

Toward Personalized Cognitive Training for Elderly with Mild Cognitive Impairment Using Cerebral Blood Flow Activation

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This paper presents a block-designed cognitive training task for elderly with mild cognitive impairment. As designed with conscious of daily conversation, the task is done by oral answering some questionnaire. An elderly firstly talks about the topics of favorite season, travel, gourmet, and daily life, and then he/she does three cognitive tasks of reminiscence task, category recall, and working memory task. With the use of the functional near-infrared spectroscopy (fNIRS), which can measure cerebral blood flow activation non-invasively, we had collected 42 CHs fNIRS signals on frontal and right and left temporal areas from 22 elderly participants (7 males and 15 females between ages of 64 to 89) during cognitive tests in a specialized medical institute. All participants are classified into three clinical groups: elderly individuals with normal cognitive abilities (NC), patients with mild cognitive impairment (MCI), and Alzheimer's disease (AD). Toward personalized cognitive training, we report a task effect measurement by the statistical tests of fNIRS signals.

1. Introduction

It is no doubt about abrupt increase in elderly patients with dementia due to growing super-aging society in developed countries. Japan has a rapidly aging society and in 2005 had 2.05 million elderly patients with dementia. The number of the patients with dementia is expected to increase to more than 3 million over the next 10 years [Awata 09]. Thus, the Ministry of Health, Labour and Welfare (MHLW) has begun projects to improve dementia treatment and quality of life from 2008, and in 2012, MHLW announced five-year measures for dementia care, *Orange Plan*, in which hospitals and geriatric facilities centered dementia care should be shift to home care support and community centered dementia care, for sustaining the elderly's activities of daily life and quality of life. The plan includes provision of various support such as watch over, health care and rehabilitation to community life support service.

On the other hand, it is also important to develop a diagnostic tool which can early detect elderly with dementia. To screen for dementia and cognitive impairment, a questionnaire test such as Mini-Mental State Examination (MMSE) [Folstein 75], Revised Hasegawa's Dementia Scale (HDS-R) [Imai 94], Clinical Dementia Rating (CDR) [Morris 93], and Memory Impairment Screen (MIS) [Buschke 99], is commonly used. In our previous study, we have studied novel approaches for the early detection of cognitive impairment in the elderly, in which we focused on the prosodic features of speech sound during the subject's answers to the ques-

tionnaire; the first was to detect signal and prosodic signs of cognitive impairment [Kato 11], and the second was to take a measurement of cerebral blood flow (CBF) [Kato 12].

In such situation, we propose a block-designed cognitive training task for elderly with mild cognitive impairment. As designed with conscious of daily conversation, the task is done by oral answering some questionnaire. An elderly firstly talks about the topics of favorite season, travel, gourmet, and daily life, and then he/she does three cognitive tasks of reminiscence task, category recall, and working memory task. With the use of the functional near-infrared spectroscopy (fNIRS), which can measure cerebral blood flow activation non-invasively, we had collected 42 CHs fNIRS signals on frontal and right and left temporal areas from 22 elderly participants (7 males and 15 females between ages of 64 to 93) during cognitive tests in a specialized medical institute. Toward personalized cognitive training, we report a task effect measurement by the statistical tests of fNIRS signals.

2. Personalized Cognitive Training

2.1 Participants

Twenty two Japanese subjects (7 males and 15 females between the ages of 64 and 93 years) participated in this study. Table 1 shows the breakdown list of participants. In this study, all participants are classified into three clinical groups: elderly individuals with normal cognitive abilities (NC), patients with mild cognitive impairment (MCI), and Alzheimer's disease (AD). All participants in disease groups are clinically conditioned that the CDR of a participant in MCI group and AD group corresponds to CDR0.5 and CDR1, respectively.

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Table 1: A Breakdown List of Participants (N=22)

Age	64-70	71-75	76-80	81-85	86-90	91-93	Total
Male	0(0,0,0)	2(2,0,0)	1(1,0,0)	1(0,0,1)	2(0,2,0)	1(0,1,0)	7(3, 3,1)
Female	4(1,3,0)	2(1,1,0)	4(1,2,1)	3(1,0,2)	2(0,1,1)	0(0,0,0)	15(4, 7,4)
Subtotal	4(1,3,0)	4(3,1,0)	5(2,2,1)	4(1,0,3)	4(0,3,1)	1(0,1,0)	22(7,10,5)

Value in bracket means the number of subjects in NC, MCI, AD clinical groups.

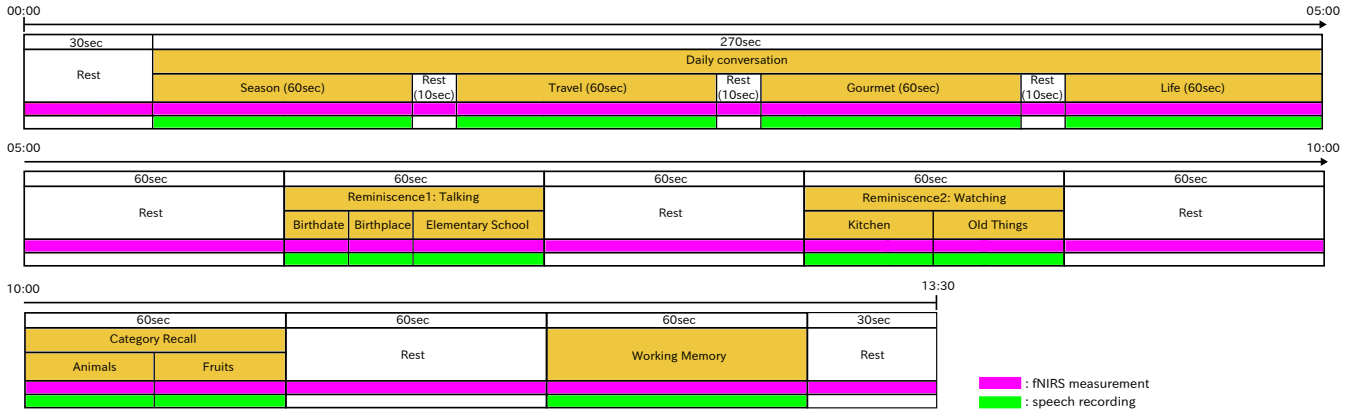


Figure 1: Block Design Task of Cognitive Tests.

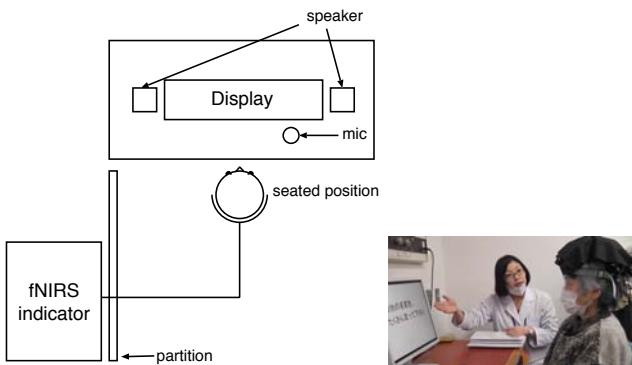


Figure 2: Snapshot of fNIRS measurement of an elderly participant having a cognitive test.

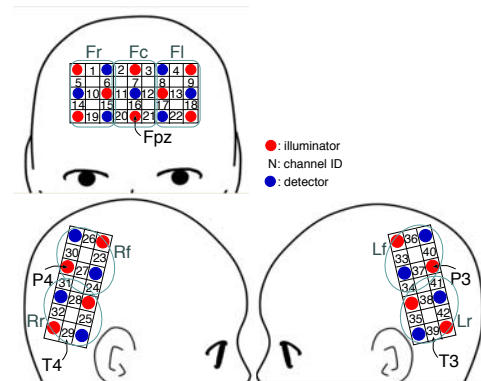


Figure 3: Channel arrangement of fNIRS measurement.

2.2 Cognitive Tasks

To measure brain function of an elderly during various cognitive tests including HDS-R, we have made a block designed task shown in Figure 1, and then conducted simultaneous voice-fNIRS measurement during cognitive tests. Firstly a participant talks about favorite season, travel, gourmet, and daily life. And then, he/she does two reminiscence tasks (1. talking about birthdate and birthplace, 2. watching old-style kitchen and old things), category recall (animals and fruits), and working memory tasks. Under the category recall task, the participant says the name of animals and fruits as many as he/she knows. Under the working memory task, the participant is told three numbers and *hiragana* characters and then replies them with sorted in ascending and dictionary order, respectively. These eight tasks are done for 60 seconds after rest gazing at a single point on the display for 60 seconds interval, and it takes

thirteen minutes in the total.

3. fNIRS Measurement

Functional near-infrared spectroscopy (fNIRS) can measure neural activity of the cerebral cortex using infrared rays that are safe to living organisms [Villringer 97]. fNIRS monitors regional relative changes of oxy/deoxygenated hemoglobin concentration to measure cortical activation utilizing the tight coupling between neural activity and regional cerebral blood flow [Villringer 95]. This measurement method requires only compact experimental systems and can eliminate physical restraint from a subject by non-invasive procedures (Figure 2).

We used the fNIRS topography system FOIRE-3000 Near-Infrared Brain Function Imaging System (Shimadzu, Kyoto, Japan), which uses near-infrared light with wavelengths of 780, 805, and 830 nm. We set 16 illuminators and

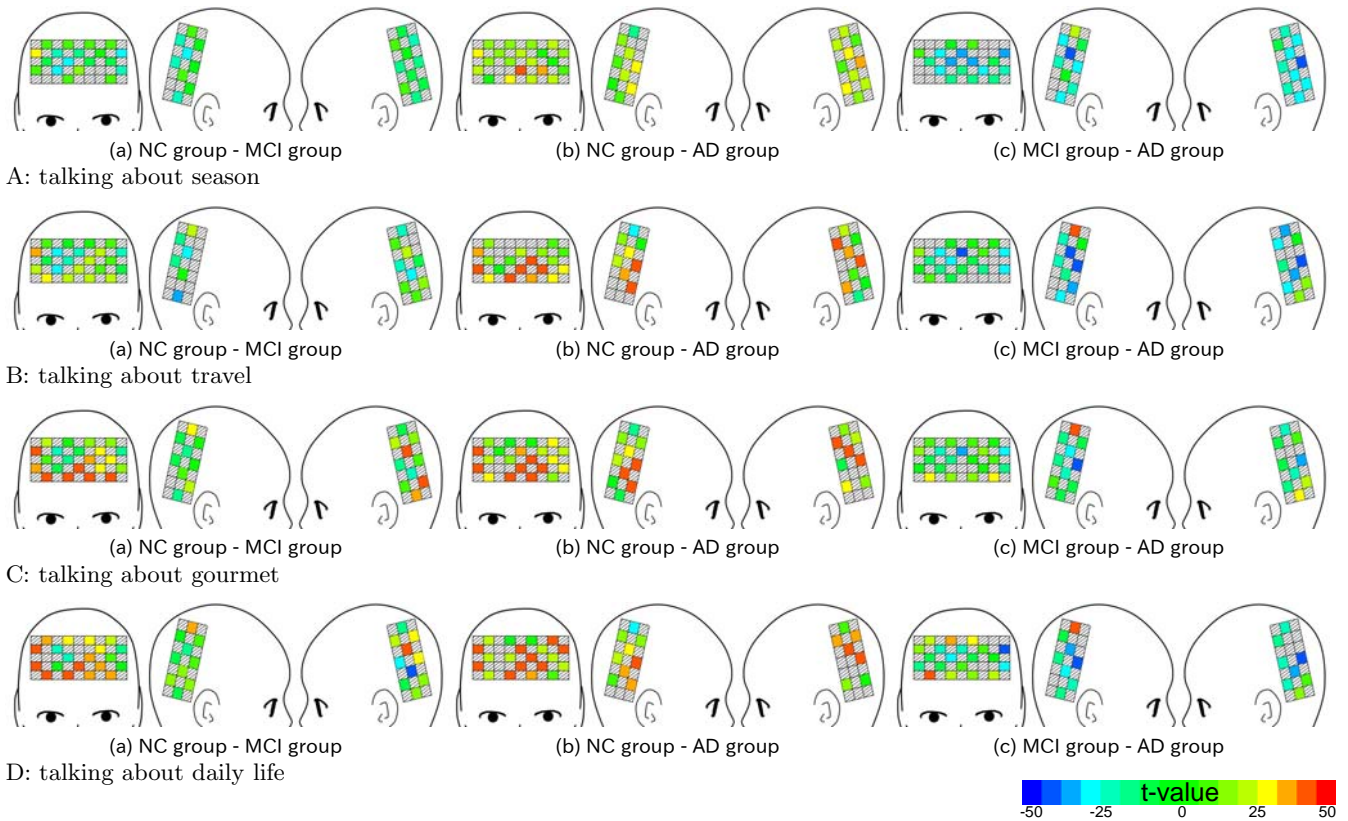


Figure 4: Results of t-test for significant differences in channel-wise fNIRS signals between any single pair from NC, MCI, and AD groups (daily conversation).

15 detectors in lattice pattern to form 42 channels (CHs) (22 CHs on frontal lobe, 10 CHs on right parietal and temporal lobe, 10 CHs on left parietal and temporal lobe) shown in Figure 3.

4. Task Effect Assessment

Toward personalized cognitive training, we assess a task effect. We have conducted statistical tests of between-group significant differences using fNIRS signals of oxy-Hb during cognitive tasks of

- daily conversation: talking about favorite season, travel, gourmet, and daily life;
- reminiscence task 1: talking about birthdate;
- category recall: answering the name of fruits as many as he/she knows;
- working memory tasks.

We used Welch’s t-test [Welch 47] with significance level of ($P < 0.001$) after applying Bonferroni’s adjustment ($1/42$). Figure 4 and 5 show the results of t-test for significant differences in channel-wise fNIRS signals between any single pair from NC, MCI, and AD groups. The CHs that exhibited significant oxy-Hb increase are colored according to the t-values, as shown in the color bar, while those below the threshold are indicated in gray.

4.1 Results

Daily conversation Figure 4 indicates the significant difference of fNIRS signals between normal group and dis-

ease groups for all topics of the conversation. Speech contains nonverbal elements known as paralanguage, including voice quality, rate, pitch, volume, and speaking style, as well as prosodic features such as rhythm, intonation, and stress. Conversation, even if it is just a casual conversation about daily living, requires a lot of interpersonal communication skills of not only linguistic competence but also some nonverbal competencies so as to recognize partner’s paralanguage and to control self paralanguage appropriately. For this reason, the results indicate that elderly people with normal cognitive ability use their brain function more actively than those who are with MCI and AD group. Maybe it is because some participants talked heatedly gradually, the difference becomes larger as a conversation progresses.

Reminiscence talk, category recall, and working memory

Figure 5 indicates the significant but slight difference of fNIRS signals between normal group and disease groups for the later three tasks. With respect to the reminiscence task, for this particular participant, regardless of whether they have cognitive impairment or not, answering his/her birthdate is very easy; it is no need to use their brain function actively. With respect to the category recall and working memory tasks, for an elderly participant, it is a little too hard to say the name of fruits as many as he/she knows for long time (30 seconds), and is also a little too difficult to listen numbers and *hiragana* characters and sort them in ascending and dictionary order, at once.

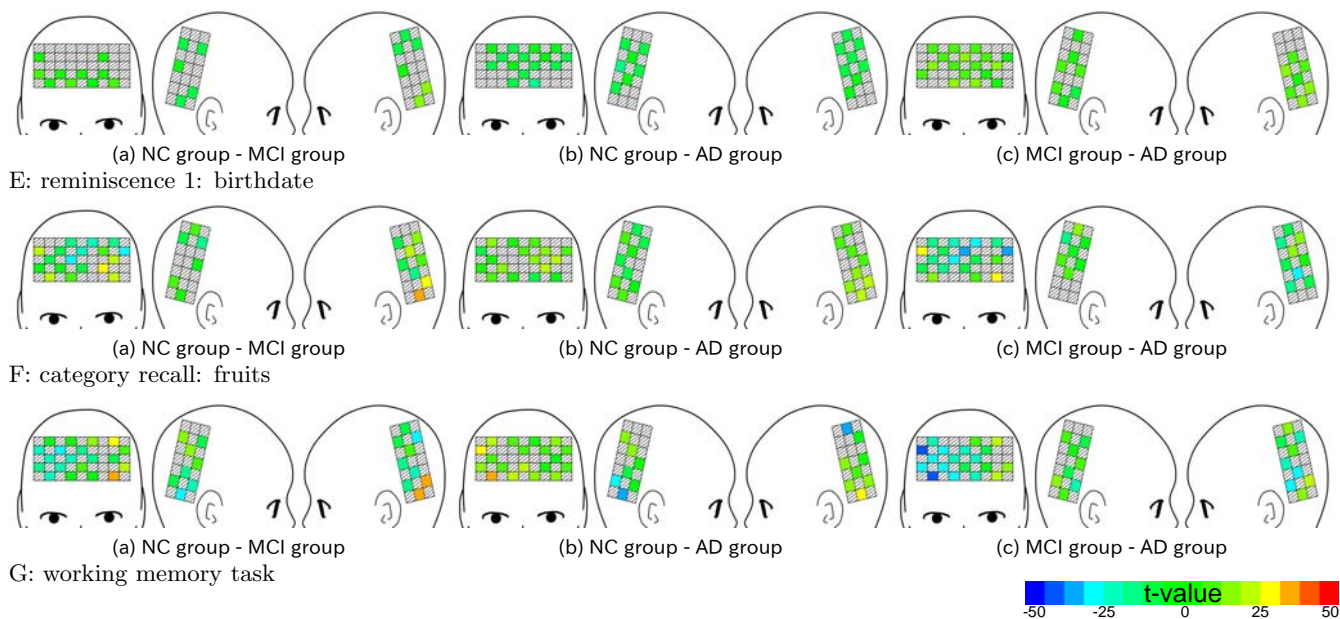


Figure 5: Results of t-test for significant differences in channel-wise fNIRS signals between any single pair from NC, MCI, and AD groups (later three tasks).

5. Conclusion

Toward personalized cognitive training, this paper presented a block-designed cognitive training task for elderly with mild cognitive impairment. With conscious of daily conversation, we designed eight cognitive tasks, under which an elderly individual talks about some topics and orally answering some questionnaire. With the use of the functional near-infrared spectroscopy (fNIRS), we reported a task effect by the statistical tests of fNIRS signals between any single pair from normal cognitive abilities (NC), patients with mild cognitive impairment (MCI), and Alzheimer’s disease (AD). Consequently, the results suggested that proposed cognitive tasks, especially casual conversation, are adequate practical to training of brain function activation for elderly people.

Acknowledgments

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