Culture and the Aging Brain

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Glossary
Working memory: Refers to the structures and processes in the brain used to temporarily store and manipulate information.
Neurocognitive system: A term used to describe the particular brain areas, neural pathways and networks responsible for specific behaviour and thought processes.
Cognitive pragmatics: A term used to describe knowledge that has been acquired through a lifetime. It differs for people who are from different backgrounds and raised in different environments
Binding process: The ability to connect a particular object to its background

Research in the cognitive neuroscience of aging has revealed several significant changes that alter the functioning of the brain over an individual's lifetime. Particularly, some of these discoveries have contributed to our understanding of age-related degenerative diseases and cognitive decline. Most of these studies have, however, been conducted in Western (North American and Western European) populations, casting doubt on the universality of these findings. Cross-cultural investigations allow for the distinction between changes in the brain that are a consequence of aging and those changes that are due to the impact of life experiences. Research suggests that different cultures place emphasis on distinct aspects of information and use different strategies for processing this information (Nisbett and Masuda, 2003). Therefore, performing cognitive studies taking into account cultural context may provide an effective avenue for differentiating between age-related neural changes that persist across cultures and those that are driven by culture specific life experiences.

For the purposes for this paper, culture is defined as behavioural patterns, beliefs and experiences shared by individuals from a similar geographic region. This paper describes different cognitive processes, such as perception and working memory, and examines studies that reveal cultural differences in these cognitive processes. Furthermore, this paper provides a glimpse of the interplay between experience (through culture) and neurobiology (through aging) that moulds the neurocognitive system. Neuroimaging techniques such as functional Magnetic Resonance Imaging (fMRI) have allowed scientists to visualize the differences between an aging brain[1] and a young adult's brain, revealing that, relative to the younger brain, the former is constantly changing and adapting to its diminishing efficiency (Reuter-Lorenz, et al;2005). Research on neurocognitive aspects specific to culture should ideally distinguish whether the continual adaptations occurring in the brain of the aging adult follows an intrinsic neurobiological design or whether the brain is responding to life experiences that alter its circuitry.

An effective way to understand the impact of culture on behaviour and the organization of neural pathways is to compare cultures that are hypothesized to be different in some fundamental neurocognitive process (Norenzayan, 1999). We will focus primarily on comparisons between East Asian and Western cultures, mostly since the majority of current research into culture and its effects on neurobiology compare these two ethnic groups. This is a particularly relevant comparison because there are documented differences in the techniques these populations use to process information. These differences include categorization, reliance on rules, and the use of logic (Norenzayan, 1999). While it has been suggested that the differences in cognitive processes can be attributed to differences in perception as well as differences in what aspects of the environment receive more attention, it has been demonstrated that East Asians and Westerners do in fact engage different networks in the ventral visual cortex, a section specialized for processing different elements of a scene (Norenzayan, 1999). East Asians place more emphasis on the contextual relationships between objects, whereas Westerners tend to give undivided attention to individual focal objects (Chua et al.; 2005). It is believed that the differences in perception, cognition, and attention can be attributed to differences in social structures and practices. The notion that East Asians emphasize the role of social relations and harmony could be explained by the fact that agriculture has played an important role in East Asia for a greater period of time than in Western culture. Agricultural settings encouraged cooperation between farmers, because it was essential for sustained crop production (Nakamura, 1964). The economy in ancient Greece[2] was quite different from that of East Asia; the land did not lend itself to agriculture due to the mountainous terrain. Common Greek occupations, such as hunting, fishing, and domestic gardening, did not require extensive social collaboration. The individual nature of the professions rendered minimal need for interaction between individuals, depending entirely on personal skill. Consequently, attention could be maintained on a focal object. Essentially, Western societies were motivated by individual successes, while East Asian cultures gave more value to the prosperity of the community. These different values may have been perpetuated throughout many generations and are now reflected in the way East Asians and Westerners perceive their environment, making it plausible to explore the divergence in their cognitive and perceptual processes (Nakamura, 1964).

Research on the behavioural aspects of aging indicates a decline in the efficiency of basic cognitive processes, such as speed of thought, working memory, and long term memory; in contrast, knowledge[3] is preserved and in some cases increases (Park, et al; 2002). In order to investigate the joint impact of culture and aging on cognition it is important to make a distinction between the different domains of cognition. Park, et al. (1999) proposed two domains of cognition – basic cognitive hardware or mechanics, such as speed and working memory, and cognitive software or pragmatics, comparable to acquired knowledge. Using these definitions, one might expect that differences in the basic cognitive processes (hardware) seen in young adults would be minimized in older adults since age-related reductions in capacity limit the flexibility of mental operations. This would render experimental results increasingly similar across cultures as the age of the participant increases. Research on old and young Americans and Chinese has supported this model. An experiment by Hedden, et al. (2002) studied the backward digit span, which assesses participants' ability to manipulate a series of numbers in working memory and then repeat the numbers back in the reverse order in which they were originally presented. Researchers found a larger cultural difference between younger adults than older adults.

1. The aging brain refers to older adults above the age of 65.
2. Ancient Greece refers to the period of Greek History lasting from 1100 BC to 146 BC.
2. Knowledge refers to information acquired throughout a lifetime.

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Moreover, in a study related to memory, in which subjects recalled the identity of the person presenting facts in a video, no cultural differences were observed; however, large differences between age groups were reported (Chua, et al. 2006). Park, et al. (1999) conducted an additional study in which multiple measures of speed and working memories of young and old Americans and Chinese were collected. The results from this study indicated that there were larger differences associated with age compared to culture.

Conversely, one might expect that culture would magnify the effects of aging on cognitive pragmatics. Cognitive pragmatics is based on acquired knowledge and the assumption that older people have more experience within a culture than younger people. This theory is supported by the findings of a study conducted by Yoon, et al. (2004). To assess differences in categorical association, groups of young and old American and Chinese were provided with the names of 105 categories – for example, kitchen appliances, fruit, and seasons of the year. They were then asked to provide five examples they associated with each category. The results indicated that of the 105 categories, only examples from 13 were the same for participants from both cultures. Namely, there was a greater similarity in the examples that were recalled between individuals from the same cultural category, regardless of age group.

Given the above results, the relatively modest impact of culture and the stronger effects of age suggest that biological changes are primarily responsible for the age-related differences in resource-demanding, strategic functions like working memory and speed of thought. In contrast, the impact of culture assumes a far greater role in the development of knowledge-based structures. With regard to the two domains of cognitive processes, these results reveal the dichotomy between the impact of biological aging and culture on the consistency and flexibility, respectively, of cognitive structures in aging brains.

We have, so far, discussed behavioural studies that have demonstrated the relative invariance in cognitive behaviour as a function of culture. Now, we look at neuroimaging studies that reveal the impact of culture on the neural structure of aging brains. Despite the relative invariance of basic cognitive behaviours as a function of culture, the underlying neuroscience of aging and culture is quite different. There is well-documented research suggesting that the aging brain undergoes constant structural and cellular changes. At the cellular level, there is a decrease in dopamine receptors with age[4] (Backman, et al. 2000), and there is evidence that a decrease in these receptors is predictive of a decline in cognitive processes (Volkow, et al. 1998). Neuroimaging techniques have greatly advanced our knowledge of the structural changes that occur in the brain and have supported theories speculating this correlation. Given the decline of multiple cognitive systems as a function of age, one might expect that neural activity would systematically decrease, paralleling the behavioural decline. However, functional neuroimaging suggests that the aging brain is a dynamic system. When behavioural performance on a working or long-term memory task is equivalent in young and old adults, the parts of the brain activated during those behaviours differ. To elaborate, when performing the same task: (a) neural activation is distributed across more brain sites and structures in old adults compared to young adults[5], (b) older adults frequently engage the same region in both hemispheres of the brain for tasks whereas younger adults activate only one hemisphere, and (c) sometimes older adults show a greater level of activation than younger adults in the same neural regions (Reuter-Lorenz, et al. 2005). Studies have demonstrated that prefrontal activity during cognitive processes, such as episodic memory, semantic memory, working memory and perception, tends to be less lateralized[6] in older adults than in young adults. This age-related increase in the use of both hemispheres for a given

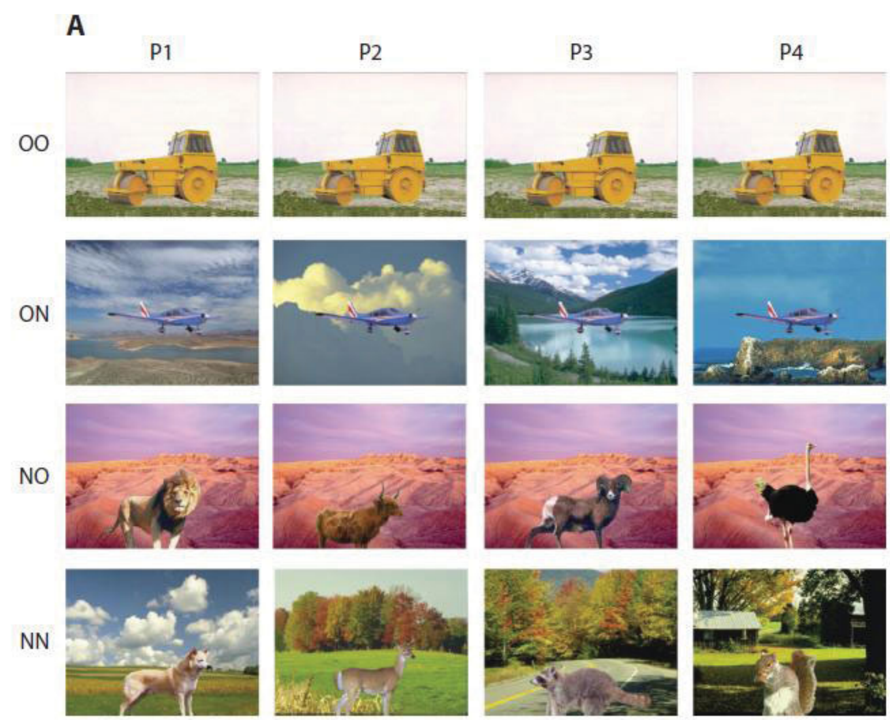

Figure 1: The four quartet conditions: four repeated objects and scenes (old object, old scene); four novel scenes with a repeated object (old object, new scene); four novel objects within a repeated scene (new object, old scene); and four novel objects with four novel scenes (new object, new scene).

4. Changes in the neurotransmitter mechanisms, including Dopamine, have been associated with normal aging. It is believed that the loss of Dopamine receptors causes alterations in frontal lobe processing and is responsible for age-related cognitive decline.

5. In this experiment, young adult participants were between the ages of 30 and 35 years.

6. When performing a specific task, lateralization refers to the localization of brain function to a particular hemisphere, right or left, of the brain.

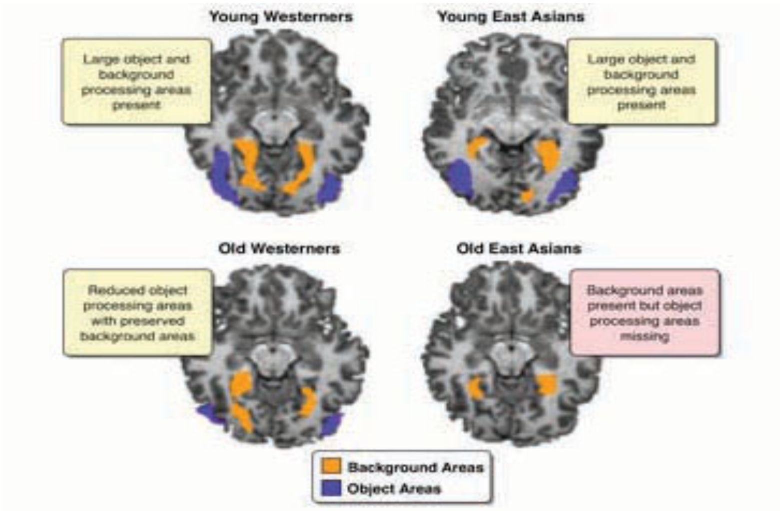

Figure 2: Mean magnitude of adaptation in young East Asians, young Westerners, elderly East Asians, and elderly Westerners. (A) Responses in hippocampal (left panel) and parahippocampal (right panel) binding regions. (B) Responses in left and right parahippocampal areas engaged in background processing. (C) Responses in left and right lateral occipital complex engaged in object processing. Standard error bars are shown.

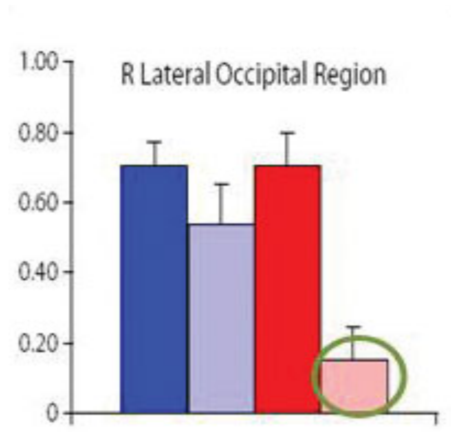

Figure 3: Object processing regions decline with age, but do so disproportionately in elderly East Asians.

task indicates the possibility that bilateral activation compensates for neural decline (Reuter-Lorenz, 2000).

Supporting evidence that the brain responds to the challenges of neurobiological aging by reorganizing, neuroimaging findings also suggest that neural structures may change as a result of prolonged exposure to stimuli. A recent study conducted by Maguire et al. (2000) has provided evidence that taxicab drivers have more posterior hippocampal volume than non taxi drivers and more importantly, within the group of taxi drivers, the subjects with more experience in the profession have a larger hippocampal volume than subjects who have been taxi drivers for a lesser number of years.

Following the notion that environment and experience may shape cognition and neural organization, we can hypothesize that differences in cultural values and customs could affect the development of neural activation patterns. In order to analyze this concept, a functional magnetic resonance imaging study (fMRI) was conducted by Goh, et al. (2007) utilizing theories from previous studies that revealed differences in visual processing among East Asians and Westerners (Chua, et al. 2005). The study investigated how culture might interact with age differences in visual processing of objects and backgrounds, as well as the contextual binding of objects to backgrounds. In order to examine this, 37 young and old East Asians and 38 young and old Americans were presented with a series of four pictures in which either the central object or the background of the picture varied; (Figure 1;).

The attenuation of the blood oxygen level dependent (BOLD) signal[7] that occurred with repetition of different elements of the pictures was measured. These measurements helped examine how specialized areas within the ventral visual cortex adapt to the repetition of different elements of a scene. That is, as subjects viewed the same images repeatedly, the object processing areas of the brain or the background processing regions of the brain adapted to the repetition. As regions adapted, they required less energy, and thus the BOLD signal in the fMRI attenuated. This method, effectively, dissociated the object processing regions, the background processing regions and binding processing regions of the brain. The pattern of results showed that adaptation in the parahippocampal gyrus is equivalent in all four groups (young and old Americans; young and old East Asians) for the processing of background information. The results also revealed that older adults in both cultures exhibited diminished binding process (Figure 2). The paper thus suggested that these findings support the theory that biological mechanisms, rather than cultural experience, are responsible for decreasing the ability of elderly people to engage their medial temporal lobe structures in binding processes to the same extent as younger adults.

The most noteworthy finding of the study by Goh, et al. (2007) is that object processing regions decline with age, but they do so disproportionately in elderly East Asians (Figure 3). The young East Asians and Westerners show relatively similar engagement of the lateral occipital cortex, but the elderly East Asians show a larger deficit of these object-processing structures than do the elderly Westerners. These findings suggest that the cultural differences in neural response are magnified over the lifespan of an individual. This data, combined with behavioural data revealing that East Asians show more eye fixations on backgrounds than on objects (Chua, et al. 2005), may indicate that after a lifetime of culturally biased information processing, the neural circuitry for looking at scenes may be sculpted in a way specific to each culture.

Research into the cultural neuroscience of aging has great potential to reveal the relative contributions of experience and biology to the process of aging. Cultural brain research may hold the key to the "use it or lose it" hypothesis – the concept that neurocognitive health is maintained by sustained intellectual engagement throughout a lifetime (Hultsch, et al. 1999). If we can identify structures that are engaged more by East Asians than Westerners, perhaps it can be postulated that these structures will maintain volume and function better in the culture that uses them more. Similarly, if certain patterns of neural recruitment are shown to

7. Almost all fMRI research uses Blood-oxygen-level-dependent or BOLD as the method to determine regions of brain activity. Neurons do not have internal reserves of energy in the form of glucose or oxygen. Thus, blood needs to release oxygen at a greater rate to active neurons than to inactive neurons. The difference in magnetic susceptibility between oxygenated or deoxygenated blood leads to magnetic signal variation which can be detected using an MRI scanner.

be universal with age across cultures, we could hypothesize that such recruitment patterns are a result of biological aging rather than experience.

Among the comparison studies that have been conducted on Western and East Asian populations, in this article we focus specifically on how they perceive their environment. The argument has long been made that Westerners, while viewing scenes, focus on the object independent of the context. In contrast, subjects from East Asian cultures are more inclined to attend to the context and to the relationship between objects and the environment. Recent findings by Masuda and Nisbett (2006) support this speculation. The authors presented Americans and Japanese subjects with two animated vignettes of scenes (e.g. a Japanese and American city) that differed in various small details. Some of the changes were made in the attributes of the salient, focal objects (such as changes the tires or the hub caps) and other changes were made in the field or context (such as the relationship between the cars and the buildings), including the background objects (such as the buildings) and location of objects. Americans detected more changes in the focal objects whereas Japanese detected more changes in the field and relationships between objects. The findings reveal subtle yet qualitatively different styles of attending to information in the environment.

Figure 4: Japanese City

Figure 5: American City

Using the results from this study, that there is a cultural difference in the viewing of scenes, we hypothesized that there must be a cultural difference in the way people navigate through their environment. To move in the environment, humans adopt different navigational strategies, which use different parts of the brain. To reach a target location, one may use a “spatial memory strategy” by learning the relationships between landmarks in the environment. This strategy is based on the formation of a cognitive map and allows a target to be reached in a direct path from any given location. This type of spatial strategy has been shown to depend on the hippocampus. Alternatively, one can navigate through the environment without knowledge of the relationship between landmarks, but instead by using a series of left and right turns. Successful repetition of this non-spatial strategy leads to a “response strategy” known to involve the caudate nucleus, a form of implicit memory or habit, (Berthoz, et al. 2001). Given the fact that we have identified two different navigational strategies that are dependent on different areas of the brain (spatial memory dependent on the hippocampus and response learning dependent on the caudate nucleus), and given what we know about cultural differences in the population regarding scenes, it can be hypothesized that we will find cross-cultural differences in navigation strategies. If a certain population is more attentive to the background, we expect them to exhibit a spatial memory strategy, i.e., using the relationships between landmarks in the environment to find a specific destination during navigation. Conversely, we expect that populations that are hypothesized to pay more attention to focal objects employ the other navigational strategy, i.e. a response learning strategy, by using a series of right and left turns from a given start position.

Cultural differences in navigation imply that a particular brain system is used preferentially over another. Results from these navigation studies have implications for neurological and psychiatric disorders, such as Alzheimer’s dementia, as well as for successful aging. During the course of normal healthy and unhealthy aging, there is an overall decrease in hippocampal volume which has been associated with cognitive decline (Moffat, et al. 2006), but in patients with Alzheimer's dementia, the atrophy is more extreme and precedes the onset of dementia (Csernansky, et al. 2006). As such, a population (Japanese) using spatial memory strategy to a greater extent may have greater grey matter in the hippocampus, thus reducing the risk for dementia. Coincidently, the incidence rate of Alzheimer’s disease is significantly lower in non-western countries, such as Japan, than in North America. The Honolulu-Asia aging study revealed that the prevalence rate of Alzheimer’s disease among Hawaiian Japanese-Americans men is similar to that seen for North Americans in general, while far exceeding rates typically seen in Japan. They thus concluded that Japanese males who immigrate to the island of Hawaii are more likely to have Alzheimer’s disease than Japanese men of the same age living in Japan, suggesting influences other than race. (White, et al.1996)

This article began by providing a glimpse into the interplay between experience (through culture) and neurobiology (through aging) that moulds the neurocognitive system. In order to further elucidate the cultural differences in cognitive processes, comparison studies between East Asians and Westerners were discussed. It was established that there are fundamental differences in the way East Asians and Westerners process information, specifically the way they perceive their environment. Studies by Masuda, et al. showed that East Asians pay more attention to the relationships between the object and the background, whereas Westerners pay more attention to focal objects. Using this knowledge, we hypothesized that if there is a cultural difference in way people view scenes, then there should be a difference in the strategies they employ to navigate through their environment. Thus, by examining studies of cultural differences in navigation and memory, we can further understand the factors involved in degenerative diseases such as, Alzheimer's disease. The world's aging population is now living longer emphasizing the effects that age-releated diseases affect their lives. It is imperative that scientists study this novel population to expand our knowledge of age related brain changes. Ultimately, findings from age-related brain research will help us elucidate the factors involved in reducing the risks of degenerative diseases and provide answers to a fast growing geriatric population.

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