Age differences in the formation and use of cognitive maps

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1. Introduction

Several behavioural studies have documented an age-related decline in the human ability to orient and navigate in the environment [1–5]. In most studies, participants solve a virtual version of the Morris Water Maze task, in which they learn to reach a location hidden in the environment [6]. This task was originally designed to assess the use spatial information in the environment and shown to depend on hippocampal function. In other studies, orienting skills have been assessed with more ecological paradigms, such as mazes with hallways leading to target locations in virtual environments [4], or the performance of routes from memory in real surroundings [5]. These studies consistently report that elderly subjects take longer to reach a target location and make more errors than younger individuals. These behavioural results have parallels in neuroimaging findings. In a recent functional magnetic resonance imaging (fMRI) study [7], elderly volunteers performing a navigational task had less neural activity than young participants in the hippocampal complex, parietal cortex and retrosplenial cortex, regions involved in spatial navigation [8–13]. Another study [14] revealed that the age-related impairments while performing spatial and non-spatial hippocampus-dependent tasks were significantly correlated with both reduced volume and neurochemical properties of the hippocampus. Thus, with normal aging the brain may undergo structural and functional changes that impair cognitive components important for navigation and orientation.

While navigating in the environment, however, one may use different strategies that in turn may rely on different brain regions. Studies in human and non-human animals [15–19] have shown that at least two different memory systems with differing anatomic substrates are involved in orientation. The striatum subserves procedural memory, which individuals use when they navigate by following habitual paths in a fairly automatic manner [15,16]. On the other hand, the hippocampal complex subserves spatial memory, which individuals use when they orient by using landmarks in the environment and their spatial relationships [12,13,20,21]. When learning to navigate in a new environment, subjects may either over-learn a habitual route, thus relying on the procedural memory, or develop a “cognitive map” [22], a mental representation of the landmarks and paths in the environment, thus relying on spatial memory. (The latter strategy has the advantage of allowing individuals to reach any target location by any route available, not just a habitual one [18].)

Many elderly individuals develop a coping strategy of avoiding unfamiliar routes and places [23]. This raises suspicion that aging may have particularly adverse effects on the use of a cognitive map of the environment. Although several studies have shown that aging affects the ability to orient and navigate, it is not yet known whether aging specifically affects the ability to form and use cognitive maps.

In this report, we asked young and older participants to perform a virtual navigation task designed to assess both formation and use...