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Ishikawa, Kenji

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Relationship between Hand Deftness and Cognitive Function

– Utility of event-related potential upon MCI detection and relationship between visual memory and upper-extremity movement capability –

Kenji Ishikawa[1], Michio Yamaguchi[2], Yasuo Naito[3], Hiroshi Ando[4]

Abstract

Objective: The purpose of the present study was to clarify the relation between hand deftness and cognitive function.

Methods: Subjects were 35 Mild Cognitive Impairment (MCI) patients, 6 Alzheimer's Disease (AD) patients and normal control group consisting of 20 people. Four neuropsychological assessments, Mini-mental state examination, Trail Making Test, Digit Cancellation Test, Wechsler Memory Scale-Revised (WMS-R), Event-Related Potentials (P300) and Simple Test for Evaluating Hand Function (STEF), were performed.

Results: Visual memory index in WMS-R and total time at STEF showed significant inverse correlation. Compared to healthy controls, MCI group exhibited longer latency in P300 components. Additionally, with regards to P300 latency and reaction time, calculated Pearson correlation coefficient indicated significant correlation.

Conclusion: It was suggested that the deftness of the hand is a skill obtained through attention and visual memory. Elderly people who can generally perform activities of daily living independently need to be screened for MCI criteria, information processing speed delay, and visual memory decline. Possibility of preventing cognitive decline through repetition of simple upper-extremity movement patterns should be explored.

Keywords:

Mild cognitive impairment (MCI), Upper-extremity movement, Event-related potentials (P300), Temporary visual memory

Introduction

Previous studies report the relation between hand deftness and cognitive function. In Alzheimer's disease (hereafter referred to as AD) patients, bilateral upper-extremity movements become slower and with the advancement of cognition deficiency, the velocity of fine movement rather than that of gross movement is reduced.1. Also, slower bilateral upper-extremity movements and reduced superiority of the dominant hand for advanced dementia patients have been reported.2. These studies suggest that occupational therapy, which excels at hand function training, may be an effective therapeutic treatment procedure for severe dementia patients. Yet, we can say that

[1] Department of Rehabilitation science, Kobe University Graduate School of Health Sciences, Kobe, Hyogo, Japan
[2] Yamaguchi Clinic, Nishinomiya, Hyogo, Japan
[3] Osaka Prefecture University Graduate School of Comprehensive Rehabilitation, Habikino, Osaka, Japan
[4] Department of Rehabilitation science, Kobe University Graduate School of Health Sciences, Kobe, Hyogo, Japan

early stage intervention for the elderly with possible mild dementia is insufficient under the current occupational therapy scene. This is because very few studies have been found that discusses the relationship between hand functionality and cognitive level of mild dementia patients whose memory loss tendency is progressing while activities of daily living (hereafter referred to as ADL) is still maintained. Indeed, there seems to be a lot of people, such as those that perform manual tasks as a hobby and a job, whose upper- as well as lower-extremity movements are maintained even while memory loss progresses. That leads to the question, with how much upper-extremity movement deterioration we suspect dementia.

Upon conducting this research, attention was brought to mild cognitive impairment (hereafter referred to as MCI) evaluated by the diagnostic standard established by an American group including Petersen, namely the Alzheimer's Disease Neuroimaging Initiative (hereafter referred to as ADNI).3. According to this concept MCI proposed by Petersen's group, cognitive function impairment is an entity based on a pathological condition.4. He also says that an effective solution to dementia is to detect patients at an early stage when the patient is suffering from MCI along with memory loss and to treat the patient to prevent further development into AD. Consequently, we decided that subjects most suitable for this study are patients who have not yet been diagnosed with dementia but has a mild cognitive dysfunction and is in the gray zone where cognitive function cannot be considered normal, or in other words, patients diagnosed with MCI.

In order to verify the relationship between hand deftness and mild cognitive dysfunction in MCI patients, we examined outpatients with memory loss tendency at a clinic and as the control group enrollees at "Silver Human Resources Center," which is a public job placement agency for the elderly.

Methods

Subjects

Thirty-five MCI patients (16 male and 19 female, mean age 74.5±6.8, years of education 11.4±2.7) and 6 AD patients (1 male and 5 female, mean age 75.8±2.1, years of education 11±1.7) were outpatients at a neurosurgery clinic in Nishinomiya city between December 2010 and March 2011. Normal control group consisted of 20 people (8 male and 12 female, mean age 72.3±6.1, years of education 12.6±2.3), who were randomly selected from "Silver Human Resources Center" enrollees. Prior to the research, all subjects received both oral and written statements explaining the assessment tests as well as personal information protection, and their written consents have been obtained. Ethics committee of Kobe University Graduate School of Health Sciences approved the ethical standard on November 24th, 2010.

MCI diagnosis was conducted according to the following diagnosis criteria established by Petersen's group in United States of America.5. 1) Complaint of memory loss by either the patient or a family member. 2) Essentially preserved general cognition. 3) Intact ADL. 4) 0.5 on Clinical Dementia Rating Scale, which is an indication of dementia severity.6. 5) Dementia or AD diagnosis criteria are not fulfilled even though memory loss can be objectively assessed. In this study, those who scored at least 23 points on Mini-mental state examination (hereafter referred to as MMSE) and showed obvious abnormality on Wechsler Memory Scale-Revised (hereafter referred to as WMS-R) were classified as MCI.7.8.

Procedure

Evaluation and monitoring

A neurosurgeon interviewed elderly patients 65 or older with possible dementia and had confirmed from the patient or a family member that cognitive function levels are deteriorating or that the ability of ADL is gradually decreasing. AD and MCI were identified based on evaluations including image diagnosis to patients at neurosurgery clinic. 9.

Neuropsychological assessments

The neuropsychological assessments were conducted in order to evaluate attention that was thought to be the basis of cognitive functions, Trail Making Test (hereafter referred to as TMT-A and B) and Digit Cancellation Test (hereafter referred to as D-CAT).10. Methods for evaluating memory capabilities were MMSE and WMS-R. These examinations were administered in a quiet room to assess of current memory abilities. In addition, all subtest values were collected and analyzed.

Event-related potentials

Electroencephalogram (hereafter referred to as EEG) were recorded using silver electrodes referenced to linked ears from Fz, Cz, and Pz, according to the international 10-20 system of electrode placement. EEG were amplified and digitized at a sampling frequency of 250 Hz. An auditory oddball paradigm was used to elicit the P300 component of Event-related potential (hereafter referred to as ERP). ERP is electric activities originating from cerebral cortex.11. Each subject was presented with a pseudo-random sequence of two distinguishable stimuli; 1000Hz tone bursts (frequent tone: 80%) and a 2000Hz tone (target tone: 20%). Stimuli were delivered binaurally through earphones at random intervals ranging from 1300 to 1700ms. When the target tone was given subjects were instructed to press a button with both thumbs. Target stimuli were presented 50 times. Before beginning the ERP recordings, several trial stimuli were presented to subjects in order to confirm their understanding of the instructions. Evoked potentials were averaged using a personal computer (SONY, Japan). The peak of the P300 component was identified as the maximum positive deflection in the time window between 280 and 550ms. Reaction time to the target of 2000Hz tone was also recorded.12.

Evaluation of hand deftness

We used Simple Test for Evaluating Hand Function (hereafter referred to as STEF) that can quickly measure the velocity of gross movement subtests (No.1〜5) as well as fine movement subtests (No.6〜10) by upper-extremity including fingers13.. The manipulation used in this test required subjects to catch or pinch the objects and carry them to the arranged area or pins to set them into holes or to turn thin clothes over. Reliability of STEF was confirmed by Yamanaka and Kawahira. The objects consisted of 10 different shapes and sizes, spheres; 70mm (five pieces), 40mm (six pieces) and 5mm (six pieces) in diameter, disks; 20mm in diameter and 10mm high (six pieces) and 20mm in diameter and 2mm high (six pieces), rectangular boxes; 100×100×47mm (five pieces), 35×35×35mm (six pieces) and 14×14×14mm (six pieces), thin pieces of cloth; 90×80mm (six pieces) and pins; 3mm in diameter and 42mm in length (six pieces).14. We recorded the both hands of each subject.

Data analysis

Statistical data was processed by SPSS II for Windows,Standard versions 2001. Groups were compared using analysis of variance (ANOVA) and post hoc analysis was executed by Tukey-HSD. Pearson's correlation coefficient was calculated to analyze correlations of two groups. Statistical significance was recognized at $p<0.05$ and $p<0.01$ respectively.

Results

Results of neuropsychological evaluations among MCI patients, AD patients and healthy controls are shown in Table 1. Performance and efficiency for TMTA and B and D-cat placed MCI patients between AD patients and healthy controls, and the values were lower than those of healthy controls. As for WMS-R, Verbal, Visual and General Indices were obtained from subjects. Compared with MCI patients, control group indicated significant difference on all WMS-R subtests. Results of upper extremity movements test by STEF are shown in Table 2. As a result, there were significant differences between MCI and healthy controls on most fine movement subtests. Pearson correlation coefficient between Visual memory Index in WMS-R and total time of STEF showed signifi-

Table 1: Demographic and psychological characteristics of subject groups

		Control	MCI	AD
Number of subjects		20	35	6
Male		8	16	1
Female		12	19	5
Age		72.3±6.1	74.5±6.8	75.8±2.1
Education		12.6±2.3	11.4±2.7	11.0±1.7
Dominant hand: Rt //Lt		20 // 0	32 // 3	5 // 1
MMSE		29.0±1.3	27.2±2.8	18.3±5.8*
TMT	: A	40.9±18.4*	63.3±28.7	70.1±41.4
	: B	118.0±63.4*	206.0±96.7	226.0±81.7
D-CAT				
	Total performance	289.4±71.1*	230.8±70.5	259.7±89.4
Index	Task: A	56.2±4.4*	50.8±8.6	41.0±10.6
	Task: B	53.2±5.0	47.4±10.7	39.0±2.8
	Task: C	55.0±5.1	49.7±9.1	39.5±2.1
WMS-R				
Index	Verbal memory	101.5±13.2*	74.5±9.9	58.7±3.5
	Visual memory	110.9±12.2*	75.9±20.8	54.3±7.5
	General memory	105.4±12.1*	72.2±14.1	65.0±16.6
	Con /Attention	104.8±15.3*	95.2±12.6	87.3±4.2
	Delayed recall	99.7±30.2*	68.6±16.1	51.1±1.7

Data are means ± standard deviations. Significant differences between MCI and AD or MCI and control group by ANOVA (Tukey-HSD) respectively. *$p < 0.05$
MMSE: Mini-mental state examination, TMT: Trail making test, D-CAT: Digit cancellation test, WMS-R: Wechsler Memory Scale-Revised, Con: concentration.

Table 2: Mean values of Simple Test for Evaluating Hand Function (STEF)

	Group	Score	Gross movement (s)					Fine movement (s)					total time
			Sphere large	Sphere medium	Rectangular box big	Rectangular box medium	Disk medium	Rectangular box small	Thin cloth	Disk small	Sphere small	Pin	
Rt. hand	Control	93.3*	6.7*	6.2	9.1*	8.7	6.6	8.4*	6.5*	11.7*	11.1	12.8*	87.5*
	MCI	86.8	7.8	6.9	10.5	9.8	7.5	9.7	8.1	14.1	12.2	20.7	106.6
	AD	81.4	9.3	8.5	12.8	13.4*	9.1	11.0	9.2*	13.1	14.1	19.8	120.0*
Lt. hand	Control	95.1*	6.6*	6.1	9.1*	8.8	6.9	8.9*	6.5*	11.3*	11.2	13.8*	89.1*
	MCI	89.6	7.9	6.9	11.1	10.2	8.1	10.4	8.4	13.9	12.9	21.2	110.8
	AD	84.0*	7.9	8.4	12.8	13.2*	9.1	12.1	7.8*	16.2	15.4	25.7	128.6*

Data are means. Significant differences between MCI and AD or control group by ANOVA (Tukey-HSD) respectively. *$p < 0.05$

Table 3: Latency of P300 component and reaction time (ms)

	Pz	Cz	Fz	RT
Control	352.3±43.2*	355.6±56.8	338.8±47.6*	329.7±47.8*
MCI	380.6±48.1	383.2±51.6	387.0±44.6	372.4±72.9
AD	437.3±119.2	432.6±121.4	423.3±127.6	353.3±106.6

Data are means ± standard deviations. Significant differences between MCI and AD or control group by ANOVA (Tukey-HSD) respectively. *$p < 0.05$

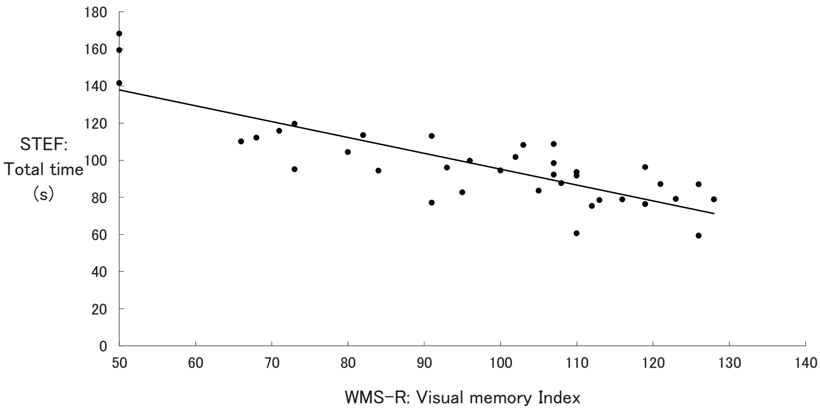

Figure 1: STEF total time and WMS-R visual memory index (n = 35: MCI)
Relation between STEF total time and WMS-R visual memory index showed significant inverse correlation. Pearson correlation coefficient: $r = -0.67$ ($p < 0.01$).

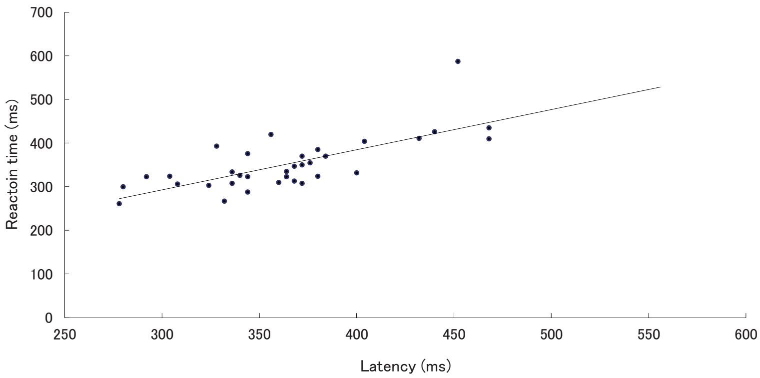

Figure 2: P300 latency and reaction time (n = 35: MCI)
Relation between P300 latency and reaction time indicated significant correlation. Pearson correlation coefficient: $r = 0.56$ ($p < 0.01$).

cant inverse correlation ($r = -0.67$, $p < 0.01$, as shown in Figure 1). This suggests that there is a close relation between upper-extremity movement efficiency and Visual memory Index. MCI group exhibited longer P300 latency in event-related potential components compared to healthy controls, and significant difference was observed as shown Table 3. Additionally, with regards to P300 latency and reaction time, Pearson correlation coefficient indicated the presence of significant correlation between them ($r = 0.56$, $p < 0.01$, as shown in Figure 2).

Discussion

The concept of MCI has been introduced to describe older individuals who are cognitively positioned between normal ageing and dementia. Nowadays, there is a particular interest in MCI because some of the patients with this syndrome are thought to be a convert to AD. Before conversion to AD, effective therapeutic interventions should be given. Before MCI was commonly discussed, Crook T et al., a work group from the National Institute of Mental Health, set forth criteria for the concept of age-associated memory impairment (AAMI) in the mid-1980s.15. These criteria served a useful purpose at establishing guidelines for studying a cohort of individuals with some degree of memory decline. Although useful, this construct could be over-inclusive when applied to many older populations. Meanwhile, in the mid-1990s, Levy R. et al. at the International Psychogeriatric Association coined the term, ageing-associated cognitive decline (AACD), which referred to individuals with cognitive impairments in multiple domains with or without a memory deficit.16. Consequently, the concept was designed to characterize the extremes of normal aging. Then, Petersen et al. advocated the concept of MCI and showed above-mentioned diagnostic criteria. The construct of MCI refers to an abnormal substrate of performance and presumably an underlying pathophysiologic state. Though MCI may seem mild, they saw it as a progressing disease with possibility of developing into a serious illness in the future. ADNI that started in 2004 is a consortium of universities and medical centers in the United States and Canada established to develop standardized imaging techniques and biomarker procedures in normal subjects, subjects with MCI, and subjects with mild AD. We are convinced that this study demonstrates validity corresponding to the idea of early detection and intervention of dementia. This is because, while this study is still under progress, it was meaningful that the objects were selected based on MCI diagnostic criteria that follow ADNI. We have conducted our experiments regarding the relationship between memory loss and hand deftness. As a result, it became clear that deficit in elaborate manual operations compared to healthy controls was apparent not only in AD patients but also in MCI patients. MCI patients showed deficit in not only verbal memory of WMS-R but also in visual memory, which makes it clear that memory loss and hand dexterity are related. In other words, maintaining manual function may be connected with maintaining visual memory and possibly with prevention of progress into severe dementia.

Memory loss tendency, which is an initial symptom of dementia, presents various symptoms that come from the attention dysfunction that cognitive function is based on. For a particular cognitive function to work appropriately, appropriate and efficient functioning of attention is necessary.17. Attention is classified into the following categories: focused attention, sustained attention, selective attention, alternating attention, divided attention.18. Among these, selective attention is related to latency, which is assumed to be an important factor for the time course information processing.19. Therefore, we decided to use an instrument that can measure P300 latency to catch symptoms. The P300 oddball tasks were chosen for measurement. We believed the examination might show the relation between attention and cognitive function. As a result, MCI patients showed significant difference against the healthy controls. We could guess that MCI patients were experiencing decrease in information processing speed. P300 was first recorded by Sutton. Target stimulus was presented following a warning stimulus and ERP was recorded. A large positive potential was elicited after about 300ms. Here, they proposed that P300 appears in relation to uncertainty from stimulus presentation and is an endogenous potential that changes with stimulus.20. Meanwhile, according to Donchin, P300 appears when subject concentrates on target stimuli, but disappears when focus is lost. P300 especially is an index of stimuli evaluation time, and information processing such as context updating is included in stimuli evaluation time. Donchin also said P300 should specify the role played by the orienting reflex in information processing. In this regard, it is probably more fruitful to divide information processing into a number of more discrete elements, such as attention, learning, and memory. 21. Therefore, it is assumed that it is necessary to investigate both P300 and the automatic orienting reflex in association with the cognitive activity. In this study, there was sufficient correlation between P300 latency and reaction time. This may be because button manipulation alertness is related to endogenous potential. ERP may be related to hand deftness. Information processing speed might have influenced hand deftness.

Close relation between upper-extremity movement efficiency and visual memory was suggested by our results. There have been some reports of this sort. Temporary visual memory in spatial discrimination task is influenced by damage to the hippocampus.22. Temporary visual spatial memory is influenced by saccade eye movement. It is based on supervisory attentive system (SAS), which is related to both sustained and divided attention.23. Stermberg calls information obtained by directing the line of sight as 'temporal activity memory', and there is a limit to the volume of information that is stored in the temporal activity memory. In order to retain this as secondary memory, repeated storage activation is necessary.24.

As have been apparent, conceptual distinction with psychological and neurobiological validity exists among

explicit (or declarative) memory, which involves the conscious recollection and recall of episodes and factual information, and implicit (or procedural) memory, which pertains to unconscious remembering expressed only through performing the specific operations comprising a particular task.25. Implicit memory is a sensory, motor, and cognitive memory used when an operational procedure is automatically reproduced. It is also called a procedural memory acquired by repeating.26. Salmon DP have reported that implicit memory used for habitual learning ability is maintained even in early AD patients and that it is possible to acquire procedural memory for fine movements. However, in this study there were significant differences between groups of MCI patients, which supposedly include early AD patients, and healthy controls. Perhaps, the above-mentioned focused attention, sustained attention, divided attention and the volume of information for temporary visual memory storage, which are required for temporary visual spatial memory, were not functioning sufficiently in MCI patients. STEF is a performance test that requires immediate execution of formalized non-habitual activity. It is possible that MCI patients could not fully take advantage of the skill abilities cultivated through individual experiences. Thus, it was suggested that the deftness of the hand is a skill obtained through attention and visual memory. The upper-extremity movement of an MCI patient may be close to normal if attention and visual memory are maintained.
Recently, the approach to patients with dementia is actively discussed. According to Yamadori, it is characterized by "acquisition of movement pattern proficiency by repeating execution until target speed is achieved."27. As a skill learning method, one report says that repetition of a simple movement pattern was effective.28. It is said that stimulation of procedural memory system affects attention and declarative memory.

This study suggests that elderly people who can generally perform ADL independently need to be screened for MCI criteria, information processing speed delay, and visual memory decline. Furthermore, since there is a possibility that cognitive decline can be prevented through repetition of simple upper-extremity movement sequence, we have established a hypothesis for the future intervention study based on this research: maintaining manual function may prevent the progress into severe dementia. Further longitudinal study of occupational therapy intervention in MCI patients is necessary.

Conclusion

MCI existed as a clinical entity based on pathophysiologic state. Patient can execute habitual activities and skills but generally shows memory deficit. For the patient, not only verbal memory but also visual memory was found to be impaired. We discovered that there is a close relation between upper-extremity movement by immediate non-habitual activity and visual memory. Generation of P300 is thought to be related to the orienting reflex during information processing procedure, which can be divided into a number of more discrete elements, such as attention, learning, and memory. According to event-related potential tests, because P300 latency was longer compared to healthy controls, MCI patients were suspected of slower information processing speed. P300 latency correlated to button operation reaction time. It suggests relationship of hand deftness and information processing. It is necessary to improve MCI's detection sensitivity to execute a more appropriate approach in the occupational therapy scene. Strategists would have to progress study on evaluation and effective longitudinal intervention.

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