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Effect of Sensory Stimulation Type on Brain Activity in Elderly Persons with Mild Cognitive Impairment

Background: Mild cognitive impairment (MCI) is also called as aging related memory damage. Decreased cognitive function due to aging is known to be associated with the frontal lobe. Alpha wave is generated in the dominance in the frontal lobe or a wide range of regions in the brain, it should be doubted that the brain function might be degraded.
Objective: To determine the effect of sensory stimulation type on learning and brain activity pattern of elderly persons with MCI.
Design: Randomized Controlled Trial (single blind)
Methods: Twenty elderly persons aged more than 65 with MCI were randonmized to simultaneous visual/auditory stimulation group (SVASG) and or auditory stimulation group (ASG). Ten peoples were assigned to each group and lectroencephalogram test was performed to individuals. In the electroencephalogram test, electroencephalography of prior to sensory stimulation, and during sensory stimulation were measured to compare brain activity pattern according to the study groups and measurement period.
Results: The relative alpha power due to a sensory stimulation type showed that the SVASG significantly decreased in the left frontal lobe and the left parietal lobe statistically compared to those of the ASG while sensory stimulation was given ($p<.05$). The relative beta power due to a sensory stimulation type showed that the SVASG significantly increased in the left and right frontal lobes, the left and right parietal lobes, and the left temporal lobe statistically compared to those of the ASG while sensory stimulation was given ($p<.05$).
Conclusions: Electroencephalographic analysis showed that the type of sensory stimulation can affect the brain activity pattern. However, the effects were not studied that which brain activity pattern help to improved cognitive function of elderly persons with mild cognitive impairment.

Key words: *Electroencephalography, Cognitive function, Elderly, Mild cognitive impairment*

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INTRODUCTION

The decline of cognitive function due to aging could cause not only reduction of individual adaptation ability as well as emotional problems such as depression or anxiety but also difficult social relationship thereby degrading life quality of elderly persons significantly [1]. As a person gets older, decline of cognitive functions such as memory loss can occur. MCI is also called as aging related memory damage, which causes memory damage and difficulty in memorizing learning information in a daily living [2].

Decline of cognitive function due to aging is known to be related to the prefrontal lobe. A patient with damage in the prefrontal lobe showed similar impairment of cognitive function as elderly persons do. Reduction of gray matter and white matter in the cerebral is believed to be the neural mechanism of cognitive aging. This reduction change was also reported in the prefrontal lobe more than any other regions clearly and consistently [3, 4]. Patients with single domain amnestic MCI and multiple domain amnestic MCI had poor blood circulation in left putamen, globus pallidus, left insula, left posterior cingulate gyrus, right parahyppocampal gyrus, and cuneus [5]. Further, perfusion reduction in the hippocampal amygodaloid complex, which is directly related to memory, increases likelihood of progress into AD [6].

Most human electroencephalogram ranges between 0.5Hz and 60Hz, and according to a range of frequency, it is divided into delta(δ) wave .2~3.99 Hz, theta(θ) wave 4~7.99Hz, alpha(α) wave 8~12.99Hz, beta(β) wave 13~29.99Hz, gamma(γ) wave 30~50Hz [7]. A alpha wave is known as the stabilizing wave generated when body and mind take a rest while a beta wave is generated when awareness of normal healthy person and high level of cognitive functions are performed [8]. A delta wave is known to be related to physical body, emotion and thinking activity in a deeply internalized and quite state. A gamma wave is generated when awareness state is high such as excessive awareness and anxiety as well as complex information processing [9].

As age increases, appearance of an alpha wave is reduced. In particular, it tends that dominance of the occipital lobe decreases while dominance of the frontal lobe increases. If an alpha wave is generated in the dominance in the frontal lobe or a wide range of regions in the brain, it should be doubted that the brain function might be degraded, which can be found in head injury complication, cerebral arteriosclerosis due to high blood pressure. However, this wave is suppressed or disappears under mental activities in particular, tension or excitement. It also disappears in the sleep state which is a decreased level of consciousness. On the other hand, in electroencephalogram in elderly persons, beta and theta waves tend to increase [10].

The activation in the cerebral cortex that is involved with object perception shows distinctive difference by ages. During object perception, a young adult activates the occipital-temporal path whereas an elderly person activates the visual area and the frontal lobe region [11]. Not only object perception but also spatial perception showed a difference by ages that an elderly person has smaller activation in the visual area compared to a young adult whereas the other regions (temporal lobe, parietal lobe et al) in an elderly person had more activation [12]. Selective attention and spatial attention had a difference of activation in the brain regions by ages too. For example, to perform a task requiring identification of letter separately located in space, an elderly person responded less accurately and more slowly in a situation requiring a divided attention task in contrast with a situation of focused attention as well as showing smaller activation in the visual area [13]. The age effect on brain activation pattern in episodic memory showed that an elderly person had smaller activation in the low parietal lobe and the low temporal lobe compared to a young adult. On the other hand, an elderly person had more activation in the premotor cortex [14].

Few studies have been done on the effect of sensory stimulation type on learning and brain activity pattern. Therefore, a study is required to find out the effect of sensory stimulation type on changes in brain activity patterns of elderly persons with MCI.

METHODS

Subjects

The subjects of this study are Twenty elderly persons, at the age of 65 and more, who did not meet the criteria for dementia and had normal daily living. However, subjects had MCI with MMSE-K score of 18-23. The general features of the subjects are shown in Table 1.

Table 1. General characteristics of the subjects

Variable	SVASG (M±SD)	ASG (M±SD)
Age (yr)	73.25±4.12	72.07±5.26
Height (cm)	159.21±3.57	160.28±4.24
Weight (kg)	55.35±1.96	56.97±2.67
MMSE-K(score)	21.25±1.08	22.17±2.17

SVASG: simultaneous visual/auditory stimulation group, ASG: auditory stimulation group auditory stimulation group, Rt: right, Lt: left, MMSE-K: Mini-Mental State Examination-Korean

Outcome measures and procedures

A cognitive test and individual interviews were conducted as a basic study after the interview survey for selection of the study subjects. Subsequently, 10 participants for each group among those who gave consent to the study were randomly assigned to ASG and SVASG. Electroencephalogram was measured at prior to sensory stimulation, in the middle of sensory stimulation. This study used QEEG-8 (Laxtha Inc., Daejeon, Korea) for electroencephalogram measurement. Electroencephalogram was measured by attaching the electroencephalogram electrode to eight regions of the head surface using a monopolar derivation mode.

Data and statistical analysis

The measured data were analyzed using SPSS version 18.0. Wilcoxon signed-rank were used to compare change in EEG before and middle stimulation in each group. Mann-Whitney U test were used to compare the change in EEG between the groups. The level of statistical significance was set to a= .05.

RESULTS

Comparison of the relative alpha power

In the SVASG, there were a significant decrease in both frontal lobes, in both parietal lobes, in both temporal lobes and in both occipital lobes in the condition with sensory stimulation compaired to the condition without sensory stimulation(p<.05). In the ASG, there were a significant decrease in right frontal lobe, in right parietal lobe and in both temporal lobes in the condition with sensory stimulation compaired to the condition without sensory stimulation(p<.05).

The relative alpha power due to a sensory stimulation type showed that the SVASG significantly decreased in the left frontal lobe and the left parietal lobe statistically compared to those of the ASG while sensory stimulation was given(p<.05).

Table 2. Comparison of the relative alpha power (unit :Hz)

Region	Group	without stimulation	with stimulation	p	p
Lt frontal lobe	SVASG[1]	.087±.021	.041±.022	.000*	.003*
	ASG[2]	.081±.034	.064±.025	.122	
Rt frontal lobe	SVASG	.113±.040	.039±.021	.000*	.059
	ASG	.104±.052	.060±.028	.008*	
Lt parietal lobe	SVASG	.102±.045	.044±.024	.000*	.030*
	ASG	.091±.055	.072±.030	.420	
Rt parietal lobe	SVASG	.127±.055	.043±.025	.000*	.063
	ASG	.111±.070	.066±.026	.035*	
Lt temporal lobe	SVASG	.128±.031	.048±.028	.000*	.063
	ASG	.119±.059	.071±.028	.008*	
Rt temporal lobe	SVASG	.113±.035	.033±.018	.000*	.105
	ASG	.111±.058	.060±.034	.014*	
Lt occipital lobe	SVASG	.094±.040	.054±.035	.002*	.051
	ASG	.081±.039	.073±.032	.586	
Rt occipital lobe	SVASG	.110±.077	.054±.033	.000*	.217
	ASG	.128±.116	.072±.036	.199	

*p<.05
SVASG[1] : simultaneous visual/auditory stimulation group
ASG[2] : auditory stimulation group auditory stimulation group, Rt: right, Lt: left

Comparison of the relative beta power

In the SVASG, there were a significant increase in both frontal lobes, in both parietal lobes, in both temporal lobes and in both occipital lobes in the condition with sensory stimulation compaired to the condition without sensory stimulation. In the ASG, there were a significant increase in both occipital lobes in the condition with sensory stimulation compaired to the condition without sensory stimulation(p<.05).

The relative beta power due to a sensory stimulation type showed that the SVASG significantly increased in the left and right frontal lobes, the left and right parietal lobes, and the left temporal lobe statistically compared to those of the ASG while sensory stimulation was given(p<.05).

Table 3. Comparison of the relative beta power (unit :Hz)

Region	Group	without stimulation	with stimulation	p	p
Lt frontal lobe	SVASG[1]	.096±.061	.184±.054	.001*	.019*
	ASG[2]	.134±.067	.152±.086	.472	
Rt frontal lobe	SVASG	.092±.073	.192±.056	.000*	.017*
	ASG	.118±.078	.160±.081	.094	
Lt parietal lobe	SVASG	.102±.077	.196±.093	.000*	.009*
	ASG	.144±.083	.158±.117	.744	
Rt parietal lobe	SVASG	.106±.079	.183±.070	.009*	.015*
	ASG	.143±.067	.142±.085	.983	
Lt temporal lobe	SVASG	.127±.076	.200±.052	.004*	.051
	ASG	.167±.080	.167±.083	.913	
Rt temporal lobe	SVASG	.142±.095	.226±.0761	.001*	.012*
	ASG	.169±.099	.183±.1011	.744	
Lt occipital lobe	SVASG	.150±.104	.235±.078	.003*	.072
	ASG	.191±.087	.211±.114	.586	
Rt occipital lobe	SVASG	.145±.103	.246±.100	.000*	.063
	ASG	.176±.088	.204±.126	.500	

*p<.05
SVASG[1] : simultaneous visual/auditory stimulation group
ASG[2] : auditory stimulation group auditory stimulation group, Rt: right, Lt: left

DISCUSSION

This study analyzed the changes in the brain activity patterns shown in the regions in the cerebral cortex as well as learning difference while changing sensory stimulation type. Using an electroencephalogram instrument, brain activity patterns were measured after auditory stimulation and simultaneous visual and auditory stimulation. For analysis of the wave forms measured through the electroencephalogram test, alpha waves of 8 to 12.99Hz, which were generated during relaxation and rest, and beta waves of 14 to 29.99Hz, which were generated during concentration and active action, were analyzed. As a result, the relative alpha power according to sensory stimulation type showed a significant decrease statistically in the left frontal lobe and left parietal lobe at SVASG compared to ASG. In case of the relative beta power, which is increased during concentration and active action, showed significant increase statistically in both frontal lobes, both parietal lobes, and left temporal lobe at SVASG compared to ASG.

As a similar result of this present study, Yordanova et al. reported that as getting older, alpha waves in the frontal lobe and the parietal lobe decreased in the middle ages compared to younger ages, while beta waves increased in the frontal lobe and the parietal lobe [15]. Kaminski et al. presented that visual stimulation increased beta waves in the parietal-occipital lobe regions while decreasing alpha waves in the occipital lobe [16]. Dahlin et al. reported that changes in increase of activation in the left frontal lobe and the both parietal lobes were shown after cognition training was done [17]. According to the study of Timmermann et al. visual stimulation and auditory stimulation had no significant change in alpha waves while beta waves had significant increase in the frontal lobe and the parietal lobe [18]. The study of Praeg et al. reported that strong activation of neurons in the parieto-prefrontal network was shown after initial visual stimulation [19].

As the opposite study results of this present study, according to the study of Lee, motor imagination while giving visual and auditory stimulations caused significant increase of relative alpha power in the frontal lobe, the parietal lobe, the occipital lobe, and the temporal lobe of the cerebral cortex while no significant change of relative beta power was shown in the parietal lobe and the temporal lobe [20].

In this study result, alpha waves of 8 to 12.99Hz, which were generated under relaxation or rest state, showed decrease in the frontal lobe, the temporal lobe and the parietal lobe while beta waves of 14 to 29.99Hz, which were generated under concentration and active state, showed increase in the frontal lobe, the temporal lobe, and the parietal lobe. The reason for this was that while giving tasks requiring attention, alpha waves were suppressed but large amplitude of beta waves, which were generated when mental activity was actively done, was generated because beta waves occurred when new learning was conducted. These results can be explained that activation in the pre-frontal lobe region at the initial time of motor learning was related to the concentration process [21]. In the cognitive phase, which is an initial phase of motor learning, a learner was interested in what to do and how to attempt while performing a new task so that this phase meant that genuine cognitive activity was actively carried out [22]. During this phase, much learning can be achieved in linguistic and cognitive attributes so that this phase is called the verbal-motor stage [23]. That was why regions of the frontal lobe, the temporal lobe and the parietal lobe, which were involved in verbal activities showed high activation at the initial phase where motor skill is acquired [24, 25, 26].

Based on the above results, presentation of simultaneous visual and auditory stimulation can be more effective than presenting only auditory stimulation in order to improve brain activity patterns in elderly persons with MCI. This study was conducted with some of elderly persons with MCI in a specific region. In the future, elderly persons with more various cognitive function disorders shall be studied for in-depth research.

CONCLUSION

This study aimed to find out the effect of sensory stimulation type on the brain activity patterns of elderly persons with MCI. The result revealed that presentation of simultaneous visual and auditory stimulation can be more effective than presenting only auditory stimulation in order to improve brain activity in elderly persons with MCI.

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