Turkish Journal of Geriatrics
2007; 10 (3): 138-149

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REVIEW ARTICLE

CRITICAL REVIEW: AN ASSESSMENT OF AGE-RELATED CHANGES OF CEREBRAL CORTEX FROM THE VIEW OF FUNCTIONAL, COGNITIVE, STRUCTURAL AND PHYSIOLOGICAL PERSPECTIVE

ABSTRACT

Some changes and developments occur in aging in human life. These developments can be in both anatomical and cognitive direction. Especially in the brain, structural, neurochemical, functional and physiological changes take part regionally or as a whole. In the last decade, scientists found certain types of changes including cortical thinning, shrinkage and synaptic loss. In these studies, although there are supplementary and supporting findings, some studies are in contradiction for special changes. But in general, most of the studies showed that the biggest changing and most of the changing types occurs in prefrontal cortex and this region is very important for understading the aging. In this subject, brain reorganization may be the most complicated problem for the scientists and there are different approaches for this problem. In this study, a critical review of cerebral cortex's age-related changes was done in the means of different areas like functional, cognitive, structural and physiological. Also sections of development of the brain, major age-related changes in the brain and age-related regional changes were given for doing a comparison among the studies.

Key words: Cerebral cortex, Aging, Age-related changes.

DERLEME

BEYİN KORTEKSİNDE YAŞLANMAYA BAĞLI DEĞİŞİKLİKLERİN FONKSİYONEL, BİLİŞSEL, YAPISAL VE FİZYOLOJİK AÇIDAN KRİTİK DEĞERLENDİRMESİ

ÖZ

İnsan yaşamında yaşlanmayla beraber bazı değişiklikler ve gelişmeler meydana gelmektedir. Bu gelişmeler hem anatomik hem de bilişsel yönden olabilmektedir. Özellikle beyin içinde yapısal, nöro-kimyasal, fonksiyonel ve fizyolojik değişimler bölgesel veya tüm beyni kapsayacak şekilde olabilmektedir. Son on yıl içinde bilim adamları beyinde kortikal incelme, büzüşme ve sinaptik kayıp gibi birçok değişiklik tipi saptamışlardır. Bu çalışmaların içinde birbirlerini destekleyici veya tamamlayıcı bulgular olmasına rağmen bazı çalışmalar sonuçları itibariyle birbiriyle çelişki içindedirler. Fakat genel olarak, birçok çalışma en büyük değişimlerin ve en fazla değişiklik çeşidinin insan beyninin ön tarafında bulunan prefrontal bölgede olduğu ve bu bölgenin yaşlanmadaki değişimleri anlamak için önemli olduğunu göstermiştir. Bu konuda, en karmaşık problem is beynin kendi içindeki yeniden organizasyonudur ve bu konuda birçok farklı görüş ortaya atılmıştır. Bu çalışmada, beyin korteksinde yaşlanmayla beraber gelen değişikliklerin fonksiyonel, bilişsel, yapısal ve fizyolojik olarak kritik edilerek değerlendirilmesi yapılmıştır. Bu alandaki çalışmalar arasında karşılaştırma yapabilmek için beynin gelişimi, beyindeki yaşa bağımlı büyük değişiklikler ve yaşa bağımlı bölgesel değişiklikler ele alınmıştır.

Anahtar sözcükler: Serebral korteks, Yaşlanma.

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Geliş Tarihi: 20/03/2007
(Received)

Kabul Tarihi: 21/07/2007
(Accepted)

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INTRODUCTION

The importance of the various functions of the cerebral cortex in aging have drawn neuroscientists' attention to the study of age-related changes in the last few decades. Age-related changes in brain structure have been explored previously using a variety of methods, including post-mortem measurement of brain volume, microscopic examination of neuronal loss and morphological change, and *in vivo* measurement of regional brain volume (1,2). The majority of post-mortem studies reported that the age-related alterations of global morphometric properties including decline in total brain weight, cortical thinning and gyral atrophy are particularly accelerating during the sixth and seventh decades (1). But nowadays, knowledge about the aging brain is derived mostly from cross-sectional studies by using medical imaging techniques (2-5).

DEVELOPMENT OF THE BRAIN

Anatomical Development

Most of the dynamic activity of the brain development occurs in utero but changes continue for the first two post-natal years. In that age, the brain has reached close to 80% of its adult weight. There are some specific examples of anatomical changes but the most consistent findings across studies include: (a) a lack of any significant change in cerebral volume after five years of age; (b) a significant decrease in cortical gray matter after 12 years; and (c) an increase in cerebral white matter throughout childhood and young adulthood (6-10). Also global thinning was prominent in anatomical development and these changes were occuring more clear by middle age (11) and some neuroimaging and post-mortem studies seem to suggest that some age-related changes are regional.

Cognitive Development

Besides the anatomical development, there is a cognitive development for the human brain. Imaging experiments have shown that older people may use different brain areas compared to young people, even when performing the same task at the same level of proficiency (12). This suggests some degree of functional plasticity in the brains of older individuals but the exact role of this plasticity remains unclear.

There are two currently popular ideas about cognitive aging. The first of these theories is that the frontal lobes are particularly vulnerable to the effects of aging. The other theory is that of age-related slowing of information processing (13-15). One might say that increased response times could be the result of the increased time necessary for engaging additional regions of cortex.

Older individuals have reduced visual activity and contrast sensitivity, suggesting that they have difficulty in ignoring irrelevant information (16).

In one investigation (17), the general location of activation in prefrontal cortex did not differ for children as compared to adults, but overall volume of prefrontal activation, particularly in dorsolateral prefrontal regions, was greater for children than adults. This difference was due to a lack of robust activity in this area for the adults. Adults showed the most robust activity in more ventral regions of prefrontal cortex. This pattern of greater brain activity in children relative to adults is suggestive of a gradual decrease in the brain tissue required to perform the task. This decrease may parallel the loss rather than formation of new synapses observed in post mortern studies.

MAJOR AGE-RELATED CHANGES IN THE BRAIN

Structural Changes

For the structural changes, shrinkage, neuronal loss, dendrite loss and synapse loss are reported in the different studies. The most striking feature of aging brains is their shrinkage and this age-related shrinkage is region specific (18-20). This age-related shrinkage also relates with the weight (21,22) and expansion of the ventricular volume in the aged brain (23). For example, human brains from individuals over 60 years old have been shown to be 17% lighter than of young adults (24)

Extensive neuronal loss in the aged brain has been suggested to be the primary factor explaining age-related neuronal shrinkage for long years. Cortical neuronal loss in the aged brain was first reported by Brody's group (18). Further study of cell loss in the neocortex showed that primarily neurons are lost during aging (18,24,25), indeed, Meier-Ruge and coworkers (26) have hypothesized that 100,000 neurons in the human brain disappear daily resulting in a 19.7% reduction in cell number at the age of 80. Some experiments have reported in the way of neuronal loss in brain structures with aging in 1990s (27,28).

Other reported type of structural change is loss of dentrites. Significant age related loss of dendrites in the cerebral cortex has been first reported by Scheibel and coworkers (29). These age-related dendritic losses include both shortening (30) and fewer dendritic branches (31). The studies provide evidence for a substantive loss of dendrites and dendritic surface of pyramidal neurons in aged brains.

In 1980s, Quantitative studies using electron microscopy revealed significant loss of synapses with age in laboratory animals (32) and humans (33).

Neurochemical Changes

The present evidence would indicate that neurotransmitter systems are affected differentially by aging. For instance, studying the concentration of serotonin, norepinephrine, and dopamine in the cerebral cortex of rat brains at different developmental stages has shown that while serotonin concentration remains unchanged until very old aged (3 years), levels of norepinephrine and dopamine progressively decrease starting at 1 year of age (34).

Functional Changes

Decreases in the functional capacity of the central nervous system with age occur universally in all living organisms. For instance, significant alteration in the gait control, sleeping cycle, and learning and memory with age are the three commonest neural impairments in aged humans (35). Mechanisms underlying these age-related deficits are still largely unknown. The formation of complex behavioral responses relies on an even more complicate activation and inactivation of different group of neurons, whose activities are determined by countless synaptic inputs.

Using functional magnetic resonance imaging (fMRI) also revealed a positive correlation between the reduction in cortical activation and cognitive performance. For instance, decrease in cortical activities in aged people has been matched with the decline in working memory formation (36). Comparing the activation of cortical tissue upon auditory stimulation also revealed significant age-related decreases (37). Thus, results from these noninvasive recording techniques support a decline in evoked cortical activity with age.

In addition, performing the same cognitive function can activate different cortical structures in young and aged brains (38). Since topographic rearrangement of sensory inputs in the cerebral cortex can be induced after damages of sensory afferents (39).

Age-Related Regional Changes

Cortical Thinning

Neuronal counting studies have suggested that degenerative changes are accelerated in specific areas of the cortex, including frontal pole and premotor cortex (1). Prefrontal change is greater than the changes in other regions and this preferential vulnerability of prefrontal cortex has been demonstrated across some studies (6,40,41).

Significant thinning was found in primary sensory (occipital lobe/calcarine), primary somatosensory and motor (pre/post central gyrus and central sulcus) and association cortices (inferior lateral prefrontal cortex), with greatest statistical significance in inferior prefrontal, precentral and supramarginal regions (Figure 1a). These regions were mainly localized to the anterior cingulate and medial orbitofrontal/subcallosal cortex. The greatest rate (>0.07 mm/decade) was found in primary motor cortex. The greatest magnitude of regional thinning was found in inferior prefrontal, precentral, and supramarginal regions (Figure 1b) (11).

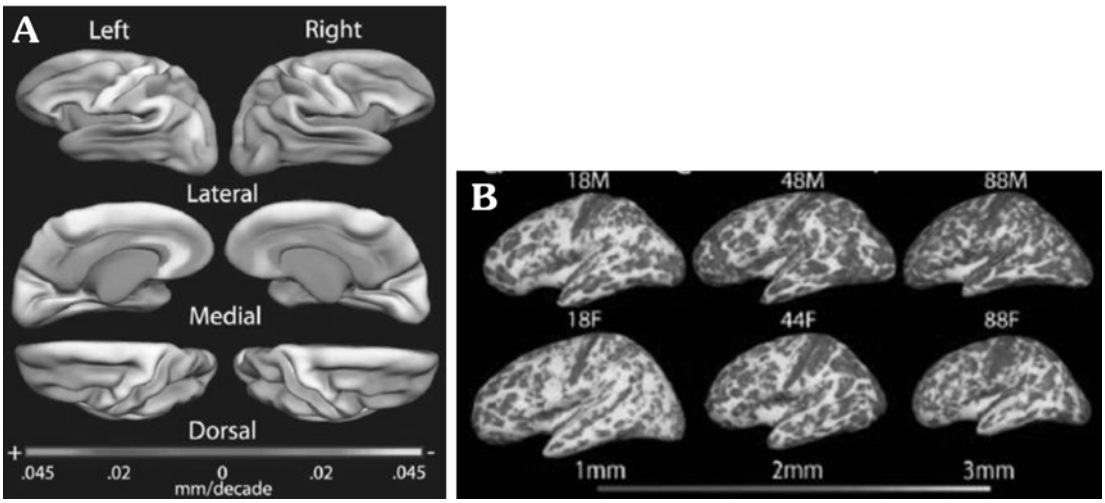


Figure 1— Reproduced with permission of Oxford University Press.

Shrinkage and Volume Changes

Haug and coworkers (42) have shown that areas 7 and 17 (parietal and occipital cortex) exhibited no shrinkage in aged brains, while >15% atrophy was found in areas 6 and 11 (extrapyramidal and orbital cortex).

There are a number of reports of general gray matter atrophy with age (43,44) and atrophy in both medial temporal and frontal regions (40,45). On the other hand there are studies that failed to find any significant atrophy in medial temporal areas (46), or that found greater loss of white matter with age than of gray matter (1,47). In addition, a recent longitudinal MRI study of brain volume in elderly adults over the age of 65 years found that frontal and posterior cortical areas showed no change (48).

Cross-sectional evidence suggests that in healthy adults, age-related volume reduction is more pronounced in gray matter (especially prefrontal), and shrinkage of sensory and entorhinal cortices is virtually nil (2).

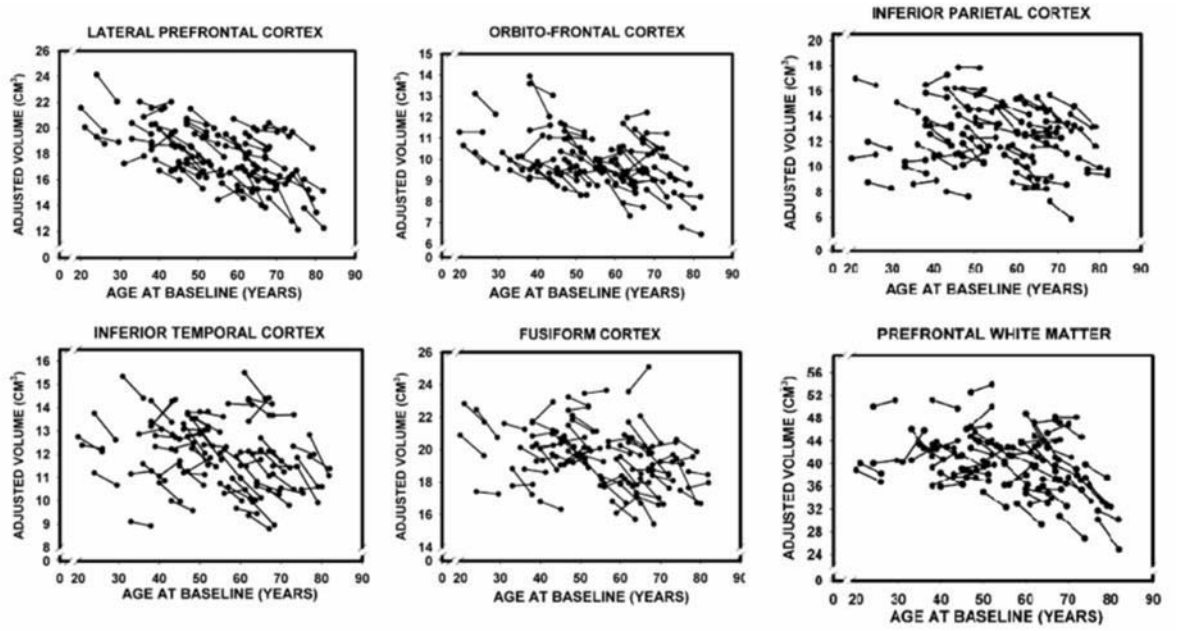
Raz's study in 2005 produced two major findings for this subject. First, in healthy adults, longitudinal changes in brain volume are not uniform. Although brain shrinkage is widespread, its magnitude varies across regions. The greatest mean shrinkage was observed in the caudate and the cerebellum, with comparable rates in the hippocampus and tertiary association cortices, and significantly smaller contraction of the fusiform (secondary association) cortex. The mean entorhinal shrinkage was minimal, and the primary visual cortex volume was stable (Figure 2 and 3). Second, longitudinal changes in brain volume during adulthood vary across individuals. The differences were especially pronounced in the cerebellum, prefrontal white matter, fusiform gyrus, visual cortex and inferior temporal cortex. In some regions, especially the hippocampus and the prefrontal white matter, shrinkage increased with age.

Changes in T1 Relaxation Time

Other age-related change was observed in relaxation times of the tissues. Preliminary results suggested that older person had significantly smaller relaxation times bilaterally that were most pronounced in inferior frontal and anterior temporal cortex, and the entire cingulated gyrus. In contrast, there were increases in portions of primary somatosensory and visual cortex (49).

Synaptic changes

Adams's group has reported age-related loss of asymmetrical synapses in the layer I region of the somatosensory cortex in aged humans (33).



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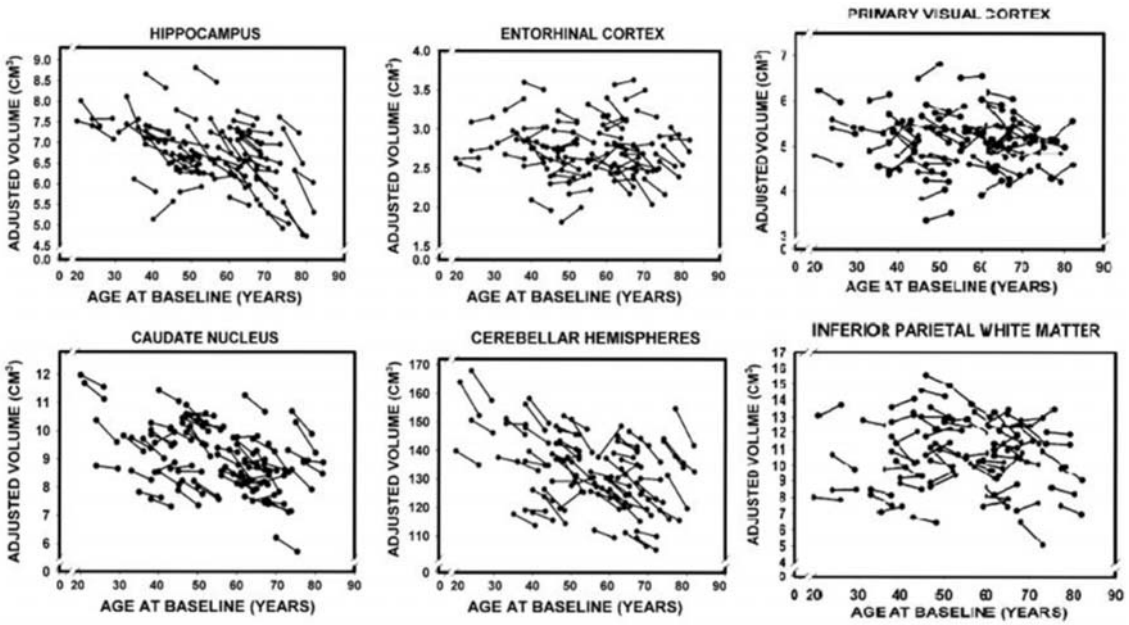

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Cognitive Changes

Memory

Cognitive processes which have been attributed to the prefrontal cortex include working memory, response inhibition and attention allocation (50-52). There is neuropsychological evidence to suggest that prefrontal function is sensitive to changes with age similar with shirinkage and volume studies (53,54). The results, from six children and six adults at the Pittsburgh site (55) demonstrated reliable activity in the right dorsolateral prefrontal cortex, right superior parietal cortex, and bilaterally in the inferior parietal cortex during the memory condition, relative to the motor condition (Figure 4).

Numerous age-related structural changes have been found in these brain areas critical for memory, including neuronal loss in medial temporal regions (1) and reduced numbers

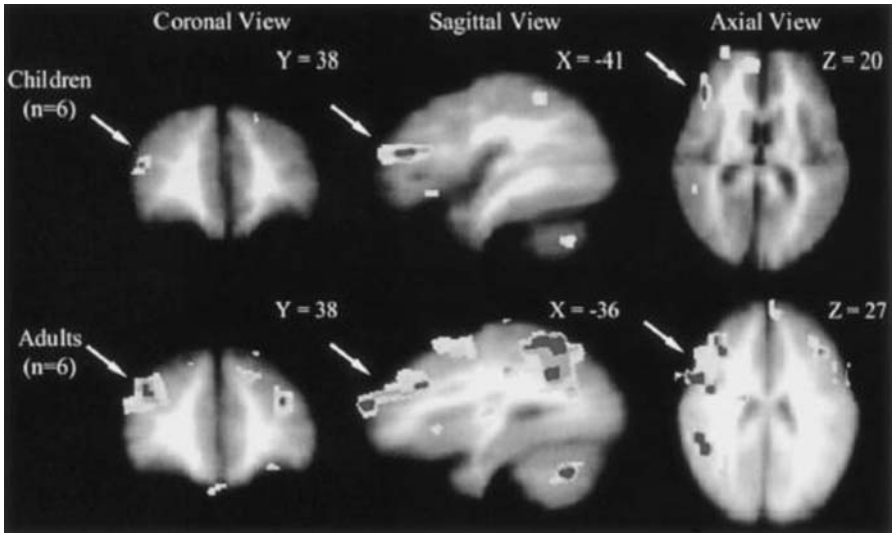
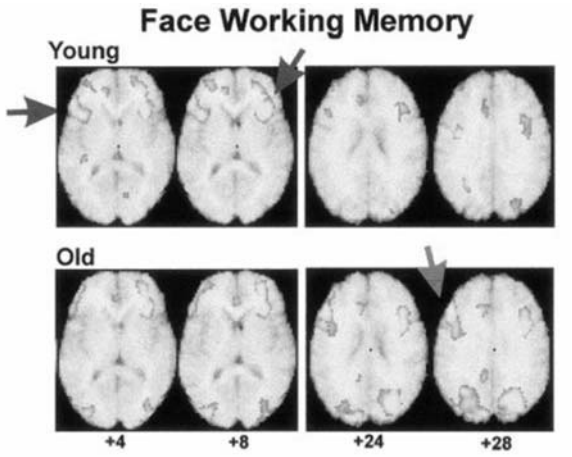


Figure 4



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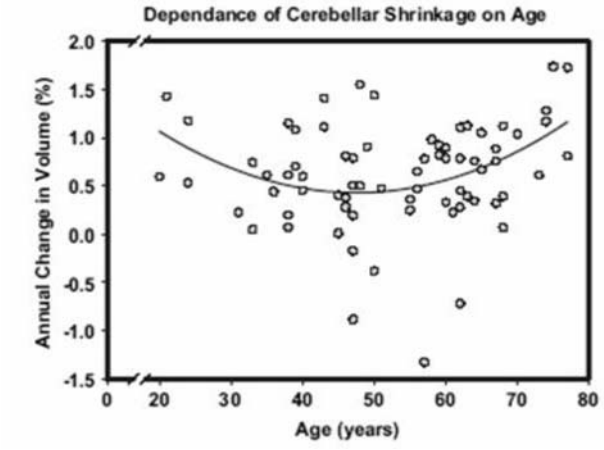

Figure 7

of dendrites and/or synapses in lateral temporal cortex (31) and prefrontal cortex (56,57). There also are physiological changes in these areas, such as reduced long-term potentiation in the hippocampus (58), that could affect older individuals' memory function.

A number of experiments have been carried out to examine age-related differences in brain activation patterns during episodic memory (12). In this study, young adults had greater activation of right ventral prefrontal cortex, and old individuals showed greater activation in left dorsolateral prefrontal cortex (Figure 5).

Visual Perception

Interestingly, a more recent fMRI experiment showed that older adults also have less activity in primary visual areas during photic stimulation (59). This indicated that although the old adults utilized the same ventral visual network for face perception, they had altered functional interactions among the regions in this network. This increased feedback from the frontal area suggested that older adults may require additional monitoring of the perceptual or response components of this task, as monitoring of behavior is one hypothesized function of frontal cortex (60). Young adults showed greater activity in prestriate and bilateral parietal cortices, whereas older adults had greater activity in ventral prefrontal cortex, lateral occipitotemporal cortex, hippocampus, and thalamus, in the left hemisphere (Figure 6).

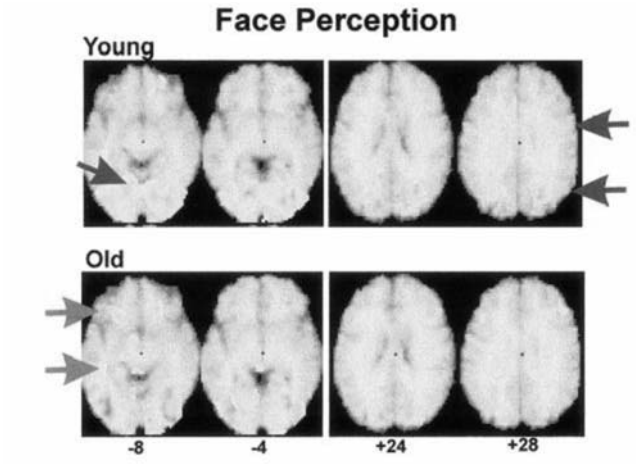

Figure 6

Attention

Also some studies showed the change of the attention in aging. In the divided attention condition (17), young participants had increased activity in posterior visual cortex compared to the central attention condition, and the old adults had increases in prefrontal cortex bilaterally.

DISCUSSION

When all these studies and different approaches are considered, it is obvious that there are many changes in the brain as a whole or regionally while aging both in negative and positive direction. These changes contain anatomical, physiological and cognitive changes. In addition, in some cases, relatively correlation can be found among these changes for the same areas, but for all cases, this can not be said directly.

In the recent years, important papers were published that showed the different aspects of the changes of the brain in

aging like how functional neuroimaging has been used to study age-related changes in cognition (12), understanding of age-related changes in neuronal structures and functions in the cerebral cortex (61), how T1 relaxation times change with normal aging using accurate reconstructions of the brain from MR scans (49), mapping of age-associated cortical atrophy as the thinning of cortex across the entire cortical mantle (11), MRI studies of structural and functional changes in the developing human brain and their relation to changes in cognitive processes over the first few decades of human life (17) and assessetment of the associations of brain volumes at baseline and brain volume changes with age, sex and vascular health (62).

The most significant change in aging is the shrinkage of the brain. For the major factors in causing the brain shrinkage with age is the loss of white matter. For one approach, damage of myelinated fibers with advancing age has been shown to be the prime factor causing the loss of white matter volume (63). But there is no conclusive evidence supporting a significant loss of neurons with age. Instead, loss of white matter could be an important factor in contributing to the brain shrinkage. In Table 1, only two studies specified that there are increasing neuronal loss in prefrontal and medial temporal cortex in aging (11,40,45).

The degree of the correlation of shrinkage and cognitive changes for the same areas can be considered. But brain shrinks with age even in reasonably healthy adults who showed no gross cognitive declines. The pace of shrinkage exceeds the predictions of crosssectional studies, varies across regions and, in some regions, increases linearly or even nonlinearly with age. For example, in prefrontal, extrapyramidal and orbital cortices, there is an increment, but in sensory, parietal and entorhinal cortices, there is no significant change (Table 1).

As shown in figure 7, trend decline in volume reduction with age is observed among younger participants, where as older individuals show a significant age-related increase in shrinkage rate (62). U-curve can be considered like acceleration and decleration at the opposite ends cancel each other.

For the reason of shrinkage, some of those factors may be genetic, such as apolipoprotein E 4/4 genotype (ApoE-e4), which has known negative effects on the brain development (64).

The other change in aging is the atrophy of the brain. A study recently reported a strong relation between order of developmental myelination and degree of age-associated volumetric atrophy, with regions developing late showing the strongest age-related atrophy (2).

As mentioned above, one hypothesis regarding structural change in aging is that regions of cortex that are late to develop are earliest to atrophy. Support for this theory has come from correlation of relative atrophy rates from volumetric studies to estimated developmental course (11). But on the other hand, the observation of prominent cortical thinning in or near primary visual cortex and motor cortex is inconsistent with this theory and argues against a 'last in, first out' model of aging. Also there are other studies (2,42) that show no shrinkage in occipital lobe, although cortical thinning and visual functionality decline are shown in other studies (11,65,66) (Table 1).

When development stages of the brain are considered, structural and neurochemical development of the prefrontal cortex have the latest timeline among the developmental events. So, prefrontal cortex provides consistent results with "last in, first out" model. However, for the reason of this situation, one possibility is that brain regions that are more plastic over prolonged periods of development are more sensitive or susceptible to environmental factors (e.g. stressors, toxins) and thus more prone to insult or injury from such environmental influences (12).

From the Table 1, it is obviously seen that the most effected brain region for both positive and negative changes is the prefrontal cortex. A few reasons are declared for the volume reduction in adolescent prefrontal cortex (67). These can be driven by experience-related pruning of dendritic arbor and elimination of excessive neurons, whereas the comparable volume loss in older adults may be inflicted by shrinkage and loss of neurons in specific sub-regions and laminae, loss of intralaminar myelin, loss of dendritic arborization, cortical thinnig or other atrophy factors. This behaviour can be observed from the figure 2 easily. Most significant decrease of volume with age is at the lateral prefrontal and orbitofrontal cortex. For supporting this decline as a cognitive part, also memory especially episodic memory and attention functions begin to less active in aging in the prefrontal cortex. Because prefrontal cortex include cognitive processes like memory, response inhibition and attention allocation (50,51,52). This decrease may parallel to the structural change and post-mortem studies. But exact comments can not be done for today, there must be more evidence for the direct relation. Because according to some studies, some cognitive network changes of the brain is possible for the aging (12).

After prefrontal cortex, Table 1 shows the medial temporal cortex as the other region that is having significant different changes. This shows the importance of the medial temporal region for the aging studies. Also this information is supported by declining the auditory functionality of the aged people.

When we look other regions of the brain rather thar cortex, some changes can be observed in different places like hippocampus, thalamus, caudate and cerebellum (Table 1).

Table 1— Comparison Table for the changes according to their occurence location for the different studies. ("+" shows the increment of the change, "-" shows the decrement of the change and "0" shows the no change for that region)

	shrinkage	neuronal loss	thinning	synapses/dendrites loss	atrophy	Relaxation time	cognitive (memory)	visual	attention
Prefrontal cortex	(+), (Raz et al., 2005)	(+), Raz et al., 1997; Jack et al., 1998)	(+), (Salat et al., 2004)	(+) (Cupp and Uemura, 1980; Peters et al., 1998)	(+) (Johnston et al., 2001)		(+) (Thomas et al., in press)		(+) (Goldman-Rakic, 1987; Diamond, 1988; Fuster,1989)
inferior lateral prefrontal cortex			(+), (Salat et al., 2004)						
orbitofrontal/ subcallosal cortex			(+), (Salat et al., 2004)						
medial frontal					(+) (Raz et al., 1997; Jack et al., 1998)				
inferior frontal						(-) (Salat, et al.)			
dorsolateral prefrontal cortex							(+) (Grady, 2000)		
ventral prefrontal cortex							(-) (Grady, 2000)	(+) (Grady, 2000)	
medial temporal		(+), (Salat et al., 2004)		(+) (Cupp and Uemura, 1980; Peters et al., 1998)	(+) (Raz et al., 1997; Jack et al., 1998), (0) (Sullivan et al., 1995; Bigler et al., 1997)				
anterior temporal cortex						(-) (Salat, et al.)			
occipitotemporal cortex								(+) (Grady, 2000)	
visual cortex						(-) (Salat, et al.)			
sensory (occipital lobe/calcarine)	(0) (Haug et al., 1983), (Raz, 2005)		(+), (Salat et al., 2004)					(-) (Sekuler and Owsley, 1982; Spear, 1993	
premotor cortex			(+), (Salat et al., 2004)						
somatosensory (pre/post central gyrus)			(+), (Salat et al., 2004)	(+) (Adams,1987)		(+) (Salat, et al.)			
somatosensory (central sulcus)			(+), (Salat et al., 2004)	(+) (Markus and Petit, 1987)		(+) (Salat, et al.)			
supramarginal regions			(+), (Salat et al., 2004)						
anterior cingulate			(+), (Salat et al., 2004)						
parietal cortex	(0) Haug et al., 1983						(+) (Thomas et al., in press)		
extrapyramidal cortex	(+) Haug et al., 1983								
orbital cortex	(+) Haug et al., 1983								
entorhinal cortices	(0), (Raz et al., 2000)								
caudate	(+), (Raz et al., 2005)								
cerebellum	(+), (Raz et al., 2005)								
hippocampus	(+), (Raz et al., 2005)						(-) (Gallagher and Nicolle, 1993)	(+) (Grady, 2000)	
thalamus								(+) (Grady, 2000)	

But most significant change occurs in the hippocampus among them. Also in cognitive studies, there is increment in visual experiments as a supporting part to occipital cortex and decrement in memory experiments as an expected behaviour. Because hippocampus plays a role in memory in general meaning.

The older brain is apparently capable of some degree of functional reorganization, in the sense that there is activation in old adults of brain areas not activated in young people, and differences in the way brain regions interact during a particular task (12). The experiments provide ample evidence that older people utilize different brain areas during cognitive activity than do young people, even when performing the same cognitive task with the same behavioral outcome. This suggests that spared cognitive ability may be related to the ability of older adults to recruit new areas into cognitive networks or perhaps alter the interactions among brain areas that form a specific cognitive network. This interpretation implies that all these are because of an age-related compensatory mechanism. However, in some cases older adults show recruitment of different brain areas, but nevertheless have reduced performance. Also the increasing activities in the ventral prefrontal cortex, hippocampus and thalamus for visual experiment (12) support this approach. Because there is no such significant changes for young individuals in visual experiment (Table 1).

These topographic changes in aged brain may be the consequence of age-related structural loss in the aged cerebral cortex. They include disappearance of dendrites, dendritic spines, and synapses in the aged cerebral cortex. Since the number of neurons probably remains rather stable in the aged cerebral cortex, the loss of these pre- and postsynaptic structures would result in a substantial loss of interneuronal connections in the aged cerebral cortex (61).

From the physicological view, the reduction of neuronal function in the aged brain is more likely caused by an imbalance between different neurotransmitter systems (61). This significant loss of dendritic structures may limit the availability of postsynaptic substrate in aged brains for synaptic connections. And this can be the reason of declining functionality in aging. And meaningful rates for the loss of synapses and dendrites were found in prefrontal, somatosensory and medial temporal cortices. For prefrontal cortex, there is a decline in memory and attention, for somatosensory cortex, there is an increase of relaxation time for the same losses (Table 1).

Consistent with many volumetric studies, marked thinning was noted in prefrontal cortex. While the one study suggests that such changes are unlikely to originate from neuronal death, post-mortem studies have found relatively comparable neuronal counts between older and younger subjects (11).

When we look at the Table 1, only a few changes can be observed for both increasing thinning and decreasing memory/visual functionality like in the prefrontal and sensory cortex. Also in somatosensory cortex, there is a cortical thinning in the presence of increasing relaxation times. As mentioned in the study, because of not having statistical significant for the relaxation times, we can not comment for both. But we can comment superficially only by looking at the Table 1, in the somatosensory cortex, there is a cortical thinning that occured because of synapses/dendrites losses. And so, in this region, relaxation times are increasing.

Besides all of them, also while studying these studies, some different unwanted changes come across that can be effect the results. This can occurred like an artifact, which somewhat overlap to regions of signal intensity changes or it is possible that changes in tissue parameters and other imaging artifacts such as 'bias fields' contribute to the present findings (68) or potential cohort effects that can be effect the system because of cross-sectional data. Some changes can occur from the changes in hardware and software that may differentially affect the measures, change in head position for an another source of error and operator differences and within-operator unreliability.

CONCLUSION

As a conclusion, different types of changes occur in the brain while aging. But these changes can be both in positive and negative direction or no change. As a most observable changing, shrinkage of the brain can be said. But in the summary of the studies, there is no relation of the increasing the shrinkage with the decreasing cognitive function. And shrinkage is observing regionally in the brain, not in general. Reasons of the shrinkage is not clear. There are some approaches like structural and genetic, but they need extra validation studies. According to an individual's sex, it does not play a significant role in brain aging according to the results of this study.

In aging studies, "last in, first out" concept is considered as the important thing for explaning the changes. There are some evidence for supporting this theory. But also in some studies, inconsistencies are shown for this concept. So we can say that there is no exact relation between late developing and greatest atrophy.

May be the most complex part of the aging studies is the brain's reorganization in the aging. Because of highly interconnected structure in the brain, solution of this new networks can not be very easy. Up to now, each study could

show the change from the one perspective but this subject has a multidimensional structure. This property obviously is shown in the studies and older individuals uses different parts or the different networks of the brain for the same tasks than youngs. This can be thought as a taking support from the other complementary parts of the brain for doing the task. One of the reason of the reorganization may be the structural change of the brain. Because there is an evidence in postmortem studies of decreasing neuronal loss. So brain may try to find another ways for the tasks. For this point, subject of the plasticity of the brain tissue should be considered and investigated much more for getting the some hints about the reorganization.

Also everyone should consider the physiological change in the aging like occuring imbalance of the neurotransmitters. Of course, artifacts, different environmental effects and overlaps are the common factors that can change the results for all studies. Decisions for the aging must be made by thinking all of these factors as a whole.

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