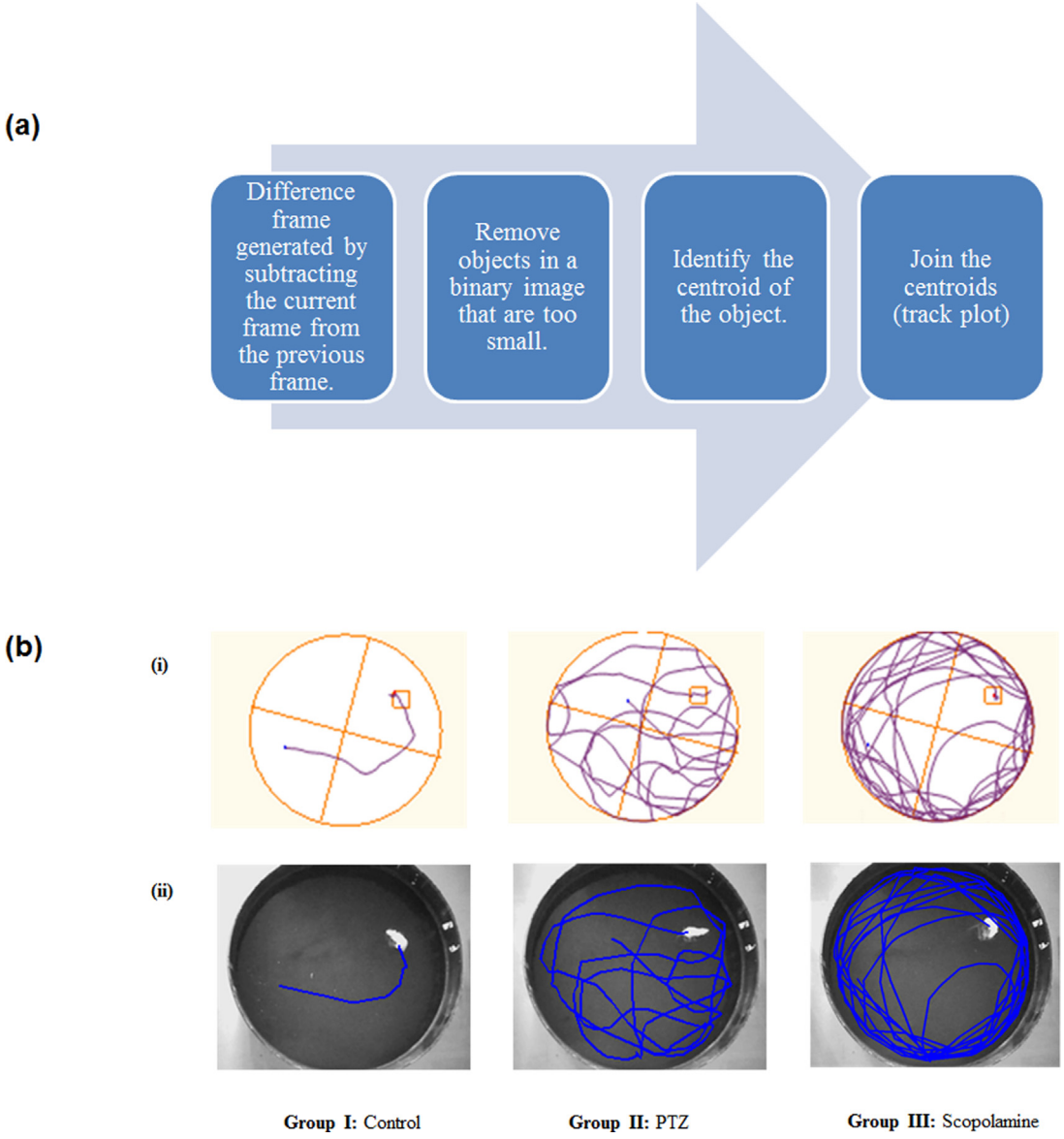

Fig. 1. (a) Plot track of animals in Morris water maze using frame differencing algorithm. (b) Track plots of animals in Morris water maze (i) from ANY-maze, and (ii) from custom written MATLAB script.

were introduced by Mandelbrot [6] to describe naturally occurring fragmented and irregular structures which exhibit self-similarity. Since then the fractal geometry has been behind an enormous change in the way scientists and engineers perceive, and subsequently model, the world in which we live [7]. Fractal analysis has been used extensively in animals to study various aspects of movement such as searching, navigation, dispersal and orientation, with a range of animals from birds to mammals to fish to insects [8]. Irregular movement (path tortuosity) in elders have been analyzed using fractal dimensions [9] suggesting strong association between path tortuosity and cognitive impairment related to dementia. Decreased path tortuosity in patients with traumatic brain injury has been shown to be associated with functional recovery [10–12]. Furthermore, spatial confusion has been found to be related to impending falls in older assisted living facility residents [13]. Fractal dimensions so far have not been used as a parameter to assess the cognitive deficits using Morris water maze. Therefore, this study aims to present fractal dimensions as an alternative parameter to escape latency and distance travelled by the animal in Morris water maze as it is a parameter that is not influenced by the time and swim speed of animals. The results of the study clearly show that fractal dimensions could be used as an independent parameter to assess the spatial learning and memory in animals. In addition, customized MATLAB scripts have been provided which can be used as an alternative open source to commercially available software's.

2. Material and methods

Adult male wistar rats (220–250 g) were procured from the Central Animal House of Panjab University, Chandigarh. The animals were housed under standard environmental conditions and had free assess to standard pellet diet and water ad libitum. All the procedures were performed in accordance with ethical guidelines for the use and care of laboratory animals and were approved by the Institutional Animal Ethics Committee (IAEC). The animals were randomly segregated into three groups with minimum six animals in each group. Control animals were given normal saline, animals