Effect of Cooking on Cognitive Functions: Daily Intervention Program and Measurement with Near-Infrared Spectroscopy

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INTRODUCTION

The social environment in Japan has changed drastically since the 1970's. Compared to the 70's, there are fewer opportunities to cook at home now. We are highly concerned about this trend. In our studies, we use the latest brain science methods. The objective is to prove that cooking positively affects the brain and to demonstrate the importance of cooking.

The prepared food market has been growing. The percentage of people eating out or relying on take-out, 45.2% in 2007, has also been increasing year by year [1]. With regard to food expenses, while the amount of money spent on fresh food is decreasing, the amount spent on drinks, snacks and prepared food is increasing proportionally[2]. This trend illustrates the increased popularity of prepared food which thus decreases the opportunity a family has to cook at home.

Moreover, not only for the above reason, but also for reasons explained below, the opportunity to eat together as a family is gradually decreasing. For example, members of some families eat at different times. Sometimes, one member or more of a family is absent from dinner. There are various reasons for this. One, parents come home late from work. Two, children participate in extra-curricular activities (cram school, sports, etc.) at night[3]. Families not eating together are naturally a factor leading to the increase in eating out and take-out.

Some studies on sensory evaluation have demonstrated that the more prepared-food and precooked-food is served at the table, the more standardized taste people have[4]. On the other hand, consumers can not only save time, but also can save money by using prepared food. This is particularly true in today's single or small households. The necessity to cook at home is less.

As a result of the above, there are fewer and fewer opportunities to teach cooking at the home. Without the knowledge nor ability to cook, more and more people prefer to buy prepared food. Furthermore, inadequate cooking knowledge and ability results in a lack of understanding and recognition of the local food culture. Japanese food culture, which has a rich tradition, has been damaged by these trends. The enactment of the Food and Nutrition Education Basic Act in 2005 shows that even the Government has acknowledged this important problem[5].

Wrangham, a biological anthropologist, stated that genus *Homo* stemmed from the control of fire and the advent of cooked meals and that cooking changed our social lives[6]. Cooking is a privilege reserved for human beings. Cooking has been, and will be, important in human society.

In our studies, we verify the following three hypotheses: "cooking activates brain functions," "daily act of cooking improves human brain functions," and "parent-and-child cooking positively affects the brain functions of children." We already know that to stop the regular practice of cooking causes elderly people to rapidly lose their memory and /or ability to take care of themselves. There is also a famous case, reported by Penfield, in which Penfield's sister lost the ability to cook due to brain damage.

Since the late 1980's, the advancement of near-infrared measurement device （NIRS） technology has made it possible to measure the brain activity of subjects performing a variety of activities[7]. Using NIRS, it had been demonstrated that reading aloud[8) 9)], basic calculation[10－13] and communication with other people[9] activate the prefrontal cortex of both the right and left hemispheres of the brain. Kawashima et al. showed that treatment, which included reading aloud and/or basic calculation, improves the brain functions of elderly people with dementia[14].

As of now, there has only been one study reported which measured the brain activity of subjects performing cooking activities. In this study, the brain activity of adult subjects was measured while the subjects were peeling apples[15]. To our knowledge, other than the above example, there have been no other experiments which measured brain activity while subjects cooked. Thus, as far as we know, the effectiveness of cooking on brain functions has not been proved yet.

On the other hand, as mentioned above, the necessity to cook at home has drastically decreased in recent years. The decrease in cooking at home is happening in spite of the fact that cooking is one way for a parent to show his/her love for a child. We are highly concerned about this tendency and worried that it will negatively affect the next generation's mental and physical development[5) 16)].

After the Food and Nutrition Education Basic Act went into effect in 2005, there has been a strong effort to promote food and nutrition education. For instance, parent-and-child cooking courses, as well as various other programs, have been held. There have also been studies which focused on children's eating habits in relationship to a mothers' role. [17－21]

Concerning higher brain functions, Iwahara et al. proved that the feeling of self-efficacy strongly affected the functions of memory and language in elderly people [22]. There have been studies which focused on the rehabilitation of higher brain functions through cooking programs[23-25]. Other studies used cooking facilities in nursing homes for elderly people[26]. From the results of these studies, it can be inferred that cooking not only improves the quality of life for elderly people, but also lessens the burden placed on their families, care-givers and society.

We believe that our studies will create more opportunities to reaffirm the importance of cooking, and that they will solidify the scientific grounds of rehabilitation programs by cooking and cooking facilities in nursing homes for elderly people. We believe that our studies can further help to succeed traditional food culture and to protect food security.

Constitution of this paper

This paper consists of an Introduction and five Chapters.

From Chapter 1 to Chapter 4 we explain our studies in relationship to the following three hypotheses: “cooking activates brain functions,” “daily act of cooking improves human brain functions,” and “parent-and-child cooking positively affects the brain functions of children.”

In Chapter 1, we investigate the “cooking activates brain functions” hypothesis. We measured the brain activity of female adult subjects while they cooked using NIRS.

In Chapter 2, we look at the “daily act of cooking improve human brain functions” hypothesis. Elderly male subjects participated in a daily intervention program of cooking. The subjects’ brain functions were measured by brain activity tests both prior to and after the program. The results of the pre-test and the post-test were compared and analyzed.

In Chapter 3, we focus on the “parent-and-child cooking positively affects the brain functions of children” hypothesis. Two methods were used in this study ; a daily intervention program and measurement by NIRS.

In Chapter 4, we looked into the effectiveness of parent-and-child cooking for parents (=not children). Two methods were used in this study ; a daily intervention program and measurement by NIRS.

In Chapter 5, after summarizing the results and discussions of the previous chapters, we state our conclusion.

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CHAPTER 1

Measurements of human brain activity when cooking using a near-infrared measurement device: optical topography system

INTRODUCTION

In recent years, the percentage of people eating out or relying on take-out has been increasing year by year. The percentage of people eating out or relying on take-out was 41.2% in 1990 and 44.7% in 2010, while it was only 28.4% in 1975 [1). We believe that the reasons for this change are people eat out more often, consume more prepared food, and also have fewer opportunities to cook at home. Several social factors, such as the increase in the number of single households[2), the low birth rate[3), an aging society[4), lack of time, and the reluctance to cook, can also be used to explain this change.

To prove our hypothesis that "cooking activates brain functions," we measured the brain activities of subjects while they were cooking. Based on previous studies, we already know that to stop the regular practice of cooking causes elderly people to rapidly lose their memory and/or ability to take care of themselves. Some reports have shown that cooking can improve the brain functions of elderly people rehabilitating from dementia or higher brain dysfunction[5) 6).

Since the late 1980's, the advancement of near-infrared measurement device (NIRS) technology has made it possible to measure the brain activity of subjects performing a variety of activities[7). Using NIRS, it had been demonstrated that reading aloud[8) 9), basic calculation[10−13) or communication with other people [9), activate the prefrontal cortex of both the right and left hemispheres of the brain. However, the reason for this effect is still unknown. In 2001, Kawashima et al. showed that treatment involving reading aloud and basic calculation improve the brain functions of elderly people with dementia[14).

In our study, using NIRS, we measured the brain activity of subjects while cooking.

METHODS

1. Ethics Statement

This study was approved by the Ethical Committee on Clinical Investigation, Graduate School of Engineering, Tohoku University, and was performed in accordance with the Declaration of Helsinki[15]. Written informed consent was obtained from each subject.

2. Period of Program and Subjects

The study was conducted between May 13th and May 15th in 2004. The Subjects were 15 married females who cook daily, from 30 to 60 years old, with a mean age of 45.3.

3. Measurement of Brain Activity

1) Measurement of Brain Activity

Measurements were performed using a near-infrared measurement device (NIRS, ETG-400, Hitachi Medical Corporation, Tokyo). Subjects were required to wear a probe set on their heads. The probe set covered the dorsolateral prefrontal cortex of the bilateral hemisphere (Fig 1).

Fig.1 Brain activity measured with the near-infrared measurement device: Subject is wearing a probe set

The concentration of oxy-hemoglobin and reduced hemoglobin in capillaries of cerebral cortex varies with the blood stream which is affected by activity of local brain cells. The near-infrared measurement device measures brain activity by determining the concentration of oxy-hemoglobin and reduced hemoglobin. The devise transmits near-infrared light onto the scalp, which penetrates the skull and comes back partially to the scalp.

2) Measured Region of Brain

The activity of prefrontal cortex, approximately 20mm beneath the scalp, was measured. The prefrontal cortex governs higher brain functions such as intention, cognition, memorization, language, communication, self-care, creativity, strategic thinking and problem solving[16].

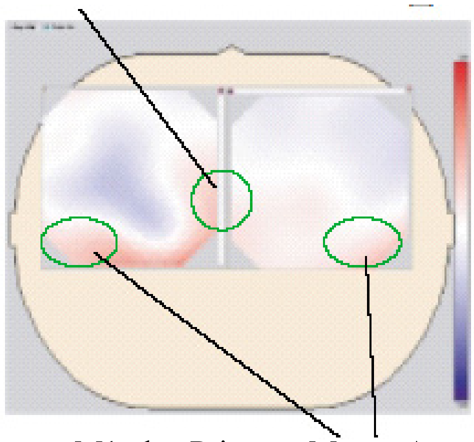
3) The Baseline: (Used as the standard and measured at a resting condition)

The baseline was determined when subjects were in a resting position and closed their eyes and thought of some relaxing music.

4）Identification of Motor Area

The probe set also covers the motor area[17], which is activated by physical movements. To distinguish which activities, movements related to cooking or simple hand movements unrelated to cooking, caused the activity in the brain, we identified the motor area by having subjects repeatedly open and close their dominant fist, for example their right fist if they were right-handed, and their left fist if they were left-handed. The parts of the brain which were activated were identified as the Primary Motor Area (M1) and the Supplementary Motor Area (SMA). M1 controls the output and regulation of physical movement. SMA controls coordination of both hands（Fig.2）

SMA : the Supplementary Motor Area



M1 : the Primary Motor Area

Fig. 2 Identification of Motor Area

Figure 2 is a two-dimensional topography image of the head taken from above. The upper part is the face, and the side parts are the ears. The prefrontal cortex of both the right and left hemispheres are shown in the two squares. White color indicates the state of the baseline. Red color indicates the brain is in an active state compared to that of the baseline. Blue color indicates the brain is in a calm state compared to that of the baseline. Deeper colors indicate a more remarkable state: the redder, the more active, and the bluer, the more relaxed.

4. Cooking Tasks

Brain activities were measured while performing two tasks; planning a menu for dinner and preparing fried dishes with a gas stove.

1）Plan a Menu for Dinner

① Outline

Subjects were required to sit down at the dining table, close their eyes, and plan a dinner menu consisting of several dishes for all family members. Subjects had to take into account what ingredients they had, what ingredients they didn’t have, and what ingredients they had to buy. Before performing this task, subjects were informed that they could take as long as they wanted to plan the menu. Subjects were then instructed to raise their hand and announce what they decided to make when they decided the menu.

② Procedures

Procedures of the test were as follows:

ⓐ Subjects close eyes and rest in a calm state (sitting) for 60 seconds (baseline measurement).

ⓑ Subjects, with eyes closed, plan a menu for dinner. Once the subjects decide the menu, they have to raise their hand.

ⓒ Subjects close eyes and rest in a calm state (sitting) for 90 seconds (baseline measurement).

2) Prepare Fried Dishes with Gas Stove

① Outline

Subjects prepared fried dishes (fried seafood and vegetables). Brain activities were measured while subjects performed three cooking tasks: cutting ingredients, frying ingredients with gas stove, and serving the dishes (Fig.3).

Fig.3 Brain activity measured with the near-infrared measurement device: Subject is frying ingredients with gas stove

In order to avoid any errors in measurements and ensure accuracy, subjects were not allowed to taste or eat any of the prepared food or ingredients while performing the cooking tasks.

Before the probe sets were placed on the subjects' heads, all of the subjects were informed that the probe set would restrict their range of mobility (i.e. ability to move and/or extend arms, etc.)

After the probe sets were set in place, and before beginning the task, all subjects were given the following instructions:

ⓐ Subjects must use all of the prepared ingredients.

ⓑ There are no restrictions on the way to cut and fry the ingredients.

ⓒ Only the prepared seasoning can be used.

② Procedures

Procedures of the test were as follows:

ⓐ Subjects have the probe set placed on head.

ⓑ Subject closes eyes and rests in a calm state (standing) for 60 seconds (baseline measurement).

ⓒ Subjects cut ingredients. No time restriction.

ⓓ Subjects close eyes and rest in a calm state (standing) for 90 seconds (baseline measurement).

ⓔ Subject moves to the gas stove.

ⓕ Subjects prepare fried seafood and vegetable dishes. No time restriction. When subjects finish, a staff member covers the frying pan.

ⓖ Subjects close eyes and rest in a calm (standing) for 90 seconds (baseline measurement).

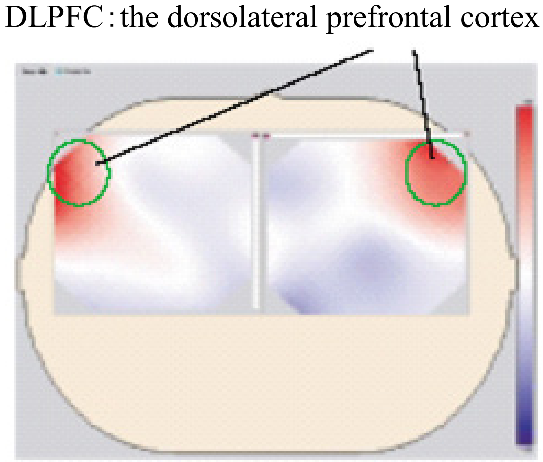
ⓗ Subjects serve the cooked dishes on two plates. No time restriction.

ⓘ Subject closes eyes and rest in a calm (standing) for 90 seconds (baseline measurement).

Even though officially there was no time restriction, each cooking task was designed to be able to be completed within 30 minutes. This was done in order to minimize the time subjects had to wear a probe set which can cause discomfort.

RESULTS and DISCUSSION

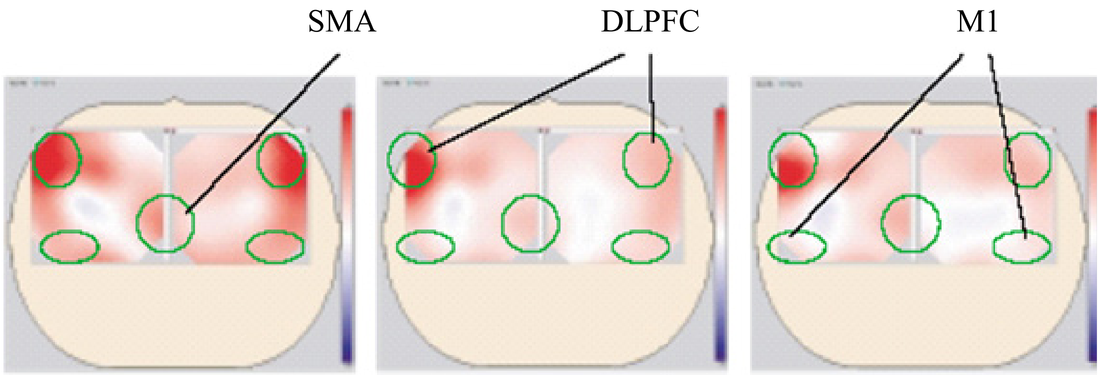
While subjects performed the task "planning a menu," significant activity was observed in the subjects' dorsolateral prefrontal cortex (DLPFC) of both the right and left hemispheres (Fig.4) of the brain. The activation of DLPFC was continuously activated until the subjects finished the task of “planning a menu.”



planning a menu

Fig.4 Brain Activity was observed while subject was planning a menu for dinner (2-D image)

Brain activity was observed in the subjects’ DLPFC, supplementary motor area (SMA), and primary motor area (M1) (Fig.5) while subjects performed the task “preparing fried dishes with gas stove” which includes “cutting ingredients,” “frying the ingredients with gas stove,” and “serving the dishes.” No statistically significant difference was found in the brain activity observed in the DLPFC for each separate task.



Cutting ingredients | Frying ingredients with gas stove | Serving the dishes

Fig.5 Brain activity while preparing fried dishes with gas stove (2-D image)

Brain activity of the prefrontal cortex, especially in both the right and left hemispheres of the DLPFC, was observed in subjects while performing all of the cooking tasks; (Fig.6) “planning a menu for dinner,” “cutting ingredients,” “frying the ingredients with gas stove” and “serving the dishes.”

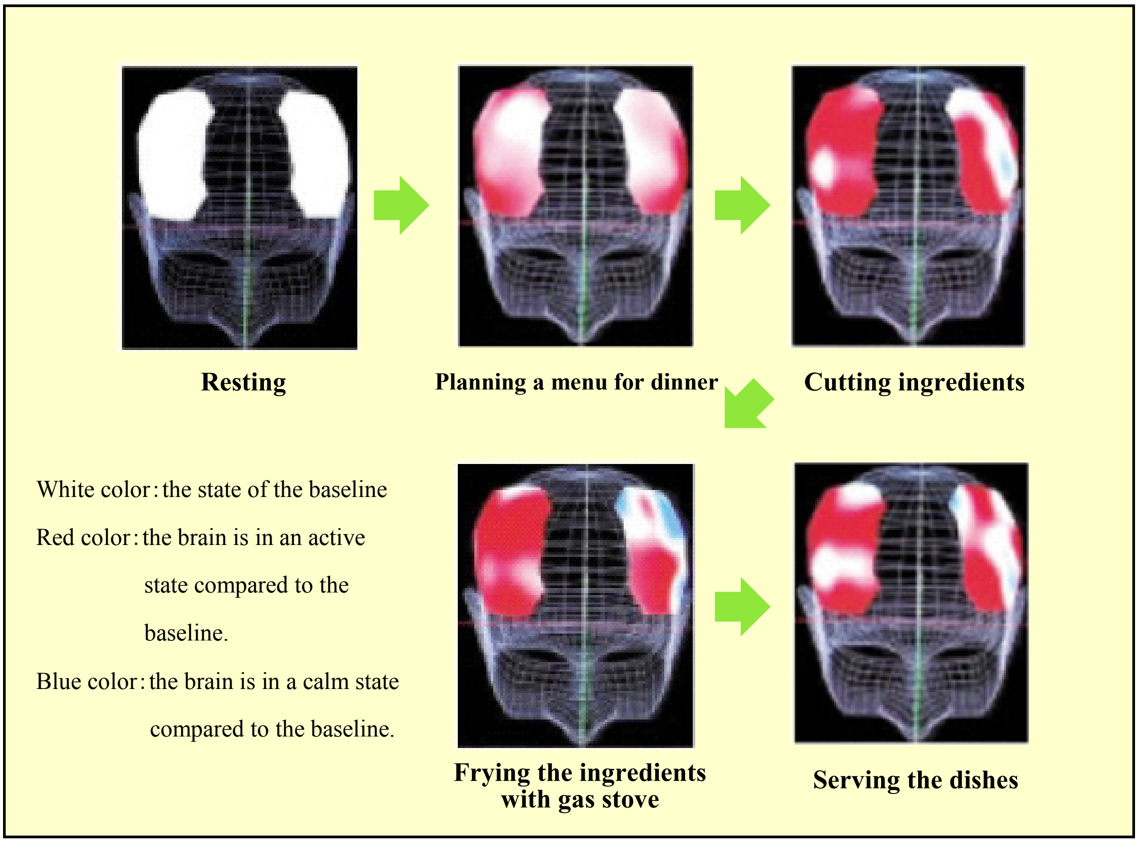


Fig.6 Brain activity during cooking tasks (3-D image)

These results appear to support our hypothesis that there is a link between cooking tasks and various functions of the DLPFC such as memorization, strategic thinking, problem solving and coping with situations. While subjects performed the “cutting ingredients” task, brain activity was observed in the SMA, which controls coordination of both hands, and the M1, which controls the output and regulation of physical movement.

This study, together with previous studies, suggest that cooking activity can improve the functions of the prefrontal cortex and can also transfer to the improvement of other important human abilities, which are controlled by the prefrontal cortex, such as communication, self-care and creativity.

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CHAPTER 2

Cooking improves prefrontal function of elderly males with an intervention method

INTRODUCTION

The proportion of elderly people aged 65 and over in Japan was 7.1% in 1970. When the Basic Law on Measures for the Aged Society was enacted in 1995, this proportion rose to 14.5%. In just 25 years, the population of this aged group increased at an amazing pace, more than doubling. According to the National Institute of Population and Social Security Research in Population Projections for Japan, the proportion of the elderly is expected to become 28.7% by 2025, 35.7% by 2050[1].

On the basis of this assessment, social assistance for elderly people is an urgent issue which must be addressed. The Long-term Care Insurance Law went into effect in April, 2000. By 2006, the number of people who were using this system had doubled. The Law was amended in 2006 in order to curb the sharp increase in insurance expenses.

Using the latest brain science, we have shown the effect which cooking has on people's brains[2]. In this study, the brains of female subjects were monitored using near-infrared spectroscopy (NIRS). The results showed that cooking activated both the right and left hemispheres of the prefrontal cortex of the brain.

From the results of this former study and measurements, it has been concluded that cooking affects the functions of the prefrontal cortex, and it can be suggested that cooking improves the ability for social life such as communication, self-care and so on.

In a previous study, Kawashima et al., using an intervention program, showed that reading aloud and basic calculation stimulate, develop and improve the functions of the brain[3]. In our study, retired, elderly male subjects participated in an intervention program in which they performed daily cooking activities. The results showed that cooking activated the prefrontal cortex.

METHODS

1. Ethic Statement

This study was approved by the Ethical Committee on Clinical Investigation, Graduate School of Engineering, Tohoku University, and was performed in accordance with the Declaration of Helsinki[4]. Written informed consent was obtained from each subject.

2. Period of Program and Subjects

This study lasted three months, between March 9th and June 2nd in 2005. 21 healthy, retired, elderly males with little cooking experience served as subjects. Their ages ranged from 59 to 81 years old, with a mean age of 68.5 years old.

There was not a control group because it is already widely known and accepted that the functions of the human brain deteriorate with age[5] .

3. Procedures

1) Procedures

The brain functions of all subjects were measured both prior to and after the intervention program (pre-test and post-test). The differences between the subject's pre-test and post-test scores were examined.

The subjects were required to participate in a cooking course. The course lasted 3 months, and class was held once a week, a total of 9 times. In addition to the once-a-week class, subjects were required to cook their own meals at home at least five times a week as well as complete and submit a homework sheet about these home cooking and shopping activities. The subjects had to submit this report every week when they attended the class.

2) Measurements of Brain Functions

The measurements of the subject's brain functions were performed by well-trained staff. The staff performed these measurements both prior to and after the intervention program, on March 9th or 10th and on June 2nd, respectively.

Subjects were interviewed before the pre-test was conducted. The interview lasted (from) 60 to 90 minutes. In the interview, the subject had to give his verbal informed consent and a staff member checked a questionnaire which the subject had to complete before the start of the interview. This questionnaire dealt with the subject's daily life and daily cooking habits.

In the study conducted by Kawashima et al., the subjects were elderly people with dementia. Two tests, the FAB and MMSE, were conducted and the effect on the functions of the brain was observed. In our study, the subjects were healthy, elderly males. We conducted the FAB and MMSE as well as three more tests in order to measure the functions of the prefrontal cortex. Therefore, in total, we conducted the following five tests:

① FAB [6] (Frontal Assessment Battery at Bedside) to measure the functions of the prefrontal cortex .

②Stroop[7] to measure the functions of the prefrontal cortex.
③Topology Test[8,9] to measure the thinking faculty.
④Digit-symbol Test[10,11] to measure the general cognitive function .
⑤MMSE[12] (Mini-mental State Examination) to measure the recognizing faculty.

The FAB measures functions of the prefrontal cortex such as verbal conceptualization and verbal planning, selection and the continued regulation of behavior. The FAB consists of 6 tasks; conception, intellectual flexibility, behavioral program (Hand-Fist-Palm), selecting response, GO/NO-GO and grasping response.

The Stroop measures the functions of the prefrontal cortex. Subjects are required to identify and then read out loud the color of the ink of the written word on the sheet (Fig.1). Reading the word out loud accurately is more difficult when color of the ink does not correspond to the meaning of the word. The time needed to complete the task is recorded as a score. This test reflects the functions of the prefrontal cortex in the left and right cerebral hemispheres.

あか	あお	あか	きいろ	みどり
きいろ	あか	みどり	きいろ	あお
みどり	きいろ	あか	みどり	あお
あお	きいろ	あか	あお	みどり

Fig.1 Example Question of Stroop Test
(Measurement of Functions of the Prefrontal Cortex)
Subjects are required to identify and then read out loud the color of the ink of the written word on the sheet.

The Topology test measures the thinking faculty. Subjects are required to identify the suitable figure composition as fast as possible. The score is determined by tallying the number of correct answers (Fig.2).

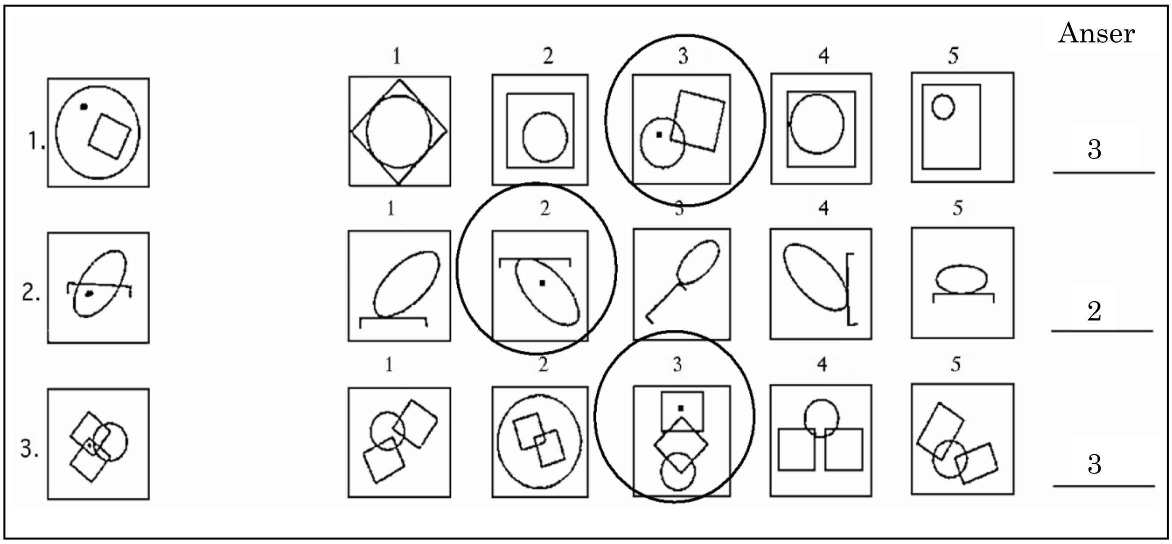

Fig.2 Example Question of Topology Test
(Measurement of the thinking faculty)
Subjects are required to identify the suitable figure composition as fast as possible. The score is determined by tallying the number of correct answers.

Digit-symbol Test measures the total task faculty (the general cognitive function). In this test, there are nine symbols, each of which corresponds to one digit, from 1 to 9, respectively. During 60-second intervals, subjects are asked to write down the corresponding symbols of the appropriate blank as fast as possible (Fig.3). The score is determined by tallying the number of correct answers.

1	2	3	4	5	6	7	8	9
–	⊥	⊃	∟	∪	○	∧	×	=

There are nine symbols. Each symbol corresponds to one digit, from 1 to 9, respectively (refer to above). Write the corresponding symbol of each number in the blanks below.

3	5	8	1	2	7	9	4	6	2

Fig.3 Example Question of Digit-Symbol Test

(Measurement of General Cognitive Function)

During 60-second intervals, subjects are asked to write down the corresponding symbols of the appropriate blank as fast as possible. The score is determined by tallying the number of correct answers.

MMSE measures the various faculties of recognition and memory.

3) Intervention Program: Cooking Course

During a three-month period, subjects attended a three-hour cooking class once a week in order to learn basic cooking techniques and maintain motivation to cook every day. The Cooking Course consisted of 9 classes which were held between March 17th and May 26th. In addition, all subjects were required to complete a homework sheet on this cooking-at-home activity and submit the homework sheet every week when they attended the class (Fig.4).

The subjects were asked to learn basic daily cooking techniques such as washing rice and boiling vegetables. The dishes which the subjects were asked to prepare were designed to be simple. Subjects used a gas cooking stove and gas range to cook. To both stimulate and maintain the subject's interest in the class, the menu was designed with a focus on seasonal food (Fig.5).

Fig.4 Subjects attended a three-hour cooking class once a week.

Fig.5 Example Menus for Cooking Course
The subjects were asked to learn basic daily cooking techniques such as Rice, Miso Soup, Japanese Fried Chicken.

4) Intervention Program: Cooking at Home

Subjects were required to cook their own meals at home at least five times a week. The cooking time to cook each meal was between 15 to 30 minutes.

Furthermore, the subjects were required to complete a homework sheet on the cooking-at-home and shopping activities, and submit it every week when they attended the class.

RESULTS and DISCUSSION

1. Results

Results are summarized in Table 1.

Table 1 Results of measurement of brain functions

	pre-test				post-test				
	Mean	MAX	MIN	SD[1)]	Mean	MAX	MIN	SD	t-test
FAB	15.4	18.0	11.0	2.2	16.3	18.0	13.0	1.4	*[2)]
Stroop	28.3	88.0	15.6	15.0	26.1	68.0	15.3	13.0	ns
Topology	4.4	8.0	0.0	2.4	5.3	8.0	3.0	1.7	*
Digit-syimbol	55.1	81.0	25.0	16.0	57.1	84.0	24.0	16.0	**
MMSE	29.1	30.0	26.0	1.3	29.0	30.0	24.0	1.4	ns

1) Standard error of the mean
2) * p<0.05 **p<0.01

1) FAB (Measurements of Functions of the Prefrontal Cortex)

The score of subjects improved from 15.4 to 16.3 ($p<0.05$). In general, scores of healthy people over 60 years old decrease with age. In addition, there is a tendency for healthy people under 60 years old to be able to attain a perfect score of 18. The results of our test showed improvement of the functions of the prefrontal cortex.

2) Stroop (Measurements of Functions of the Prefrontal Cortex)

The score improved from 28.3 to 26.1 minutes (ns).

3) Topology (Measurements of Thinking Faculty)

The score improved from 4.4 to 5.5 ($p<0.05$).

4) Digit-symbol Test (Measurement of the Total Task Faculty (General Cognitive Function))

The score improved from 55.5 to 57.1 ($p<0.01$).

5) MMSE (Measurement of Faculties of Recognizing and Memory)

A very slight change, from 29.1 to 29.0, was observed in the score of the subjects after the intervention program.

2. Discussion

The scores of the FAB, Topology Test, and Digit-symbol Test statistically significantly increased in the elderly subjects. This increase shows the improvement of the functions of the prefrontal cortex, thinking faculty and total task faculty (general cognitive function) after our intervention program. Usually, as mentioned before brain functions deteriorate with age. Our measurement study, together with previous studies, showed the possibility that daily cooking activities can activate the functions of the prefrontal cortex, thus improve and/or prevent the deterioration of the brain functions which are controlled by the prefrontal cortex. In particular, the affected functions include communication, self-care and emotional control. However, we have to admit that there is no way for us to measure any influence a family or environment may have on the subjects.

From a nutritional perspective, elderly people benefit from cooking daily. Even if an elderly person lives alone, he/she can make nutritionally balanced meals as they like. It is believed that healthy bodies, which are ones filled with nutritious foods, make it easier to maintain a mentally healthy state. This mentally and physically healthy environment not only helps the elderly individual himself/herself, but also reduces the physical and psychological burden of the individual's family and care-givers. Furthermore, this occurrence can lead to a decrease of the family's financial burden, thus reducing the nursing-care expenditures of the national budget.

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CHAPTER 3

Effect of parent-and-child cooking on cognitive functions of children: daily intervention program and measurement with near-infrared spectroscopy

INTRODUCTION

The Japanese social environment and the food environment have drastically changed since the 1970's when Japan achieved industrial and economic success. This change has affected the daily life of children in Japan.

First of all, while most Japanese children have little time to play outside, they spend long hours watching TV and playing video games inside[1]. Secondly, as the number of children and the number of family members in a household has decreased[2], children's participation in housework has also decreased[3]. Thirdly, as the frequency of eating out and /or buying prepared or pre-cooked food has increased[4], the frequency of cooking at home has subsequently decreased. In such an environment, today's Japanese children lack the opportunity to cook with their parents in the home. The Ministry of Education, Culture, Sports, Science and Technology of Japan reported that unbalanced nutrition and irregular eating habits cause both obese and excessively underweight or underdeveloped children[5]. Haruki et al.[6], who conducted a study on the relationship of breakfast and elementary school children, reported that while 87.6% of 4th grade children (10-11 years old) eat breakfast every morning, only 74.0% of 6th grade children (11-12 years old) eat breakfast. In addition, the study also showed that children who eat breakfast tend to go to bed early, have an appetite when they get up, have self-confidence, pride and good social skills, and seldom behave over-aggressively. We are concerned about the negative influences of going to bed late at night and skipping breakfast on children's physical development and cognitive functions.

We focused on parent-and-child cooking as a way to improve children's eating habits. We feel that parent-and-child cooking increases the opportunity for communication. More opportunity for communication facilitates the ability of parent's to recognize as well as praise the efforts of their children, thus boosting the child's confidence and cognitive functional ability.

Our hypothesis is that the parent-and-child cooking positively affects the cognitive functions of children. To prove this hypothesis, we conducted a daily intervention program experiment.

However, to our knowledge, the scientific relationship between cooking and cognitive functions still remains unclear. Chevignard et al.[7] found that children who suffered from moderate to severe traumatic brain injuries showed poor cooking ability compared to that of same-aged children who had not suffered any brain injuries. Since the act of cooking requires visual-spatial perception, concentration, decision-making, memory, and the execution of complicated hand movements, we hypothesized that the dorsolateral prefrontal cortex (DLPFC) of the brain plays a key role in these functions. Therefore, in our study, we measured the activity of the DLPFC in children during parent-and-child cooking using a near infrared spectroscopy device (NIRS). The NIRS is a non-invasive technique because it uses low-intensity light of two or three wavelengths [8] so that it can be applied to monitor the brain functions of children[9] .

Concerning past studies involving brain activity measured with the NIRS during cooking activities, only one report has been found to date. This specific study found that DLPFC of adult subjects was activated while the subjects were peeling apples[10] . To our knowledge, brain activity measurements during other cooking activities, or any studies involving the brain activity of children while cooking, have not been conducted yet.

Our studies produced interesting results, which we would like to share.

METHODS

1. Daily Intervention Program of Parent-and-Child Cooking

1) Subjects

The subjects were children, aged 8 to 10 years old, with a mean age 8.8. The subjects conducted the cooking with one of their parents, aged 35 to 46 years old, with a mean age 39.4 years old. 29 subjects participated in this study. Following the provisions of the Helsinki Declaration, all subjects and their parents were given both a written and an oral explanation of the purpose of the test and the safety procedures. In addition, a written informed consent was obtained from all the subjects and one of the parents of each subject.

Prior to the experiment, the 29 parent-and-child pairs were randomly divided into two groups: the intervention group, which followed the intervention program for 3 months, and the control group which conducted all daily activities as usual. The intervention group consisted of 16 children (8 boys and 8 girls, with a mean age 8.9 years old) and one of their parents (15 mothers and 1 father). The control group consisted of 13 children (2 boys and 11 girls, with a mean age 8.8 years old) and their parents (12 mothers).

2) Procedures for Intervention and Evaluation of the Cognitive Functions

This study was conducted during a three-month term between May 27th and September 2nd in 2006. Measurements of cognitive functions were performed on all participants (pre-test). The intervention group followed the three-month intervention program. The control group did not participate in this intervention program and did their daily activities as usual. After the three-month program, the same measurements conducted in the pre-test were performed on all participants (post-test). The differences between the pre-test and the post-test scores of each subject's cognitive functions in the intervention group and each subject's cognitive functions in the control group, as well as the differences between the pre-test and the post-test scores between each group, were examined by two-way analysis of variance (ANOVA). After that, we performed the paired t-test as a post hoc examination. Statistical significance was set at $p < 0.05$.

3) Intervention Program

For 3 months, the subjects were required to attend a cooking course once a week and to cook at home more than three times a week.

The cooking course was held 10 times from June 3rd to August 24th. Through the course, the children learned daily basic cooking techniques, which they could use to cook everyday with their parents. The cooking course menu (Table.1) consisted of simple dishes using seasonal ingredients. Each parent-and-child pair prepared all dishes by themselves. Gas stoves and gas ovens were used.

Table.1 Menus for Cooking Course

No.	Date	Style of Dishes	Menu
1	June 3	Chinese dishes	Chinese Dumpling
			Stir-fried Shrimps with Ketchup
			Soup
			Rice
2	June 10	Western dishes	Omelet and Fried Rice
			Croquettes
			Salad
3	June 24	Japanese dishes	Beef and vegetables Roll
			Spinach Salad
			Miso Soup
			Rice
4	July 1	Western dishes	Macaroni au Gratin
			Green Salad
			Millefeuille
5	July 15	Western dishes	Pizza
			Soup Pasta
			Jelly
6	July 27	Japanese dishes	Grilled Salmon with Corn and Mayonnaise
			Rice Cooked with Green Soybeans
			Cucumber and Sea Weeds
			Watermelon
7	August 3	Chinese dishes	Mapo Tofu
			Eggplants Salad
			Rice
			Almond jelly
8	August 10	Western dishes	Sandwiches
			Vegetable Soup
			Cupcake
9	August 17	Japanese dishes	Chicken Teriyaki
			Peas Salad
			Rice Cooked with Soybeans and Vegetable
			Miso Soup
10	August 24	Western dishes	Curry with Rice
			Salad
			Lassi

Regarding the home cooking, the intervention group subjects were required to cook at least three times a week, for 15 to 30 minutes each time. Each parent-and-child pair completed a homework sheet about the home cooking, and submitted it every week when they participated in the cooking course.

4) Cognitive Measurements

The measurements of cognitive functions were performed on all of the children and parents of both groups by well-trained staff, prior to and after the intervention program, on May 27th and on September 2nd, respectively. 8 tests were used to measure the functions of association cortices.

① Measurement of General Cognitive Function

To measure the general cognitive function, we conducted the digit-symbol test [11,12]. In this test, there are nine symbols (−⊥⊃∟∪○∧×＝), each of which corresponds to one digit, from 1 to 9, respectively. During 60-second intervals, subjects are asked to write down the corresponding symbol of each digit in each blank as fast as possible (Fig.1). Each subject's test score reflects the number of correct answers.

1	2	3	4	5	6	7	8	9
−	⊥	⊃	∟	∪	○	∧	×	＝

There are nine symbols. Each symbol corresponds to one digit, from 1 to 9, respectively (refer to above). Write the corresponding symbol of each number in the blanks below.

3	5	8	1	2	7	9	4	6	2

Fig.1 Example Question of Digit-Symbol Test
（Measurement of General Cognitive Function）

② Measurement of Functions of the Prefrontal Cortex

To measure the functions of the prefrontal cortex, a number memorizing test, a conception test and an arranging test were conducted.

The number memorizing test is used to measure short-term memory. Subjects are required to memorize and write the groups of numbers, which are read aloud by the speaker, in the correct order (Fig.2). Each subject's test score reflects the number of correct answers (i.e. correctly memorized number groups).

Groups of numbers will be read aloud by the speaker. First, memorize the order of the numbers in each group. Then, after hearing the instructions "Please start," write the group of numbers in the correct order in the blanks. Do not begin writing before you hear the instructions.

Fig.2 Example Question of Number Memorizing Test
(Measurement of Functions of the Prefrontal Cortices)

The conception test measures the ability of forming conception. Subjects are required to find a similar or common characteristic between pairs of nouns. For example, for "grapes and watermelon," appropriate answers could be "fruits" or "have seeds" (Fig.3). The duration of the test is 60 seconds, and number of correct answers accumulated during this 60-second interval is recorded as the score.

Find and write a similar or common characteristic.

Word 1	Word 2	Answer
grape	water melon	

Example of appropriate answers; "fruits" or "have seeds."

Fig.3 Example Question of Conception Test
(Measurement of Functions of the Prefrontal Cortices)

The arranging test measures the ability to infer. The subjects are shown pictures of a story, but in random order. Subjects are required to put the pictures in an order, which makes a sensible story (Fig.4). The duration of the test is 60 seconds, and number of correct answers accumulated during this 60-second interval is recorded as the score.

③ Measurement of Functions of the Parietal Association Cortex

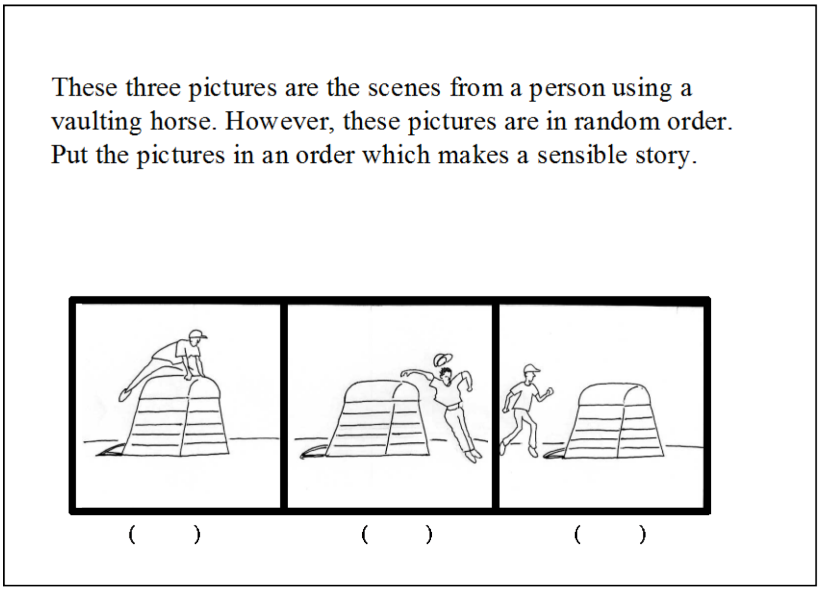

Fig.4 Example Question of Arranging Test
(Measurement of Functions of the Prefrontal Cortices)

To measure the functions of the parietal cortex, which controls the ability of spatial perception, we conducted three tests; a maze test, a 2-D mental rotation test and a 3-D mental rotation test.

In the maze test, subjects are required to find the way from the “start” to the “goal” by drawing a line (Fig.5). The duration of the test is 60 seconds, and number of correct answers accumulated during this 60-second interval is recorded as the score.

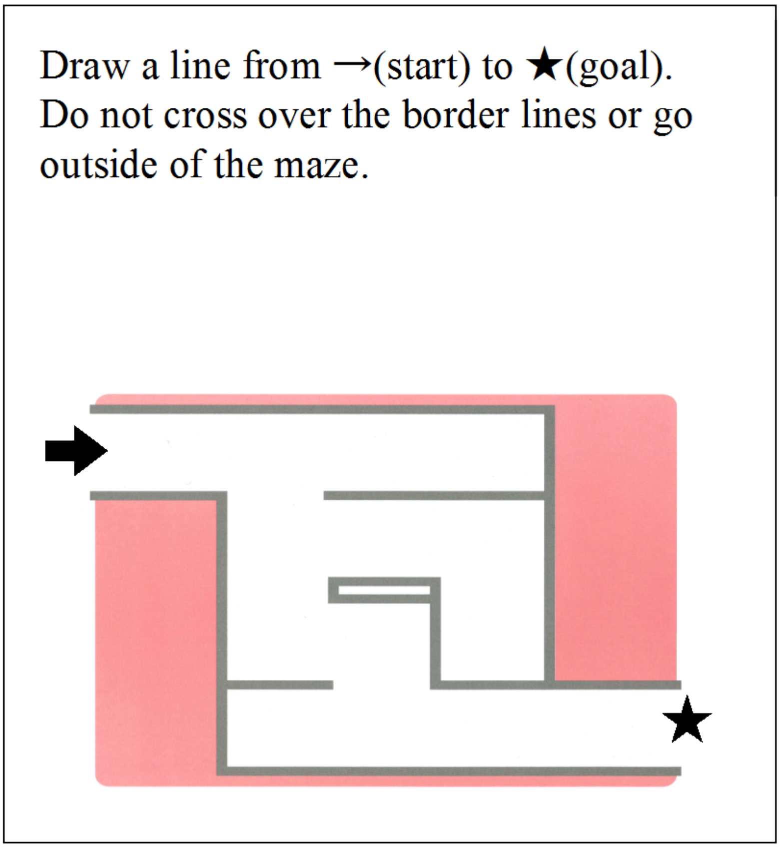

Fig.5 Example Question of Maze Test
(Measurement of Functions of the Parietal Association Cortex)

In the 2-D (two-dimensional) mental rotation test, subjects are shown pairs of Japanese letters, one letter on the left side and one letter on the right side. The letters on the left side are positioned in an upright (normal) form. However, the letters on the right side are positioned in various forms; upside down, reversely, etc. Subjects are required to rotate the letter on the right side mentally and determine whether this letter is identical to the letter on the left or not (Fig.6). The duration of the test is 60 seconds, and number of correct answers accumulated during this 60-second interval is recorded as the score.

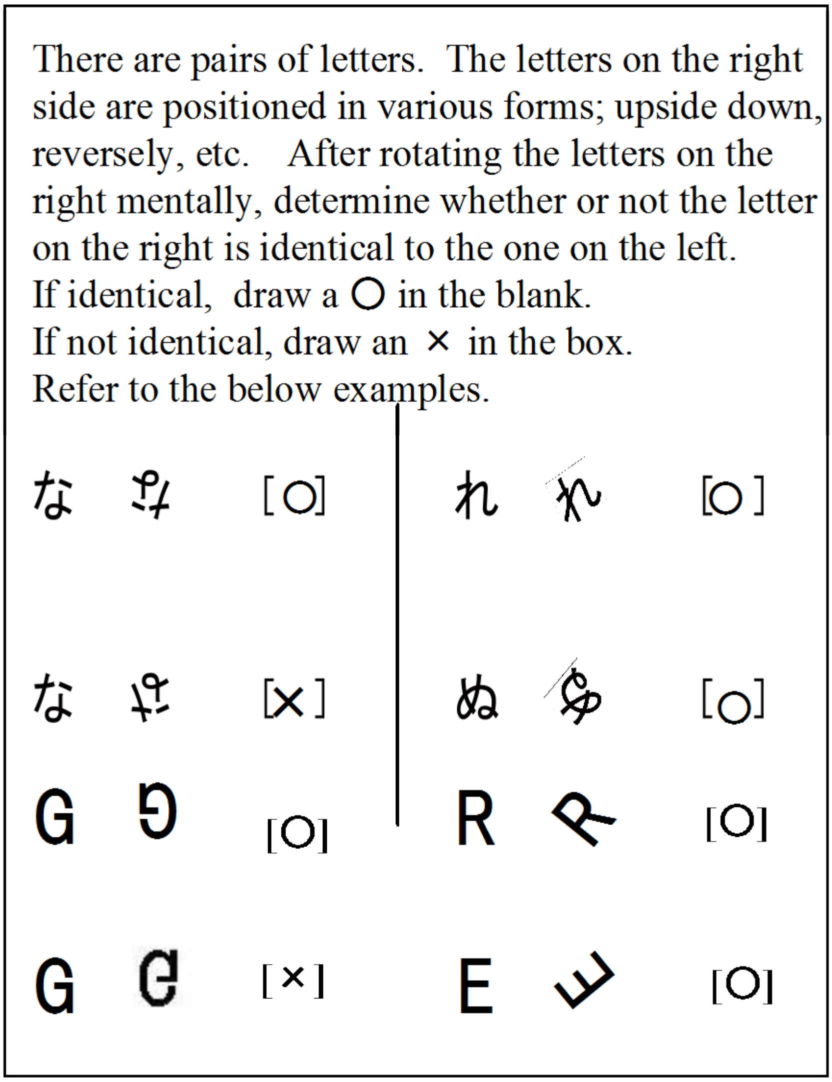

Fig.6 Example Question of 2-D Mental Rotation Test
(Measurement of Functions of the Parietal Association Cortex)

In the 3-D (three-dimensional) mental rotation test, subjects are shown pairs of three-dimensional figure, one figure on the left side and one figure on the right side. The figures on the left side are positioned in an upright (normal) form. However, the figures on the right side are rotated in various forms; upside down, reversely, etc. Subjects are required to rotate the figures on the right side mentally and determine whether this figure is identical to the figure on the left or not (Fig.7). The duration of the test is 60 seconds, and number of correct answers accumulated during this 60-second interval is recorded as the score.

There are pairs of figures. The figures on the right side are positioned in various forms. After rotating the figure on he right mentally, determine whether or not the figure on the right is identical to the one on the left.
If identical, draw a ○ in the blank.
If not identical, draw an × in the box.
Refer to the below examples..

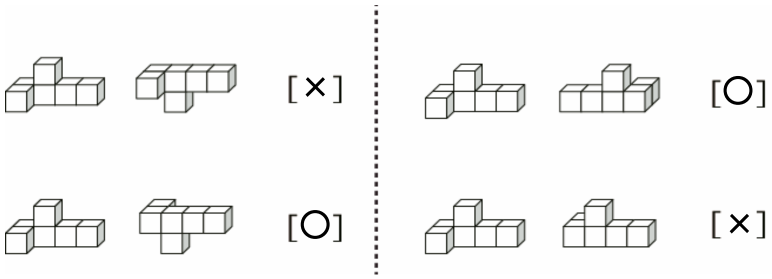

Fig.7 Example Question of 3-D Mental Rotation Test (Measurement of Functions of the Parietal association Cortex)

④ Measurement of Functions of the Temporal Association Cortex

To measure the functions of the temporal cortex, which controls the ability of recognition of figures, we conducted a matching test (Fig.8). Three figures (each one different) appear in a box. Below the box, the figures in the box above, as well as other various figures, are randomly aligned in a row. Subjects are required to start from the left, proceed to the right, and check off only the figures which appear in the box above. Subjects can only go through the rows of figures once. Subjects are to leave all figures which do not appear in the box above untouched. The duration of the test is 60 seconds, and number of correct answers accumulated during this 60-second interval is recorded as the score.

Three figures (each one different) appear in a box. Below the box, the figures in the box, as well as other various figures, are randomly aligned in a row. Start from the left, proceed to the right, and check off only the figures which appear in the box. Only go through the rows of figures once, from left to right. Leave all figures which do not appear in the box untouched.
Refer to the below example.

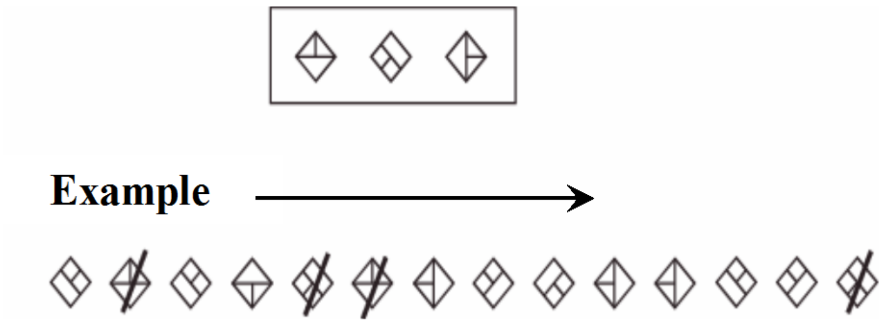

Fig.8 Example Question of Matching Test
(Measurement of Functions of the Temporal Cortex)

2. Measurement of Brain Activity

1) Subjects

Eight healthy right-handed children aged 8 to 11 (with a mean age 10.3 years old) participated in this study. Following the provisions of the Helsinki Declaration, all subjects and their parents were given both a written and an oral explanation of the purpose of the test and the safety procedures. In addition, a written informed consent was obtained from all the subjects and one of the parents of each subject.

2) Measurement Device

The measurement was performed using the NIRS (NIRS ETG-400, Hitachi Medical Corporation, Tokyo). The subjects are required to wear a probe set on their heads. This probe set covered the DLPFC of the bilateral hemisphere (Fig.9).

Fig.9 Measurement of Brain Activity with the NIRS: Subject Wearing Probe Set

3) Assessment of Brain Activity

In this study, we measured the changes of oxy-hemoglobin concentration as an indicator of cortical activity. Sampling rate was 100 msec (microseconds). We set the region of interest (ROI) over the DLPFC according to the atlas [13], and calculated the mean concentration of oxy-hemoglobin in the ROI for each sampling time. In this study, we used a conventional block design. The baseline was a 60-second resting condition in which the subjects were asked to close their eyes, relax, stay calm and try not to think of anything. Regarding statistical analysis, we analyzed the average oxy-hemoglobin concentration during this 60-second interval as well as deviation of noises during each task between the two baseline conditions of prior to and after the task.

The noises consisted of physiological noises such as heartbeat and respiration, physical noise from various apparatus, and unknown extra noises. We compared the brain activity while performing the cooking task to the brain activity in the baseline. Brain functions were considered "significantly activated" when the mean concentration of the oxy-hemoglobin while performing the cooking task became more than twice the standard deviation of noises during the baseline compared with the average concentration during the baseline. Then, we compared mean activity during each cooking task by analysis of variance (ANOVA; subject x task) for each ROI. In this ANOVA analysis, statistically threshold was set at $p < 0.05$.

4) Cooking Tasks

① Outline

Measurement of brain activities was performed using two tasks; making pancakes with gas stove and serving the pancakes. First, the subjects were required to make pancakes. Then, the subjects were required to serve these pancakes with fruit (bananas and strawberries) and whipped cream to two people on two separate plates.

Prior to setting the probe sets on the subjects' heads, all subjects were informed that because of the probe set, their range of mobility (i.e. ability to move their arms, ability to reach, etc.) would be restricted while performing the task. After applying the probe set and prior to beginning the cooking tasks, in addition to the above instructions, the following instructions were also given:

ⓐ Child can verbally ask parent for help during while performing any part of the cooking tasks.

ⓑ Child and parent can talk to each other while performing any part of the cooking tasks. (Note: Child and parent are not allowed to talk to each other during the baseline measurements)

ⓒ Child can serve the pancakes with fruit and whipped cream in any way they like.

ⓓ In order to avoid errors in measurements and ensure accuracy, both child and parent are not allowed to taste or eat any of the prepared food or ingredients while performing the cooking or serving tasks.

② Procedures

The procedures of the test were as follows:

ⓐ Child (subject) places the probe set on head.

ⓑ Child and parent move to the gas stove table.

ⓒ Parent act as a model and demonstrate how to make pancakes.

ⓓ Child and parent each close their eyes and remain standing for 60 seconds (baseline measurement).

ⓔ Child and parent stand in front of the gas stove.

ⓕ Child makes pancakes while receiving verbal assistance from parent (task 1 measurement).

ⓖ Child and parent each close their eyes and remain standing for 60 seconds (baseline measurement).

ⓗ Child serves pancakes (with fruit and whipped cream in any way they like) for two people (task 2 measurement). After finishing this task, child is required to raise his/her hand. No time restrictions.

① Child and parent each close their eyes and remain standing for 60 seconds (baseline measurement).

In order to facilitate the subject's performance of the cooking tasks as well as to reduce stress (irritation) signs in the subject due to the discomfort of the probe set, the pancake mix was prepared for the subject in advance.

RESULTS

1. Daily Intervention Program of Parent-and-Child Cooking

The results are summarized in Table 2.

Table 2 Results of measurement of brain functions

	Intervention Group				Control Group			
	pre test n=16	post test n=16			pre test n=13	post test n=13		
	Mean[1] ± SEM[2]	Mean ± SEM	paired t-test		Mean ± SEM	Mean ± SEM	paired t-test	ANOVA[3]
Digit -symbol	27.3 ± 1.4	33.2 ± 1.8	***[4]		26.8 ± 1.9	33.6 ± 1.9	***	ns
Memorizing nembers	0.8 ± 0.2	1.1 ± 0.2	ns		0.8 ± 0.2	0.8 ± 0.2	ns	ns
Conception	6.5 ± 0.6	9.5 ± 0.5	***		6.8 ± 1	7.6 ± 1.0	ns	***
Arranging	3.6 ± 0.3	4.0 ± 0.3	ns		3.1 ± 0.5	3.9 ± 0.5	ns	ns
Maze	5.8 ± 0.4	6.8 ± 0.4	**		5.5 ± 0.4	6.2 ± 0.4	*	ns
2-D	19.3 ± 1.4	28.9 ± 1.8	***		18.8 ± 2.2	24.0 ± 2.2	*	*
3-D	9.7 ± 1.5	12.5 ± 2.5	*		7.2 ± 0.7	8.9 ± 0.7	*	ns
Matching	37.2 ± 3.5	50.1 ± 3.9	*		35.9 ± 4.1	45.2 ± 4.1	**	ns

1) Test score : Number of correct answers in measurement of cognitive functions
2) Standard error of the mean
3) Analysis of variance
4) * $p < 0.05$ ** $p < 0.005$ *** $p < 0.001$

① Measurement of General Cognitive Function

In the digit symbol test, no statistically significant difference of variation between the two groups was observed. However, the score of the children in the intervention group improved from 27.3 to 33.2 ($p<0.001$) after the 3-month intervention program. Similarly, the score of the children of the control group also improved from 26.8 to 33.6 ($p< 0.001$) during the 3-month interval.

② Measurement of Functions of the Prefrontal Cortex

In the memorizing test, no statistically significant difference of variation between the two groups was observed.

In the conception test, improvement of the score was statistically significantly high in the intervention group compared with the score in the control group ($p < 0.001$). The post hoc test showed that the score of the intervention group improved significantly from 6.5 to 9.5 ($p<0.001$) after the intervention program. However, no such significant difference was found in the control group.

In the arranging test, no statistically significant difference of variation between the two groups was observed.

③ Measurement of Functions of the Parietal Cortex

In the maze test, no statistically significant difference of variation between the two groups was observed. However, the score of both the intervention group and the control group improved from 5.8 to 6.8 ($p<0.005$) and 5.5 to 6.2 ($p<0.05$), respectively during the 3-month interval.

In the 2-D mental rotation test, improvement of the score was statistically significantly high in the intervention group compared with the score in the control group ($p < 0.05$). The post hoc test showed that the score of the intervention group improved significantly from 19.3 to 28.9 ($p<0.001$), while the score of the control group showed improvement from 18.8 to 24.0($p<0.05$).

In the 3-D mental rotation test, no statistically significant difference of variation between the two groups was observed. However, while the score of the intervention group improved from 9.7 to 12.5 ($p<0.05$), the score of the control group showed improvement from 7.2 to 8.9 ($p<0.05$).

④ Measurement of Functions of Temporal Cortex

In the matching test, no statistically significant difference of variation between the two groups was observed. However, while the score of the intervention group improved from 37.2 to 50.1 ($p<0.05$), the score of the control group improved from 35.9 to 45.2 ($p<0.005$).

2. Measurement of Brain Activity

In all subjects, activation of the dorsolateral prefrontal cortex (DLPFC) of both hemispheres was observed in each cooking task, “making pancakes with gas stove” and “serving pancakes（Fig.10）.” No statistically significant difference was observed in activity of the DLPFC when comparing the activity during each separate task.

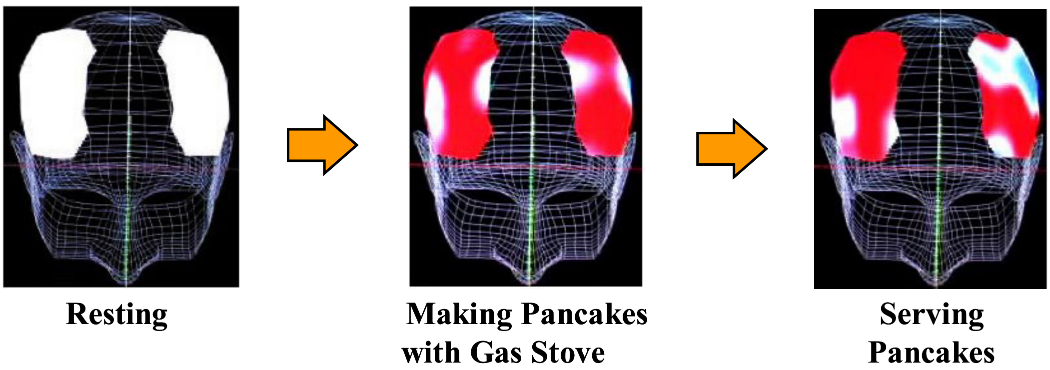

Fig.10 Brain Activation during Making Pancakes and Dishing up Pancakes (3-D Image)

DISCUSSION

The findings of this study were striking. Regarding the conception test and the 2-D test, the results of parent-and-child cooking showed a greater statistically significant variation in the intervention group compared with that in the control group. In addition, activation of the DLPFC was observed in all 8 subjects during the cooking tasks. To our knowledge, this is the first study, which shows the improvement in children’s cognitive functions and the activation of children's DLPFC through performing cooking tasks. According to the results of parent-and-child cooking, it appears that a child's prefrontal cortex, which controls conception and strategic thinking, can be stimulated by talking with the parent and by thinking of and preparing for the next procedure.

Likewise, a child’s parietal cortex, which controls coordination of both hands, can be trained by performing cooking tasks such as cutting ingredients with a knife, adjusting the gas fire, and serving dishes.

Many of the child subjects acknowledged a boost in self-confidence as well as a definite improvement in cooking ability after the daily intervention program. Praise from the parent also seemed to play a role in the positive reaction of the child. Even though many parents stated that it was more difficult to cook daily with the child than they expected, many parents also expressed satisfaction in the child's improvement of skills and boost of self-confidence.

From this study, parent-and-child cooking together appears to provide opportunities for children to be recognized and praised by their parent, thus improving the child's self-confidence and cognitive functions.

This study, together with other common knowledge of brain functions, previous brain science studies, and our previous study with the near infrared spectroscopy, suggests the possibility of the improvement in the development of brain functions through parent-and-child cooking.

Previous practical studies showed that reading aloud or simple calculation activates brain functions. Moreover, the studies showed that introduction of such tasks into daily life further improves the brain functions, which can also transfer to the improvement of other important human abilities[14], which are controlled by the prefrontal cortex, such as communication, self-care, creativity, and learning.

Therefore, parent-and-child cooking can also be expected to provide the same positive effects.

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CHAPTER 4

Effect of parent-and-child cooking on cognitive functions of parent: daily intervention program and measurement with near-infrared spectroscopy

INTRODUCTION

The Japanese family environment has gone through drastic changes in recent years. The birthrate in Japan is rapidly declining.

One factor affecting the declining birthrate is the apparent tendency of present-day women to feel less fulfillment from raising children than women in the past. According to a basic study on child-raising conducted by the Benesse Educational Research and Development Center, the percentage of mothers who can recognize their child's intellectual and emotional growth is decreasing year by year. On the other hand, this study also showed that mothers who communicate more with their child find a greater sense of fulfillment in child-rearing[1)].

Our previous study, which was a daily intervention program experiment of parent-and-child cooking, showed a positive link between the development of children's brain functions and parent-and-child cooking[2)] . Furthermore, after the conclusion of the experiment, we received several intriguing comments from the parents. In general, they stated that while it was more difficult to cook daily with their child than they expected, they found great pleasure in seeing a boost in their child's self-confidence as well as cooking skills.

From this one can draw the conclusion that communication through parent-and-child cooking not only positively influences children, but also positively influences parents too. In order to prove this hypothesis, first we analyzed the results of the daily intervention program experiments. Then, using a near-infrared spectroscopy device (NIRS), we measured the activity in the dorsolateral prefrontal cortex (DLPFC) of parents who were conducting the parent-and-child cooking.

Only a few other studies involving brain activity which was measured using NIRS during cooking activities have been found to date. These specific studies revealed that the DLPFC of adult subjects was activated while peeling apples[3)], the DLPFC of female subjects was activated while performing cooking tasks[4)], and the DLPFC of child subjects was activated while participating in parent-and-child cooking[2)]. Moreover, we recently discovered some studies which used NIRS to measure brain activity while subjects conducted "seasoning experiments [5)-10)]." Some of the studies located were a study of taste encoding and a cognitive and behavioral study on adding salt to clear soup stock. However, to our knowledge, there has never been a study measuring the brain activities in adults who were conducting parent-and-child cooking before ours.

Now, we would like to share the interesting results produced by our study.

METHODS

1. Ethics Statement

This study was approved by the Ethical Committee on Clinical Investigation, Graduate School of Engineering, Tohoku University, and was performed in accordance with policy of the Declaration of Helsinki. Written informed consent was taken from each family.

2. Daily Intervention Program of Parent-and- Child Cooking

1) Subjects

The subjects were parents of schoolchildren, aged 35 to 46 years old, with a mean age of 39.4 years old. The subjects conducted the cooking activities with their children, aged 8 to 10 years old, with a mean age of 8.8 years old. 28 subjects participated in this study.

Prior to the experiment, the parent-and-child pairs were randomly divided into two groups: the intervention group and the control group. The intervention group consisted of 16 parents (15 mothers and 1 father, with a mean age of 39.9 years old) and their children (8 boys and 8 girls, with a mean age of 8.9 years old). The control group consisted of 12 parents (12 mothers, with a mean age of 38.8 years old) and their children (2 boys and 11 girls, with a mean age of 8.8 years old).

2) Procedures for Intervention and Evaluation of the Cognitive Functions

This study was conducted during a three-month period between May 27th and September 2nd in 2006. Measurements of cognitive functions were performed on all participants (pre-test). The intervention group followed the three-month intervention program. The control group did not participate in this intervention program and did their daily activities, uninterrupted, as usual. After the three-month program, the same measurements conducted in the pre-test were performed on all participants (post-test). The differences between the pre-test and the post-test scores of each subject's cognitive functions in the intervention group and each subject's cognitive functions in the control group, as well as the differences between the pre-test and the post-test scores between each group, were examined by two-way analysis of variance (ANOVA). After that, a paired t-test was performed as a post hoc examination. Statistical significance was set at $p < 0.05$.

3) Intervention Program

During the three-month period, the intervention group was required to attend a cooking course once a week and cook at home at least three times a week.

The cooking course consisted of 10 classes held between June 3rd and August 24th. Though parents were instructed to do the cooking activities with their child, they were also urged not to do “too much” or interfere with or interrupt the child while cooking. The intervention group subjects were required to cook at home with their child at least three times a week, for 15 to 30 minutes each time. In addition, each parent-and-child pair was required to complete a homework sheet about the home cooking and submit it every week at the cooking class.

4) Cognitive Measurements

We performed measurements of cognitive functions on all of the parents and children of both groups, before and after the intervention program, on May 27th and on September 2nd, respectively. We conducted measurements of the functions of association cortices on all subjects using 8 separate tests[2).

① Measurement of General Cognitive Function

To measure the general cognitive function, we conducted a digit-symbol test[11) 12)]. During 60-second intervals, subjects were asked to write down the corresponding symbol of each digit as fast as possible.

② Measurement of Functions of the Prefrontal Cortex

To measure the functions of the prefrontal cortex, we conducted a number memorizing test, a conception test and an arranging test.

These tests measured short-term memory, the ability to conceive ideas, and the ability to infer, respectively. In the conception test, subjects were required to find a similar or common characteristic between pairs of nouns. In the arranging test, subjects were required to put pictures in order making a sensible story.

③ Measurement of Functions of the Parietal Association Cortex

To measure the functions of the parietal cortex, which controls the ability of spatial perception, we conducted three tests; a maze test, a 2-D mental rotation test, and a 3-D mental rotation test.

④ Measurement of Functions of the Temporal Association Cortex

To measure the functions of the temporal cortex, which controls the ability to recognize figures, we conducted a matching test. Subjects were required to recognize figures and then appropriately check off three figures as fast as possible.

3. Measurement of Brain Activity

1) Subjects

Nine healthy, right-handed adults 35 to 42 years of age (9 mothers, with a mean age of 37.9 years old) and their children（3 boys and 6 girls, with a mean age of 9.0 years old）participated in this study.

2) Measurement Device

We performed the measurements using the NIRS (NIRStation OMM-3000, Shimadzu Corporation, Kyoto) and the subjects were required to wear a probe set on their heads. This probe set covered the DLPFC of the bilateral hemisphere (Fig.1).

Fig.1 Measurement of Brain Activity with the NIRS: Subject Wearing Probe Set and Fixing Eyes on One Point and Trying Not to Think of Anything.

3) Assessment of Brain Activity

In this study, we measured the changes of oxy-hemoglobin concentration as an indicator of cortical activity. The sampling rate was 100 msec (microseconds). We set the region of interest (ROI) over the DLPFC according to the atlas[13)]and calculated the mean concentration of oxy-hemoglobin in the ROI for each sampling time. We used a conventional block design. The baseline was a 60-second resting condition in which the subjects were asked to fix their eyes on one point, relax, stay calm and try not to think of anything. Regarding statistical analysis, we analyzed the average oxy-hemoglobin concentration during this 60-second interval as well as deviation of noises during each task.

Brain functions were considered “significantly activated” when the mean concentration of the oxy-hemoglobin while performing the cooking task became more than twice the standard deviation of noises during the baseline compared with the average concentration during the baseline.

4) Cooking Tasks

① Outline

The parent-and-child pairs prepared two dishes for lunch: ketchup-flavored rice with chicken and onion and tomato salad. To make the latter, they seared a tomato, took it in cold water and peeled it. Measurements of brain activities were performed using three tasks; searing a tomato, frying onions, and cooking rice with gas stove (Fig.2).

Fig.2 Measurement of Brain Activity with the NIRS: Cooking Rice
Subject asks her son to turn down the heat.

We informed all subjects prior to placing the probe sets on the subjects' heads, that because of the probe set, their range of mobility (i.e. ability to move their arms, reach, etc.) would be restricted while performing the task.

In addition, we informed both the parent and child that after the probe set was set in place and prior to the beginning of the cooking tasks, they were allowed to talk to each other while performing any part of the cooking tasks, but they were not allowed to talk to each other during the baseline measurements.

② Procedures

The procedures of the test were as follows:

ⓐ Parent or child places the probe set on his/her head.

ⓑ Parent and child move to the gas stove table.

ⓒ Parent and child fix eyes on one point, try not think of anything and remain standing for 60 seconds (baseline measurement).

ⓓ Parent and child stand in front of the gas stove.

ⓔ Parent and child sear a tomato with fire from the gas stove.

ⓕ Parent and child fix eyes on one point, try not think of anything and remain standing for 60 seconds (baseline measurement).

ⓖ Parent and child fry onions for 60 seconds.

ⓗ Parent and child fix eyes on one point, try not think of anything and remain standing for 60 seconds (baseline measurement).

ⓘ Parent and child cook rice with gas stove. (Using a pot with rice and water which is set on the gas stove, child first turns on the gas stove, and then turns down the gas stove when the water in the pot comes to a boil.)

ⓙ Parent and child fix eyes on one point, try not think of anything and remain standing for 60 seconds (baseline measurement).

Each parent-and-child pair performed the above procedures (ⓐ-ⓙ) twice. One time, the parent wore the probe set. The other time, the child wore the probe set. In 5 pairs, the parent wore the probe set first, and the child wore the probe set the second time. In the other 4 pairs, in an effort to nullify any influence of "order" on the results, the child wore the probe set first, and the parent wore the probe set the second time.

RESULTS

1. Daily Intervention Program of Parent-and- Child Cooking

The results are summarized in Table 1.

table1 Summary of the results of cognitive assessments

	Intervention Group			Control Group			
	pre test n=16	post test n=16	paired	pre test n=13	post test n=13	paired	
	Mean[1] ± SEM[2]	Mean ± SEM	t-test	Mean ± SEM	Mean ± SEM	t-test	ANOVA[3]
Digit -symbol	48.8 ± 4.6	52.2 ± 4.8	***[4]	53.8 ± 8.0	57 ± 6.0	*	ns
Memorizing nembers	1.3 ± 0.6	1.7 ± 0.6	*	1.3 ± 0.7	1.8 ± 0.8	*	ns
Conception	14.7 ± 3.4	16.8 ± 3.6	*	12.9 ± 3.2	14.8 ± 2.6	*	ns
Arranging	5.2 ± 1.0	5.5 ± 1.0	ns	4.8 ± 1.0	5.2 ± 1.0	ns	ns
Maze	7.3 ± 0.9	7.6 ± 1.0	ns	7.1 ± 1.1	7.6 ± 1.0	ns	ns
2-D	44.4 ± 15.8	50.4 ± 18.4	*	50.1 ± 13.9	54.8 ± 17.0	ns	ns
3-D	9.4 ± 3.6	11.1 ± 7.6	ns	9 ± 3.2	9.3 ± 3.2	ns	ns
Matching	53.6 ± 9.4	59.6 ± 11.5	*	61.2 ± 13.9	66.2 ± 15.0	ns	ns

1) Test score: Number of correct answers in measurement
2) Standard error of the mean
3) Analysis of Variance
4) *p<0.05 ＊＊＊p＜0.001

1) Measurement of General Cognitive Function

In the digit symbol test, no statistically significant difference of variation between the two groups was observed. The score of the intervention group improved from 48.8 to 52.2 ($p<0.001$) after the 3-month intervention program. Similarly, the score of the control group also improved from 53.8 to 57.0 ($p< 0.05$) during the 3-month period.

2) Measurement of Functions of the Prefrontal Cortex

In the memorizing test, no statistically significant difference of variation between the two groups was observed. The score of the intervention group improved from 1.3 to 1.7 ($p<0.05$). Similarly, the score of the control group also improved from 1.3 to 1.8 ($p< 0.05$).

In the conception test, no statistically significant difference of variation between the two groups was observed. The score of the intervention group improved significantly from 14.7 to 16.8 ($p<0.05$). The score of the control group also improved from 12.9 to 14.8 ($p< 0.05$).

In the arranging test, no statistically significant difference of variation between the two groups was observed. The score of the intervention group improved from 5.2 to 5.5 (ns) after the 3-month intervention program. Similarly, the score of the control group also improved from 4.8 to 5.2 (ns). However, no statistically significant difference was found in either group.

3) Measurement of Functions of the Parietal Cortex

In the maze test, no statistically significant difference of variation between the two groups was observed. The score of the intervention group improved from 7.3 to 7.6. Similarly, the score of the control group also improved from 7.1 to 7.6, during the

3-month period. However, no statistically significant difference was found in either group.

In the 2-D mental rotation test, no statistically significant difference of variation between the two groups was observed. The score of the intervention group improved significantly from 44.4 to 50.4 ($p<0.05$). The score of the control group also improved from 50.1 to 54.8, but no statistically significant difference was found.

In the 3-D mental rotation test, no statistically significant difference of variation between the two groups was observed. While the score of the intervention group improved from 9.4 to 11.1(ns), the score of the control group improved from 9.0 to 9.3(ns). However, no statistically significant difference was found in either group.

4) Measurement of Functions of Temporal Cortex

In the matching test, no statistically significant difference of variation between the two groups was observed. The score of the intervention group improved from 53.6 to 59.6 ($p<0.05$). The score of the control group also improved from 61.2 to 66.2, but no statistically significant difference was found.

2. Measurement of Brain Activity

In all subjects, activation of the dorsolateral prefrontal cortex (DLPFC), both the right and left hemispheres, was observed in each parent-and-child cooking task: searing a tomato, frying onions, and cooking rice with gas stove (Fig.3). No statistically significant difference was observed in brain activity of the DLPFC when comparing the activity during each separate task.

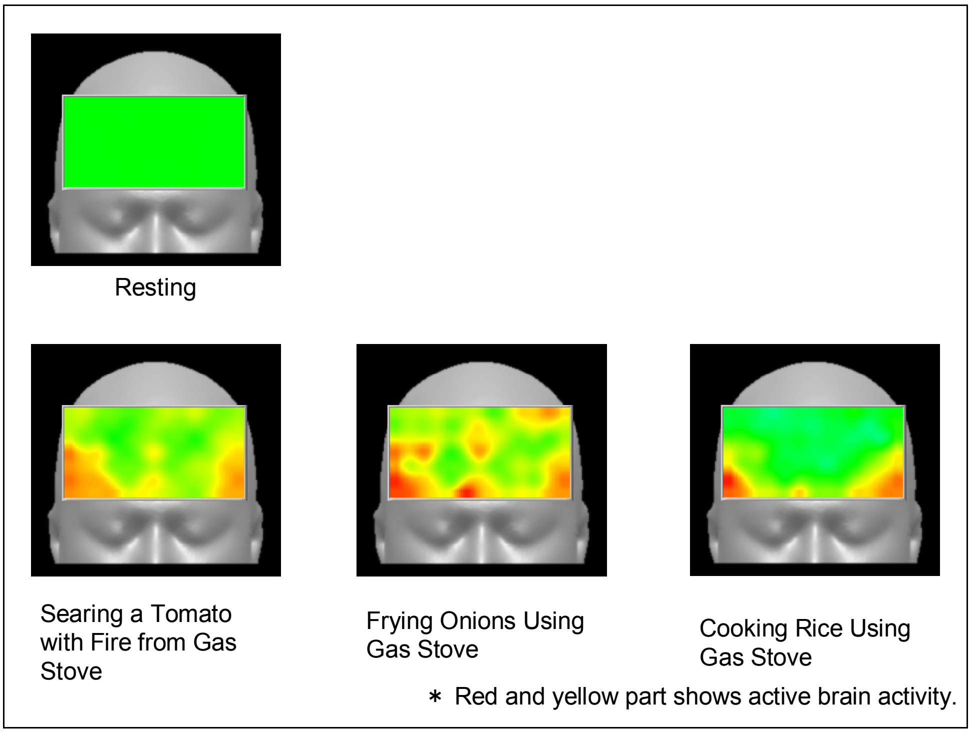

Fig.3 Brain Activation during Cooking Tasks (2-D Image)

DISCUSSION

In the daily intervention program, a statistically significant improvement of the scores was found in the intervention group, compared with those in the control group, regarding the 2-D test, which measures the functions of the parietal cortex, and the matching test, which measures the functions of temporal cortex. The parietal cortex controls coordination of both hands, and the temporal cortex controls mainly language functions. This improvement of scores indicates that these areas of the brain were stimulated by cooking acts and conversation while participating in cooking activities with the child. In the measurement of brain activity of parents with the NIRS, brain functions in the prefrontal cortex of both right and left hemispheres were activated in all of the cooking tasks. The activation was significant in the dorsolateral prefrontal cortex (DLPFC) which controls working memory, strategy, problem solving etc.

Concerning the difference of variation in the intervention program, contrary to the results of the children in our previous study, no statistical significance was found between the intervention group and the control group in the adult subjects. This may be due to the fact that parents of both intervention and control groups cook on a daily basis, thus negating any possible effect of the intervention program. One explanation which also supports this idea comes from a different study we had conducted in the past. In this study, we had conducted intervention cooking experiment programs on elderly males, and found that the brain activity of those males who cooked every day was stimulated [14]. On the other hand we had one father among the subjects in our intervention program. We can not exclude the influence of the gender of the parent.

Recognizing child's intellectual and emotional growth is important for mothers in order to obtain self-efficacy and self- confidence[1]. According to interviews, conducted after the program, children gained self-confidence by learning a variety of skills through cooking with the parent. And parents gained the opportunity to observe the child's intellectual and emotional growth which resulted in a higher self-efficacy regarding child-rearing. Iwahara et al. proved in their study on middle and elderly people that self-efficacy has effect on higher brain functions, especially for memory and verbal function [15]. Physical and mental health of mothers in child-rearing is affected by parenting stress[16][17]. Tachibana et al. proved that mother-child play activity has a beneficial effect on decreasing parenting stress[18].

Through parent-and-child cooking, parents not only teach their children how to cook, but also can attain a higher self-efficacy and a higher sense of fulfillment regarding child-rearing, which can decrease parenting stress. In addition, parent's brain functions are positively stimulated by these interactions. From this study, along with our previous studies, we have found that parent-and-child cooking is beneficial to both the parent and child.

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CHAPTER 5: CONCLUDING REMARKS

Chapter 1

Measurements of human brain activity when cooking using a near-infrared measurement device

The objective of this study is to measure brain activities. Measurements were obtained using a near-infrared measurement device (NIRS).

We performed the measurements of brain activity on 15 female adult subjects (mean age 45.3) while they conducted cooking activities, using a near-infrared measurement device (optical topography system). While the measurements were being taken, the subjects performed the following tasks; "planning a menu for dinner," "cutting ingredients," "frying the cut ingredients with gas," and "serving the dishes." In the optical topography system, a near-infrared light is directed at the head. This light passes through the skull and continues until it reaches the cerebral cortex. The information contained in this lights is related to the activities of the cerebral cortex. The cerebral cortex controls communication, self-care, creativity, thinking, memorizing, learning, self-control, emotional-control, vitality etc.

The results showed that the cerebral cortex of both hemispheres of the brain was activated during all cooking tasks. Thus, it can be concluded that cooking activities stimulate the cerebral cortex.

Chapter 2

Cooking improves the prefrontal functions of elderly males with an intervention method

The objective of this study is to prove that daily acts of cooking improve human brain functions.

We performed the daily intervention program, which involved cooking on 21 healthy male subjects aged 59 - 81 (mean age 68.5), during a three-month period. We conducted brain activity tests to measure the subjects' brain functions prior to and after the three-month intervention program. The results of the pre-test and the post-test were compared and analyzed. The brain tests conducted in the interview method were FAB

(Frontal assessment battery at bed side), Stroop, Topology Test, Digit-symbol test and MMSE (Mini mental state examination).

In the intervention program, the subjects attended a cooking course once a week in order to learn daily basic cooking techniques and cooked at home 15 - 30 minutes per day at least five times a week.

The results of the brain tests showed a statistically significant improvement in the scores after the three-month intervention program compared to before the intervention program.

From these results, we can come to the conclusion that daily acts of cooking can improve the abilities which are controlled by the prefrontal cortex of the brain and are associated with communication, self-care, self-control and emotional-control etc.

Chapter 3

Effect of parent-and-child cooking on cognitive functions of children: daily intervention program and measurement with near-infrared spectroscopy

The objective of this study is to demonstrate that a child's daily participation in parent-and-child cooking improves a child's brain functions.

We performed a daily intervention program of parent-and-child cooking, and measured brain activity using NIRS.

In the daily intervention program, 29 child subjects and their parents were randomly divided into two groups. The intervention group consisted of 16 children (mean age 8.9) and their parents. The control group consisted of 13 children (mean age 8.8) and their parents. The children and parents of the intervention group attended a cooking course once a week and performed daily cooking activities together during a three-month interval. Before and after this interval, 8 tests were conducted to measure the children's brain functions. The variations between the pre-test and the post-test measurements were statistically examined through a paired t-test. The results were analyzed to determine whether the variations were statistically significant or not.

In the measurement study, a probe set was placed on the head of 8 children (mean age 10.3), covering the dorsolateral prefrontal cortex. The subjects' brain activities were measured while subjects performed two cooking tasks; "making pancakes with gas stove" and "serving pancakes."

The results of the daily intervention program showed a significant improvement in subjects' score on the conception test for the intervention group. In addition, we found a statistically significant difference of the variation between the intervention group and the control group for the conception test and the 2-D test.

The measurement study showed that the prefrontal cortex of both the right and left hemispheres of the brain was activated during both cooking tasks.

Together with previous studies, our study, involving the daily intervention program and the measurement study, suggests the possibility of the development of a child's brain functions through parent-and-child cooking.

Chapter 4

Effect of parent-and-child cooking on cognitive functions of parent: daily intervention program and measurement with near-infrared spectroscopy

The objective of this study is to demonstrate the effects of parent-and-child cooking on the parent’s brain functions.

We performed a daily intervention program of parent-and-child cooking and, we measured the subjects’ brain activity while they conducted cooking activities using NIRS.

In the daily intervention program, 28 adult subjects and their children were randomly divided into two groups. The intervention group consisted of 16 parents (mean age 39.9) and their children. The control group consisted of 12 parents (mean age 38.8) and their children. The parents and children of the intervention group attended a cooking course once a week and performed daily cooking activities together during a three-month interval. Before and after this interval, 8 tests were conducted to measure the parents' brain functions. The variations between the pre-test and the post-test measurements were statistically examined through a paired t-test. The results were analyzed to determine whether the variations were statistically significant or not.

In the measurement study, a probe set was placed on the head of 9 parents (mean age 37.9), covering the dorsolateral prefrontal cortex. The subjects’ brain activities were measured while subjects prepared two dishes for lunch: ketchup-flavored rice with chicken and onion, and tomato salad. The parent-and-child cooking tasks included; ”searing a tomato,” “frying onions,” and “cooking rice with a gas stove.”

The results of the daily intervention program showed a significant improvement in the subjects’ scores on the 2-D test and the matching test for the intervention group. However, no statistically significant difference of variation was shown between the intervention group and the control group. This could be a result of the fact that the parents of both groups cook on a daily basis.

The measurement study proved that the prefrontal cortex of both hemispheres of the brain was activated while subjects performed all cooking tasks.

According to interviews conducted after the study, parents said after the parent-and-child cooking program that they not only could teach their children how to cook, but also could observe their child's intellectual and emotional growth. This enabled the parent to gain confidence and feel a strong sense achievement and well as a higher sense of fulfillment with regards to raising their child. In addition, parents' brain functions were positively affected by these interactions.

This study, together with our previous studies, demonstrates the effectiveness of parent-and-child cooking on both the parent and child.

Conclusion

We studied on the effects of cooking. We performed a daily intervention program, and measured the brain activities using NIRS.

In the daily intervention program, statistically significant results were found particularly in elder males and children. In the measurement study, we found an improvement of the brain activities in all subjects (females and parent and child pairs) regarding all cooking tasks. The results suggest that cooking has positive effects on human brain functions.

Cooking is an act which only human beings can do. It has and always will be an important act for us. We firmly believe that our studies, based on brain science, proved the positive effects that cooking has on human brains and also reaffirm the importance of cooking.

A List of Refereed Journal Articles

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CHAPTER 1: Measurements of human brain activity when cooking using a near infrared measurement device: optical topography system (in Japanese)
Machiko Yamashita, Ryuta Kawashima, Kazuki Iwata, Masaru Hotehama, Kochizu Tao, Mika Takakura (2006/09/30),
Journal for the Integrated Study of Dietary Habits,
17, 2, 125-129

CHAPTER 2: Cooking improves prefrontal function of elderly males with an intervention method (in Japanese)
Machiko Yamashita, Ryuta Kawashima, Sachie Mihara, Ikuko Fujisaka, Mika Takakura (2007/09/30),
Journal for the Integrated Study of Dietary Habits,
18, 2, 134-139

CHAPTER 3: Effect of parent-and-child cooking on cognitive functions of children: daily intervention program and measurement with near-infrared spectroscopy.
Machiko Yamashita, Ryuta Kawashima, Yuko Sassa, Kazue Yamamoto, Mika Takakura, Kimiko Minami, Tetsuya Onishi (2011/09/30),
Journal for the Integrated Study of Dietary Habits,
22, 2, 88-97

CHAPTER 4: Effect of parent-and-child cooking on cognitive functions of parent: daily intervention program and measurement with near-infrared spectroscopy
Machiko Yamashita, Yuko Sassa, Kazue Yamamoto, Mika Takakura, Kimiko Minami, Tetsuya Onishi, Motoko Matsui, Kimiko Otani, Ryuta Kawashima (2012/12/30),
Journal for the Integrated Study of Dietary Habits,
23, 3, 154-160