An fMRI study of neural activations in the aged and illiterates

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Introduction: A large area of the frontal and temporal cortices has been shown on fMRI or PET to mediate episodic encoding. Verbal information encoding preferentially activates the left inferior frontal cortex and left medial temporal lobe, nonverbal information encoding activates the medial temporal lobe bilaterally, and encoding of unfamiliar faces predominately activates the right medial temporal lobe. In addition, functional neuroimaging studies have consistently shown a greater left frontal lobe involvement in tasks promoting long-term memory encoding and a greater right frontal lobe involvement during memory retrieval. Previous studies have also examined the differences in neural activations between native and second languages. The left middle frontal cortex (BA 9) is strongly activated in native Chinese speakers during a variety of linguistic tasks, but its activation is either absent or weak in native English speakers performing the same tasks. To the best of our knowledge, the previous studies were performed in younger literates, the literature is deficient in similar data from aged literates and there is no data from aged illiterates. In this study, we suppose that healthy aging per se may not adversely affect the patterns of neural activations during working memory tasks; education may enhance efficiency in working memory tasks and offer back-up mechanisms to maintain essential cognitive operations under the challenge of normal aging or other pathological conditions.

Materials and Methods: 24 aged healthy Chinese volunteers (12 men; 12 literates; 65-70 years old) and 12 young healthy male Chinese literates (mean=22 years) were studied. All subjects had no experience of driving and strongly right-handed scored 40 or more on a handedness inventory. We used a GE 1.5 T MRI scanner with a maximum gradient strength of 23 mT/m. fMRI volume images were collected from 24 axial slices parallel to the AC-PC line (TR = 3000 ms; TE = 60 ms; flip angle = 60o; matrix = 64 x 64; field of view = 24 cm x 24 cm; slice thickness = 5.0 mm; no inter-slice gap) first during the verbal working memory task and next during the nonverbal task. A block design of RARA was adopted for both verbal and nonverbal working memory tasks with R representing rest and A representing stimulation, and each period lasted 45 s. There were 30 single Chinese characters in the verbal working memory task and 30 meaningful road-signs in the nonverbal working memory task. Both young and aged literates achieved full accuracy upon the initial presentation of the Chinese characters or road signs. The aged illiterates were taught on the meaning of the characters and road-signs twice before the fMRI scanning. Post-processing of fMRI data was done using SPM99. BA designations were applied using the Talairach Daemon.

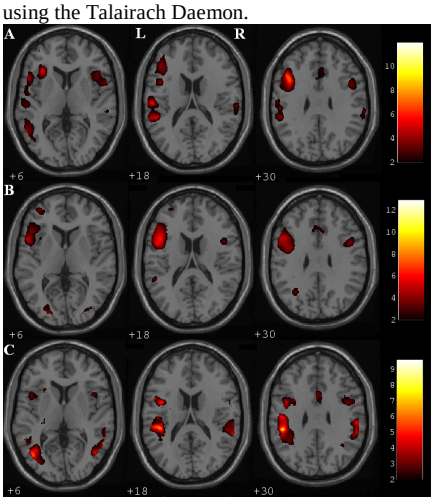

Fig. 1. Verbal working memory task.

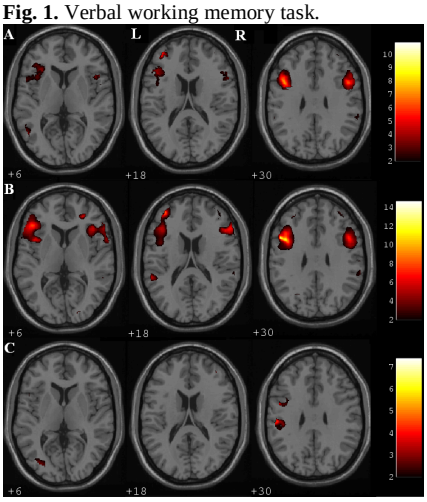

Fig. 2. Nonverbal working memory task

Results: Chinese Character Recognition. In the aged (Fig. 1A) and young (Fig. 1B) literates, main activations were found in the left middle frontal gyrus (BA 9/46, 44). Relatively small activations were seen in the left inferior frontal gyrus (BA 45), the left inferior parietal lobule (BA 40), the left parietal postcentral gyrus (BA 40), and the left superior temporal gyrus (BA 42, 22). In addition, there were weak activations in the right limbic cingulate gyrus (BA 32) and the left middle temporal gyrus (BA 37). There was no significant difference in the neural activations between young and aged literates. In the aged illiterates (Fig. 1C), main activations were found in the left and right inferior parietal lobules (BA 40). Relatively small activations were seen bilaterally in the superior (BA 22) and middle (BA 37) temporal gyri. Weak activations were noted in the left and right inferior frontal gyri (BA 9), the left frontal precentral gyrus (BA 44), and the right limbic cingulate gyrus (BA 32). **Road Sign Recognition.** In the aged (Fig. 2A) and young literates (Fig. 2B), main activations were observed in the left and right middle frontal gyri (BA 9/46). Weak activations were seen in the left inferior frontal gyrus (BA 45). There was no significant difference between young and aged literates. In the aged illiterates (Fig. 2C), only very weak activations were found in the left inferior parietal lobule (BA 40), left inferior frontal gyrus (BA 9), and the left middle temporal gyrus (BA 37).

Discussion and Conclusion: Unlike previous studies of working memory tasks, our work is focused on the effects of healthy aging and education on neural activations. In general terms, our findings from the literates indicate that processing verbal task involves the principal anterior and posterior language areas. Syntactic operations engage both the Broca's and Wernicke's areas. Processing of road-signs in the literates involves not only sites of nonverbal working memory but also the principal anterior language areas. There are two significant novel observations. First healthy aging per se does not alter the patterns of neural activations during verbal and nonverbal working memory tasks. Second, education has a potent and long-lasting effects on the patterns of neural activations during the tasks.The present results suggest that healthy aging per se does not affect the patterns of neural activations during the working memory tasks. This is good news for the global aging of populations. Education may offer an opportunity for our brains to wire in such a way that does not only enhance efficiency but also offer more back-up mechanisms to support essential cognitive operations when they are under the challenge of normal aging or other neurological conditions. Thus it is important to reduce the rate of global illiteracy through education.