Relationship between Food Intake and Finger Plethysmograms

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Abstract: The purpose of this manner of research was to investigate the influence of food intake on the human body, by means of data showing the chaotic fluctuations of fingertip pulse wave, through the use of nonlinear analysis. For the measurement of the fingertip pulse wave, 5 types of meals were utilized, using both meals where a single person ate alone with no conversation, and meals where several persons ate and conversed, using water, hot soup, and cold soup, measurements were taken at various times (just before food intake, just after food intake, and 30 minutes after food intake). At result, with meal intake, there was a temporary and significant drop in LLE levels, followed by a rise in LLE when several persons ate and conversed. Most of the participants saw little change in levels after intake of cold soup, or water. With intake of hot soup, it was observed that a little climb in LLE levels 30 minutes after eating. Many people increased levels from heat stimulation of the sympathetic nerve, then afterward a decrease, and there is speculation that there is a kind of "relaxation effect". It seems evident that partaking of warm food while in the company is a good practice.

1 INTRODUCTION

In regard to meals, one's diet has a physical and emotional effect on maintenance of life activities, maintenance and quality of health, recovery from and prevention of disease, enjoyment of life, a sense of contentment, seasons of life, etc. Also, in societal relationships, communication and enjoyment of one's family, cultural traditions, cultural aspects regarding ceremonial occasions, etc., diet has a large role and meaning, and is an essential part of daily human life.

In recent years, in dual-income families, generally speaking, in relationship to daily lifestyle in society, eating alone, always eating the same food, unbalanced diet, dependence on "fast food", etc., has become a real problem. Because of this, in kindergartens, elementary schools, and junior high schools, there has been an increased realization of the importance of "nutrition education". In a survey (Shinohara 2012), where there is a great deal of instruction regarding proper diet, the effects of "concern for good eating", "manners", "rhythm of daily life", "proper body weight", "proper bowel movement", etc., can be clearly seen. Where children are given good instruction in nutritional education, the importance of good diet has become very evident. Outside of activities to promote nutritional education, there has been an expansion of research in the following areas: studies involving the effect of food aroma (Kunieda 2011), research in improvement of dietary habits (Fujita 2012), studies regarding eating/swallowing disorders in nursing care facilities (Okada 2009).In addition, when measuring levels of Chromogranin A found in saliva, research showing the correlation between diet and relief from stress, as well as levels of Cortisol found in the bloodstream and levels of active NK cells reveal the level of enjoyment of meals, research into the influence of eating and exercise on the value of oxidation stress markers, and information regarding the value of diet on the living body can be observed.

However, regarding the relationship of diet and brain activity, various research has been conducted where brain waves are measured in connection with food aroma (Sumiya 2007, Ishiguchi 2008), but there are only a few articles that deal with prevention of dementia in elderly persons by controlling diet, and research using information regarding how diet itself affects brain activity in living persons is lacking. By analyzing the fluctuation of the fingertip pulse wave, data regarding the effect of the Largest Lyapunov Exponent (LLE) index upon brain activity, as well as

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information related to balance of the autonomic nerves can be obtained. By obtaining information on how eating cause fluctuation of the fingertip pulse wave, more understanding can be gained as to the influence of diet upon the human body. Knowledge regarding the meaning of human lifestyle and diet, obtained by data collected from these kinds of measurements is thought to be both objective and meaningful. Also, with Oyama and others, based on the outcome of advances in research by observing fluctuation of the fingertip pulse wave, information regarding brain activity has been newly obtained, and comparisons of fingertip pulse wave and its correlation to food intake have been observed.

The purpose of this manner of research is to investigate the influence of food intake on the human body, by means of data showing the chaotic fluctuations of fingertip pulse wave, reflecting variations of brain activity, through the use of nonlinear analysis technique.

2 METHOD OF STUDY

2.1 About a Finger Pulse Wave and Calculation of Lyapunov Exponent

By means of nonlinear analysis of data from fluctuations in fingertip pulse wave, it is possible to obtain a numerical value of "mental revitalization", using the Largest Lyapunov Exponent index value. Using advanced research methods, effectiveness of various activities directed at mental health can be verified. Also, using data gathered from fluctuations of fingertip pulse wave, it is possible to determine autonomic nerve balance (whether the sympathetic nerve or parasympathetic nerve is dominant).

Figure 1 shows the flow diagram showing the procedure from the measurement of pulse waves to calculation of the Lyapunov exponent (Oyama 2006). To construct the attractor, we set a delay time and the number of embedding dimensions according to Tarkens theory. We used four embedding dimensions and a delay time of 50 msec. The figure on the right illustrates the method of embedding in three-dimensional phase space. Although effective information can be obtained from the shape of the four-dimensional attractor, we calculated the Lyapunov exponent, which is an index of trajectory instability and has a chaotic characteristic. (Figure 1)

By measuring the fingertip pulse waves for one minute, 43 Lyapunov exponents are obtained. We compared each condition using an average of these values (Oyama 2007).

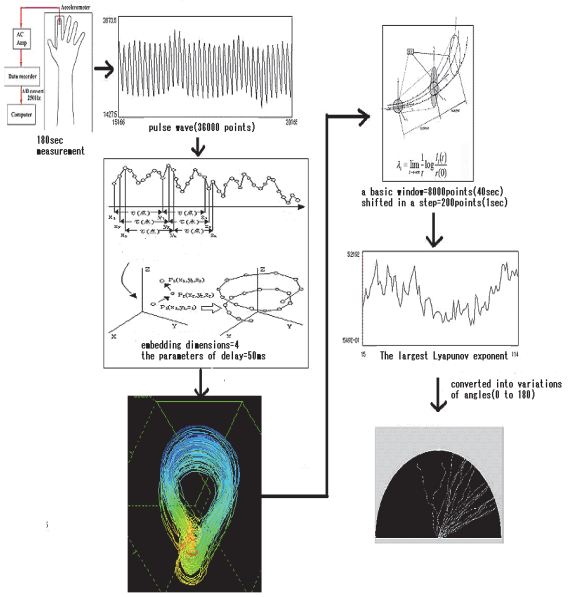

Figure 1: Flow diagram showing the procedure from the measurement of pulse waves to calculation of the Lyapunov exponent.

2.2 Method of Measurement

2.2.1 Study Subject

For this research, 20 students currently enrolled between the 2nd and 4th year of studies at "N" University were used. All of the participants were female, from 20 to 22 years of age. All were in generally good health, with no known mental or physical abnormalities. Before sampling fingertip pulse wave of the participants, vital signs (body temperature, heart rate, blood pressure) were measured each time, and no one showed any abnormal condition. The number of times the experiment was conducted varied according to food intake, from 1 to 5 times. In order to make comparisons regarding intake of water, hot soup, and cold soup, the same individuals were utilized.

2.2.2 Study Location

"N" University, located in "H"

2.2.3 Study Period

January, 2013

2.2.4 Measurement Detail

With each of the participants, personal data was collected and prior explanation of the experiment

was given, and care was given to insure adequate ethical treatment of those involved. In addition, a consent form was obtained from each participant, documenting their willing cooperation with the research.

On the day of the experiment, each participant's vital signs (body temperature, heart rate, blood pressure) were measured, and verification was made that there were no signs of unusual physical abnormality, prior to commencement of the experiment.

For the measurement of the fingertip pulse wave, 5 types of meals were utilized, using both meals where a single person ate alone with no conversation, and meals where several persons ate and conversed, using water, hot soup, and cold soup, measurements were taken before and after eating. At various times (just before food intake, just after food intake, and 30 minutes after food intake), 3 different readings were taken. For obtaining the measurements, a chaotic Lyspect device was utilized. A cuff was used with the device, and placed on the tip of the participant's right index finger, and each time a measurement was taken for 3 minutes. The subjects were asked to sit in an armchair, and rest their arm quietly on a table for the duration of the measurement. During measurement, the subjects were asked to not speak and maintain a quiet, unmoving position. A plan was followed where in a single experiment 5 people were observed and their readings were taken. In accordance with the measuring devices, the beginning of each experiment was carried every 5 minutes.

For the environment used in taking the measurements, the subjects were asked to not communicate with one another, and a large, quiet room was used. The room temperature was 22 degrees C. The participants were seated separately in armchairs at tables, and after taking the pre-experiment readings were allowed to eat. After taking the reading immediately following the meal, the subjects were asked to sit quietly and look at picture books. In order to prevent any influence of written words on the body, picture books with no words made by artist Anno Mitsumasa were used exclusively.

The room where the subjects ate while communicating was comparatively small, but was free of noise and the room temperature was maintained at approx. 22 degrees C. The participants sat around tables, and enjoyed pleasant conversation while eating the meal.

The meal consisted of store-bought sandwiches and onion soup (150 ml.). The sandwich size was an amount such that the female college students were sufficiently full after eating. The hot and cold soups were store-bought creamed corn soup (180 ml.), and were consumed either after heating, or after taking directly from the refrigerator.

Analysis of the experiments was conducted using Lyspect software on computer, but data regarding fluctuation of fingertip pulse wave was analyzed immediately using nonlinear analysis technique.

3 RESULTS

3.1 Meal Intake

There were 10 participants who ate their meal alone, one person at a time. During the meal, there was no communication interaction with others. 5 individuals were 2 groups of 5 people, and the experiment was conducted 2 times.

7 participants ate a meal with pleasant communication. One group consisted of 5 members, but due to absence of some members, so the remaining groups worked in pairs, conducting the experiment 2 times.

3.1.1 LLE Index Values for Those Who Ate Alone

1) 4 participants saw elevated LLE index levels immediately following the meal. Of this group, 3 saw levels initially drop, and then rise again. And 1 individual saw the LLE level climb gradually.

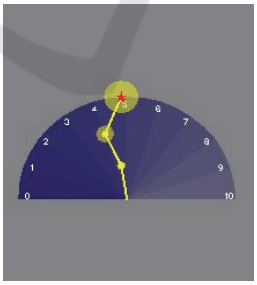

Figure 2: No.3's LLE.

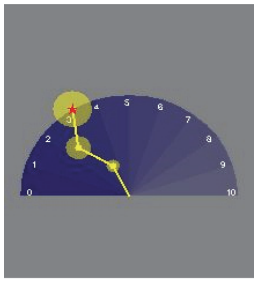

Figure 3: No.9's LLE.

2) 3 participants saw LLE index levels drop immediately following the meal. Of this group, 2 saw levels gradually drop, and 1 person saw their level greatly increase and then decrease.

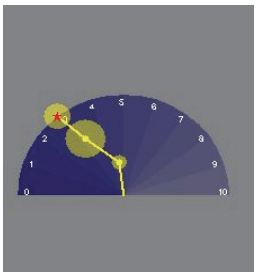

Figure 4: No.5's LLE.

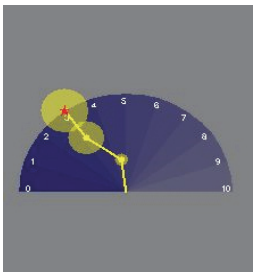

Figure 5: No.7's LLE.

3) 3 participants saw either no change or only very slight changes in their LLE index level.

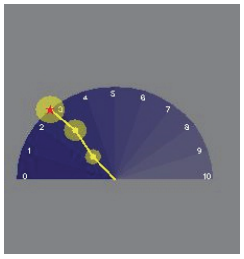

Figure 6: No.6's LLE.

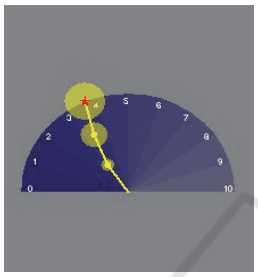

Figure 7: No.10's LLE.

3.1.2 LLE Index Values for Those Who Ate While Visiting with Others

1) 4 individuals saw LLE index levels increase after the meal. Of this group, 3 people saw their levels increase after temporarily seeing a sharp decrease.

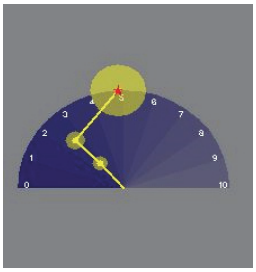

Figure 8: No.16's LLE.

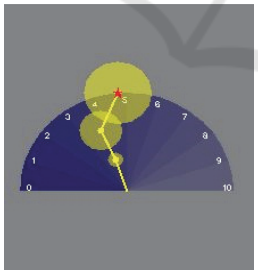

Figure 9: No.23's LLE.

2) 1 person showed almost no change in LLE index levels after the experiment. This person experienced a temporary rise and fall of the level, with the final level nearly equal to the original level.

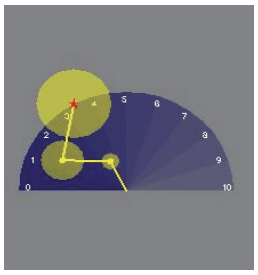

Figure 10: No.15's LLE.

3) 2 participants saw LLE index levels drop. However, they saw a large drop and then a large increase in the levels, and while there was a great fluctuation, the final level was nearly the same as before the experiment began.

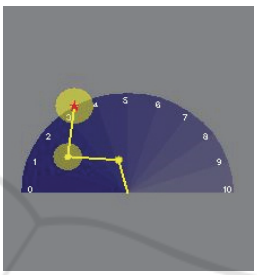

Figure 11: No.13's LLE.

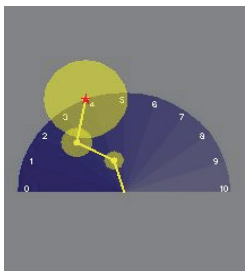

Figure 12: No.22's LLE.

4) 5 individuals saw their LLE levels rise after completing the meal. Only 1 person saw their level decrease immediately after eating, and only one person saw nearly no change to their level.

There was a marked result in that many saw very little fluctuation of their fingertip pulse wave.

3.1.3 Autonomic Nerve Balance Levels after Meal Intake

There were many individuals who saw rise in sympathetic nerve activity immediately following food intake. Among 17 participants, 13 experienced this. By chewing food and movement of the jaws, and by intake of warm food, it is thought that sympathetic nerve activity was stimulated. This is attributed to increased nervousness and bodily activity. Athletes experience the same kind of thing when they chew gum.

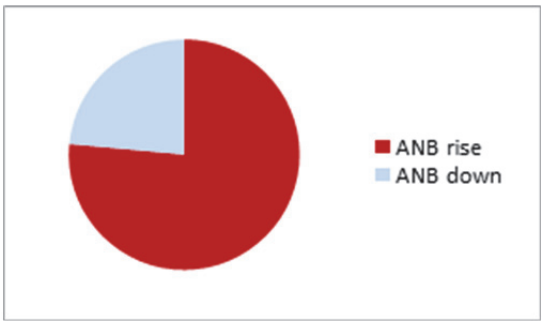

Figure 13: Autonomic nerve balance following food intake.

Among 17 participants, 11 people saw a mountain-shaped drop in levels 30 minutes after food intake. That is, immediately following food intake there was a temporary dominance of sympathetic nerve activity, and then with the start of digestion, within 30 minutes there was a shift to dominance of the parasympathetic nerve activity.

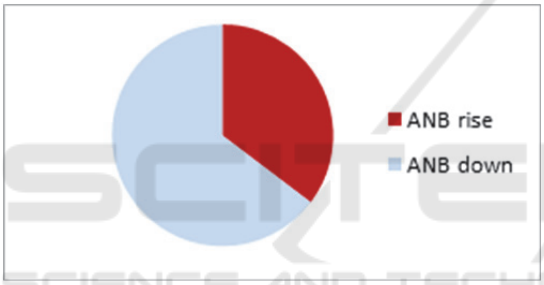

Figure 14: Autonomic nerve balance 30minutes after food intake.

3.2 Intake of Hot Soup

There were 13 participants who ate hot soup. Groups of 3-5 members were formed for the experiment.

3.2.1 LLE after Hot Soup Intake

1) 8 people showed little change (nearly flat reading on chart)

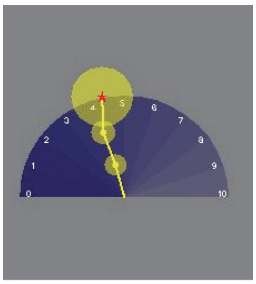

Figure 15: No.3's LLE.

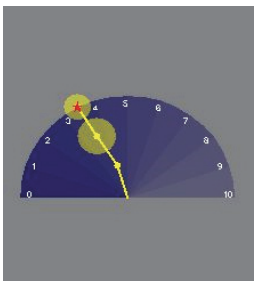

Figure 16: No.4's LLE.

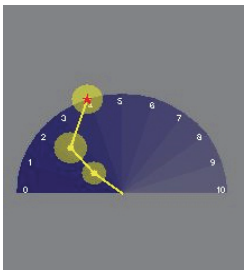

Figure 17: No's LLE.

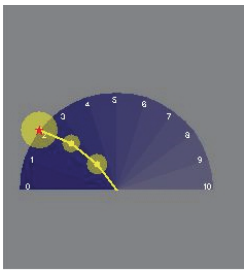

Figure 18: No's LLE.

2) 3 people showed a slight increase (no decrease after eating)

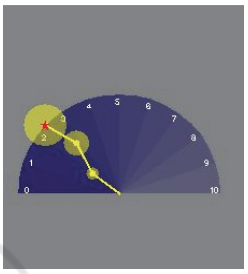

Figure 19: No.2's LLE.

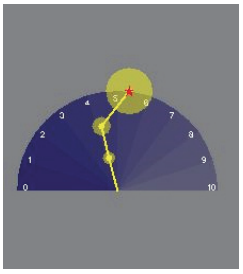

Figure 20: No.11's LLE.

3) 2 people showed a marked decrease, then an increase (of these, 1 person's final reading was lower than start)

3.2.2 Autonomic Nerve Balance Levels after Hot Soup Intake

1) 8 people showed sympathetic nerve increased activity immediately following meal (marked increase)

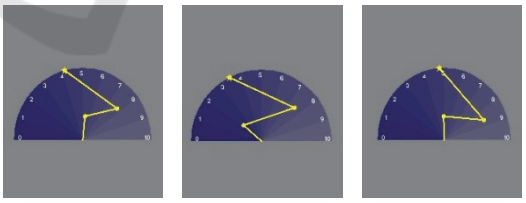

Figure 21: No.6, 11 and18's autonomic nerve balance.

2) 7 people showed a mountain-shaped increase, then decrease of autonomic nerve balance.
3) 4 people showed sympathetic nerve decreased activity immediately following meal
4) 1 person showed no change
Warm drinks (hot milk, etc.) will cause drowsiness with some people.

3.3 Intake of Cold Soup

13 individuals drank cold soup, and measured their fingertip pulse wave before and after the meal.

3.3.1 LLE after Cold Soup Intake

1) Out of 13 people, 8 people showed little change in readings before, immediately after, and 30 minutes after food intake.

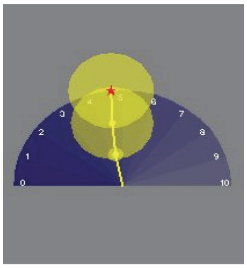

Figure 22: No.1's LLE.

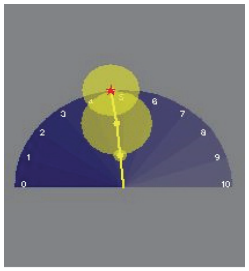

Figure 23: No.3's LLE.

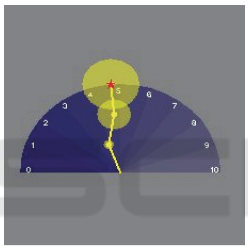

Figure 24: No.4's LLE.

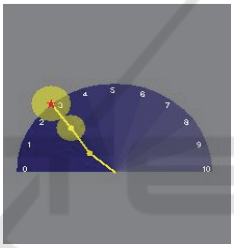

Figure 25: No.14's LLE.

2) 3 people showed an increase in LLE.
3) 1 person showed a temporary rise in LLE, followed by a decrease, and then a return to the same level as before the meal.
4) 1 person showed a temporary rise in LLE, followed by a decrease to a level lower than before the meal.

As with eating meals and drinking hot soup, there was not one case where a person saw a temporary drop in LLE followed by a large rise.

3.3.2 Autonomic Nerve Balance Levels after Cold Soup Intake

1) 8 persons showed a decrease in levels in the period from before the meal until 30 minutes afterward (when the 3rd reading was taken).
2) Among these, 6 people saw a steady decrease in levels from immediately after eating until 30 minutes later, and 2 people saw levels temporarily rise sharply, followed by a decrease to lower than original levels.
3) 2 people saw increased levels after the experiment.
4) 2 people saw little change in levels.

The body temperature may decrease.

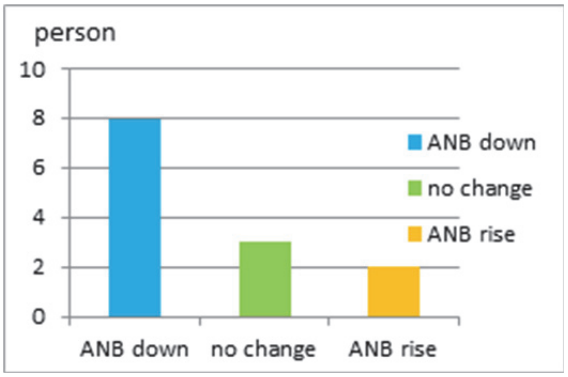

Figure 26: The change of autonomic nerve balance after cold soup intake.

3.4 Intake of Water

12 individuals took readings of their fingertip pulse wave before and after drinking water.

3.4.1 LLE after Water Intake

1) From 12 people who took readings before, immediately after, and 30 minutes after drinking water, 5 persons showed little change in LLE levels

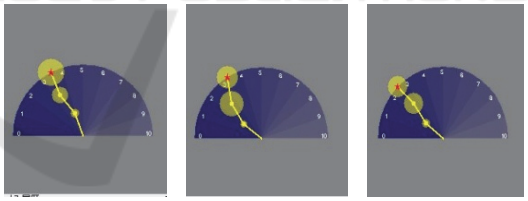

Figure 27: No.4, 14 and18's LLE.

2) 4 people showed an increase in LLE levels. Among these, 3 people saw an immediate rise, and 1 person saw a temporary drop in LLE, followed by an increase.
3) 3 people saw an immediate drop in LLE levels.

3.4.2 Autonomic Nerve Balance Levels after Water Intake

1) 5 people experienced an increase in comparison of readings before water intake (1st reading), and 30 minutes after water intake (3rd reading).
2) Among these, 3 people showed a temporary decrease in levels just after water intake, followed by an increase. 2 people saw an immediate rise in

levels. 1 person saw an initial rise, followed by a decrease.
3) 5 people saw a decrease in comparison of readings before water intake (1st reading), and 30 minutes after water intake (3rd reading).
4) Among these, 3 people saw a temporary slight rise in levels immediately following water intake, and then a drop to levels lower than before intake. 2 people saw a drop in levels, followed by an increase to a back to a level lower than at the beginning.
5) 1 person saw only a slight change in their levels.
6)- All told, the split between people who saw a rise after water intake, and those who saw a drop was 50/50.

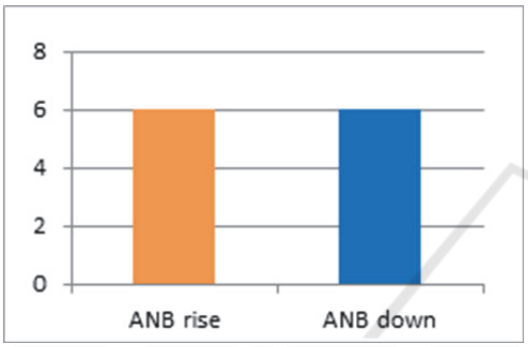

Figure 28: Change of ANB after water intake.

Because of cold soup and corn pottage, and because of long periods of time where the stomach was in a cold condition, it is considered that this is why there was a small proportion of persons whose levels rose 30 minutes after food intake. In the case of water, it is thought that this is due to absorption of the water within 15 minutes of intake.

4 CONCLUSIONS

With food intake, the frequent pattern was that immediately following a meal, there was a temporary and significant drop in LLE levels, followed by a rise in LLE. Most of the participants saw little change in levels immediately after intake of hot soup, cold soup, or water. By observing this only, it was learned that meals have a significant influence on the body. When well-chewed food enters the stomach, it appears that the brain's natural response is to trigger a "digestion" bodily activity, and due to a change in blood flow, it is thought that the LLE level, which indicates temporary brain activity, is lowered. It has been verified that LLE shows the adaptability of the outer portion of the mind, however, "immediately following food intake" centers on the act of eating, so it is understood to be a natural result that LLE adaptation in the outer portions become less. Therefore, when a major activity is being undertaken, before a test, ensuring that participants do not have a full stomach is considered the appropriate means, and is verified by bodily information. However, in the group where several people enjoyed a meal and afterward had enjoyable conversation together, LLE levels in everyone increased, and participants' sense of awareness was also much enjoyed. When considering that these participants' felt the food was delicious and were totally satisfied, it was realized that it is desirable to enjoy meals with close friends or family, and even though LLE levels immediately following eating were low, after this there was a great shift with LLE levels increasing, and an increase of mental activity.

Regarding results immediately following food intake, it was observed that many individuals saw the sympathetic nerve become dominant. However, as mentioned above, movement of the mouth and chewing activity is considered to cause a sharp increase in sympathetic nerve activity. In order to see parasympathetic nerve domination within 30 minutes of eating, activity like making the mouth move by chewing gum is thought to be effective. For this study, because the setting involved food intake, the phenomenon of decreased LLE levels immediately following food intake was seen, but there is a great interest to verify what effect simply chewing of food has on LLE levels. From the results of this survey, since it was observed that following food intake the parasympathetic nerve became dominant, it is obvious that, as expected, "rest from food" becomes necessary. Hypothetically, predicting that food intake has a healthy effect on the mind, it was possible to predict that after food intake LLE levels would rise. However, it was observed that initially LLE levels dropped before rising, and following the meal parasympathetic nerve activity and digestion activity commenced, and it was observed that resumption of work activities while the body experienced rest from food was appropriate. It is obvious that the activity of eating food is a significant source of work in humans, and an important activity in daily life

However, for participants of the group who took their meals alone, there were many cases where LLE levels either immediately lowered, or had very little fluctuation. This group included individuals who always were relaxed while eating and then became drowsy, and were aware of the effect of eating. In this way, it could be observed that there are varying

levels of awareness as to the effects of eating on the body, and that for about 30 minutes after food intake, many people experience mental fatigue.

With intake of only small amounts of soup, LLE levels fluctuated very little. However, with intake of hot soup, it was observed that a significant number of participants who initially experienced little LLE fluctuation did see a climb in LLE levels 30 minutes after eating. Many people increased levels from heat stimulation of the sympathetic nerve, then afterward a decrease, and there is speculation that there is a kind of "relaxation effect" that they experienced. It seems that if a person wishes to be calm and relaxed, drinking something warm is effective. Similar to the fast absorption of plain warm water, for this experiment we used pottage soup, warm milk, kudzu starch gruel, etc., and it seems that hot beverages for comparatively long times in the stomach are beneficial.

Regarding intake of cold food, since it appears that there are many people whose LLE levels and autonomic nerve balance see little variation, it is thought that rather than cold food, hot food has a better effect on the body.

For participants who drank water and after 30 minutes saw a rise in sympathetic nerve dominance, it is believed that the result of seeing low levels after taking cold pottage soup is due to the fact that absorption of the liquids is rapid.

From these results, it seems evident that partaking of warm food while in the company of friends or family is a good practice. In Japanese society, the recent and rapid increase of young people and elderly who live alone and eat cold food appears to be a hindrance to overall health of the mind and body, and adversely affects quality of life. It seems obvious that eating of meals and good nutrition are very necessary for QOL (Quality of Life), and that this has been verified by the readings measured in the human body during this experiment.

In the future, it seems apparent that more research should be done to investigate the effects of what occurs when one eats food that is liked, what is the optimum environment and time for meals, as well as other variables.

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