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The Effects of EEG Power and Coherence on Cognitive Function in Normal Elderly, Non-Demented Elderly With Mild Cognitive Impairment, and Demented Elderly During Working Cognition Task

Dong-wook Han, Ph.D., P.T.
Dept. of Physical Therapy, Silla University

Abstract

The purpose of this study was to find out the effects of electroencephalograph (EEG) power and coherence on cognitive function in normal elderly, non-demented elderly with mild cognitive impairment, and demented elderly during working cognition tasks. Forty elderly women (19 demented elderly, 10 non-demented elderly with mild cognitive impairment, 11 normal elderly) participated in this study. All subjects performed working cognition tasks with Raven's CPM while EEG signal was recorded. EEGs were measured continuously at rest and during the working cognition task. EEG power and coherence was computed over 21 channels: right and left frontal, central, parietal, temporal and occipital region. We found that there were more correct answers among normal elderly women than in other groups. During the working cognition task, Θ wave at Fp1, Fp2 and F8, a wave at Fp2, ß wave at Fp1, Fp2, F4 and F8 of the frontal region was increased significantly in the demented elderly group. On the other hand, Θ wave at Fp1, Fp2 and F7, ß wave at Fp1, Fp2, F3 and F7 of the frontal region was increased significantly in the group of non-demented elderly with mild cognitive impairment. In contrast, in the normal elderly group, all of the Θ wave and ß wave at Fp1, Fp2, F3, F4, F7 and F8 of the frontal region (except ß wave at F3) was increased significantly. These results suggest that the nerves in prefrontal and right hemisphere regions were most active in the demented elderly group during problem solving, and the nerves in the prefrontal and left hemisphere lobe were most active in the group of non-demented elderly with mild cognitive impairment. In contrast, the majority of nerves in the frontal region were active in the normal elderly group.

Key Words: Demented elderly; Electroencephalograph; Non-demented elderly with mild cognitive impairment; Normal elderly; Working cognition task.

Introduction

Failing of brain function with aging generally occurs with decrease in the number of neurons, changes of neurotransmitter and synaptic transmission in neurons, biochemical changes, such as oxidization and inflammation, and pathological changes, such as amyloid deposition. Symptoms of failing of brain function with aging include decline in logical thinking, processing speed, and short-term memory (Compton et al, 2000).

Cognitive function refers to memory, visual-spatial capacity, frontal lobe performance, and linguistic and calculation ability. A person who once performed normal daily activities with normal cognitive function may suffer from a decrease in cognitive function resulting from acquired degenerative changes or vascular problems, and these overall symptoms are called dementia (Choi, 2005). Accordingly, dementia is a cognitive function disorder which is chronic and progressive and includes damage to memory, thinking, understanding,

Corresponding author: Dong-Wook Han *dwhan@silla.ac.kr*
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orientation, learning, judgment, and linguistic ability (Mckhan and Drchman, 1984). Mild cognitive impairment, which develops into dementia, is defined to show a level of cognitive function, somewhere between normal and demented (Jiang, 2005). Mild cognitive impairment does not cause great inconvenience in daily and social activities (Korea Dementia Association, 2006). Generally, people who suffer from mild cognitive impairment have clear and logical thinking ability and lead normal activities of daily living, but they have a significantly poorer memory, especially short-term memory, when compared with people of the same age who received same level of education (Lee, 2005).

There are several methods which are used to diagnose dementia. Recent studies show that electroencephalography (EEG) is useful for evaluating brain function, as changes in brain function can be examined while the brain is performing cognitive activities (Kikuchi et al, 2002; Hwang et al, 2005). Moreover, analysis of electroencephalogram helps classify the group of mild cognitive impairment (Jelic et al, 2000).

EEG is more useful than other methods in some aspects. While single-photon emission computed tomography (SPECT) and positron emission tomography (PET), which use isotope in measurement, are relatively slow in measurement of speed. EEG, which uses electric signals in measuring brain activation, is faster than other methods (Chance et al, 1993). Functional magnetic resonance imaging (fMRI) and PET are useful for determining the focuses, but lack time accuracy (more than one second). In other words, they capture images of the brain after some changes occur, so it is difficult to grasp real time changes in the brain. In the case of EEG, however, it is possible to identify real time changes (Dale and Halgren, 2001).

This study is designed to identify electroencephalogram differences in normal elderly, non-demented elderly with mild cognitive impairment, and demented elderly at rest and during a working cognition task. The results are to be used as a basic resource in diagnosis of dementia and mild cognitive impairment and in developing effective cognition rehabilitation methods.

Methods

Study Design

Subjects were divided into three groups of normal elderly, non-demented elderly with mild cognitive impairment, and demented elderly. To identify electroencephalogram changes in each group at rest and during the working cognition task, quasi-experimental design and pretest-posttest nonequivalent control group design were employed. The study covered the period from January 2 to February 28, 2008.

Subjects

Researchers randomly selected three geriatric institutions in the Busan area. Subjects were selected from the female elderly in those institutions who voluntarily agreed to participate in the study after having listened to purpose of the study. The subjects were able to perform normal daily activities, without any impairment in vision, audition, and language communication. The subjects were also free from any kind of encephalopathy, such as a cerebrovascular accident (CVA), and they scored under 21 on the Korean-Geriatric Depression Scale (K-GDS) (Jung et al, 1998), signifying they do not suffer serious depression. Forty subjects were divided into three groups: dementia (19 persons, average age: 79.3 yrs), mild cognitive impairment (10 persons, average age: 81.5 yrs), and normal (11 persons, average age: 80.3 yrs).

Experiment Method

Tools for Subject Selection and Selection Standard

Subjects were divided into three groups based on the results of Mini-Mental State Examination-Korean (MMSE-K), Clinical Dementia Rating (CDR), and Global Deterioration Scale (GDS). At Mini-Mental State Examination-Korean (Park and Kwon, 1989), those who scored more than 24 points were classified as normal, 20 to 23 points as having mild cognitive impairment, and under 19 points as having dementia. For Clinical Dementia Rating (Korean Association for Geriatric Psychiatry, 2003), point 0 was normal, .5 was mild cognitive impairment, and 1 to 3 was dementia. As for the result of Global Deterioration Scale (GDS) (Reisberg et al, 1982), GDS 1 and GDS 2 were classified as normal, GDS 3 and GDS 4 as mild cognitive impairment, and GDS 5 to GDS 7 as dementia. To be classified into one of the three groups of dementia, mild cognitive impairment, and normal, the subjects had to get the same results from at least two of the three measurement scales mentioned above.

Instruments

Cognitive Function Test

Computerized Neurocognitive Function Test (CNT)[1] was used for the cognitive function test of this study. It is designed to examine various neuro-cognitive functions, such as attentiveness, memory, cognition-movement coordination, and comprehensive cognitive thought. Among 18 cognition measurement programs, the study used Raven's CPM (colored progressive matrices), which can be applied to anyone regardless of literacy (Figure 1). Raven's CPM consists of 36 items, and the assessment was made based on the number of correct answers.

Electroencephalography (EEG)

A wireless portable electroencephalograph[2] was used for electroencephalogram measurement; the electroencephalography was performed by a neuro-physiologist who works at D hospital in Busan, and has extensive experience in measuring electro-encephalograms (Figure 2). In accordance with the ten-twenty electrode system, the electrodes were attached to Fp1, Fp2, Fpz, F3, F4, F7, F8, Cz, C3, C4, T3, T4, T5, T6, Pz, P3, P4, O1, O2, and ear lobes (Kim et al, 2005). Fp1, Fp2 fall on the prefrontal lobe, Fpz on the median frontal lobe, F3, F4 on the median and rear frontal lobe, F7, F8 on the rear frontal lobe and front temporal lobe, Cz on the median central part, C3, C4 on the central part, T3, T4 on the median temporal lobe, T5, T6 on the rear temporal lobe, Pz on the median parietal lobe, P3, P4 on the parietal lobe, and O1, O2 on the occipital lobe (Kim and Choi, 2001).

Procedures

Electroencephalography was carried out on normal elderly, non-demented elderly with mild cognitive impairment, and demented elderly at resting state. Before the electroencephalography, subjects were asked to take a rest on a comfortable chair for five minutes with their eyes closed. Electroencephalogram

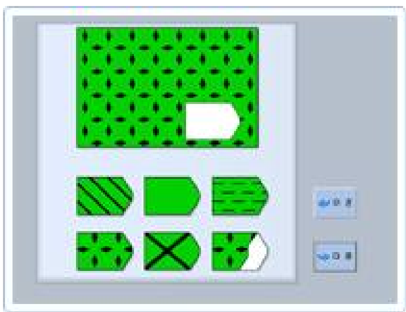

Figure 1. Cognitive function test.

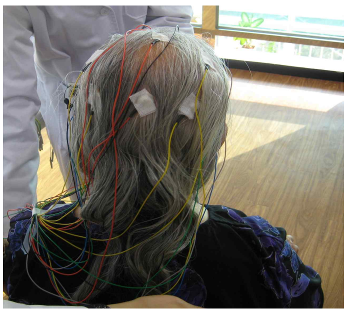

Figure 2. Electrodes position.

Figure 3. Cognitive function test and EEG.

1) CNT, MaxMedica Inc., Korea.
2) EEG, Nihonkhoden Inc., Japan.

was measured for five minutes at this resting state. After the electroencephalography, a cognitive function test was carried out with the Computerized Neurocognitive Function Test (CNT). During the cognitive function test, electroencephalography was also carried out at the same time to examine the changes in waveform and active parts of brain (Figure 3).

Statistical Analysis

With independent variables of the demented group, the non-demented with mild cognitive impairment group, and the normal group, One-Way ANOVA was carried out to examine general characteristics of the subjects and the difference in waveform during cognitive function and resting state. Additionally, to examine waveform difference in each group during the working cognition task, a paired t-test was carried out. Windows SPSS version 14.0 was used as the analysis program during the study, and the significance level was α=.05.

Results

Cognitive Function of Study Subjects

The number of correct answers on the cognitive function test was different among the subject groups, as the average number of correct answers in the demented group was 6.58, the non-demented with mild cognitive impairment group was 7.30, and the normal group was 11.82. The number of correct answers in the normal group was larger than that of the demented group and non-demented with mild cognitive impairment group ($p<.05$) (Table 1).

The Effect of Working Cognition Task on Θ Wave of Frontal Lobe

When the effect of the working cognition task on Θ wave of the frontal lobe was examined, Θ wave at Fp1, Fp2 increased during the working cognition task in the demented group ($p<.05$), non-demented group with mild cognitive impairment group ($p<.05$), and normal group ($p<.05$). Θ wave at Fz, F3, F4 increased in the demented group, non-demented with mild cognitive impairment group, and normal group ($p<.05$), but statistical difference was shown only in the normal group. In the case of at F7, F8, the numbers in all three groups increased, but significant increase was shown in the non-demented group with mild cognitive impairment group ($p<.05$), the normal group ($p<.05$) at F7 and in the demented group ($p<.05$) and normal group ($p<.05$) at F8 (Table 2).

Effect of Working Cognition Task on α Wave of Frontal Lobe

When the effect of the working cognition task on a wave of frontal lobe was examined, α wave at Fp1 increased in demented group and non-demented with mild cognitive impairment group but decreased in the normal group. However, there were no statistical differences among the results. In the case of α wave at Fp2, the demented group and non-demented with mild cognitive impairment group showed increase ($p<.05$), but the normal group showed decrease even though there was no statistical significance. At Fz, the demented group ($p<.05$) and non-demented with mild cognitive impairment group ($p<.05$) showed decrease, and the normal group also showed decrease without statistical difference. At F3, all three groups showed decrease without statistical difference. At F4, the demented group showed decrease ($p<.05$), the non-demented with mild cognitive impairment group showed increase though there was no statistical difference, and the normal group showed decrease. At F7, α wave decreased in all three groups, but there was no statistical difference. In the case of F8, the demented group and normal group showed decrease, but the non-demented with mild cognitive impairment group showed increase without statistical difference (Table 3).

Effect of Working Cognition Task on ß Wave of Frontal Lobe

When the effect of the working cognition task on ß wave of frontal lobe was examined, ß wave at Fp1,

Table 1. Cognitive function of study subjects (Unit: number)

Cognitive function test	Dementia	MCI[b]	Normal	F	p
CPM[c]	6.58±3.46[a]	7.30±3.65	11.82±6.51	4.92	.013

[a]Mean±SD.
[b]MCI: Mild cognitive impairment.
[c]CPM: Colored progressive matrices.

Table 2. Effect of working cognition task on Θ wave of frontal lobe (unit: ㎶)

		At rest	During working cognition task	t	p
Fp1	Dementia	2.54±1.78[a]	8.32±10.59	−2.526	.021
	MCI[b]	2.37±1.96	11.63±8.43	−3.585	.006
	Normal	.85±.43	10.03±6.49	−4.804	.001
Fp2	Dementia	2.72±1.95	10.05±13.04	−2.560	.020
	MCI	2.19±2.05	10.75±7.47	−3.668	.005
	Normal	.88±.48	11.27±7.93	−4.463	.001
Fz	Dementia	3.02±2.42	3.06±2.82	−.101	.920
	MCI	2.55±4.95	3.04±2.84	−.529	.610
	Normal	.97±.65	1.96±1.05	−3.080	.012
F3	Dementia	2.60±2.10	3.00±2.61	−.909	.375
	MCI	1.88±3.23	2.96±2.37	−1.105	.298
	Normal	.81±.58	1.85±.91	−3.581	.005
F4	Dementia	2.62±1.99	3.05±2.61	−.993	.334
	MCI	1.88±3.11	3.69±4.51	−1.174	.270
	Normal	.85±.57	2.29±1.43	−3.172	.010
F7	Dementia	1.56±1.22	2.06±1.21	−2.052	.055
	MCI	.92±1.12	1.83±1.15	−2.292	.048
	Normal	.43±.22	1.20±.41	−5.218	.000
F8	Dementia	1.66±1.30	2.30±1.41	−2.344	.031
	MCI	1.00±1.19	2.52±2.39	−1.930	.086
	Normal	.49±.25	1.52±.56	−5.314	.000

[a]Mean±SD.
[b]MCI: Mild cognitive impairment.

Fp2, Fz, F3, F4, F7, F8, Pz, P3, P4 increased in all three groups during the working cognition task. Demented, non-demented with mild cognitive impairment, and normal groups showed statistical significance at Fp1 and Fp2 ($p<.05$). The normal group showed statistical difference at Fz, and the non-demented with mild cognitive impairment group showed statistical difference at F3 ($p<.05$). Statistical difference was shown at F4 of the demented and normal groups, at F7 of the non-demented with mild cognitive impairment and normal groups ($p<.05$), and at F8 of the demented and normal groups ($p<.05$) (Table 4).

Discussion

According to synergetic interpretation of brain function, it is interpreted that the brain functions through autonomic synergy of entire neurons (Haken, 1996). It is known that the prefrontal lobe of the

Table 3. Effect of working cognition task on α wave of frontal lobe (unit: μV)

		At rest	During working cognition task	t	p
Fp1	Dementia	1.57±.98[a]	1.98±1.22	−1.382	.184
	MCI[b]	1.48±.94	2.12±.90	−1.769	.111
	Normal	2.31±2.74	2.17±1.05	.145	.888
Fp2	Dementia	1.64±1.00	2.32±1.41	−2.217	.040
	MCI	1.41±.82	1.84±.73	−1.336	.214
	Normal	2.32±2.79	2.26±.96	.071	.945
Fpz	Dementia	2.19±1.46	1.27±.80	3.206	.005
	MCI	1.80±1.04	1.02±.75	2.347	.044
	Normal	3.18±3.98	.71±.26	2.021	.071
F3	Dementia	1.96±1.24	1.44±.89	1.862	.079
	MCI	1.59±.89	1.32±.94	.908	.388
	Normal	2.64±3.12	.97±.58	1.686	.123
F4	Dementia	2.12±1.38	1.42±.82	2.688	.015
	MCI	1.58±.85	1.64±2.20	−.087	.933
	Normal	2.69±3.20	1.00±.44	1.672	.125
F7	Dementia	1.10±.68	.99±.55	.700	.493
	MCI	1.06±.57	1.04±.74	.102	.921
	Normal	1.66±2.00	.60±.14	1.699	.120
F8	Dementia	1.27±.78	1.02±.52	1.585	.130
	MCI	1.09±.55	1.37±1.88	−.475	.646
	Normal	1.70±2.07	.62±.16	1.686	.123

[a]Mean±SD.
[b]MCI: Mild cognitive impairment.

cerebrum controls the arousal state of the cerebral cortex and the process of mental operation, contributing to cognition, thinking process and creativity (Frith and Dolan, 1996; Koechlin et al, 1999). When one does a learning activity that requires complicated brain function, it is reported that the prefrontal lobe is highly activated among the parts of the brain which function together to perform learning, storing, and restoring processes (Daffner et al, 2000; Kim et al, 2000). Park et al (2002) reported that it is possible to analyze the activation state of the brain through electroencephalogram measurement at the frontal part of the brain which includes the prefrontal lobe since thinking process is performed through the synergy effect of entire neurons, especially the ones at the frontal lobe. Therefore, an electroencephalogram of the frontal lobe was used for analysis for this study.

Brain development and mental development in humans progresses in a way that is discontinuous and dynamic, which means that fast growing and stagnancy are repeated. Therefore, from the biological viewpoint, mental ability in accordance with brain development is hard to measure through a simple paper examination or observation of changes in behavior. Since an electroencephalogram shows action potential of numerous neurons in the cerebral cortex in a clear and objective way, it is recognized as the most objective method to interpret brain function, which is free from social and cultural effects (Lee et al, 1997). Therefore, this study used electroencephalography to interpret cognitive function of brain.

Electroencephalogram generally shows that a wave

Table 4. Effect of working cognition task on β wave of frontal lobe (unit: μV)

		At rest	During working cognition task	t	p
Fp1	Dementia	.42±.44[a]	1.52±1.83	−2.714	.014
	MCI[b]	.29±.29	1.62±2.02	−2.368	.042
	Normal	.25±.16	2.05±2.44	−2.482	.032
Fp2	Dementia	.43±.50	1.69±1.95	−2.981	.008
	MCI	.21±.08	.89±.53	−3.929	.003
	Normal	.25±.23	1.82±1.75	−3.073	.012
Fz	Dementia	.27±.14	.44±.45	−1.988	.062
	MCI	.22±.09	.49±.45	−1.890	.091
	Normal	.17±.06	.31±.19	−2.953	.014
F3	Dementia	.37±.25	1.06±1.59	−1.961	.066
	MCI	.27±.12	1.70±2.04	−2.321	.045
	Normal	.22±.12	1.28±1.68	−2.080	.064
F4	Dementia	.36±.25	.92±1.06	−2.480	.023
	MCI	.24±.11	1.27±1.47	−2.190	.056
	Normal	.21±.10	1.20±.97	−3.467	.006
F7	Dementia	.35±.29	1.12±2.34	−1.458	.162
	MCI	.22±.12	1.73±2.08	−2.351	.043
	Normal	.14±.07	.51±.34	−3.967	.001
F8	Dementia	.38±.35	.91±1.18	−2.118	.048
	MCI	.28±.27	1.58±2.65	−1.539	.158
	Normal	.17±.14	.61±.40	−4.394	.001

[a]Mean±SD.
[b]MCI: Mild cognitive impairment.

is dominant under normal conditions whereas ß wave becomes dominant under excited conditions. When rest or relaxation continues, a slow wave, such as Θ wave or δ wave, which is slower than a wave, is generated (Kim and Chang, 2001).

Θ wave is related to physical, emotional, and mental activities under internalized and quiet conditions or at a sleepy state, and δ wave appears dominantly while sleeping when the brain is completely relaxed (Kim and Choi, 2001). When one becomes excited or concentrates on a certain subject, ß wave drastically appears dominant. ß wave is a fast wave with low amplitude and high frequency, and it is related to mental activities. When a normal person is asked to perform an assignment which needs attention, ß wave appears with large amplitude (Kim and Chang, 2001). The study conducted by Fernández et al (1995) also suggested the same result that when α wave blocking occurs in the electroencephalogram, ß wave appears with large amplitude. Andreassi (1989) also reported that ß wave is related to cortex awakening and that when a person performs mental activity, ß wave is activated.

Park et al (2002) conducted research on the relationship between thinking activity and the prefrontal lobe activation of high school students, and reported that the activation of Θ wave increases the most during thinking activity, followed by ß1 and ß2 wave. Kim (2003) found Θ wave dominancy during thinking activities, which include creative pattern problems or mental arithmetic, and he argued that learning activity, which is related to solving problems with information stored in brain, is performed through high activation of Θ wave, which is a slow wave. Han and Saito (1992) also reported when a person is involved in adding numbers or in a mental test which requires attention, Θ wave increases about 6~7 ㎐ in electroencephalography. Accordingly, when a normal person is assigned to activities which require concentration and attention, Θ wave is related to effective and active problem solving processes, contributing to stabilization of brain and creativity (Hutchison, 1991).

Steriade et al (1985) proved that resting potential at thalamus is related to the rhythm of α wave and that it is inversely related to mental activity, which is activation of neurons. With the same ground, Roberts and Kraft (1989) interpreted that when α wave is blocked at one cerebral hemisphere, the hemisphere shows more activation. Therefore, it can be concluded that α wave becomes less activated during a problem-solving process.

The result of this study showed that Θ wave and ß wave increased and α wave decreased at the frontal lobe when the normal group performed the working cognition task. The demented group showed that Θ wave and ß wave increased at the prefrontal lobe and right cerebral hemisphere, and α wave increased at the right cerebral hemisphere and prefrontal lobe, which was different from the results of the normal group. The group of non-demented with mild cognitive impairment showed that Θ wave and ß wave increased at the prefrontal lobe and left cerebral hemisphere. These results are identical to the results of other researchers' studies, suggesting that Θ wave and ß wave increase in all groups during working cognition tasks. It was confirmed that the normal group showed increased activation at the frontal lobe, that the demented group showed increased activation at the prefrontal lobe and right cerebral hemisphere, and that the non-demented with mild cognitive impairment group showed increased activation at the prefrontal lobe and left cerebral hemisphere. Therefore, it is thought to be possible that dementia and mild cognitive impairment is detected before the symptoms progress.

However, the subjects of this study were elderly females over 65 years old, which means there was no gender verification. Since the number of normal elderly and non-demented elderly with mild cognitive impairment was relatively lower than that of demented elderly, and the subjects were restricted to ones who were living in geriatric institutions, it is hard for the results of the study to be generally interpreted. With the lack of analysis data from electroencephalograms of normal elderly, demented elderly, and non-demented elderly with mild cognitive impairment, the study could not provide a full comparison. Therefore, more research on the cognitive function test and the electroencephalography of the three groups is required. On the basis of the results of the study, various cognition programs for activating the prefrontal lobe can be developed, and it will be necessary to verify the effect of those programs.

Conclusion

Researchers randomly selected three geriatric institutions in the Busan area. Subjects were selected among the female elderly in those institutions who voluntarily agreed to participate in the study after having listened to purpose of the study. Forty elderly females were selected (19 for the demented group, 10 for the non-demented with mild cognitive impairment group, and 11 for the normal group). We found that there were more correct answers among normal elderly women than in other groups. The number of correct answers on CPM is 6.58 for the demented group, 7.30 for the non-demented with mild cognitive impairment group, and 11.82 for the normal group. The normal group showed a higher number than the demented group and non-demented with mild cognitive impairment group. And we found that the demented group depends upon the prefrontal lobe and frontal lobe of the right cerebral hemisphere during working cognition tasks and the group of non-demented with mild cognitive impairment depends upon the prefrontal lobe and left cerebral hemisphere for solving problems, whereas the normal group uses the entire frontal lobe for solving problems. Therefore, it can be concluded that when cognition rehabilitation is required for demented and non-demented with mild cognitive impairment, programs which draw reaction from the entire frontal lobe should be developed and applied.

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