Thesis for Doctorate

Research on the Phonetic Recognition of Feelings and A System for Emotional Physiological Brain Signal Analysis

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Summary

Human mind and emotions, which may belong to the fields of psychology, medicine or bioscience in academic terms, have long been out of the scope of scientific quantitative research. Feelings are somewhat elusive and therefore difficult to experiment with since people may feel differently with the same kind of stimulation. Or feelings may fluctuate in subtle ways due to minute changes of circumstances or conditions. On the other hand, it is known to everyone through experience that facial expressions and vocal tones react to inner feelings. There has therefore been much research on how such phenomena can be utilized for the objective valuation of human feelings, with no methodology established to date due to the fact that nothing but the person's subjective claim can tell how any specific person may feel at any specific point in time. In short, there is no way to define, let alone measure, human feelings by any means. This is what hinders scientific approaches to feelings and emotions. Having said that, however, there have been a few scientific approaches to the subject. Historically, hypotheses such as feelings are "physical reactions," "nervous reactions" and "matters of recognition" have been presented and all of these were to some extent "proven" to be plausible through experiments. The author tried to penetrate deeper into the arena of feelings by introducing a new classification of "emotions" as physiological phenomena and "feelings" as perception through recognition. And the first step was to establish a Feeling Analysis System for the scientific research of feelings. To start with, "Emotions" are defined as physiological reactions,. If an "emotion" arises, it must be associated with physical change in brain, vocal chords, pulse, hormones, motion, expression or speech. Vocal tones were chosen by this research because they are easily captured and analyzed for correlation with emotions. It has been known that vocal tones are affected readily by state of mind but anatomical closeness between the vocal chords and the part of the brain that controls emotions induced the author to consider the idea of possible phonetic recognition of feelings. After numerous trials of traditional analytical methods such as spectrum analysis and others, the author succeeded in isolating fundamental frequency from noise signals. By combining the frequency with amplitude of the voice and its variation, it has now become possible to quantify the level of emotions with considerable accuracy and this has been established as Vocal Emotion Analysis or VEA. "Emotions" are physiological but "Feelings" are defined as labels that are derived through human recognition process. An automatic labeling mechanism was developed by having multiple appraisers categorize thousands of vocal records into anger, joy, sorrow and ordinary feeling categories and decide the excitement levels. The author formalized the decision-making process as a general algorithm. The experimental results show that the valuation of the excitement levels is fairly universal or independent of the individuality of the appraisers. On the other hand, categorization is quite dependent on the appraiser and this confirmed the general belief that other people's feelings can be hard to identify in general terms. Comparison of VEA and brain fMRI suggested a relationship between "Emotions" and the motion of periphery portions of the brain. Technical innovations achieved through this research include: the algorithm that allows reasonably accurate valuation of human emotions and subjective feelings based on voice tones, without using conventional analysis methods such as Possibility Model or Neural

Network, and its realization in the form of VEA; noise suppression mechanism that effectively suppresses 80dB from 130dB fMRI and thereby exposing fundamental frequency; a real time analytical system to simultaneously measure brain-, vocal- and physiological signals as well as emotions as the output of VEA; a stable isolation method of fundamental frequency from the vocal tones which had been difficult by conventional technology; and, the discovery of standardized emotion level that shows accordance between appraisers. This series of experiments confirmed that almost all indications of vocal tone feelings contain emotional elements and that data was utilized in the analysis of physiological brain signals for feelings and emotions. These findings will enable observation of feelings and mental status directly related to the cerebral state by use of phonetic recognition and scientific criteria of emotions and feelings. The study introduced a classification of "Emotions" as physiological phenomena and "Feelings" as labels through recognition process and has proven that "Emotions" are objectively identifiable and that "Feelings" on the other hand are elusive- often undefinable even to the person experiencing them.

Keywords : Basic problem of feelings (emotion) , Cognitive problem of feeling (emotion), Passive feelings (emotion) evaluation, Active feelings (emotion), Subjectivity, Introspection, Subject, Drive, Incentive, Fundamental frequency , Mask mike, fMRI, VEA

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Chapter 1

Introduction

The human mind and human emotions are difficult to measure and standardize; standardization thereof requires a collaborative, cross-sectional study over the fields of psychology, medicine and science. Moreover, due to the incompletion of sensor technology development (in engineering), to this date science has not been able to adequately quantify human emotions. Both psychology and cognitive sciences have not reached the conclusion as to how emotions are formed.

Meanwhile, the late 1990s saw the first trials of emotional sensing technology, where facial and vocal expressions were recorded for emotion recognition. However, conventional emotion recognition research has fallen short of taking into account the impact of environmental factors on human emotions, placing the standard on subjective human claim in the past years of research [10][11] [12] [13][14][15][16][17][18] [19][20] [21][22][23][24][25][26][27].

It can be easily inferred that the human perspective is readily affected by surrounding environments and changing circumstances. This brings us to the point of selecting the right standards and a system that corresponds to human subjectivity. My hypothesis on emotional mechanisms refers to past findings of physiological and psychological research, and utilizes emotions categorized from past emotional research. Basing on this hypothesis, I was able to achieve vocal emotion recognition and examine the fluctuations of human subjectivity. Thorough medical examinations (clinical tests) are crucial to the validation of my hypothesis of emotional mechanisms. As sensing technology is a key factor to this study, I constructed a system that analyzes the brain's signals of emotions.

In this thesis, it is assumed that human sentiments are at any time subjective and fall into one of the two following categories: "emotions," which are physiologically driven, and "feelings," which are labeled in perceptive recognition. The hypothesis of conscious sentiments is drawn from these two reactions. I utilized the relations among voice, brain and hormones, to compare voice and physiological reactions with emotions and feelings.

Physiologically vocal chords are directly related to the part of the brain that controls emotions. Knowing that fundamental frequencies originate from vocal chords, I created the Vocal Emotional Analysis (VEA) system. The VEA utilizes parameters and logics of human subjectivity, to identify emotions and degrees of intensity through capturing real time voice in a computer. This system analyzes human subjectivity and assigns the category of emotion, while minimizing the factor of environmental influence. Using the real time VEA display system, I was able to compare evaluations of the individuals' introspection (taken directly after speech), subjective perspective (taken a certain period of time after speech), and from a third person's perspective. The established system displays voice parameters, analyzes corresponding feelings from voice, and compares them to human subjective claim.

I established the experimental mechanism necessary to examine cause and effect relation among human subjectivity, introspection (inner feelings), and emotions. Using this method I was able to conduct an analysis of emotions comparing voice to human subjectivity and introspection. As a result I was able to prove the concept of perceptive recognition, and verify the traits of emotions and feelings through comparing VEA evaluation logic with human subjective claim.

Using the above comparisons, I was able to establish that firstly, feelings are "labels assigned based on human subjectivity and introspection," secondly, that "emotions are constant standards despite of human subjective claim," and lastly that "both emotions and feelings are strongly related to fundamental frequencies of the vocal chords."

As a result, I am able to validate my hypothesis that feelings (anger, happiness, sadness) are labels assigned from human subjective claim, that vocal chords show emotional excitement, and that recognition and external factors influence one's subjectivity. The methods

By stimulating the mind with images, I measured physiological responses (heart rate, blood pressure, eye movement etc.) and brain image analysis (fMRI), basing my method on the physiological drive of emotions and brain activity. Additionally, the preliminary experiments of this method indicated the relations between emotions and the limbic system.

Additionally, in fMRI of 130dB, by canceling out noises of 80dB with a masked microphone, the method proved to be successful in detecting fundamental frequencies. Employing the masked microphone and the VEA, subjects with their heads secured, speaking with conversation partners outside of the fMRI, real time detection of brain activity was achieved. At the same time, through looking at the dispersion and range of displayed fundamental frequencies, I was able to determine the emotional excitement level of the subjects.

I compared the method of VEA to the conventional cepstrum technique to verify the degree of precision. To do so I displayed both the proposed VEA and the cepstrum simultaneously, created a tool to display voice cadence, utilized a conversation where both subject and partner with emotionally elevated, and compared the frequencies to the cepstrum technique.

Making use of results from testing of real-time brain activity, physical reactions and detection of fundamental frequencies, this study was able to accomplish the quantification of the "heart" and human emotions, and to establish an analytical system of the brain's emotional signals.

1.1 Research Background

There is a need for a technique where machines can detect human emotions without the distance that is felt between human and machine. Human beings estimate one another's emotional states from facial expressions, conversational content, the surrounding environment and contextual references. Human beings are able to gather and receive such complicated information and make educated guesses on another person's emotional state (hereon referred to as passive emotional evaluation). Research on emotions and natural languages in this perspective is abundant. [28][29][30] [31] [32][33][34] [35][36][37] [38][39][29] [40][41][42] However, even professional analysts and doctors cannot fully comprehend another human being's mental or emotional state (hereon referred to as active emotions). Additionally, there are no traces of research on both passive and active emotions using computer sciences. In this case, since there is no evident cause and effect link based on theoretical knowledge, it is essential to draw a hypothesis based on past research results. The hypothesis should also include a cause and effect relationship that is to be proven, and provide the solution as to how to demonstrate this association.

Machines, able to recognize emotions through human voice and respond using a predetermined scenario database, have been developed in the past. The unfolding of the scenario corresponds to the emotions that are detected. Since humans convey emotion in the cadence of their speaking voices, the same voice recognition utilized by electronic dictionaries and the pickup of rhythm were used to create this system.

However, in the actual application of this system, the system fell short on conducting accurate voice recognition. To solve this issue, voice recognition and emotion recognition functions were separated, and the focus shifted to rhythm to detect emotion. On the other hand, depending on the evaluator's subjective perspective, discrepancies with emotion recognition appeared. This indicates that there is no absolute, objective answer in assessing emotions. With this in mind, there is the need to create an environment where scientific observation, the quantification analysis of emotions, is possible. [43]

1.2 Research History

The study of emotions, contradictory to common perceptions, has been overlooked for over a century in what can be said to be the most of psychology research history [44]. In her 1991 publication, Carroll E. Izard points out that, although the importance of emotions has always been recognized since ancient times, psychology has neglected the study of emotions until the 1980s. Izard claims that it is not possible to study human beings without understanding their emotions scientifically [45]. Apart from the field of psychology, current developments in image-analysis of brain activity and the medical treatment of mental disorders have been able to achieve scientific, physical examination of the human "heart"[7][46][8][44][47][48][9]. Nevertheless the analysis (or quantification) of emotions/feelings have yet to be accomplished in these disciplines. It is until recent times that relations between brain activity (particularly in the peripheral region) and emotions (or excitement) have been verified by a number of studies [49][50][51] [52][53][54][55][56] [57] [58][59][60] [61][62][63]. This is noted in Antonio R. Damasio's study published in 2003, 「Looking for Spinoza: Joy, Sorrow, and the Feeling Brain」. Change in emotions and brain activity during conversations have not been confirmed in research, however. Physiological studies of feelings and facial muscles[64] [65] [66] [67] [68] [69] are existent. The following section goes on to discuss past research in emotions.

1.2.1 The Fundamental Problem of Emotions

The most famous debate in the study of emotions is perhaps that of James-Lange(1890) vs Cannon-Bard(1927) vs Schachter-Singer(1964). James-Lange argues that feelings are physiological elements [70][71], while Cannon-Bard reasons that they are tied to brain nerves [72][73], and Schachter-Singer who claims that humans misinterpret their own emotions due to environmental surroundings [74].

The three theories described above have not come to a solution. I will refer to this debate as the "fundamental problem of emotions," and the conflict of the theories as the "problem of emotional perception, " and examine the issues in this study.

Details of the fundamental problem of emotions are listed below.

James-Lange's Theory

- Emotions originate from physical perceptions
- Emotions occur in this order: external stimulation - physical reaction - acknowledgement of the physical reaction
- Physical reactions result directly from recognition

- Emotions are affected by (acknowledgments of) physical reactions
- Relevant evidence include "alcohol affects mood," and "female crime rate is 62% one week before menstruation while it is 2% directly after menstruation"

Cannon-Bard's Theory

- Cannon proposes that the thalamus adjusts emotional reactions, and Bard proves this through animal testing
- Emotions occur in this sequence: senses - thalamus reacts - emotional reaction/occurrence
- Cannon is the pioneer in the research of emotions and physiology. A dog that has its cerebral cortex removed shows "sham rage" as opposed to genuine rage. In a similar test done on cats, when removing the cortex, thalamus, and the hypothalamic area, only when the entire hypothalamus is removed does this emotional reaction disappear. Thus it can be deduced that human emotions are related to the hypothalamus, cerebral limbic system, reticular nucleus, and cortex.

Schachter-Singer Two-Factor Theory

- Emotions have two crucial components: physiological arousal and cognition (two-factor theory of emotion).
- Adrenaline were given to college students in Schachter and Singer's experiment.
- Results were that given the same physiological arousal, emotions vary according to the situation.
- Emotions are not perceptions of physiological reactions (Lange), but rather, labels of cognitive interpretations that explain the cause of those physiological reactions.
- Six experimental groups were formed, "subjects who were told about the effects of adrenaline," "subjects that were deceived about the effects," and "subjects that were not told about the effects at all." "Each of the three categories were given adrenaline or saline injections. After the injection, the subjects were put in a room with role-players who played "anger" or "playfulness." Among the subjects, even with the same physical conditions (injected substance), their emotions were different depending on perception.

Please refer to AppendixA.4（p.120）for further reference (Japanese).

1.2.2 Emotional Research on Physical Reaction Succeeding James-Lange

The understanding of prior research in emotions and corresponding physical reactions is key this study in which I attempt to quantify emotions and measure them scientifically. This next section refers to prior investigations in relations between the physical body and feelings. [48][75].

For references to emotion studies preceding James-Lange in biological secretion of substances, please refer to Appendix B.1（p.121）. For a complete list of categories of emotions please refer to Appendix A.3（p.103）.

The Autonomic Nervous System (ANS) and Its Functions

1. Perspiration, heart rate and internal organ reactions are controlled by ANS.
2. The ANS is roughly comprised of the sympathetic nervous system (SNS) and the parasympathetic nervous system (PSNS) which function in opposition to each other.
3. The SNS becomes more active during times of stress or strong emotions. It also prepares the body to respond to threat (such as the release of adrenaline).
4. The PSNS is active when the body is in rest, slowing down bodily reaction and saving energy.
   (a) polygraph: Device that measures bodily reactions corresponding to emotion. Measures pupil dilation, saliva glands, sweat glands, peripheral blood vessels, blood vessels in brain/muscles, heart rate, blood pressure, digestive system, electromyogram, brain waves, peripheral skin temperature, blood flow, and so forth.
   (b) skin's reaction to electricity: when receiving stimuli, resistance decreases (perspiration increases[76]). Utilized in lie detectors.
   (c) fear stimulus: increase of heart rate, controlled breathing, GSR increase of the palm, contraction of blood vessels in the head. Contrastingly, subjects who do not become frightened under the same stimulus, display contrary reactions - low heart rate, expansion of blood vessels (according to experiment of spiders with female college students)[76]
   (d) increase of respiration rate, heart rate, skin conductance level.

This brings to question the relationship between feelings and physiological reactions.

1.2.3 Emotional Research on the Brain and Nervous Systems Succeeding Cannon-Bard

Next I take a look at research that relates emotions to bodily reactions, following Cannon-Bard's studies, which say that emotions originate from the brain. The brain functions with chemical substances and electrical signs. If emotions are connected to these physical indicators, the quantification of emotions becomes possible. We referred to previous studies that examined the relations between feelings and chemical substances in the brain[48][75]. We summarize below some of the representative studies in the linkage between feelings and physiological indicators, in the fields of psychology and physiology.

1.2.4 Studies in Brain Physiology

Excerpts from studies in feelings and psychology follow[48] [46][8][7].

The Link Between Emotions and the Brain In the mid 19th century, Phineas Gage, a worker who injured his frontal lobe in the handling of dynamites, underwent a drastic change in personality from being a cautious, sensible character to becoming emotional and impulsive. Stirling2000[77]Also, Damasio established the link between frontal lobe damage to handicaps in emotions and planning [78]. Chapter 3.2（p.26）Figure. 3.1applies. Appendix C.2（p.135）of Figure C.2 applies.

Judging Emotion from Facial Expression Humans are unable to judge another person's emotions based on a picture. An analysis of facial expression (FACS) based on facial electromyogram (fEMG) to quantify facial muscle movement and detect changes was conducted. However, no significant results were gained in these studies: Cacioppo et al 1990[64] Tassinary&Cacioppo2000[65] Dimberg1982[66] Lundqvist1995[67] Dimberg&Petterson2000[68] Dimberg et al (2000)[69].

Emotional Detection Based on the ANS (1) Physiological awakening (emotional reaction) is measured from the ANS. Electrodermalactivity (EDA) is used to measure skin conductance (SCR) for any emotional reactions of anxiety in perspiration of the hand and feet. Conventional slides are utilized in this series of experiments. EMG, heart rate, blinking and SCR were used to capture responses to fear (Ohman&Soares1994[79])(Van den Hout et al.,2000[80]). However, due to familiarization to the stimuli, results from second trials are less significant. There is a high correlation between heart rate and blood pressure (Gendolla&Krusken(2001)[81]). Chapter 4.6.1 (p.71) goes into detail.

Emotional Detection Based on the ANS (2) Measurements are conducted based on heart rate and the cardiovascular system. Methods such as the EDA can be used to in measurements of action inhibition (Fowles1983 [82] Fowles1988 [83].) Other studies show that when controlling the expression of unpleasant emotions, the level of SCR rises (Gross & Levenson1993 [84]) (Gross & Levenson 1997 [85]) (Petrie et al,. 1998 [86]). However, when using the ANS as a reference index, there is a need to consider using stimuli to bring about emotion. Refer to Chapter 4.2.2 (p.60) for details.

Emotional Detection Based on SCR (action restriction) and the Brain (1) Emotions are detected from the relationship between SCR (peripheral reaction) and the brain (nerve reaction). SCR reactions of patients with brain damage are examined. Subjects with damage in both sides of the ventromedial frontal cortex, the lower right temporal region, and both sides of the cingulate gyrus demonstrate a lack of SCR reaction (Tranel&Damasio1994[87]). There is no proven relationship between the amygdale and SCR. The link among both sides of the ventromedial frontal cortex, the lower right temporal region, and both sides of the cingulate gyrus and the secretion of GADA remains unclear.

Emotional Detection Based on SCR (action restriction) and the Brain (2) SCR (peripheral reaction) and PET (nervous reaction) area measured for emotions (hypothalamus, or upper brain). When shown emotional slides, the right amygdala and thalamus are related to negative emotions (Liberzon et al,.2000[88]). The amygdala does not control SCR. There is, however, it is assumed that the amygdala carries the function of adjusting the strength of reaction. The relationship between the amygdala and emotions serves as a reference in this study.

The Somatic Marker Hypothesis, Damasio 1994 The ventromedial orbital frontal cortex, where emotional and bodily reactions are shown, affect decision making abilities which the dorsolateral prefrontal cortex is in charge of. The link between damage in the orbital region and SCR is also plausible (Bechara et al,. 2000[89]). Consequently, an indicator that reflects SCR and the feedback function of the brain center is possible (Tranel2000[90]). Simultaneous measurements of event-related fMRI and SCR show that, in the left medial prefrontal cortex, SCR is centripetal (Critchley et al,.2000[91]). The relationship between the orbital cortex and the frontal lobes serves as a reference in this study. Chapter 3.2 (p.26) Figure.3.1applies., Appendix C.3 (p.141) Figure. C.2applies.

Emotion Detection in Vocabulary (A Comparison with the Perception Method of Psychology) Brain waves also known as ERPs(Fabiani et al,.2000[92]) , are measured in the process of recognition - the allocation of the information necessary to process emotion, and the update of the working memory (Donchin1981[93]). Negative/positive assignment to a list of particular adjectives is used to test intention (Cacioppo et al,.1994[94]). Additionally, in a test of LPC with new and old vocabulary, (Rugg1995[95]) (Rubin et al,.1986[96]) achieved positive results for reactions to test stimuli. Studies done by (Danion et al,.1995[97]) (Leiphart et al,.1993[67]) (Maratos et al,.2000[98]), showed that emotional vocabulary had higher search rates that neutral words. The connection between words and vocabulary remains difficult to justify, however, the link between depression and intended vocabulary is important.

Emotion Detection in Blinking The test detected more blinking in the use of negative language versus the use of positive language (Stern1984[99]) . This indicator cannot be scientifically observed. Refer to Chapter 4.2.2 (p.60) for details.

Emotion Detection Using Methods Employed by Neurosciences - PET PET is effective in testing long lasting emotions based on subjective emotional experiences. The rostral portion of the anterior cingulate gyrus is activated when detecting happiness, sadness and disgust (Lane1997[100]). There is a direct relationship between the level of emotional awareness detected by the LEAS scale and the level of self-evaluation (Lane2000[101]). Chapter 3.2 (26) Figure. 3.1applies. Appendix C.3 (p.141) Figure. C.2applies.

Emotion Detection Using Methods Employed by Neurosciences - fMRI There are two methods, the event-related fMRI design (temporary brain activation) and the block fMRI design (brain activation within a period of time). Looking at the Schachter-Singer Two-Factor Theory, it is generally accepted that feelings occur automatically, before recognition takes place (Le Doux 1996 [63]). However, since humans control emotions, it is crucial to understand the neural base. Chapter 3.2 (p.26) Figure3.1applies. Appendix C.3 (p.141) Figure. C.2applies.

Block fMRI Design and Neuroimaging The right amygdala and hypothalamus play a crucial role in evoking emotions. To control emotions the right frontal cortex and right cingulate gyrus have to be activated (Beauregard 2001 [102]). These are results from tests on self control and the brain. Refer to Chapter 4.6.1 (p.70) Chapter3.2 (p.26) Figure. 3.1, AppendixC.1 (133) Figure. C.1, and Appendix C.2 (p.135) Figure. C.2.

Event-Related fMRI Design and Subliminal Priming Facial expressions of strong resentment and then of moderate resentment are shown to subject. In response to strong resentment, the rostral portion of the anterior cingulate cortex, and the medial frontal cortex showed reaction. On the other hand, this reaction and the reaction of the fusiform gyrus were negatively correlated. This method allows a high degree of experimental freedom. (Funayama et al,.2001[103]). Refer to Chapter 3.2 (p.26) Figure. 3.1, Appendix C.1 (p.133) Figure. C.1, and Appendix C.2 (p.135) Figure. C.2.

Detection of Stress and Emotion in Biochemistry Cortisol is one of the hormones that responds to stress and other unpleasant emotions. With the neuropeptide CRH function triggered by the hypothalamus, the pituitary glands secrete ACTH and the adrenal cortex responds by producing cortisol. Chapter 1.2.2 (p.4) . The hormone level reflects the degree of stress and comfort.. (Lovallo&Thomas(2000)) prove that such emotions are also detectable in saliva. This is also deemed a valid indicator of emotional state (Buchanan1999[104]) (Hanson et al,.2000[105]) (Smyth1998[106]). Furthermore, the indicator is standardized for common use by (Lovallo&Thomas2000[107]). Chapter 3.2 (p.26) Figure. 3.1, Appendix C.1 (p.133) Figure. C.1, and Appendix C.2 (P. 135) Figure. C.2applies.

Indicator Based on Psycho-Neuroimmunology (1) There are numerous immune indices (Ader et al,.2001[108]). A non-invasive saliva assessment was able to identify secretory immunoglobulin A(s-IgA). (Jemmott & Maglore 1988 [109]) (Deinzer et al,.2000[110]) (Willemsen et al,.1998[111])are renowned studies of stress.

Stone et al,.1987[112]is a prominent study in pleasant/unpleasant emotions. (Willemsen et al,.2000[113])is a well-known study in novelty issues. Levels of s-IgA increased when experiencing pleasant emotions, and decreased when experiencing unpleasant emotions. s-IgA appears to be related to alpha-adrenergic nervous activity (Ring et al,.2000[114]). Chapter 3.2 (p.26) Figure. 3.1, Appendix C.1 (p.133) Figure. C.1, and Appendix C.2 (p.135) Figure. C.2applies.

Indicator Based on Psycho-Neuroimmunology (2) In acute stresss, there is a transient increase (under 10 seconds) in the level of s-IgA (Willemsen et al,.1998 [111]). Regardless of the degree of difficulty, when facing new things there appear to be big reactions (Willemsen et al,.2000[113]), Levels of s-IgA increased when experiencing pleasant emotions, and decreased when experiencing unpleasant emotions. (Stone et sl,.1987[112])The level of s-IgA appears to be related to alpha-adrenergic nervous activity (Ring et al,.2000[114]). The level of s-IgA increases in boredom or relaxation. Secretion of s-IgA occurs when there is a change from accustomed standards. Studies in the standard value (Kugler et al,.1992[115]) and circadian rhythm (Huklebridge et al,.1998[116]) of s-IgA provide a good overview of its key properties, and reinforce the value of a emotional biorhythm and quantification index. Chapter 3.2 (p.26) Figure. 3.1, Appendix C.1 (p.133) Figure. C.1, and Appendix C.2 (p.135) Figure. C.2applies.

Indicator Based on Psycho-Neuroimmunology (3) Tests in the exposure to/suppression of pleasure-displeasure and stress show that antibodies for the type B hepatitis virus increase under exposure to trauma (Petrie1995[117]), Moreover, there is an increase in natural killer (NK) cell activity (Christensen et al,.1996[118]). Cortisol is secreted and the impediment of NK cells is lowered (Strauman1993[119]). Self attention → Arousal of insecurity → Reaction promotion in the endocrine system → 【Immune compromise】

1.2.5 Summary of Studies in Emotion

The previous studies revealed the challenges in the scientific analysis of emotions through facial expression. In testing biological reactions, subjects' familiarization (in the second trials) urge caution in using results as physiological indicators. Also, there is no correlation between blood pressure and heart rate.

Clinical practice in pathology and brain damage, as well as the link between biology/neural networks and emotions, prove as well scientifically-backed references for considering relationships between human subjectivity and the brain.

Research has established that there is a close relationship between the brain and emotions. However, as research is still undeveloped in this area, the link between physiological reactions, the secretion of substances and emotions is unclear. We cannot directly apply those associations to an analysis system. The same can be said for the link between the brain and its neurotransmitters.

Hence, there is a need for a quantitative method to examine the link between subjective labeling and physiological indicators in the physiological study of emotions. Furthermore, it is required to establish consistent terminology that can be applied to both physiology and psychology in explaining the fundamental problem of emotions.

1.3 Defining Emotional Terminology

The Schachter-Singer Two-Factor Theory explained in Chapter 1.2.1 (p.4) indicates that emotions are not bodily reactions, but rather, cognitive interpretations that explain bodily reactions. On the other hand, James-Lange argued that emotions are perceptions of physical reactions. Among the categories of feeling, emotion, mood, and sentiment, the question between the link of the physical reactions of anger, joy, sorrow, excitement, and their cause-effect relations remain unanswered. And then again, Cannon-Bard relates emotions to nerve activity. In addressing all these different points of views, there is a need to establish common terms. This study assigns the following attributes to human emotions.

1.3.1 Feelings (Perceptive Labels)

Neuroscience is a field with the soundest scientific evidence. According to the definition [120]given in neuroscience, feelings are influenced by perceptions such as bodily reactions, situational judgment, and predictions. They are relatively longer in effect, and reflect the state that is assessed from physical reactions and labels.

1.3.2 Emotions (Physiological Reactions)

Emotions are, on the other hand, relatively shorter in duration and stronger in intensity. [120]They portray an excited state of the brain, hormones, DNA, immune system and biological substances. The cause of emotions and whether they are related to internal or external factors is unspecified.

1.4 Problems in the Research of Feelings

As illustrated in thought experiments, there is no consistency among human subjectivity, introspection, and action. Therefore, in experiments with human subjectivity, I make many references to psychology research methods that are credible. Appendix A.1 (p.99) provides details on psychological research in emotions. However, despite the number of researches in this area, they do not provide for the quantification of emotions nor give solid scientific evidence.

Since psychological experiments have premises and desired conditions, subjects become influenced by the intent of the study and their responses tend to follow the premises. Consequently, it is a key factor to keep the intentions of the experiment confidential. An experiment that is intended to disguise the purpose of the study will influence the subjects' responses. Experiment results are also greatly affected by the subject's morale, receptivity, and personality, as well as the way the test is composed (the abstractness of the questions, etc.). Other factors of uncertainty include interview tests and questionnaires that are subjective to listener, influences of time lag, representation, way of listening, and perception that is affected by memory. Under these circumstances even generalized problems cannot be solved. These problems are noted by researchers that also conduct emotion perception research through voice and imagery analysis[10][11] [12] [13][14][15][16][17][18] [19][20] [21][22][23][24][25][26][27]In observation, the standards are determined by the observer thus making evaluation not possible. Especially in researching the subject of emotions, with its principles and mechanisms unclear, varying standards are used to measure varying factors of subjective claim. In carrying out these studies, it is essential to create a fixed standard to reorganize and measure individual and environmental difference, and time lag. Then, relating these elements to introspection, using a list of active emotions, compare them with a third person's subjective view and voice parameters. These then can be evaluated against physical indicators such as brain activity and heart rate.

1.5 Problem-Solving Research

This study divides emotions into active and passive sentiments. Active sentiments are created by the subject willingly, or resulting from external stimulus. On the other hand, passive sentiments are those resulting from analysis of subjective claim. In other words, active sentiments fall into the debate of the origin of emotions, while passive sentiments refer to how humans perceive "feelings." Consequently it is easier to approach only the influence of perception. However, this leads to the question whether the feelings recognized by humans are really feelings or emotions. In the stage of testing recognition accuracy, the volatility of subjective claim impedes any assessment. In fact, in several of the tests conducted, later explained in Chapter 3,data dispersion resulting from the elapse of time and discrepancies in subjective claim[121][122], made it difficult to standardize human subjective claim. Research is carried out to determine the cause of the fundamental problems such as the discrepancies of subjectivity.

The link between human mind and emotions and the physical structure of speech are examined to determine the standards of human emotions that will serve as the guidelines in this study. Human emotions affect voice through vocal chords. It is well known in past research that emotional traits in voice are found in fundamental frequencies[21][19] [17] [18][24] [13][14]. There are still problems in the automated collection of fundamental frequencies, as often errors need to be fixed manually. In the reality of experimental environments, variations in machinery and microphone distance cannot ensure stable performance. In this study I created a reliable method for measuring fundamental frequencies which is superior to that of previous methods (the cepstrum). We created the critical logic from standardized use of power and FO variations to determine parameters. We then ensured that they have comparable capabilities to human subjectivity and employed them in the examination of issues of emotional perception.

We collected large amounts of voice data to carry out the analysis for this study. Using the data that I collected, by assigning labels subjectively, I built a vocal emotional database that I later used as basic underlying data for this research. With this database I was able to test subjects' cognitive ability of emotions for both nonverbal and speech communication. Scientific emotion recognition from voice is achieved through parameters and threshold values taken from cadence analysis (intonation of the voice, variations in fundamental frequencies). With the attained information I was able to create the Vocal Emotional Analysis (VEA), which I then used to find relations between the speaker and the evaluation system, and between a third party and the evaluation system. In doing so, I investigated the problem of emotion recognition, through looking at the fixed, constant VEA and the human variant. Furthermore, I was able to create an analytical system of cerebral physiological signs of emotions, which was based on brain image analysis, and physiological/vocal emotional signs (including heart rate, blood pressure, eyeball movement, body temperature, etc.) gathered by VEA. In developing the analytical system, my process of introspection (observation of my own inner feelings) was used as a reference in creating a dynamic model[2].

A full-scale collaborative study of the brain and emotions was conducted with the Brain Information Group of the National Institute of Information and Communications Technology (NICT) in Japan, to study the dynamics model and bio-robotics.

1.5.1 Research Goal

Firstly, our goal is to create a hypothesis for emotion perception, and create a VEA system that has comparable emotional detection capacity to that of humans, from non-linguistic rhythms. Then, I compare VEA evaluation system to humans to attain a solution on the problems of emotional recognition. As preparatory research, I utilize the VEA to measure brain activity and excitement levels. By eliminating unwanted noise in fMRI, I collect steady fundamental frequencies during conversations with the subjects and use fMRI to detect brain activity at the same time. Lastly, I verify the operations of the analytical system of cerebral physiological signs of emotions, which will make physical observation of the heart and emotion mechanisms possible.

1.6 Structure of Thesis

The structure of this thesis is as follows. .

Chapter 1 explains mechanisms of the brain and emotions from past literature review and research results for reference.

Chapter 2 uses past research results from Chapter 1 to propose a hypothesis of emotional mechanisms. The emotional model of the hypothesis is also illustrated.

Chapter 3 explains how the problem of emotional recognition mentioned in the hypothesis is carried out by first creating a vocal emotion recognition system, and then by comparing it with human subjective labeling.

Chapter 4 describes the experiment that uses the hypothetical mechanisms described in Chapter 2This chapter also explains the analytical system that utilizes physiological parameters, VEA, and brain image analysis, and provides overall discussion and a conclusion.

Chapter 2

Hypothesis

This thesis is based on the concept that "human emotions and feelings are linked to the entire human body (the brain, nervous system, DNA, immune system, and physiological reactions reflecting hormone influence); there is a system that works to maintain a certain degree of homeostasis (stability), " from findings presented in Appendix A.1 (p.99), Appendix A.3 (p.103), Appendix B.1 (p.121), Appendix C.1 (p.133). Furthermore, "feelings are labels assigned from human subjectivity and introspection, while emotions are physiologically motivated; based on these two mental reactions, the fundamental problem of emotions arises" is the hypothesis of this thesis.

This hypothesis is able to resolve, without contradiction, the discrepancies between the different emotion/feeling theories proposed from prior research: Cannon-Bard's theory which says, "emotions plays a central role among the reactions and occurrences taking place in the brain," James-Lange that argues feelings are labels gained from bodily reactions, and Schachter-Singer which reasons that they are based on cognitive influences of the environment.

To verify my hypothesis, I bring the focus to the fact that emotions have a strong influence on human vocal chords, due to driving or triggering factors, and the influence of internal feeling labels.

A physiologically caused emotion is typified by excitement. Excitement is assumed to be related to the overall intensity of emotions. Since physiological reactions are measurable, they are used as the quantitative standards. While emotions are physiological, feelings are regarded as cognitive labels that are influenced by subjectivity, induction and the surrounding environment, thus leading to the assumption that they are more uncertain than emotions. My approach is to measure this uncertainty with constant standards (rather than the probability model or NN, but with clear, constant logic), and by comparing emotions and feeling labels to human subjective claim, verify my hypothesis on the cognitive problem of feelings.

2.1 The Physiological Mechanism of Emotion

From looking at previous research in fields of psychology, clinical psychoanalysis, physiology, and neuroscience, as indicated in Appendix B.1 (p.121), there is a circulatory relationship of hormones and physiological reactions of the brain/emotions. Consequently, if the subjective perspective and cognition can be compared to physiological mechanisms, past problems of emotional research can be inspected and resolved. The segmental zed fields of physiology and medical research have yet to conduct cross-sectional, quantitative research in neural paths, hormones and cognitive information, and this study will provide one such opportunity. To examine the cognitive problem of feelings, experimental results and academic review aforementioned are depicted in Figure 2.1.

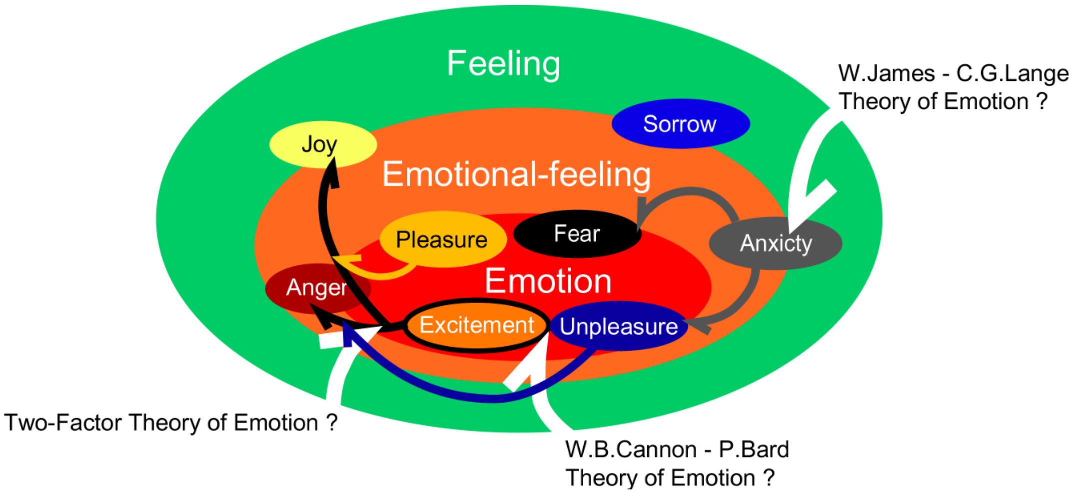

Figure 2.1: A Theorized Relationship of Feelings Based on Experimental Results

This concept does not only apply to this essay. For instance, vasopressin is proven to be a secretory substance that affects emotional homeostasis controlled in the pituitary gland, as discussed in Appendix B.1 (p.122) . Furthermore, following Cannon-Bard's research, Papez Papez[123]discovered the flow of emotions in the neural circuit and the brain; this was named the Papez circuit. Furthermore, he clarified the link of dopamine and noradrenaline to emotions.

Considering the facts that amygdala has a strong, direct influence on emotions, and that functions such as logic and reason are associated with prefrontal region, by looking at Tetsuro Hori's model Figure 2.2 which elaborates on the Papez circuit, we can predict that the cerebral cortex, amygdala, hypothalamus, and hippocampus all directly take part in the flow of emotions. Additionally, since the hippocampus has a great influence on memory, the idea that memory can be controlled by emotions makes this relationship increasingly complex.

2.2 The Hypothetical Mechanism of Emotion

The purpose of this thesis is to build a system that will verify the different theories of emotions: Cannon-Bard's theory that "emotions plays a central role among the reactions and occurrences taking place in the brain (or the neural circuit, as referred to by Cannon-Bard at the time), " James-Lange that argues feelings are labels gained from physiological reactions, and Schachter-Singer's theory that says feelings are based on cognitive influence.

Based on a review of psychological and physiological research summarized in Chapter 1.2.3 (p.5) Appendix C.1 (p.133) Figure C.1 displays the relationship between physiological indicators and emotions indicated by the James-Lange and Cannon-Bard theories. Utilizing this relationship, a model of the mechanism of the mind/feelings based on subjectivity and physiology was built and used as the foundation of the verification system for the cognitive problem of feelings

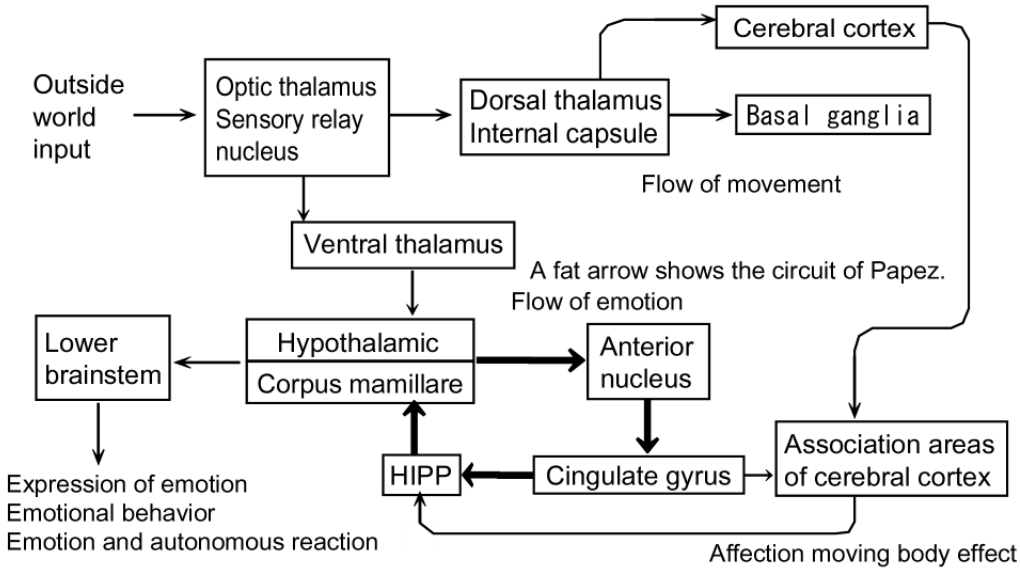

Figure 2.2: A Model of the Emotional Circuit (Tetsurou Hori,1991[1])

2.2.1 A Dynamic Model of Emotional Homeostasis (Active Emotions)

As an archetype for the mechanism of emotions, I created a dynamic model and a physics model portraying the mechanism of my mind to depict how human creates emotion, and presented it at the Institute of Electrical and Electronics Engineers (IEEE) between 2002 and 2003 [124][125] [2]. Figure 2.3illustrates the concept of emotional homeostasis as a circuit for easier understanding.

Regions of spontaneous instinct, as feedback from hormones, were regarded as having equivalent functions as that of the cerebral limbic system (amygdala, cerebellum, hypothalamus, and hippocampus). Also, the thought circuit that manipulates self-control of emotions and the influence of external stimuli is regarded as having the equivalent functions of the prefrontal region of the brain.

This concept refers to emotions mechanically, and regards it as a control system of hormones, self and external stimuli.

Figure 2.3 displays the mechanism of feelings in a flow chart.

2.3 Interpreting Feelings as Mechanisms

From looking at the mechanism of feelings in Figure 2.3 , the following considers the fundamental structure and cognitive problem of feelings.

1. The Fundamental Structure of Feelings : Feelings are divided into those occurring from triggers of external stimuli (others, environment, situation, etc.), and those created from internal agents (internal organs, DNA, immune system, neural circuit and the brain, hunger, hormonal state, physical conditions, etc.). I refer to them as active feelings. Rather than occurring randomly, active feelings result from interactions of bodily factors, which then affect brain activity and hormone secretion (sympathetic vibration, resonance), reacting and working cyclically. Emotions have a big impact on memory, which affect individual decision patterns and behavior, mutually. Consequently, emotions, as powerful

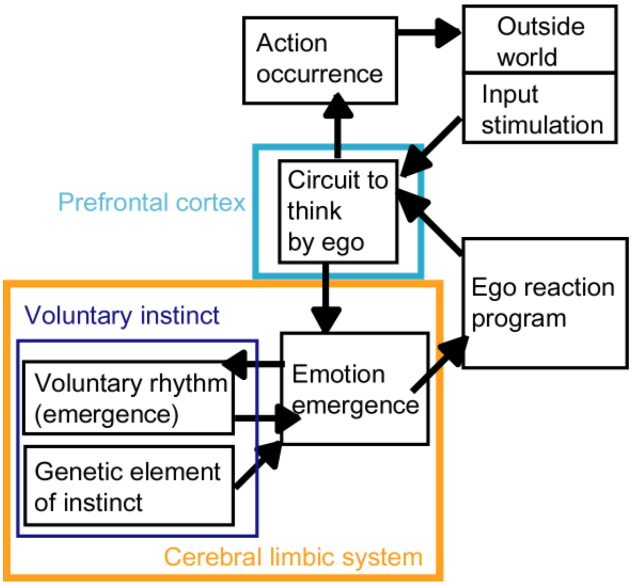

Figure 2.3: The Mechanism of Emotion（[2]）

elements of the mind, are more deeply rooted than memory and thought. This is what forms the archetype of personality or what is called as sensitivity.

2. Interpreting the Cognitive Problem of Feelings : Referring to the dynamic vector of Figure 2.1 created from the relationship between physiological indicators and feelings depicted in Figure C.1and Appendix C.1（p.133）, feelings are more likely to be affected by the entire body and physiological reactions of emotions, rather than hormonal influence and brain activity. There is a possibility that the brain reconfirms such activity and influences, and then creates cognitive labels. On the other hand, excitement (an emotion), is regarded as ignitions (activity) of regions of the brain (limbic amygdala, cerebellum, hypothalamus, and hippocampus). The subject, however, is unable to detect brain activity directly. Since humans are unable to perceive ignitions of the brain, influences from bodily reactions and the surrounding environment[74], are processed into 'anger,' 'delight,' 'sadness,' and so forth and given cognitive labels.

   This is seen in comparisons of excitement and subjective agreement of other feelings such as 'anger,' 'delight', and 'sadness,' comparison trials of subjects using constant standards (rather than the swaying standards such as the probability model or NN), and the consistency between the degree of cognitive authentication influence and subjectivity. In this case, it can be predicted that as physiological reactions, primitive emotions have a high correspondence to human subjectivity and standards. Also, feeling labels are predicted to have relatively low correspondence to human subjectivity. By the verification of this prediction and hence the cognitive problem of feelings, and the verification of Cannon-Bard's through simultaneously measuring physiological reactions and activity in the emotional brain, the fundamental problem of feelings will be solved. Specifically, it can be analyzed by comparing active emotions to the finding of passive, cognitive influence as feeling labels, from the Schachter-Singer Two-Factor theory which says "feelings are initially recognized through labeling (cognitive authentication influence). " Also, it can be done by a comparison with the labeling of physiological reactions, as pointed out by the James-Lange theory. As a result, by the comparison of excitement and the cognitive influence and labeling of other feelings, and of the brain and physiological reactions, the relationship between the primitive emotion of excitement and the labels of 'anger,' 'delight,' 'sadness' will become clear.

The clarification of 2. "The Cognitive Problem of Feelings" will contribute to the verification of the 1. "The Fundamental Structure of Feelings. " Consequently, the clarification of part 2 requires a system that can quantitatively analyze feeling labels, physiological reactions and the brain. The purpose of my thesis is to create one such system and to inspect the Schachter-Singer Two-Factor theory. This will be achieved through a cross-sectional study of psychology, physiology and engineering.

2.4 Inspect the Cognitive Problem of Feelings

There is a need for a comparative method of human-assigned feeling labels and physiological indicators with an emotion measurement, to examine James-Lange vs Cannon-Bard vs Schachter-Singer issue, which is regarded as the cognitive problem of feeling. There are two types of labels: passive feelings of evaluation and active feelings. Passive feelings come from subjective evaluation, while active feelings come from physiological indicators including the brain and subjective introspection. Humans create feeling labels from face, voice, body language, and situation. Thus, specific measurement methods of passive emotions include facial expression analysis from image recognition of the face, feeling analysis of the voice, image analysis of body language and situation judgment, all to be conducted by machines and standardized. .

2.4.1 Measurement Method of Passive Feeling Evaluation

Referring to past studies on feeling assessments from facial expressions in Chapter 1.2.4 (p.6) , it is difficult even for humans to evaluate facial expressions for the labeling of feelings. Under current image processing technology, even if slight emotional change can be picked up from facial expressions, the accuracy and performance cannot be ensured. Likewise, evaluations from body language and situational judgment are increasingly difficult. However, it is possible to recognize symbolic facial expressions (accentuations) [39]. I will create a method that compares the automatic labeling of passive human feeling evaluations from voice and the actual human labeling of feelings. This will be used as the method for passive feeling evaluation and to verify the cognitive problem of feelings.

2.4.2 Measurement Method of Active Feelings

To analyze physiological reactions and brain activity of feelings, heart rate, blood pressure, body temperature, eye pupils, blinking, and vocal chord kinetic information (fundamental frequency analysis) are measured.

2.4.3 Relative Model for Active Feelings Based on Feeling Labels

Appendix A.3 (p.103) lists 223 conditions of the mind. To understand all 223 conditions of the mind, in hierarchical layers and as an overall structure, it is preferable to have visualization for better understanding. Of the 223, the first 1-157 feeling labels are used as the foundation, from where groups are created and symmetry is checked for comprehension. This method is effective in the case where engineering is applied to recreate the mechanism of the mind. I developed a method where visualization facilitates the comparison of feeling group symmetry, and a model that captures the relationships between condition/elements of the mind, and feelings labeled from human subjectivity.

The model that deciphers feelings is created from the list of mind conditions, previous research, personal introspection and mind changes resulting from my daily life, elaborated on Plutchik shown in Appendix A.2（p.102）, and the method utilizing colors of the spectrum.

Since the model is created from my own introspection, it does not portray relationships of overall human feelings. However, using this diagram, I was able to confirm personal conditions, and it also proved valid for introspect evaluations of three co-researchers. Additionally, because this diagram was made from previous research results of the emotional brain, biological substances, and DNA, it woks with physiological indicators and works cyclically. The diagram also separates feelings into layers; the center layer is proven by neuroscience studies that these emotions are formed within the first six months that a baby is born. Figure 2.4 illustrates the feelings model.

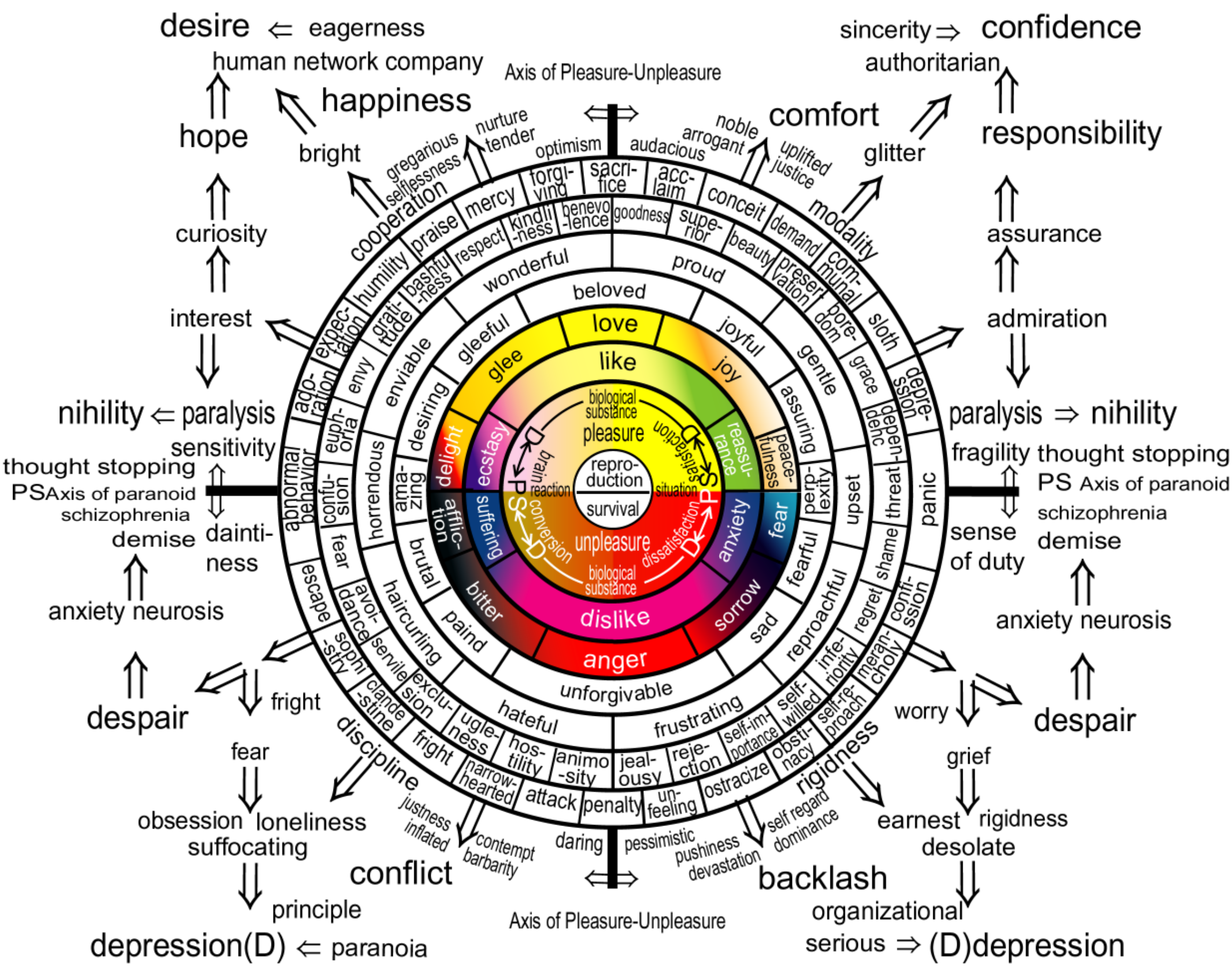

Figure 2.4: Relative Model for Active Feeling Labels Based on the Author’s Introspection

2.4.4 An Explanation of the Feelings Model

The uncertainties of feeling are brought forth by factors such as hormones, physiological reactions, the brain and its circulatory system of complex reactions, creating fluctuations in cognitive influence as well as reactions of the mind. The circulatory system is regarded as being based on the relationships between the biological substances and the brain, which are located in the central layer of Figure 2.4As a concept of clinical psychoanalysis, fluctuations occur because "human thought takes place amidst instabilities between paranoid schizophrenia (PS) and depression (D)," also known as Bion's PS ⇔ D Move [126].

Even if emotions depicted in Chapter 1.2.1 (p.4) are created from ion exchange and reactions to chemical substances in the brain, it is not possible to ignore hormonal in Chapter 1.2.1 (p.3) influence.

On the other hand, as shown in the second experiment of Chapter 1.2.4 (p.5) , emotions are influenced by sympathetic vibrations and resonances from internal and external relations of the subject. Under such complex circumstances, if Bion's theory, that fluctuations of the mind are closely related to emotions and mental thought, is true, the analysis and recreation of the uncertainties of feelings, based only on the neural network simulation of the probability model, cannot be done. Moreover, it is impossible to find parameters of probability just from hormonal feedback and a comparison between established feelings and human subjectivity. With that, I simulate a differing diagram of emotions to that of Figure 2.4 , based on facts gained from experimental research in developmental psychology and neuroscience, a visualization of the emergence mechanism of active feelings is created.

Looking at the Feelings Model Figure 2.4 displays the fluctuating condition between opposing elements of feelings that sway to "physiological reactions (physical state depicting hormones and ion exchange of the brain on the left half of the center circle)," and "situational reaction decisions (emotional homeostasis that circulates within the body and the feeling wave property of reactions of sympathetic resonance and vibration). "

I created the opposing model of active feelings in Figure 2.4 to simulate a dynamic model of emotions, capturing the uncertainties of the mind instinctively. Based on the feeling labels created in Chapter 1and the dynamic vector created from on the physiological reactions indicated in Appendix C.1 (p.133) , I sorted out the relation between influences of secretory substances and feeling labels.

The structure of the dynamic vector is centered on the primitive drivers of survival and production. This is based on the principles of primeval forms of life and their primitive driving forces of behavior.

Feelings are placed radially from the center of concentric circle. Going outwards are actions, behaviors, and mind conditions brought about by the mind-set. An increase in stimuli of stress, unrest, and happiness, and influences from cognitive information of the situation and environment are displayed. In the same concentric circle are emotions, feelings, and mind conditions. The basic structure is that emotions are indicated by color, and that the innermost of the circle shows the more primitive conditions. On the left side of the circle are reactions taking place in the brain, feelings that are created from the influence of chemical substances. On the right side are feelings resulting from situational judgment. However, depending on the subject, the left and right hand sides can move simultaneously and put the brain in a state of unrest. Under the influence of hormones and substances in the brain, feelings of suffering can take to pleasure. For that purpose, the perimeter of the central part of concentric circle can rotate clockwise and counter-clockwise, rearranging due to the influence of hormones. The inner part of the colorless section of the concentric circle shows feelings formed from primitive desires, with the subject's mind-set on the inside and subjective feelings in two lines of adjectives on the outside.

The Axis of Pleasure-Unpleasure is placed in the center, and radiating from there are results gained from past clinical tests on hormones and emotions (refer to Chapter 1) The Axis of Pleasure-Unpleasure takes into account the influences of the brain, biological substances, and situational judgment. The arrows depict influence from hormones and biological substances on the mood.

Moving towards the Axis of Paranoid Schizophrenia, feeling pairs on opposite sides inside the concentric circle can be both true under any one contradicting situation. This is suggesting a link between the PS ⇔ D reaction in the brain and the PS ⇔ D judgment based on situational judgment. Furthermore, because females have more complex influence of hormones than males, there is the tendency for the concentric circle to sway. In this case, not only reverse spin, but irregularities are possible.

Moving towards the Axis of Pleasure-Unpleasure, feeling pairs on opposite sides inside the concentric circle are inversely related, but under any triggering influence (hormone or situational change, abnormal personality), can easily turn the other way around. Empathy and sympathy are created from the main body and its relationship with others (sympathetic resonance and vibration), as shown on Chapter 1.2.4 (P.5) . Because aspects of the feelings are subject to change due to the three-dimensional axis of excitement, they are not portrayed in this diagram.

Chapter 3

Recognition Experiment of Emotion Labeling by Voice Emotion Analysis System

In Chapter 2, I discussed the qualities necessary for mechanism research of feelings, based on the psychology and biology research results discussed in Chapter 1. Much cross-academic research is necessary for researching the mechanism of feelings. Therefore, it is necessary for researchers of psychology, medicine, and biology to have a system they could use in common. It is important to create a system that could analyze the mechanism of accurate biological indicators (body reactions, sounds etc), the brain, and emotions. Hypothetically I will assume that the assessment method of emotion labeling is effective for scientific study, based on emotion biology measurements. I will now contemplate how emotion biology indicators and emotion qualities relate to emotion labels (subjectivity). Because there are over 223 emotion labels, simple indicators such as heartbeats, blood pressures, and muscle electric rates are clearly not enough to compare all of the emotion labels. As it was proved in the experiments explained in 1.2.4, it is difficult for humans to accurately differentiate emotions simply from looking at facial expressions, I chose sound as the first biology indicator for emotion labeling.

3.1 Implementation Plan for the Experiment

There are some problems with measurements and experiments using human subjectivity. Understanding and solving those problems is key to attaining reliable results. Thus, I have dealt with the following problems. Reference: [127][128][129]

3.1.1 Problems of Measurement: Target Qualities and How to Achieve Them

In order to get an accurate measurement of pressure demanding a specific reaction from the subject, it is important to deal with target qualities.

1. Dealing with target qualities: an environment in which the speaker's natural, non-self-conscious voice could be recorded was made. An evaluation system especially for subjectivity evaluation was made in order to conduct a subjectivity evaluation method that is not influenced by experiment conditions, is interpreted in the same way by any evaluator, and satisfies the evaluator.

2. Treatment of independent variables and measurements of dependent variables were put in different contexts. In order not to let the subject know that s/he was being experimented on, a third party who acted naturally, prepared a recordable environment.

3. Post-experimental Assessment of demand quality: In order to check if demand qualities worked or not, an interview and investigation was held after the experiment. A Debriefing as to relieve the subject of the stresses of the experiment, was conducted. Subject received a thorough explanation of the experiment.

3.1.2 Problems of Measurements: Effect of Experimenter

There are cases where the experimenter skews the experiment results with wrong interpretations of measurement results and psychological influences caused to subjects. Here, I will explain the effects the experimenter has on the experiment.

1. Observation reaction: Once the subject realizes that s/he is being observed and experimented on, s/he reacts in unnatural ways. These influences were put into consideration.

2. Experimenter effects: To avoid the influence the experimenter may have on experiment results by having too high expectations and/or interpreting data in a biased manner, the evaluation and analysis of a third party was obtained. The experimenter's expectation-effect serves as a demand quality, and skews the experiment results, especially when the researcher is also the experimenter. Except the biological experiments, the researcher's participation in the experiment was avoided as much as possible. Because the researcher may subconsciously effect results through his/her mannerisms, expressions, posture, etc, the researcher himself/herself did not take part in explaining.

3. Dealing with experimenter effects: Because it is necessary not to let the experimenter have any expectations, the following points were put into consideration.

   (a) Hire experimenters who were are not aware of the purpose/hypothesis of the experiment. (The researcher and experimenter must not be the same)
   (b) By not informing the experimenter what conditions the subject is experimented under, the experimenter is free of expectations. Therefore, automation of changing of independent variables and a system where a different person changes the independent variables was founded.
   (c) In order to minimize the effect of experimenters, multiple experimenters were hired from cooperating corporations.
   (d) Standardization of experiment procedure was done (Including trouble-shooting).

3.1.3 Problems of Measurements: Limitations and Solutions for Introspection Method

There is a common claim that you understand your own feelings, or that you are the only one who understands your own feelings. However, there are instances when even you yourself don't understand your own feelings.

1. Among the phenomena being covered in this thesis, there are many that cannot be explained by the introspection method, since they cannot be brought to the conscious level. Therefore, biological indicators and third party subjectivity comparisons etc. are

conducted simultaneously. Moreover, because evaluating the levels of anger, happiness, sadness, and normalness is difficult, a yes or no question whether any sort of emotion was felt, was asked instead.

2. Because measurements according to reports are not accurate translations of psychological states, they were not used. Real-time automated evaluation systems and subjectivity evaluation labeling systems were founded and put into effect.

3. Reports on introspection were inevitable, and the reported introspections are dependent variables that must be explained. Therefore, there are limitations in using reports as tools for explaining, and there is the need for interpreting statistical data. Comparisons with biological indicators were essential for justifying the introspections also.

Dealing with limitations of Introspection method

1. Emphasis was put on action measurements, biological measurements, standardized language measurements along with mutually complementary real-time evaluations.

2. In order to use language measurements of introspections as a tool for explanations, the cause and effects dealt in the researches must be backed by rules of knowledge and theories.

3.1.4 Problems of Measurements: Ethical Problems and Solutions

In psychological experiments, it is sometimes inevitable to give stress and pain to subjects, intrude the privacy of subjects, and give subjects false information. The following precautions were taken at the least, so confidentiality of personal information was guaranteed and consent of the subject was taken.

1. In order to reach the same goal, it is crucial to choose a way that has less risk for the subject (ex. choose to measure a subject who is already in a certain situation, rather than forcing a subject to be in that certain situation). Fortunately, this experiment did not concern much risk, and only the fMRI in Chapter 4 which required long hours of biological experiments, were conducted with extra precautions.

2. All subjects must participate in the experiment by free will, so we constantly had an environment in which the subject may express the will to discontinue or reject the experiment.

3. Anonymity was essential-the subject's name stayed anonymous.

3.1.5 Proceduralization of Measurements

Depending on what you are measuring, conceptual variables can be proceduralized in various types such as language measurements and action measurements. I will explain the characteristics of the proceduralization of each of the different types of proceduralization.

Action measurements

The subject's action towards the outer world (external action) is observed directly and recorded. Even when observing the same action, according to the purpose of the research, a direct or indirect observation may be made. (The action itself may be recorded/the internal feelings etc may be indirectly observed through action)

1. Strong points of Action measurement

   Compared to language measurements, action measurements are not as influenced by the bias through observational reactions

   → Has ample impact, subject is deeply involved in the situation of measurement.

   → By being creative, subject's consciousness of being observed may be removed.

   (a) Problems of Action measurement

      i. A single action is influenced by multiple causes (errors which decrease reliability of results are bound to occur), thus standardization and automation of environment were realized to avoid these erroneous influences.

      ii. Low sensitivity. Often measured as "a or b," and can't measure different levels of action. Therefore, a level-differentiating method was used independently for the evaluation of excitement. For other emotions, differentiating levels of the emotion was often too influenced by subjectivity and was difficult to evaluate, so an "a or b" method was used.

Selection of measurements

Proceduralization was founded based on three factors: standardized measurement derived from reliability, standard relation adequacy, and structure concept adequacy, the resistance it had to observation reaction bias, and the possibility of repeating the experiment. For biology comparisons and precision analysis by the human him/herself, preparatory experiments were carried out to choose the best measurement.

Ways of controlling personal variables

To even out the different types of the experiments, the following points were considered.

1. Plan within the subject: the same subject must experience all the independent variables. The same subject conducts multiple experiments while changing the conditions. Therefore, the subject is not affected much by the previous experiment.

2. Organizational distribution: By measuring personal variables in another experiment beforehand and distributing them accordingly, I can separate the subjective evaluations and the biology evaluations.

3. Mean equivalence method: Distributing the subjects so that the average of personal variables is about the same in the multiple experiments.

4. Equalization method: Precision was attained by distributing subjects with equal personal variables in different experiments. Although personal variables are not necessarily measurable all the time, I made it possible by automation. Personal variables are not necessarily singular, but the evaluator was given the choice of writing down the image of the evaluation, or writing "non-assessable" if s/he cannot think of an evaluation.

5. Random distribution:

   (a) I randomly distributed the emotion voices. Although there may be cases where random distribution is impossible, it was possible in this experiment. We paid extra attention not to miss systematic errors (errors that occur when using non-accidental factors; not detectable through statistical tests).

(b) Does not depend on personal variables. Enables use of statistical tests to the fullest degree. (high justifiability)

(c) When accidental errors become too big, the independent variables' effect cannot be seen. I made sure the experiments were precise, so as to make the errors as small as possible.

(d) If an abnormal incident occurs after a random distribution, the random distribution becomes invalid (ex/ if some mice die during an experiment, the experiment will be under the condition, 'surviving mice'). Therefore, to avoid abnormal incidents, subjects were as similar in quality as possible.

(e) Because reliable results cannot be obtained without the repetition of the experiment, this became a large-scale experiment.

3.1.6 Method of Controlling Personal Variables

A subject is not necessarily consistent in his/her decisions. I tried to control this.

Counter-balance: I controlled personal variables deriving from the persistence effect, made measurements in several different orders, thus controlling time variables along with other variables. I regulated the average order in which the experiments were conducted. Because people have different paces for getting accustomed to the environment, I had intervals between the experiments, in addition to the regulation of the average order.

3.1.7 Differences Caused by Experiment Environment

Depending on the method and environment of the experiment, the method and environment themselves become a condition, narrowing the range of control, and making generalizations difficult. Therefore, I have dealt with the following problems.

1. Experiments in labs: Generally, labs are widely available and lack reality, but I have used it to compare biology and brain activity. There are instances when ethical reasons make experiments difficult to carry out. Therefore, as a preparatory investigation, operation verification was carried out by researcher. Therefore it was difficult to achieve "representativeness of subject," subjects were limited to those who can come in the lab, and standardization was difficult. Thus, I have decided to mainly conduct operation verifications when comparing biology and brain activity, and yield to clinical experiments similar to medical practices in the future.

2. Survey experiments: Because experiments were automated, the surveys were not taken.

3. Scene experiments: Because scene experiments pose ethical problems, the experimenter himself prepared the experimental conditions for comparing the biology and brain activities, as a preparatory experiment. I decided to compare the biology and brain activities, since actions and reactions can be verified even when the subject is the researcher. The researcher controlled excess variables by purposefully manipulating independent variables and conducting random distributions. The researcher also prepared and compared environments outside the MRI labs, and confirmed the reliability of MRI experiments.

4. Natural experiments: Because natural experiments depend on introspection of emotions and subjectivity, it does not effect relations with society, thus I did not conduct natural experiments.

3.1.8 Preliminary Tests

Completely controlling excess variables is difficult, sometimes even unrealistic. Preparatory experiments were conducted so that some sort of cause and effect could be specified. Even though they were not based on random selection, they met the requirements, "more than one preparatory testing," "multiple conditions" and "introduction of uneven dependent variables." By giving up controlling excess variables, I succeeded in overcoming the following problems: '@low realistic-ness," "low possibility of practice because of ethical problems and opportunities of practice," "difficulty of achieving representativeness of subject." Preparatory experiments are effective especially when random distribution is difficult and controlling of excess variables is not completely possible. Although the identification of cause and effect is cannot be perfect, they have a high practicality. Because the actual experiments are done in the clinical scene, the preparatory experiment serves as the action verification of the practical experiment.

1. Cross-sectional sub-experiments

   I compared multiple conditions cross-sectionally at the same point in time.

   (a) Tests before and after experiment of uneven groups:

   I conducted preparatory experiments to investigate human subjectivity ability and compare physiology (e.g. heartbeat), and specified cause and effect to a certain extent. For uneven groups which homogeneity was not guaranteed, I conducted preparatory tests by putting them in same condition environments where just one variable differed, thus confirmed homogeneity. It is most desirable to conduct preparatory multiple times in order to avoid substitutive explanations, but since physiological comparison experiments in the clinical scene is difficult both practice-wise and also financially, I only conducted action confirmation.

   (b) Multiple condition:

   Confirming that the dependent variables are matching by establishing multiple conditions is an effective way of increasing the certainty of cause and effect. Because it is most favorable to have similar experiment conditions, preparatory tests were carried out.

   (c) Uneven dependent variables:

   I prepared dependent variables that may be influenced by causes other than the independent variables I was focusing on. By observing this change, I could check if there is a cause other than the independent variable, and see if there is a dual cause in the emotion.

3.2 Verification Method of Schachter-Singer Two-Factor Theory through Vocal Analysis

I can verify the two-factor theory phenomenon by observing the human subjectivity changes occurring when the experiment environment changes. The emotions subjectivity evaluation through sound and sound emotion analysis system which has an evaluation method by the emotional characteristic of sound were used. The emotion will be measured as excitement, and depending on whether it is anger, sadness, or happiness, the relation between emotion and feeling level may be defined. If emotions are reacting in primitive parts of the brain, it can be predicted that reactions will not change much depending on subject. Moreover, if feeling levels are labeled in the prefrontal region of the brain and are receive recognition influence, it will mean that Schachter-Singer Two-factor theory and Cannon-Bard can be compatible with each other. In such a case, the personal differences of feeling labels will most likely be greater than the personal differences of emotion reactions. → Figure 3.1 describes the reference study discussed in Chapter 1, and explains the mechanism of relation between the central system and secretion of stress, which is a cause of emotion, and the influence it has on sounds.

→ Figure 3.2 illustrates the mechanism of the occurrence of emotion based on the sound hypothesis.

→ The broken line arrows in Figure 3.2 show the circuit caused by the recognition influences in the hypothesis.

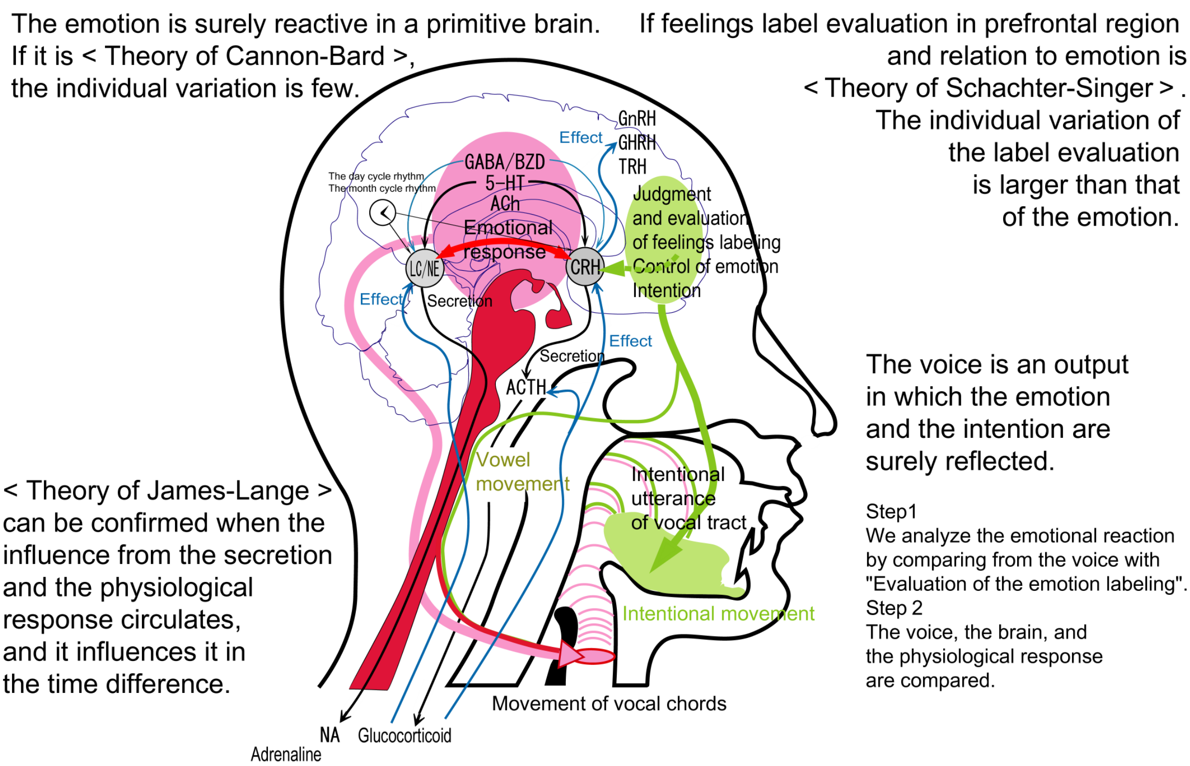

Figure 3.1: The structure of feeling utterance from the viewpoint of the brain and the pharynx-oral structure

3.2.1 Feelings Dealt with in Sound Analysis

The colored section in Figure 2.4 describes the feelings associated with pleasure, based on the growth stage of infants up until six months old. The uncolored section describes the feelings acquired with age. The lower half section is categorized as "displeasure." The right half mainly describes the direction developed by the input of the situation information. The left half mainly describes the direction developed by physical reactions. The center of the circle is a part that creates active feelings, and the outer parts of the circle describes outside influences of active feelings. Moreover, the colored outer sections (anger, joy, happiness) are what are prone to be influenced after recognition, according to Schachter. Based on this relation, I narrowed down the important feelings are "pleasure and displeasure," "excitement and stagnation," "fear," "anger," "sadness," "hatred," "happiness," "surprise," "pain," "relief," "like," "joy," "pleasant," "distress." Among these emotions, I have decided to deal with the sounds of happiness, sadness,

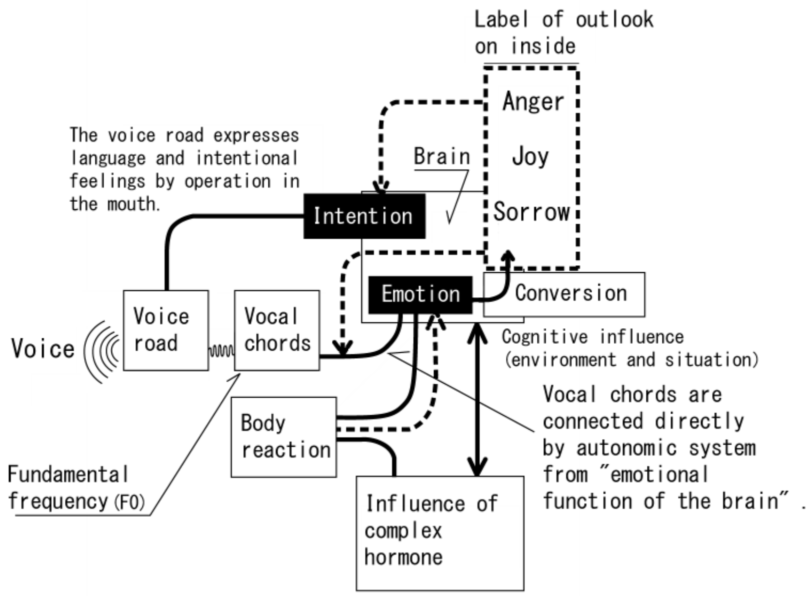

Figure 3.2: Mechanism of feeling utterance according to hypothesis

excitement, normality. "Like," "joy," "pleasure" have been categorized under "happiness." "Hatred" is rarely expressed as sound, and "fear" is hard to be expressed as sound as well. "Surprise" is hard to differentiate from excitement and difficult to be expressed as sound as well. "Pain" and "distress" are categorized as "displeasure," but collecting documents is difficult since ethical problems arise. For example, separation of "puzzlement" and "fear," separation of "fear" and "anxiety," separation of "surprise" and "excitement," separation of "hatred" and "anger" are abstract, and dependent on evaluator's subjectivity and subject's introspection. I have decided to omit these complicated emotions at a beginning stage.

3.2.2 Emotional expressions of humans

Figure 3.3 describes my interpretation of "aspect of human emotional expressions" based on Figure 3.1. This was extracted from reference [4]. by passing through the brainstem, the cerebellum, the midbrain, the limbic system, and the autonomic nerve.

1. I will presume that the vocal cords are heavily influenced by emotions [77] by passing through the brainstem, the cerebellum, the midbrain, the limbic system, and the autonomic nerve.

2. Because intentionality has a big impact on the sounds that are made in the vocaltract, it is difficult to differentiate between feelings and intentions.

For the above reasons, I have separated the fundamental frequencies and formant informations. Regarding 1, as far as I know, although the nervous system and vocal cords has been confirmed to be connected, the actual relation of nerve path and the sections of the brain has not been proven. Moreover, vocal cords move even when plain words are spoken; not necessarily emotional contents. So far, I will presume the effectiveness of fundamental frequencies through the "comparison of human subjectivity evaluation the speaker's evaluation" of the emotion recognition system according to 1.

The vocal cords in 1 are equivalent to a reed of a brass instrument, and are also known as sound source. This reed's vibration makes the basic component of sound. On one hand, an instrument player covers the holes on the brass instrument according to the score, thus music is played. This is equivalent to vocaltract 2 of the human voice. Looking at the music score is a way of expressing something intentionally. Because one must change the vocaltract by changing shape of tongue and throat, position of teeth, and size of mouth intentionally, it is similar to reading the score and covering the right holes on the instrument accordingly. Therefore, I presumed that intention/will was a strong influence on voice. Naturally, this means that a skilled actor may intentionally manipulate his/her own vocaltract, just as a skilled instrument player may play music smoothly. This, I assume, can influence the passive emotion evaluation of humans. However, this natural voice and intentional sound are most likely very difficult for computers to differentiate. Therefore, I have decided to study the characteristics of emotion vocalization on the basis of F0, the fundamental frequency.

From this, I can say that the human vocal cords are heavily influenced by the brain's emotional reactions which are in turn influenced by the brain structure, structure of mouth, and connection of nerves. Moreover, the vocal cords are also influenced by the introspection of emotions more or less. In this thesis, I have raised "Validation of the influence emotions and feelings have on vocal cords" as a hypothesis.

Figure 3.3 describes the conditions of emotional vocalization

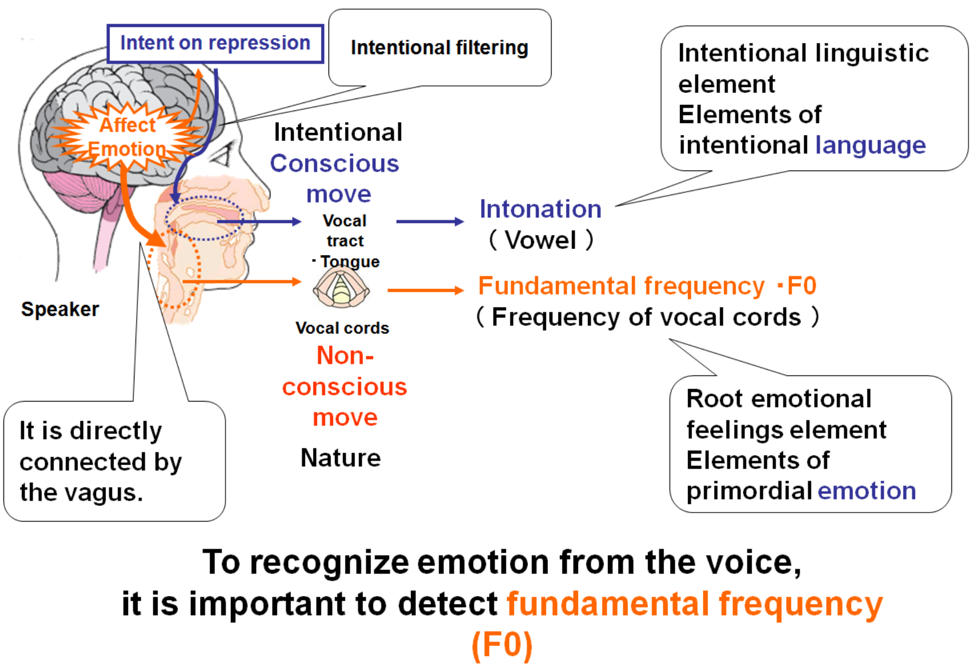

Figure 3.3: Feeling vocalization of humans ([3][4])

3.3 Emotions analysis system of voice

I need a real-time automatic emotion labeling method and a means to compare those labels with the labels evaluated by humans. I will call this means, "Voice Emotion Analysis" system.

In Chapter 3, I will extract the important basic emotions that are analyzable through voice by filtering the 223 psychological states raised in Chapter 1, through the emotional mechanism discussed in Chapter 2.2. Then, I will refer to the emotion mechanism discussed in Chapter 2.2 to illustrate the structural relationship of voice and emotions, and create an analysis method based on it. Furthermore, I will make a VEA system that can be compared to human subjectivity, and verify the emotion recognition problem.

3.3.1 Creation of Emotion recognition system of voice

In recent years, research in the field of voice information processing (ex/ voice recognition and voice synthesis) has advanced substantially, and much research is done for conversational voices. Consequently, the possibilities of emotion recognition through voice recognition are broadening, but conversational voices are not necessarily generated according to grammar, and sentence structure analysis is a difficult task. The same word can be emotionally interpreted in different ways depending on rhythm. Therefore, it is important to analyze not only the words of a spoken voice, but also the rhythm and nuances of words.

The active emotions of a speaker's voice are influenced by the amplitude and pitch of voice. I considered the vibration and power of the vocal cords as an important factor of natural emotions. When natural emotions are reflected on the voice, a bigger impact is given by parts of the brain related to emotions such as limbic system, hypothalamus, hippocampus[46], cerebellum, medulla oblongata, right hemisphere of brain (cadence and tone of emotion)[77], and vocal cord that directly connects to recurrent laryngeal nerve, as shown in Figure 3.1, rather than influence from language information made in prefrontal regions of brain[77], and built in Wernicke's speech center and Broca's speech center[46], and coming through the vocal tract. Therefore, I will utilize the changes in F0 (fundamental frequencies), rhythm information, range of voice, and change of power to recognize emotions in voice. There are past examples of analyzing the relations between F0 and emotions. In past researches, most of the experiments were done by using acted voices, not natural voices. Very little evaluative data has been collected, and because there is no organized database for voices, each researcher has had to prepare it himself/herself. In this thesis, I have picked up "anger," "joy," "sadness," and "normality," and aimed at a recognition rate equal to that described in Chapter 3.5 (p.33) .

I will try actualizing a emotion recognition method based on rhythm information. In order to do so, I recorded as many of the emotions discussed in Chapter 3.4.1 (p.31) as possible, used a voice database categorized according to subjective evaluation. I will use the range of voice and F0 frequencies as described in Figures 3.1 and 3.3 as factors for recognizing emotions through rhythm. In using these, I will modelize the range of voice and adopt a relatively noise-immune F0 detection method.

3.4 Emotion Vocalization Database

A huge database is necessary for grasping the characteristics of fundamental frequencies, intonations, and rhythm of human emotion vocalization voices. It is also necessary to attach labels corresponding to subjective evaluation and speaking will to those voices. The researcher had to collect all of the above database himself. Chart 3.1 explains the emotion vocalization database.

Table 3.1: Emotion Vocalization Database ([4])

	Content	No. of speakers	Selected No. of files	Comment
Data A	Conscious emotional speech (Closed) Unit of utterance	Male 26 Female 26 (Closed) 5200 file Subjectivity evaluation attaching	Training set 1000 (Unit of utterance)	Speech element was prepared and spoken with intentional emotion. This is called given or conscious conversation.
			Test set 1087 (Unit of utterance)	The same element was spoken with different emotions. Also, different elements were spoken with the same emotion. Each element duration was 2 to 3 seconds.
Data B	Spontaneous emotional speech (Open) Continuous utterance	Male 10 Female10 (Open) 24876 file Voice of making to division	Test set 528 (Subjectivity evaluation attaching) Voice of making to division	A pair (friends) were asked to make a natural conversation. Conversation was continued for more than 1 hour. We selected the part of the conversation when the speaker seemed to be unconscious of our recording.
Data C	Spontaneous emotional speech (Open) Continuous utterance	Male 4(Open) Total time 648min Continuous utterance	Test set 648 (1 min continuous utterance) After 3 weeks or more passed (Number where subjective assessemnt corresponds to emotion recognition syst)	Since emotional evaluation was expected to be different between the sexes, same-sex friends of two years were used in the the conversation.
Data D	Spontaneous emotional speech (Open) Continuous utterance	Male 2(Open) Total time 42min Continual utterance	Test set 42 (1min Continuous utterance) Immediately after utterance (Number where subjective assessemnt corresponds to emotion recognition syst)	Friends of eight years (same sex) were used in the conversation.

3.4.1 Collection of voice

26 men and 26 women were gathered, I prepared a few lines, and made them speak those lines as sincerely as possible. The collection of data was based on the methods of Chapter 3.1 (p.21) . Each line was about 2〜3 seconds long, and these were the units for vocalization. A line that corresponded to a certain emotions were prepared, and also a line that corresponded to all the emotions. The line that corresponded to all the emotions were made so that it wasn't unnatural no matter which emotion it was spoken in. Chart3.2 illustrates the number of times of vocalization and examples of lines for each emotion. Recording was done using a laptop (Toshiba Dynabook G4/U17PME) connected to a USB audio device (Roland AUDIO Capture UA-3FX) and a uni-directional microphone (Primo MOVING COIL MICROPHONE UD-320 UNI-DIRECTIONAL) with a sampling frequency of 11.025kHz with quantum level of 16 bit. The microphone was set 50cm apart from the subject. 5200 voice samples were taken according to the above method.

3.4.2 Labeling according to subject evaluation

n psychology, researchers have shown that children understand emotion words concerning introspective states/situations as a very early stage (1 and a half〜2 years old) and use them to interact with close members of the family [130][131][132]. It is thought that by attaching/labeling proper words to their emotions, they can effectively tackle conflicts and frustrations. Therefore, it can be said that labeling based on human subjectivity is effective. [48] Figure3.4 is the

Table 3.2: Spoken lines by emotion

Emotion	Dialog being uttered
Anger	20 utterance (例：ほんとむかついてきた)
Sorrow	20 utterance (例：生まれてこなければよかった)
Joy	20 utterance (例：ディズニーランドいきたかったんだー)
Calm	20 utterance (例：生年月日を言ってください)
Common emotions to any	20 utterance (例：やっときたよ)
合計	160 発話

labeling tool used for subjectivity evaluation.

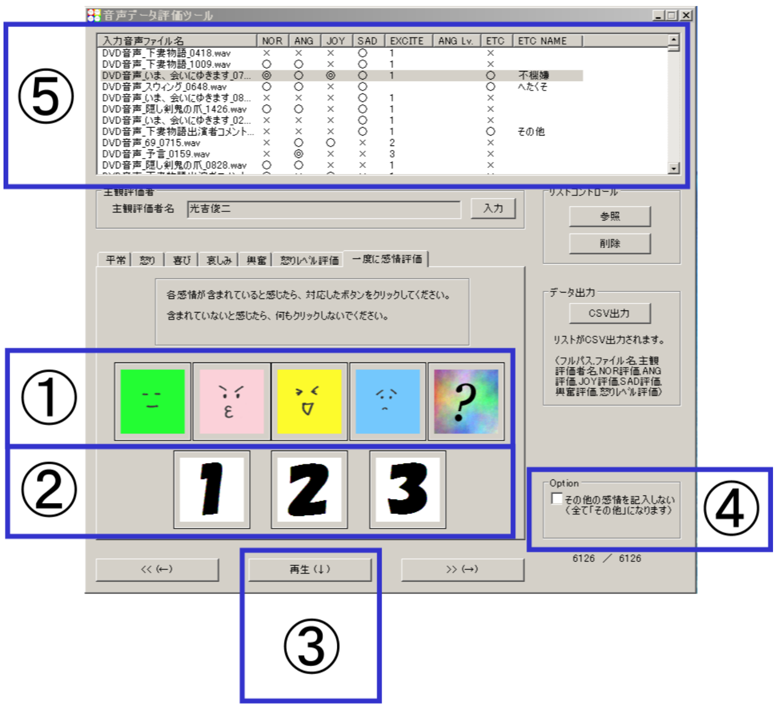

Figure 3.4: Automatic labeling tool

Based on Chapter3.1（p.21）, and considering the problem of measurement (i.e. the limitations of subjective evaluation), I divided emotion labels into 5 categories: anger, joy, sadness, normalness, and unknown, and subjects would either “feel” or “not feel” the emotions. (Refer to Figure3.4) Because the emotion, “excitement” exists in “anger,” “joy,” and “sadness,” I treated it separately from the rest. When evaluating “excitement,” (Refer to Figure3.4) I used the 3-level magnitude scale and attached a label to it. The subjective evaluation conducted in this thesis is as follows:

1. Prepare voice database for analysis.

2. Based on Chapter3.1（p.21）, present a random voice3.4 from database to 3 men and 3

Table 3.3: Human's voice feelings recognition ability 1: Result of feelings utterance evaluation of Nativ by non-native's evaluator (Data A, B -Table 1) ([4])

Element	Chinese	American	Average
Emotion	58%	53%	55%
Excitement	47%	40%	44%
Gender	97%	100%	99%

women, and have them conduct a subjective evaluation.

Thus, I attached labels of 6 people's subjective evaluations to a voice sample. However, if it was difficult to choose between the 4 main emotions, I allowed them to choose "unknown." "Excitement" was also investigated in the same manner. At first, I considered using all of the recorded voices, but since there were many voices that could not be categorized in any of the main emotions, I decided to remove those unclassified voices and tested 2087 voices.

1. Prepare voice samples for analysis.
2. Present a random voice from database to 3 men and 3 women, and have them conduct a subjective evaluation.

Thus, I attached labels of 6 people's subjective evaluations to a voice sample. However, if it was difficult to choose between the 5 emotions, I allowed them to choose "unknown."

3.4.3 Sorting of database

Data C and Data D were records collected during real-time evaluation experiments. I will explain further in Chapter 3.12

3.5 Emotion Recognition Ability Through Human Voice

In this thesis, I investigated how much humans can recognize emotions through voice. When humans recognize emotions through voice, words as well as rhythm are put into consideration. Here I tried to find out how much emotion one can recognize just through rhythm, without any understanding of words. (experimented on foreigners who do not understand Japanese) Experiment was based on method explained in Chapter3.1 (p.21) . Using database in Chapter 3.4 (p.30) , a recognition experiment of emotion vocalization was conducted with foreigners (3 Americans and 3 Chinese). As a result, 55% of the time, the foreigners could tell what emotion the speaker intended. For excitement, they could guess right 43.5% of time (Americans 40%, Chinese 47%). This result serves as standard guideline for emotion recognition through rhythm. Chart3.3. 3 explains a comparison of humans' emotion recognition ability in a non-verbal state.

Using the same database, an experiment on Japanese people was conducted. Chart3.4 shows results.

To evaluate emotions, I used F0 as a parameter and data mining tool to create a decision tree. This tree takes the emotions judged by multiple subjects, and applies a IF-THEN rule to the parameter mentioned above. A tree is made for each subject, and multiple trees were combined to recognize emotions [4]. Figure3.5 illustrates the flow of emotion recognition.

Table 3.4: Human's voice feelings recognition ability 2: Result of feelings utterance evaluation of Nativ by native's evaluator (Data A,B -Table 1) ([4])

Conscious emotional speech (DataA)	86%
Spontaneous emotional speech (DataB)	62%
Average (DataA,B)	74%

Table 3.5: Parameters for Emotion Recognition ([4])

Parameters	Description
Attack1 (Inclination)	Beginning of the emphases of the accent and the intonation, etc.
Attack2 (Maximum value)	is detected by seeing standing up (rise) of power.
Attack3 (Continuance length)	The influence is strong in joy and anger. (Refer to fig 3.6)
Keep1 (Continuance length)	Section from rise and downtrend of power.
Keep2 (Power average)	This seems that it influences the continuation of the emotion etc.
Keep3 (Δ Power average)	(Attack → Keep → Decay) becomes the hill of a single voice.
Keep4 (Variance)	(Refer to fig 3.6)
Decay1 (Inclination)	The delimitation of the intonation is found by seeing the downtrend of power.
Decay2 (Maximum value)	The influence comes out in sadness etc.
Decay3 (Continuance length)	(Refer to fig 3.6)
Δ power1 (Average)	Δ power value subdivided (Refer to fig 3.1)
Δ power2 (Variance)	The average and decentralization are seen.
F0 1(Average frequency)	Fundamental frequency , The change in the emotion influences through vocal chords.
F0 2(Variance)	The logarithm average and decentralization were requested in consideration of the difference between men and women. .

3.6 Parameter for emotion recognition

In many experiments that analyze emotions through voice, the relation of factors such as the change in power, fundamental frequency, and speed of speech, and emotions are analyzed. In this thesis, I will pay attention to the change in power and fundamental frequency. Chart3.5 shows the rhythm information used in the experiment. Below, I fill explain each parameter.

3.6.1 Change in Power

A recent technology report introduced a method of utilizing change in power [11][22][18] and accent [20][17] as analysis parameters. However, the report did not present a method of how to analyze the flow of overall power. Figure3.6 illustrates the typical power change when vocalizing a sentence. Note that power was calculated for each frame, and the average of 3 frames was used.

From my experience of developing emotion recognition systems in the past, I think that there a cause of emotion recognition in the *attack* and *decay* of power. I also think that in between

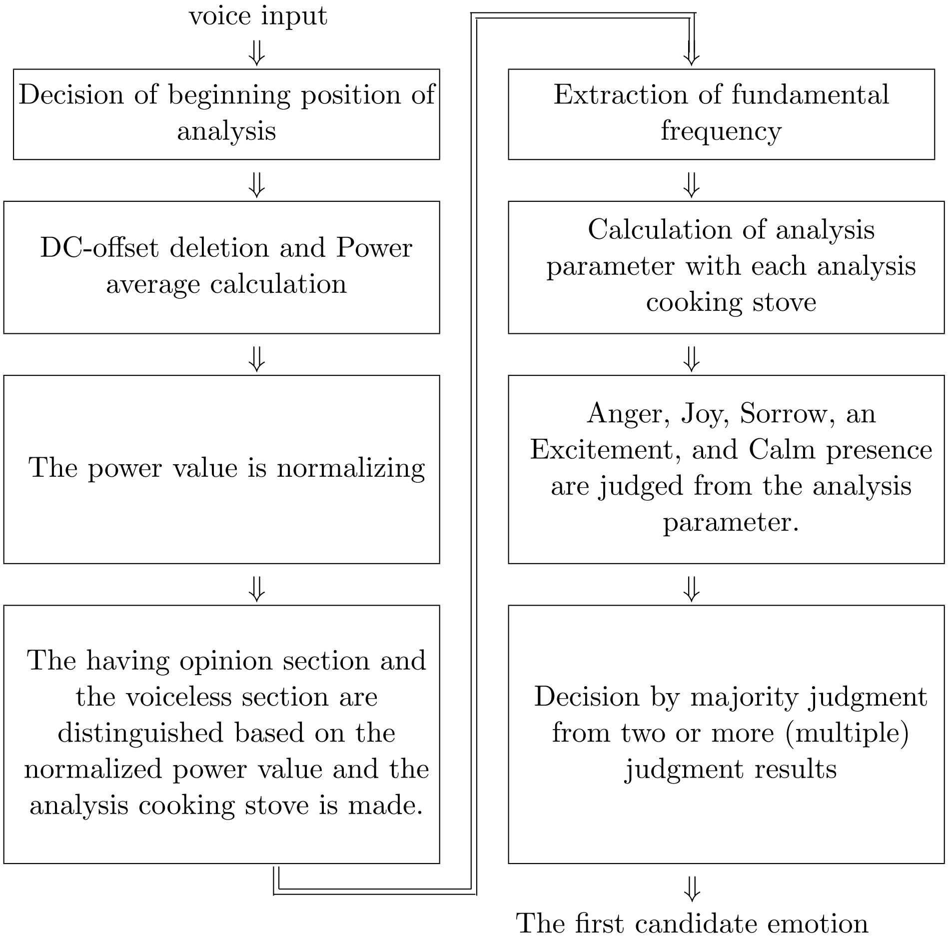

Figure 3.5: The flow of feeling recognition ([4])

the two, there is a continuous interval called "*Keep*." I will call this $Attack - Keep - Decay$ $(A - K - D)$. Multiple $A - K - D$'s exist in one vocalization. Therefore, I will classify voices according to $A - K - D$ units. In this thesis, I will call this $A - K - D$ intervals. The starting point of *attack* is described as the point where delta power exceeds the extreme number.(Refer to expression 3.1)

$$\Delta p = p_n - p_{n-1} (n = 1, 2, 3, 4, ...) \tag{3.1}$$

Attack interval continues while $\Delta p > 0$ after starting point is detected. (n describes frame number) In between frames, the point where $\Delta p \leq 0$ is detected is the end of *Attack* interval. The end of the *Attack* interval is the start of the *Keep* interval. The condition for continuation of *Keep* interval is that Δp does not exceed the extreme number. Once delta p exceeds the extreme number, the *Keep* interval ends.

The end of the *Keep* interval is the start of the *Decay* interval. *Decay* interval continues while $\Delta p < 0$. If $\Delta p \leq 0$ is detected, *Decay* ends, and so does a unit of $A - K - D$.

I will have to calculate the *Attack* value (refer to Equation 2), length of *Attack* interval (refer to Equation 3), slope of *Attack* (refer to Equation 4), length of *Keep* interval, power average of *Keep* interval (refer to Equation 5), the $\Delta Power$ average within the *Keep* interval(refer to

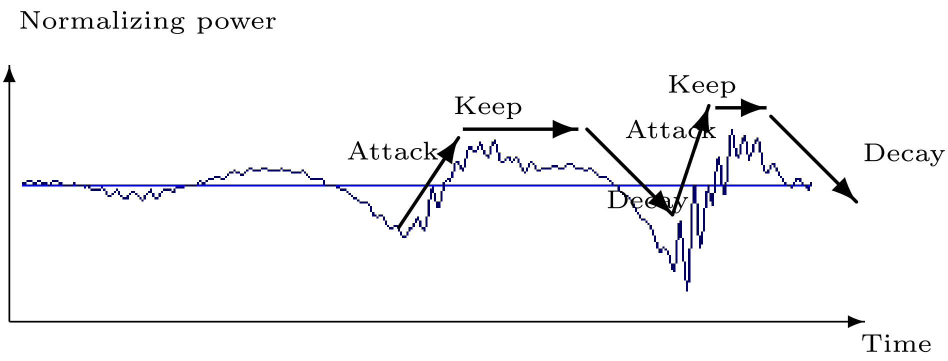

Figure 3.6: The rise and fall of power ([4])

Equation 6), *Decay* value (refer to Equation 7), length of *Decay* interval (refer to Equation 8), and *Decay* slope (refer to Equation 9).Below is the calculation method of each value.

Attack value is calculated by: power of starting point of *Attack* is p_{sA}, and ending point is p_{eA}.

$$Attack = p_{eA} - p_{sA} \tag{3.2}$$

is the equation. The length of *Attack* interval is: starting point of *Attack* is L_{sA} while ending point is L_{eA}

$$\Delta t_A = L_{eA} - L_{sA} \tag{3.3}$$

is the equation. *Attack* slope is described as the following within the *Attack* interval:

$$\Delta t_A = \frac{Attack}{\Delta t_A} \tag{3.4}$$

Keep interval's length is describes as L_k. The average power value of the *Keep* interval is as below within the *Keep* interval:

$$Keep = \frac{1}{L_k} \sum_{n=0}^{L_k-1} p_n \tag{3.5}$$

The average of $\Delta Power$ within the *Keep* interval is as below within the *Keep* interval:

$$\Delta Keep = \frac{1}{L_k - 1} \sum_{n=1}^{L_k-1} (p_n - p_{n-1}) \tag{3.6}$$

The *Decay* value is as below when *Decay* starting point is p_{sD} and ending point is p_{eD}:

$$Decay = p_{eD} - p_{sD} \tag{3.7}$$

The length of the *Decay* interval is as below when the *Decay* starting point is L_{sD} and ending point is L_{eD}:

$$\Delta t_D = L_{eD} - L_{sD} \tag{3.8}$$

The *Decay* slope is as below within the *Decay* interval:

$$\Delta Decay = \frac{Decay}{\Delta t_D} \tag{3.9}$$

A single vocalization includes multiple $A-K-D$'s, so the average of all the $A-K-D$ intervals were calculated. Additionally, the average of Δp and distribution were calculated for the entire vocalization, and this was added as $\Delta Power1$ and $\Delta Power2$ in the parameter.

3.6.2 Fundamental frequency

There are many methods for finding the estimation of fundamental frequency [133] [134] [135] [136] [137] [138] . However there is no certain method. However, it is difficult to find an accurate pitch frequency among many noises. Estimation of fundamental frequency using Cepstrum is most popular, but as Figure 3.7 shows, much dispersion was verified when using this method, and I concluded that it is not suitable for out experiment. Below, I will illustrate the method of fundamental frequency analysis using Cepstrum.

Estimation of fundamental frequency using Cepstrum analysis In voice recognition researches, it is generally considered important to extract spectrum envelope from vocaltract specter formant, and spectrum's minute structure by the voice source's fundamental frequency. Below, I will reference general textbook [139]explanation of estimation of fundamental frequency through Cepstrum analysis. Estimation of fundamental frequency is defined as the detection of wave shape and cycles of voice source. Cepstrum analysis is defined as a non-parametric analysis method that enables the separation of spectrum envelope and the spectrum's minute structure.

It is often used to analyze vocaltract language output as shown in Figure 3.3 and Figure 3.1. As for the estimation of fundamental frequencies, high quefrency area's peak value is calculated.

Voice waveform x_n is described as a fold-in of vocal cord waveform g_n and vocal tract impulse response v_n.

$$x_n = \sum_{k=-\infty}^{\infty} g_k \cdot v_{n-k} = g_n * v_n \tag{3.10}$$

On the other hand, the Z conversion is described as: $X(z) = \sum_{i=-\infty}^{\infty} x_i \cdot z^{-i}$ (Fourier transformation)

$$X(z) = G(z) \cdot V(z) \tag{3.11}$$

The power spectrum $S(z)$ is described as:

$$S(z) = |X(z)|^2 = |G(z)|^2 \cdot |V(z)|^2 \tag{3.12}$$

When log of both ends are taken,

$$\log|X(z)|(= \frac{1}{2}\log S(z)) = \log|G(z)| + \log|V(z)| \tag{3.13}$$

Becomes true and when the spectrum strengths' logarithm are expressed, it becomes the sum of the logs of $G(z)$ and $V(z)$. Spectrum of $S(z)$, S_k has an inferior peak in terms of linear spectrum strength. Spectrum strength is often described in terms of logarithm. Equation 3.13 is the same operation as these expressions. Thus, as in equations 3.14,3.15,3.16, Cepstrum C_n is defined.

$$C_n = \frac{1}{2N} \sum_{k=-(N-1)}^{N-1} \log S_k \exp(j\frac{2\pi kn}{N}) = \frac{1}{2N} \sum_{k=-(N-1)}^{N-1} \log S_k \cos(\frac{2\pi kn}{N}) \tag{3.14}$$

$$= \frac{1}{N} \sum_{k=-(N-1)}^{N-1} \log G_k \exp(j\frac{2\pi kn}{N}) + \frac{1}{N} \sum_{k=-(N-1)}^{N-1} \log V_k \exp(j\frac{2\pi kn}{N}) \qquad (3.15)$$

$$= \frac{1}{N} \sum_{k=-(N-1)}^{N-1} \log G_k \cos(\frac{2\pi kn}{N}) + \frac{1}{N} \sum_{k=-(N-1)}^{N-1} \log V_k \cos(\frac{2\pi kn}{N}) \qquad (3.16)$$

Through the Cepstrum analysis as above, the minute structure of the spectrum concentrate in large quefrency values, and the spectrum envelopment concentrate in the small quefrency values. The log power spectrum can be calculated by discrete Fourier transform of Cepstrum:

$$\frac{1}{2} \log S_k = \sum_{n=-(N-1)}^{N-1} C_n \exp(-j\frac{2\pi kn}{N}) = \sum_{n=-(N-1)}^{N-1} C_n \cos(\frac{2\pi kn}{N}) \qquad (3.17)$$

The spectrum envelopment information included in Cepstrum's low quefrency is liftered, and only the low quefrency parts are transformed by discrete Fourier to calculate the log spectrum envelopment. By erasing the exponent of log spectrum envelopment, one can change it into linear axis spectrum envelopment.

Autocorrelation and detection of fundamental frequency through regression line
The Cepstrum analysis' extraction of minute structure from high quefrency values as mentioned before, doesn't serve in accurately estimating the fundamental frequency of voice, since it picks up noise and disperses the voice source's wave shape and cycles. In order to overcome this problem, I tried using logarithm's autocorrelation and regression line to detect fundamental frequencies.

However, to use regression lines, I will establish a margin of error at the point of origin, based on experience. In this experiment, I determined the margin of error based on the voice analysis database I collected.

For sake of comparison, I show both Cepstrum analysis and proposal analysis in Figure 3.7. The circles indicate the dispersions. The continuation of frequencies in the proposal analysis' post-autocorrelation threshold after it has passed the point of origin seems to have gone well even compared to the Cepstrum analysis. On the other hand, because it could also be thought that noise influence and ambiguous parts are omitted by Cepstrum's minute structure extraction, I can identify the easily dispersed areas by comparing the Cepstrum analysis, autocorrelation, and regression line method. These information become useful when analyzing the condition of voice, the back brain, and biology indicators. Therefore, I am not completely disproving the Cepstrum analysis method. F0 mentioned above is introduced frame by frame, but all existing frames in a vocalization were accounted for, by calculating the average and dispersion of each.

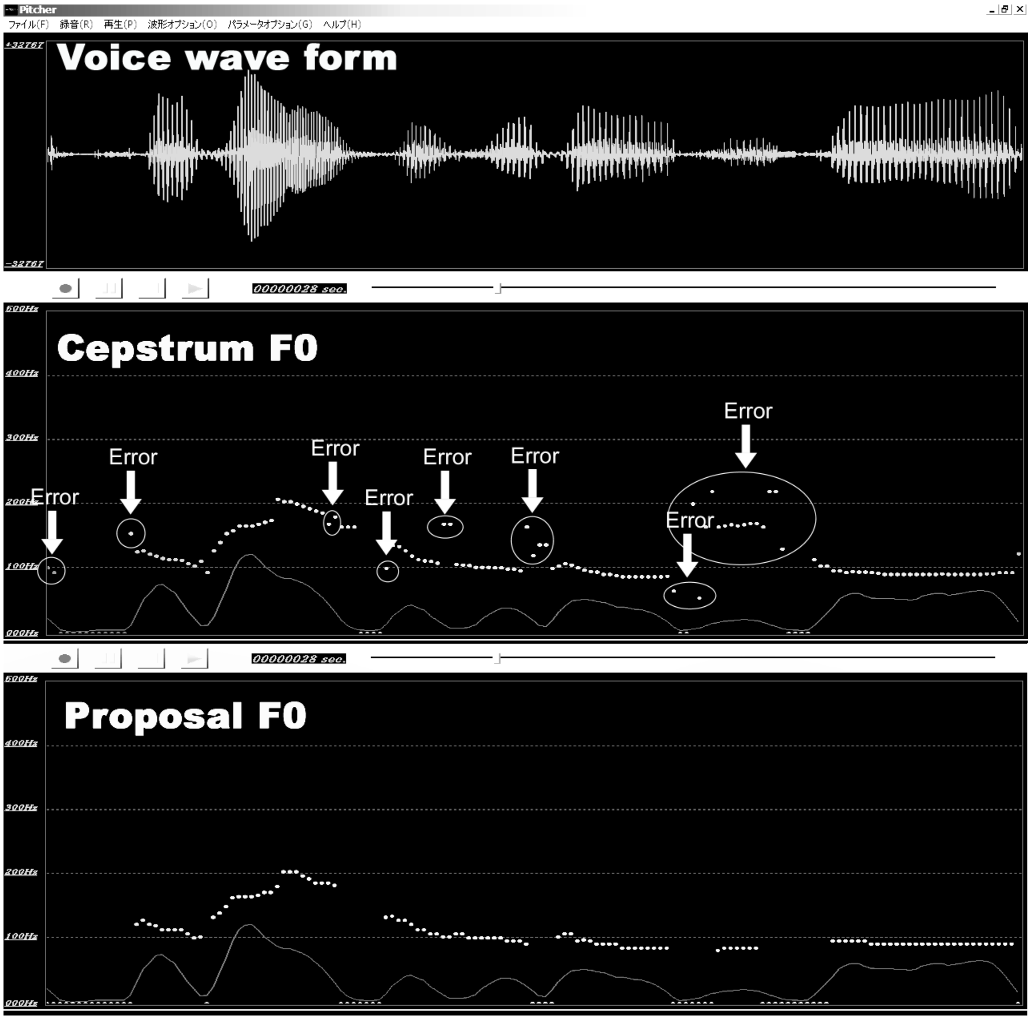

Figure 3.7: Detection of Fundamental Frequency

3.7 Decision Tree and Parameters for Emotion Evaluation

The decision logic based on experience from parameters has been previously made, but now there is a need to reflect the increase of parameter and human subjectivity. So, based on human subjectivity evaluation results, a decision tree for each feeling attribute was made by using the parameters of voices in Chart 3.5. A data mining tool was used for the creation of the decision tree. A data mining tool is a tool to calculate the threshold needed for categorization, from the given parameter set. The threshold calculated by a data mining tool is called the decision tree. Each decision tree is an IF-THEN comparison of the parameter and the threshold. The decision tree is created by each of the 6 subjectivity evaluators based on the following steps.

1. Prepare voice data that are labeled by subjective evaluation.
2. From the prepared voice data, create the various parameters.
3. As data set of a data mining tool, create combinations of parameters and subjective evaluations.

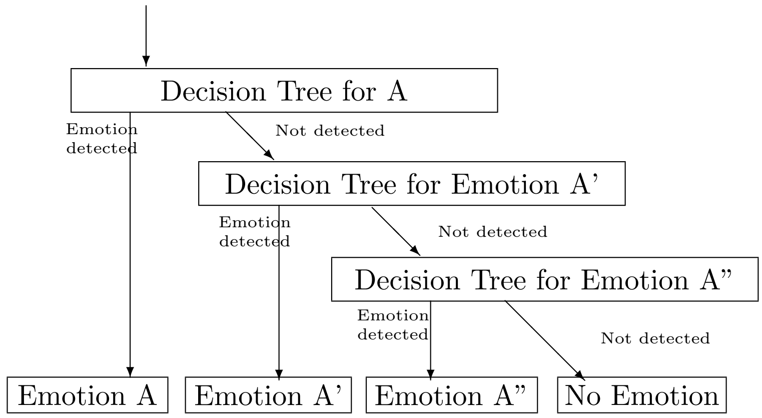

Figure 3.8: Decision Logic of Feelings ([4])

4. Create the first decision tree at a data mining tool.

5. If the concerned feeling was not detected after comparing the evaluation result of the decision tree and the result of the subjective evaluation, a data mining tool is applied again and a new decision tree A' is created.

6. In turn, decision tree A" and A"' are created, until it is no longer possible to create a decision tree.

The reason multiple decision trees were created is to prevent failures to pick up feelings in the process of discerning them. The parameter characteristics of the decision tree are different for each feeling, and there is a need to broaden the range of decisions. Therefore, the decision tree was made on multiple levels and turned into a decision logic.

Figure 3.7 describes an example of the decision logic of feeling recognition.

3.8 Multiple Decision Logic for Final Decision

When using a particular person's decision logic, the decision is bound to become biased towards the person's subjectivity. Therefore, multiple people's decision logic will be used in this thesis. Specifically, multiple people's decision logic will be used simultaneously to for feelings decision, and if the number of times a decision logic admitted the existence of feelings exceeded the standard value, it was decided that the voice includes aspects of feelings. The standard value defers depending on which feeling it relates to. This is because for some feelings, decisions are harder to make than others. This method of using multiple people's decision logic is called Multiple Decision logic. From each feelings' multiple decision logic, multiple feelings could be detected.

3.8.1 Method of Final Decision-Making

If more than one feeling is detected using the multiple decision logic, one must make a final decision as to which feeling is the strongest. The different feelings that were detected are combined in different ways and each combination is used to make a new data mining tool decision tree.

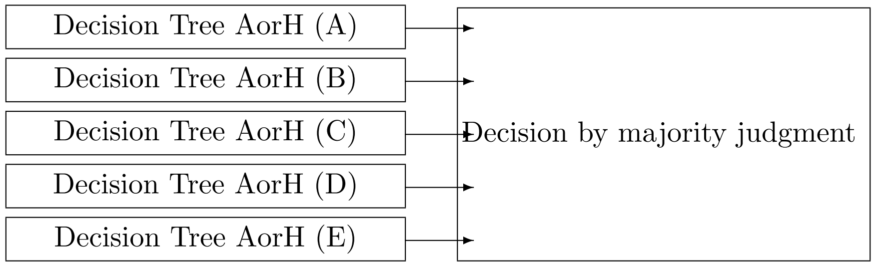

Figure 3.9: A-H decision logic

Making the decision tree

1. The results of the decision logic are named A for anger, H for happiness, S for sadness, N for normality.

2. As a final decision maker for instances where more than one feelings were detected, a method is made to decide which feeling is stronger as below. This is called the dual-feelings decision logic.

   (a) A-H decision logic (decide between A and H)
   (b) A-S decision logic (decide between A and S)
   (c) H-S decision logic (decide between H and S)
   (d) N-S decision logic (decide between N and S)
   (e) N-A decision logic (decide between N and A)
   (f) N-H decision logic (decide between N and H)

3. Example for dual-feelings decision logic is as follows: When dealing with A-H decision logic, use the training set of the database and extract data of individuals that only detected A or H from the voice database and parameter, and from a data mining tool create A-H decision tree for each subjective evaluator. Make these decision trees for each dual-feelings.

Figure 3.9 describes a conceptual overview of dual-feelings decision example.(A-H)

Procedure of decision-making

1. If more that one feeling is detected from the multiple decision logic, make a dual-feelings decision logic for every single feelings combination as described above.

2. The decision within each dual-feelings decision logic is made by taking the majority judgment of the decision result of multiple people's decision tree.

3. The final decision is made by taking the majority judgment of each dual-feelings decision logics' decision.

Figure 3.10 shows a conceptual diagram of the procedure of making the final decision. However, if two final decisions have the same majority judgment, the result of the concerned feeling's dual-feelings decision logic is deemed the final decision. If he majority decision is three or more, the final decision is categorized as unknown.

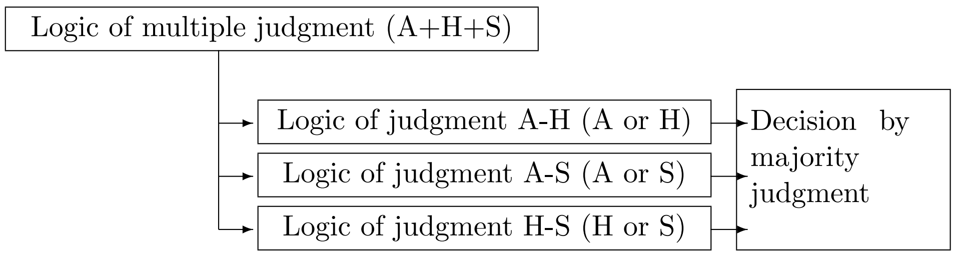

Figure 3.10: Final judgment

3.9 Feelings and Parameters

Using the feelings vocalization voice database, a tool that displays the subjectivity-evaluated voice file was made to investigate the relation for each parameter. Each parameter's separation situation depending on individual subjectivity was investigated. By comparing database that reflects multiple people's subjectivity and a particular person's subjectivity, effective parameters and important decision trees can be determined. For the parameter of excitement, which is an emotion, the relation of fundamental frequency and power serves to separate. Moreover, when considering multi-level separation of active feelings apart from human subjectivity, comparison between biology indicators become necessary.

It was difficult to make clear separations when analyzing each parameter individually, since anger, happiness, sadness, normality all differ in terms of subjectivity and introspection for each person, and multiple people's subjectivity were being used as database. However, parameters which were made by converting fundamental frequencies into logarithms were found to be effective.

On the other hand, according on the combination of parameters obtained when finding the logarithm of the parameter of excitement parameter and fundamental frequency, the separation of feeling labels were analyzed. The separation situation of the most effective separations made by different combinations of the parameter will be described below.

3.9.1 The Separation of Anger and Happiness

Figure 3.11 indicates the separation of anger and happiness. The yellow dots describe the location of the voice file that was evaluated as happiness, and the red dots describe those of anger. One can hear the voice sample simply by clicking on the dots. One can check the condition of separation by looking at the excitement parameter and fundamental frequency's logarithm average. Because in this case, the separation is quite clear, it will be used for the decision tree. However, the overlapping parts are considered difficult to separate. Anger and happiness were difficult to differentiate, even for the subjective evaluations. Moreover, since the two are similar feeling labels of the same emotion of excitement, they are bound to have significant recognition influences from Schachter-Singer Two-factor theory. Therefore, it can be conjectured that the results were as the diagram below. In this case, other parameters' separations can be referenced to make the borderline parts influential on multiple levels. This method is applied to the multiple decision logic.

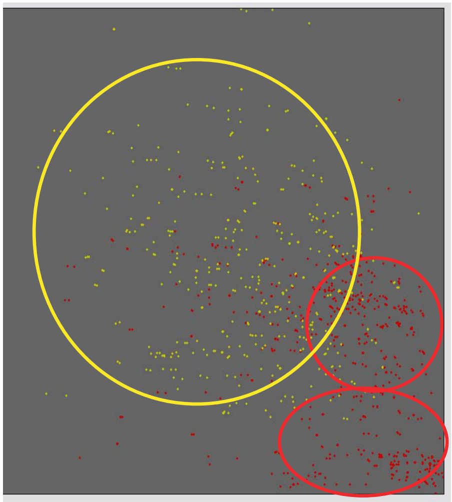

Figure 3.11: Separation of Anger and Happiness

3.9.2 The Separation of Happiness and Normalness

Figure 3.12 describes the separation of happiness and normalness. The yellow dots describe voice files that were evaluated as happiness, and the green dots describe that of normalness. One can check the condition of separation by looking at the excitement parameter and fundamental frequency's logarithm average. Because in this case, the separation is quite clear, it will be used for the decision tree. However, the overlapping parts are thought of as difficult to separate. In this case, other parameters' separations can be referenced to make the borderline parts influential on multiple levels. This method is applied to the multiple decision logic.

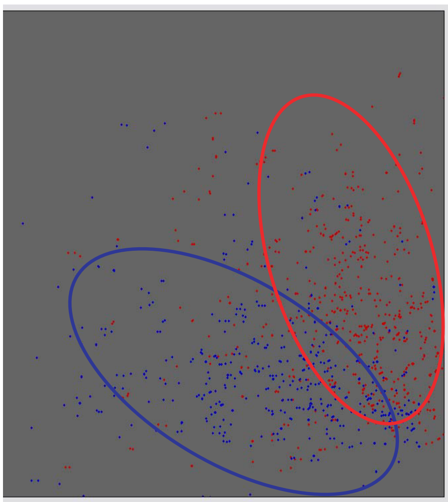

Figure 3.12: Separation of anger and sadness

3.9.3 Separation of Sadness and Normalness, Anger and Normalness

Figure 3.13 describes the separation of sadness and normalness, anger and normalness. The green dots were evaluated as normalness, and the red as anger. Blue dots describe voice files of sadness. One can check the condition of separation by looking at the excitement parameter and fundamental frequency's logarithm's standard deviation. Because in this case, a symmetrical separation can be seen, it will be used for the decision tree. However, the straight-line areas near the border that show overlapping are thought to be difficult to separate. In this case, other parameters' separations can be referenced to make the borderline parts influential on multiple levels. This method is applied to the multiple decision logic. However, because human subjectivity is used, it cannot be said that separation is being done according to genuine active feelings. Moreover, because perfect separation by subjectivity is difficult, comparisons with biology indicators were be referenced.

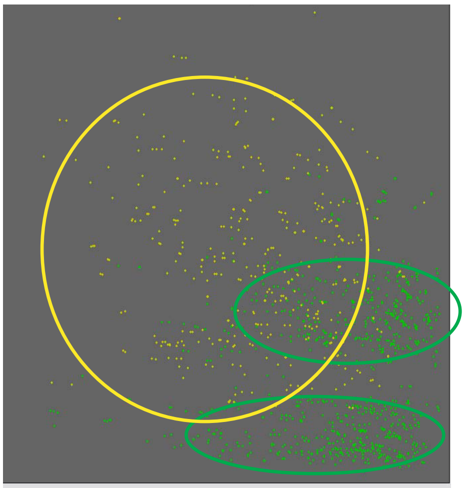

Figure 3.13: Separation of happiness and normalness

3.9.4 Separation of Sadness and Normalness, Anger and Normalness

Figure 3.14 describes the separation of sadness and normalness, anger and normalness. The green dots were evaluated as normalness, and the red as anger. Blue dots describe voice files of sadness. One can check the condition of separation by looking at the excitement parameter and fundamental frequency's logarithm's standard deviation. Because in this case, a symmetrical separation can be seen, it will be used for the decision tree. However, the straight-line areas near the border that show overlapping are thought to be difficult to separate. In this case, other parameters' separations can be referenced to make the borderline parts influential on multiple levels. This method is applied to the multiple decision logic. However, because human subjectivity is used, it cannot be said that separation is being done according to genuine active feelings. Moreover, because perfect separation by subjectivity is difficult, comparisons with biology indicators were be referenced.

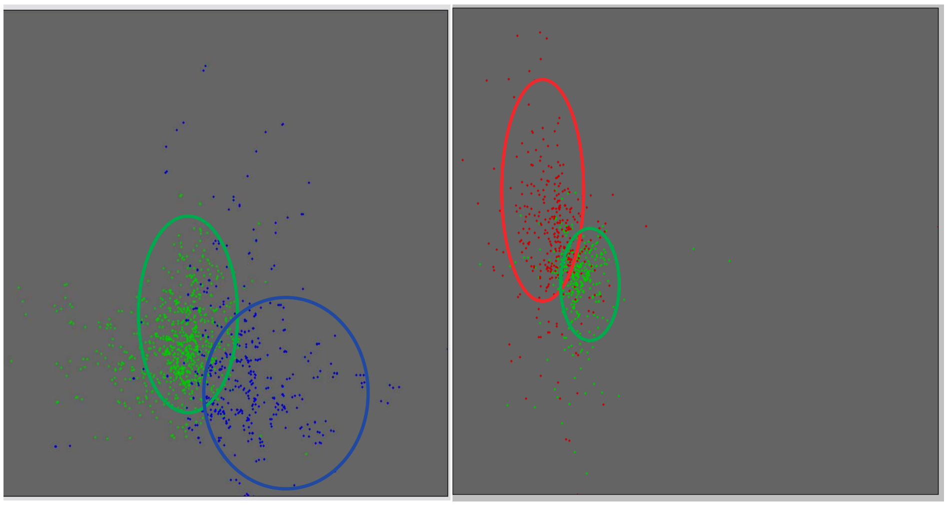

Figure 3.14: Separation of sadness and normalness, anger and normalness

3.9.5 Separation Characteristics of Excitement and Feeling Labels According to Parameters

To find out the relation between excitement, an emotion, and feeling labels such as anger, happiness, sadness, normalness, a common parameter of the feeling labels was found. The separation was clearly possible in two aspects; separation by standard deviation of the logarithm between the parameter of excitement and fundamental frequency, and separation by averaging the logarithm of parameter of excitement and fundamental frequency. This is a sign that excitement is deeply related to feeling labels in general, and that fundamental frequency is a big part of recognition influence and label decision.

3.10 Feeling Recognition Experiment through Voice

The decision logic and decision tree both reflect human subjectivity. Therefore, when one wants to know how each parameter is related to each feeling, the parameter must be individually separated and the subject's introspection, brain and biological reactions must be compared to make analysis. However, since VEA reflects human's passive feelings, it is possible to know its efficiency by comparing human subjectivity and subject introspection.

In order to evaluate the speaker's natural vocalization using the method explained previously, an evaluation system that judges real-time conversations of the speaker was created. For the evaluation system, a one-directional microphone was used to record one speaker's voice for one minute, with the minute divided up into smaller voice units. As mentioned in the proposed method, the emotion results of the judgment are displayed on the screen real-time. Figure 3.15 illustrates the display of feeling recognition evaluation system. The emotional attribute is displayed along the squares as shown in the upper half of the diagram. The very top of the squares is the final judgment result. Depending on the order of the speech, the final decision result is displayed from the left side of the horizontal lines. The middle section displays other feelings also included in the final decision, and the lower section displays the most basic three levels of excitement. By looking at the upper, final decision result section, the evaluator may evaluate the decision results real-time for each voice unit of the speaker's voice.

The evaluation system records the voices simultaneously with the real-time evaluations, and

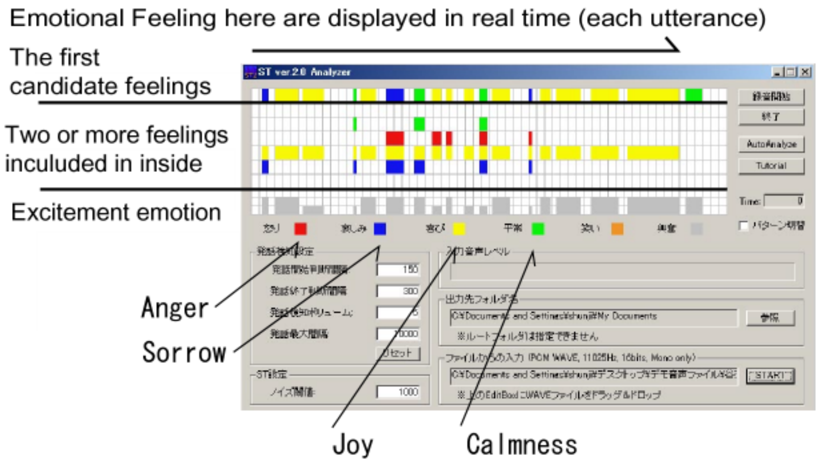

Figure 3.15: The VEA evaluation system ([4])

saves the information of feeling decision result labels attached to each voice. This way, the speaker and the counterpart may evaluate the judgment of the system after they have conversed. Figure 3.16 shows how one may evaluate the evaluation system real-time while holding a conversation. Because this experiment deals with human subjectivity and introspection, it was held based on the implementation planning method discussed in Chapter 3.1 (p.21) .

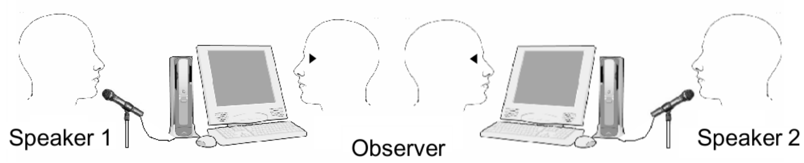

Figure 3.16: Real-time conversation experiment using VEA evaluation system (DataC,DataD-Table-1) ([4])

3.11 Feeling Recognition Experiment by VEA Evaluation System

In order to verify the effect of the validity of the proposed method, the congruency of human's natural feelings and judgment of proposed method was studied. Moreover, it can be assumed that compared to the excitement emotion, anger, happiness and sadness as feelings are more easily influenced by personal differences in feeling labeling because of recognition influences of biology reactions and environmental situations. The following experiment was conducted to prove the above as a part of the hypothesis.

Figure 3.17 shows the relation between VEA and the vocalization feeling from the experiment results. In order to prove that the proposed method can be used for natural feeling recognition continuously, the percentage of correct answers of real-time judgment of the speaker of the natural feeling continuous vocalization voice, and friend of the speaker (2 yr and 8 yr relationship with speaker) were studied. A similar experiment right after the speaker's conversation was also held. The subject of this experiment was different from the speaker of feeling database or the

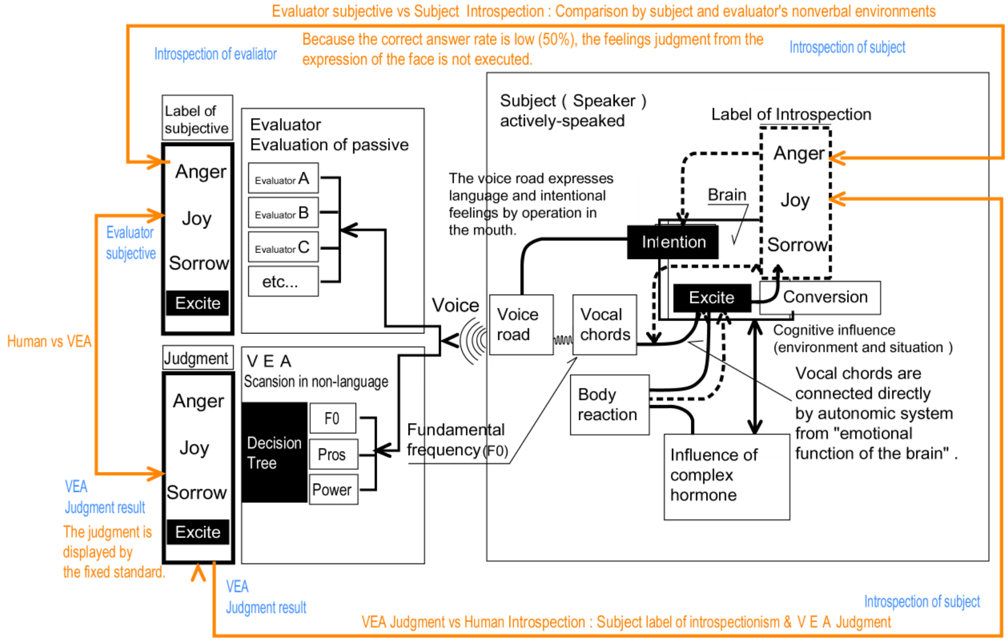

Figure 3.17: Recognition comparison chart of feelings using VEA evaluation system

subject who did the labeling in Chart 3.1.

3.11.1 Method of the Experiment

The procedure of the experiment is as follows:

1. 1 operator of the evaluation system, 2 subjects, 2 observers were prepared. 1 system per subject was prepared.
2. The subject and observer were well-acquainted with each other. (2 yr and 8 yr relationship with subject)
3. The subjects relaxed and held everyday conversations.
4. The topic of the conversation was up to the subjects, but they were told beforehand that it must be about "something bad," "something fun," "something painful," "something sad" that happened recently.
5. When the system operator decided that the conversation was becoming smooth after a while, the evaluation system was started.
6. The evaluation system runs automatically for a minute, displays the judgment and records the result and the voice voices.
7. Simultaneously, the observer will listen to the subject's utterances and judge whether or not the system's judgment is right. The percentage of correct judgment is counted.
8. After a minute, the subjects themselves replayed their utterance and evaluated the correctness of the system's judgments.

Table 3.6: The percentage of correctness of VEA evaluation system during natural feeling continuous conversation (subjective evaluation of friend of 2 yrs)(description of [4])

Evaluation	A (Number of evaluation utterances)	B (Number of evaluation utterances)	C (Number of evaluation utterances)	D (Number of evaluation utterances)	Total correct answers (Number of evaluators × Number of utterances)
Number of correct answers	50(73)	74(138)	81(136)	85(139)	290(486)
Percentage of answered correctly	68%	54%	60%	61%	60%

Table 3.7: The percentage of correctness of VEA evaluation system during natural feeling continuous conversation (Speaker's own subjective comparison) (description of [4])

Evaluation	A (Number of evaluation utterances)	B (Number of evaluation utterances)	C (Number of evaluation utterances)	D (Number of evaluation utterances)	Total correct answers (Number of evaluators × Number of utterances)
Number of correct answers	64(89)	17(24)	17(26)	15(23)	113(162)
Percentage of answered correctly	71%	71%	65%	65%	70%

9. Conversations continued after judgment, but the system operator waited until the conversation became smooth again to start the evaluation system again. This process was repeated.

Following the above procedure, the percentage of correctness of the system was finally calculated using the equation below:

$$\text{Percentage of correctness} = \frac{\text{the number of times the displayed judgment felt right}}{\text{number of evaluators} \times \text{number of utterance}} \times 100 \tag{3.18}$$

3.11.2 Evaluation Between Friends (2-year Relationship) Using the VEA Evaluation System

Experiment 1 was implemented by four friends (all 2 yr relationship) of subject. Chart 3.6 and 表 3.7 show the results. The charts show the number of evaluation utterances of each evaluator and the percentages of correctness. For example, in evaluator A's case, s/he evaluates B, C, and D in Chart 3.7 , and in Chart 表 3.7 evaluates A's (subject) utterance. In other words, Chart 3.7 shows the percentage of correctness of evaluators besides the subject, and Chart 3.6shows the percentage of correctness of the subject him/herself.

The former percentage of correctness was 60%, and the latter was 70%.

Table 3.8: Percentage of correctness of VEA evaluation system during natural feeling continuous conversation (subjective evaluation of friend of 8 yrs right after utterance)

Evaluation	E (Number of evaluation utterances)	F (Number of evaluation utterances)	Total correct answers Number of evaluators × Number of utterances)
Number of correct answers	10(11)	25(31)	35(42)
Percentage of answered correctly	90%	80%	85%

Table 3.9: The percentage of correctness of VEA evaluation system during natural feeling continuous conversation. Comparison with subject's own introspection right after utterance

Evaluation	E (Number of evaluation utterances)	F (Number of evaluation utterances)	Total correct answers Number of evaluators × Number of utterances)
Number of correct answers	10(11)	26(31)	36(42)
Percentage of answered correctly	90%	84%	86%

3.11.3 Evaluation Between Friends (8-year Relationship) Using the VEA Evaluation System

In order to see if intimacy of a relationship impacts the percentage of correctness using the proposed method, the same experiment as 3.11.2 was conducted with friends of longer relationships. Judgment was made by replaying utterances right after conversations. Chart 3.8 and 3.7 show the results.

Chart 3.8and 3.7 show that there is almost no difference in the evaluation of the subject and the friends. The percentage of correctness was an 85% average. Chart 3.10compares the difference of intimacy of DataC and DataD.

3.11.4 Comparison Experiment of VEA Evaluation System and Human Subjective Evaluation

Feeling recognition rate measures its congruency with the speaker's feelings. The congruency with the subjective evaluation of someone other than the speaker was studied. Using the feeling voice database in Chapter 3.4 (p.30) (Chart 3.1), a comparison between the recognition of the evaluation system, third person subjective evaluation, and speaker's own subjective evaluation was explored.

$$\text{Matching Rate}(\%) = \frac{\text{The Number of VEA-Human Evaluation Matchings}}{\text{The Number of Recognition Result}} \times 100 \qquad (3.19)$$

Experiment description: In order to know the characteristics of feelings, a comparison of the recognition result by VEA evaluation and subjective evaluation by multiple subjects needs to

Table 3.10: Comparison of DataC and DataD ([4])

	Number of correct answers	Number of utterances	Percentage of answered correctly
DataC	113	162	70%
DataD	36	42	86%

Table 3.11: Observer subjectivity and VEA evaluation system judgment's congruency comparison for each feeling (DataA,B -Table 1) ([4])

	DataA	DataB
Anger	71%	55%
Sorrow	52%	47%
Joy	55%	73%
Calm	66%	94%
Avg.	61%	67%

be made. For each feeling, the congruency of subject's subjective evaluation and the recognition rate of VEA evaluation system were studied.
Chart 3.11 shows the recognition congruency for each feeling.

Because of the influences of time and sensitivity, more than 40% of the time, the subjective evaluators' evaluations are not congruent. [121][122].

Because there is no absolutely correct standard that can be used to encode human subjectivity, there is no way of examining a completely precise system. So, when it is impossible to use an absolutely correct standard, it is effective to compare results with results when feelings were randomly selected. In this experiment, the margin of error was less than 5%.

Comparison of subjective evaluation of emotions The emotion of excitement is included in most feelings. Using DataA and DataB, both judged to include feelings, a subjective evaluation was made as described in Chapter3.11.1 (47) , with excitement being independent from other feelings.

A comparison between the recognition result by the proposed method and subjective evaluation was made for excitement. The results are shown in Chart 3.12. In Chart 3.13, evaluation was made using three levels of excitement, none to little, medium, and strong.

3.11.5 Comparison with Old Version of VEA Evaluation System

Previously, we developed a voice recognition system that recognizes the aspect of feelings (ST version 1.0; AGI Inc.1999). The system parameterized the absolute value of power used in the analysis, and the frequency analysis of the utterance. At that time, this system was the only voice feeling recognition device in the market. By using the same database, we compared the qualities of ST2.0 (used in this thesis) and ST1.0. Chart 3.14 shows results. In Chart 3.14, the recognition rate of ST1.0 is 55%, while ST2.0's rates are between 70% and 86%. This indicates that when consciously uttered and when naturally uttered, the method that considered rhythm

Table 3.12: Congruency comparison of observer subjectivity and VEA evaluation system judgment from the standpoint of emotion (excitement) （DataA,DataB -Table 1）

	No (System)	Yes (System)
No (Evaluator)	1099	61
Yes (Evaluator)	675	295
Concordance rate	62%	83%
Unclear (Evaluator)	162	60

Table 3.13: Congruency comparison of observer subjectivity of emotions and VEA evaluation system judgment （DataA,DataB -Table 1 Three stage evaluation of excitement）

	No (System)	Low (System)	Strong (System)
No (Evaluator)	1099	36	25
Low (Evaluator)	623	154	41
Strong (Evaluator)	52	63	37
Concordance rate	62%	60%	36%
Unclear (Evaluator)	162	41	19

of speech, such as F0 and A-K-D are effective.

3.11.6 Verification of Influences of Evaluator Using Display of VEA Evaluation

The VEA system allows evaluator to judge whether the analysis results are right or wrong as the experiment proceeds (real-time). However, as the Schachter-Singer Two-factor theory proves, there is a possibility that human judgment and feeling evaluations change because of recognition influence. Therefore, there is a need to find out whether the evaluator's evaluation is wavered by the analysis display results.

Experiment Because the experiment removes the influence by display to evaluate, I will use Chapter 3.1（21） as a standard and use the same voice used when displaying VEA and record the results of it when using a separate subjective evaluation tool(refer to Figure 3.4). I then compared the congruency with the VEA evaluation afterwards. Because real-time utterance experiments (DataC and D) are too fast-paced to for recording of human feeling evaluation, DataA and B were used. Figure 3.18 shows the image of the experiment.

Results The comparison results showed a 25% influence [121], but whether this is the influence of human subjectivity or the display is not discernable. However, as Schachter-Singer Two-factor theory proves, it was verified that human judgment and feeling evaluation is indeed impacted by recognition influence.

Table 3.14: Comparison with recognition methods of the past ([4])

	Content of recognition	recognition rate
Human	DataA+DataB Avg.	Subjectivity comparison in non-native language 55% Subjectivity comparison in native language 74%
Emotion recognition of the past	Absolute value of power , Frequency analysis ; Analysis of the entire utterance	Introspection comparison in utterance subject 55%
VEA (Non-verbal)	Rhythm analysis ; F0, normalized power, A-K-D analysis	Subjective comparison in utterance subject 70% Introspection comparison in utterance subject 86%

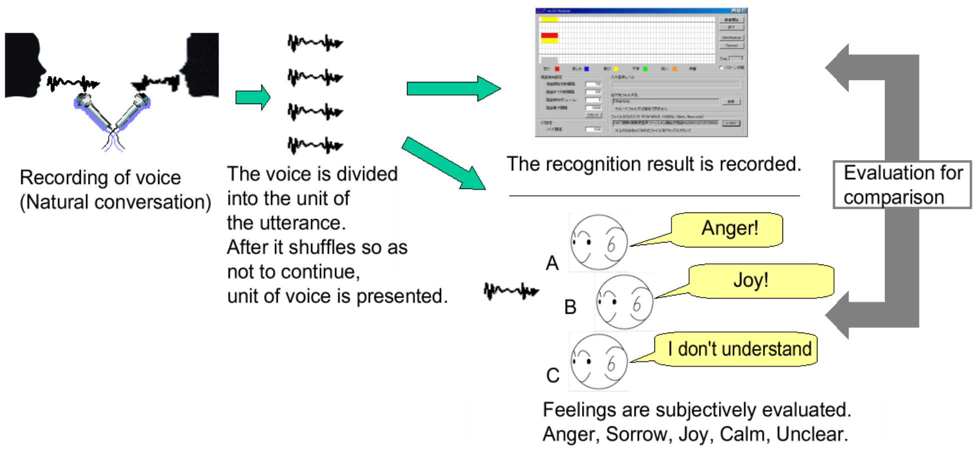

Figure 3.18: Evaluator's influence verification experiment by display (Japan SGI)

3.11.7 Verification of Influences of Evaluator's Habituation

When humans hear conversational voices continuously, the factor of habituation, or "getting used to," must be considered. I investigated whether the same recognition results could be attained by listening in continuous conversational voices and discontinuous, separated voices.

Experiment Humans get used to human voices after a while, even if the speaker is a stranger. To find out if the factor of "getting used to" can be omitted, I will use Chapter 3.1 (21) as a standard and use the same voice used when displaying VEA and record the results of it when using a separate subjective evaluation tool (refer to Figure 3.4). I will then compare the congruency with the VEA evaluation afterwards.

Figure 3.19 illustrates the image of the experiment.

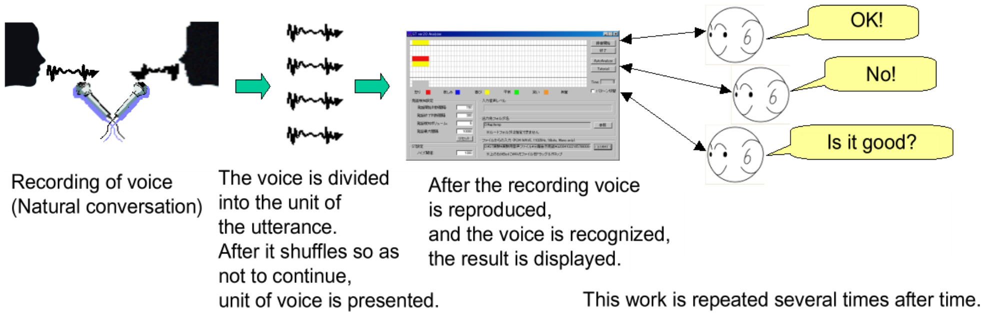

Figure 3.19: Verification experiment of influences of evaluator's habituation (Japan SGI)

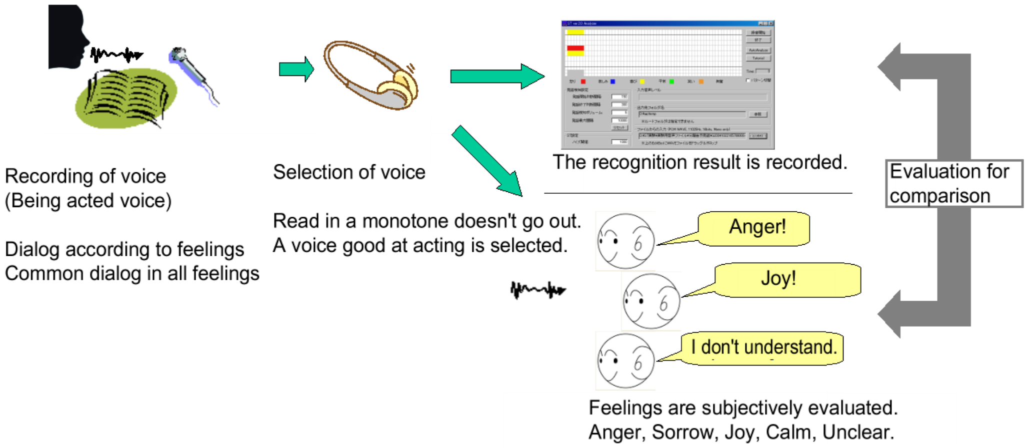

Figure 3.20: Verification of recognition influenceusing acted feelings (Japan SGI)

Result Recognition rate when voices were discontinuous and separated: 62%. Recognition rate when voices were continuous: 62%. Both had equal recognition rates.

3.11.8 Verification of Recognition Influence Using Acted Feelings

Whether or not the same recognition rates could be attained using acting voices was investigated.

Experiment Humans can recognize intentional feeling voices. In order to find out if feeling recognition logic is true for intentional feeling voices as well, lines were prepared and performed based on Chapter 3.1 (21) . Afterwards, outstanding voices were chosen and evaluated. The same voice used when using VEA was recorded by the same person using a separate subjective evaluation tool (refer to Figure 3.4) and afterwards its results were compared to the VEA evaluation result to see its congruency. (One must note that the act of choosing a good "actor" is involved in this process) Figure 3.20 shows the image of this experiment.

Results The average congruency of acted utterances was 10% higher than those of natural conversations' recognition rates.

Table 3.15: Comparison results of VEA and humans（Jpanan SGI.Inc.）

Method of comparison	Result
VEA is presented and a natural continuous utterance is evaluated.（Avg.）	62%
VEA is presented and the natural continuous utterance is evaluated.（Spraker subject）	70%
VEA is presented and the natural continuous utterance is evaluated.（Excluding speaker）	60%
VEA is presented and the natural separation utterance is evaluated.（DataA,B）	62%
The natural separation utterance is evaluated without presenting VEA.（DataA,B）	37%
The acted utterance is evaluated without presenting VEA.	51%

3.12 Verification of Schachter-Singer Two Factor Theory through Comparison Result of VEA and Humans

As a result of verifying discrepancies of evaluations of VEA under the following conditions: continuous or discontinuous, presented or not presented, natural or intentional (acted), it was found that the greatest impact on recognition rate is whether VEA is presented or not. This indicates that human feelings are greatly impacted after recognition verification. Thus, the Schachter-Singer two factor theory phenomenon is verified.

Real-time display by VEA and speaker's introspection are easily congruent, while a third party's subjectivity of separation utterances and VEA are rarely congruent. Depending on which you consider being the standard; subject introspection or third person subjectivity, the interpretation differs. If feelings are defined by labels, only comparison of brain activities and biology indicators can be used to determine the cause and effect of emotions and feeling labels, this the influence of recognition verifications. However, because VEA's standard is a fixed judgment logic that is reflected by human subjectivity, by comparing VEA with brain and biology indicators, one can study the cause and effect of emotions and feeling labels. Thus the system needed for mechanism investigation of feelings for basic problem-solving of feelings is constructed.

Chart 3.15 shows results.

3.12.1 Examination

As Chart 3.3shows, the standard for human's feeling recognition is 55%. Comparing this to a quality experiment of the VEA evaluation system, it can be said that the recognition rates are the same as that of humans. Moreover, Chart 3.4shows the recognition rate of people who understand the language. For natural feelings, the discerning ability of emotions in a non-verbal state is high. However, human subjectivity is difficult to match, so accurate examinations cannot be conducted. Therefore, the experiment in Chapter 3.11.2（p.48）and Chapter 3.11.3（p.49）are considered to be feeling's recognition efficiency. In Chart 3.11DataB's natural utterance is strong in VEA.

For anger, which is considered to be a strong feeling, human subjectivity and VEA have high recognition. For natural conversations, Japanese tend to e normal when comparing humans and human subjectivity. Even during normalness, human subjectivity and VEA recognition rates were high. This indicates that VEA recognizes strong feelings and naturally out-bound feelings, and analyzes its qualities.

Chart 3.4 shows that for humans and human subjectivity, DataA shows the highest recognition rate. It is understandable that humans can recognize intentional (acted) feelings more easily. Anger, especially was easy to act according to actors, and easy to evaluate according to evaluators. Then, it can be assumed that because human subjectivities are highly congruent, human subjectivity and VEA are also highly congruent. Charts 3.8and 3.7 show that when the speaker is talking to a well-acquainted friend, the speaker's subjectivity and VEA are highly congruent. From the above, it can be said that VEA reflects human's feeling judgment characteristics and is analyzable. However, in the multiple third party subjectivity evaluations shown in DataA and B, the probability of human subjectivities matching was only 60%; not sufficient to satisfy a standard. Moreover, in DataA and B, it was found out that 20% of the subjects were influenced by the display of VEA in their final judgments. In DataC and D, because it wasn't possible to see the speaker and his/her feelings at the same time, the subjectivity evaluation right after the utterance was used as a standard. Even for subject judgment, time played a factor in wavering results, and weren't necessarily reliable.

Chapter 4

Analytical System for Cerebral Physiological Signals of Emotions

To solve the limitative problem of subjective evaluation in Chapter 1, it is necessary to compare human physiological indicators with brain activity. For that purpose I conduct the research on the analytical system for cerebral physiological signals of emotions, based on physiological indicators and VEA emotional analysis. According to Schachter, excitement is an unconscious feeling, and is included in most sentimental elements (especially anger, delight, extreme sadness, etc.) [74]. In fact, Chapter 1 established that elements of feelings in voice consist of excitement. Using excitement, a system for quantitative analysis of humans' "active feelings and emotions" based on a comparison of brain activity and other physiological indicators is built. With this, evaluations of passive feelings of the evaluator do not need to be relied upon ; it becomes possible to measure simultaneously the subject's active feelings, emotional conditions, physiological indicators, and brain activity, an d compare the introspective and subjective perspectives. Furthermore, this method will be effective in solving both the "fundamental problem of feelings" and the "cognitive problem of feelings" of psychiatrists and doctors. Figure 4.1 displays an image of the experiment. The blue section displays cognitive influence of feeling labels. The green section depicts influence of complex hormones and other secretory substances, through physiological reactions. The orange section depicts the comparative relationship between VEA judgment, brain, bodily (heart rate, etc.) reactions, and the subject's emotions obtained through fundamental frequencies of the vocal chord.

4.1 Experimental Procedure of the Analytical System for Cerebral Physiological Signals of Emotions

This section describes experimental procedure of the quantification of emotions. The experiment follows the implementation plan explained in Chapter 3.1 (p.21) .

Several theories relate the cause of emotions: James-Lange, Cannon-Bard, and Schachter-Sing theories. It is unknown whether emotions are created in the brain or physiologically. As a result, it is necessary to measure brain activity and physiological reactions simultaneously when emotion occurs due to certain stimulation. The experiment will provide the stimulus that creates emotion in the subject, and resolve the problem of the occurrence of emotions, mentioned in Chapter 1.2.1 (p.3) , by measuring simultaneously the brain activity and physiological indicators.

This method has the following cause and effect relationships.

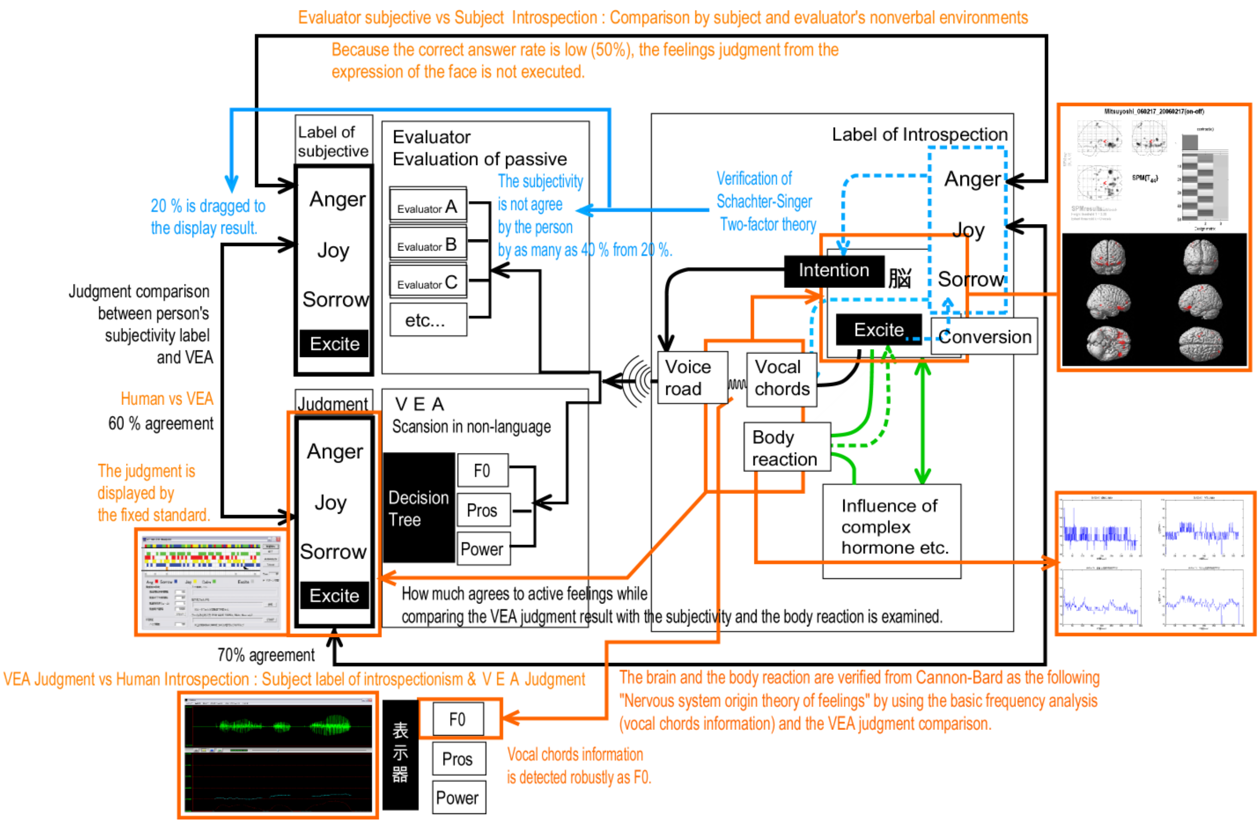

Figure 4.1: A Relationship Diagram of Human Subjectivity, VEA, Subject's Emotions, and Active Emotions Based on Introspection

Stimulation → Physiological reaction → Brain activity → Cognition Stimulation → Physiological reaction → Cognition → Brain activity

Or

Stimulation → Brain Activity → Cognition → Physiological Reaction Stimulation → Brain Activity → Physiological Reaction → Cognition

By recording the chronological order and time with which the above took place, it is possible to see the cause and effect links.

The study of VEA in Chapter 3 is used for reference to stimuli causing emotions. In past research, the following problems have arisen.

1. There has not been a control on the physical strength nor the length of the stimuli. Because conversational voices were used as stimuli, the length of each sentence was not controlled.

2. Since there are loud noises in fMRI, audio stimuli did not prove appropriate for noninvasive measurements of brain activity. It is predicted that detection was difficult because of the noise variable.

3. The feelings of intended study were anger, delight, sadness, and normality. Stimuli used in past research were specialized elements of mental disorders such as unrest, and fall out of the range of the research of this paper.

4. In past research, the labeling of feelings based on subjective evaluation had been done on sound. The labeling of feelings, however, is influenced by intention, thought, physical condition and so forth, and causal associations were difficult to draw.

To solve these problems, stimulations were created in this process.

1. Video imagery stimuli appropriate to the measurement of fMRI were created.

2. Imagery that arouses unrest and excitement (especially imagery of birth and death that are universal) were chosen.

3. Length control was carried out.

4. Contrasting imagery (daily scenery, relaxation themed and so forth) that did not create unrest or excitement were also created.

   In regards to the problem of subjective evaluation, labeling based on subjective evaluation was not conducted. Instead, a system of physical values based on measurements of brain activity and physiological indicators was created to solve the problem.

4.2 The Experimental Device

The purpose of the experiment is to measure physical reactions (physiological indicators) and brain reactions simultaneously. A measuring device for brain information and a measuring device for physiological indicators were used for simultaneous measurement.

4.2.1 Measuring Device for Brain Information

To measure brain activity, the following instruments were considered.

fMRI fMRI is a device that pinpoints active regions of the brain by measuring blood flow (hemoglobin) in the brain with magnetic energy. The active regions of the brain are not only on the surface layers, but inner layers can be detected as well. Between the initiation of activity and blood flow, there is a time lag and as a result time resolution is low.

On the other hand, because the fMRI generates a powerful magnetic field, other magnetic measuring devices cannot be used at the same time. The subject is also not allowed to move when the measurement is taking place. Moreover, loud noise is generated from the coil when generating magnetic fields during the measurement. Not only is there a barrier to using audio stimuli during the experiment, noise-related stress can become an extraneous variable.

MEG MEG is a device that measures magnetic fields of electrical currents in the brain. Its time resolution is high; real time measurements of nervous activity are possible. However, the location of activity cannot be pinpointed (especially when more than one region is active).

On the other hand, there is a need to resolve the inverse problem from collected data, the device is not suitable for measuring under long periods of time, and measurements of deeper regions of the brain are difficult (due to weakening of signals).

Near-infrared spectroscopy (NIRS) NIRS is a device that applies near-infrared light (wavelengths 700 nm 1000 nm) of high permeability to the head, muscles and other body tissues, analyzing the light that passes through the tissues to find the oxygenated state of hemoglobin in the blood, done safely outside of the human body. It has the advantage of being able to conduct measurement in motion with wearable headgear. However, only surface layer measurement of the brain can be done.

Selection According to the Cannon-Bard theory, emotions are influenced by the hypothalamus. In the field of neuroscience, emotions are influenced by the amygdala. Since both are located in the inner region of the brain, NIRS, which is only capable of detecting activity on the surface layer, is not appropriate for the purpose of this experiment. Additionally, since the purpose is to find the origin of emotion, rather than MEG, which is inefficient in pinpointing location, fMRI is the ideal device for detecting the location of activity. This experiment will utilize fMRI to perform measurements of the brain, and simultaneously measure physiological indicators that can be assessed under an environment using the fMRI.

4.2.2 Measuring Device for Physiological Indicators

As indicated in Chapter 1.2.4 (p.6) , Chapter 1.2.4 (p.6) Chapter 1.2.2 (p.5) Chapter B.1 (p.121) physiological indicators that are related to emotions and can be measured under a fMRI environment are listed. The following will be measured.

Heart rate As indicated in Chapter 1.2.4 (p.6), Chapter 1.2.2 (5), Chapter B.1 (121) , past research indicates change in heart rate due to fear. Also, subjective reports have conveyed "heart racing" due to excitement; it can be assumed that emotions have an influence on heart rate. Hence, a heart rate meter is used to measure heart rate.

Blood pressure Like the heart rate, blood pressure, which has an effect on blood flow, is chosen. However, because blood pressure cannot be measured without applying constriction, the resulting influence on the mind may become an extraneous variable. Regardless, it is supposed that there is no correlation between blood pressure and heart rate, as indicated in Chapter 1.2.4 (p.6.

Body temperature As pointed out in Appendix B.1 (p.123), secretory substance ACTH (pituitary gland, the brain) is related to body temperature. Also, expressions of "getting hot," "going cold all over," imply that the letting out of feelings has a relationship to body temperature. Body temperature is also incorporated into this experiment.

Pupil diameter Chapter 1.2.4 (p.6) andAppendix B.1 (p.121) relate that past research have found relationships between pupil diameter and emotions, and that pupils dilate when encountering objects of interest. Pupil diameter will be measured in this experiment.

Blinking As indicated in Chapter 1.2.4 (p.6) andChapter 1.2.4 (p.7) , blinking frequencies vary due to surprise and nervousness. Blinking will be measured incorporated into this experiment.

Eye movement In the references there has been no indication of the relationship between feelings and eye movement. However, it is conceivable to think that sentiments of discomposure, surprise, and confusion are related to eye movement. Eye movement will be measured.

Voice From Chapter 3, it can be seen that voice and feelings have a strong cause and effect relationship, and that humans carry out emotional communication through facial expressions and voice. Psychoanalysis is also conducted with the use of voice. Hence, voice will be measured in this experiment. (However, because fMRI creates a great amount of noise, there is a need to reduce the generation of noise).

4.2.3 Measurement of Cognitive Results

The following instruments are considered for cognitive results.

Subjective verbal response "Method in which cognitive results are collected through verbal interview following the experiment"

In this method, since there is no need for taking any measures during the experiment, there is little influence on the measurement of fMRI. However, the only way is to conduct a verbal interview with the subject immediately following the experiment. As a result, results cannot be synchronized with the measurements. This method is also dependent on subjectivity, and the subject's vocabulary. Emotions that are not aware to the subject him or herself cannot be evaluated.

Response using buttons "Method in which cognitive results are collected by button pressing inside the fMRI" Using this method, while taking into account the time lag that is created in converting cognition to action, it is possible to be conducted almost in real time. However, types of emotional responses are limited to the number of buttons, and movement is required while inside the MRI. With the intention of button pressing, it is possible that this information is recorded in the brain, and thus results as an extraneous variable. Also, a certain amount of training is necessary to prevent erroneous button press actions (under training, it is possible to perform the action almost unconsciously). On the other hand, due to the subject's presumed emotions before the experiment, and subjective perspective, emotions that are not aware to the subject cannot be evaluated. Additionally, activity can be observed in the motor area of the brain during button press actions. Since the motor area is located near the amygdala, the region that is said to be closely involved with feelings, experiment results may be affected.

Method that uses sample stimuli with pre-conducted subjective evaluations "Stimulation that creates universal emotional response is prepared. Supposing the same emotions will be aroused in subjects, emotional tests are carried out." Real-time assessment can be done with this method. Additionally, no memory, intention, nor action is required of the subject. However, there is no way to guarantee the uniformity of the emotions that have arisen. On implementation, subjective evaluations are used to create test samples, therefore emotions that are not recognized cannot be evaluated.

Utilization of feeling recognition technology "Method in which the VEA system used for feeling recognition is applied to detection of emotions" The VEA system used here is created from logic based on subjective evaluations provided by several individuals. It can automatically categorize ordinary subjective evaluations (such as anger, delight, sadness and normality), and perform measurements in real-time. Additionally, subjective evaluation of the test subject is not needed, and to a certain degree, emotions that are not aware to the subject can be evaluated. However, there is no guarantee on the identification of emotions. Therefore, it is necessary to compare test results to those of other experiments. In administering the test, subjects' voices are collected. To collect voice data within the fMRI, the 3 following issues have to be resolved:

1. There is loud noise within the fMRI (130 dB). To be able to record sound in the fMRI, there must be a way to decrease the noise level.
2. When the subject makes sound, head movement makes it hard for the fMRI to conduct measurements accurately.
3. Phonation should have intended meaning. It must be ensured that sound making happens in a natural environment, such as by creating stimulation samples in conversation form

All possible methods mentioned here have both advantages and disadvantages; it is best to use them in combination.

4.2.4 The Actual Experimental System for Emotional Measurement

The method utilized by the experimental system for emotional measurement in this thesis follows the combination of tests described in the previous section. The system uses VEA, and creates an experimental environment where fMRI, heart rate, blood pressure, body temperature, pupil size, blinking and eye movement can be all measured at the same time. In the experiment, image projection and audio stimulation through headphones are used to arouse emotions in the subjects. Synchronization signals are used and starting times are recorded to prevent any time disparities in the measured data.

4.3 Experiment Plan for the Analysis of Physiological Signals

The experiment follows the implementation plan explained in Chapter 3.1 (p.21)

4.3.1 Measurements

In actual tests, the relationships between the mind, brain, and physiological indicators are not assessed by only subjective evaluations, but with coordinates of brain images and phenomenon identification (of behavioral science). Hence, examination of the verification methods is significant. To attain accurate results, tests of physical quantification are required (verification of coordinates in the brain, behaviors, and physiological indicators that do not rely on subjectivity). In this case, corresponding regions of brain activity for "excitement, anger, delight and sadness" dealt with by the VEA, and "surprise, disdain, unrest and fear" illustrated in Chapter 3.2.1 (p.27) are checked against physiological indicators that do not rely on subjective perspective, such as that of body temperature, heart rate, blood pressure, and voice. This verification method which uses a comparison with the feelings model proves affective. The relationship between results, coordinate transitioning of regional brain activity, and physiological indicators of feelings, is compared to information gathered from VEA and the vocal chords, where parameter adjustments are made to ensure better accuracy. The traits and differences between active and passive feelings are also analyzed for improved accuracy, and examination based on the subject's opinion and subjective evaluation is conducted.

4.3.2 Physiological Indicators Required of the Experiment

Physiological indicators used in this experiment are: heart rate, body temperature, sleep inducement, brain images, pupil reactions, and voice analysis. These elements are difficult to analyze with behavioral science. However, autonomic nerve information is useful in its analysis. Because the analysis of blood, hormones and other internal secretion are carried out at medical institutions, this paper does not conduct those tests.

4.3.3 Samples Needed for the Experiment

The experiment is conducted by using samples that bring about excitement and tranquility (the opposite of excitement), and methods that provoke feelings through free conversation. The implementation plan explained in Chapter 3.1（p.21）is followed and developed.

Types of excitement Types of excitement targeted in this study are: sexual, achievement, non-attainment, original discovery, excitement of achievement or the lack thereof, excitement of non-achievement or the lack thereof, sexual excitement or the lack thereof, and so forth. Stimulation samples that provoke these elements without fail are collected.

Excitement stimulation After showing a certain stimulus for a period of time, an instantaneous flash of another stimulus is shown, and results are assessed. In the preliminary tests, this method is checked for whether it is able to distinguish precisely between neural response (brain stimulation) and biological response (hormone convection). In a block design (at alternating intervals with the experiment, within the same period), with a minimum threshold of 15 seconds, average of one random stimulation per every 20 seconds, for 8 times, in a period of 10 minutes. This is repeated for 3 times for a total of 72 stimuli.

4.3.4 Experimental Procedure for the Analysis of Physiological Signals

With the results gained in the sturdy examination of fundamental frequency, following the implementation plan explained in Chapter 3.1（p.21）, the procedure here is used to conduct a comparative test between physiological parameters and “active feelings” based on VEA.

1. Stimulation selection: Appropriate auditory, visual, and visual-auditory (video images accompanied by human voice) stimuli are selected. Then, stimulation samples from the randomly chosen videos are edited. Note that movies were home videos chosen from commercial films acknowledged by the ethical committee of videos in Japan (the ”Eizou Rinri Iinkai”), of which content comply to ethical standards. Stimuli used for excitement were made from captured images or human voices, and contents were kept from the subjects prior to the experiment.

2. Preliminary tests: Before the experiment, preliminary tests were conducted with the stimulation samples. Stimuli that aroused greater excitement and higher heart rates were selected for the experiment. Stimuli with relatively lower heart rates were used as control stimuli.

3. Experiment: The main experiment is conducted by alternating 20 second intervals with and without giving stimulation. The physiological parameters described in 8.1 are measured simultaneously during the experiment. Participants are asked to press the button once, every time they begin to feel excitement. Following the sessions, subjects report

their subjective evaluations of the presented stimuli. There were three subjects (SM, YT, TM).

4.4 The Structure of the Analytical System for Cerebral Physiological Signals of Emotions

Figure 4.2illustrates the entire physiological analysis system, including the voice recognition system. The system is connected to the 3T fMRI control system (Trio, Siemens Inc., Germany). A trigger pulse (5V pulse wave, 5msec), initiated by the onset of the overall system by stimulation to the visual and hearing senses, records a signal on each sensor the exact same point in time of stimulation. The pulse is generated by parallel PC ports and controlled by experiment-managing software called "Presentation" (Neurobehavioral Systems Inc., U.S.A.). The MRI system includes the superconductive coil, RF coil, and head coil for detecting changes in magnetic fields of living bodies, in addition to a visual presentation system (head projector) and an auditory system (air headphone and microphone for conversational purpose). Loud noises are created with any movement of the superconductive coil. Data collection of the 3T fMRI control system (Trio, Siemens Inc., Germany) relies on the software Matlab (MathWorks, Inc., U.S.A.) and uses 2 Gaussian filters for analysis. Figure 4.3 depicts the scan, filter and hemodynamics properties of the fMRI system. The trigger signal initiates scanning of the MRI system and the analytical system for physiological parameters, which is composed of heart rate, blood pressure (Magnitude, Invivo Research Inc., U.S.A.) and body thermo sensing systems. The body thermo sensing system comprises of the following:

1. A handmade temperature sensor (thermocouple)
2. Copper wire
3. Voltage multimeter (189 True RMS Multimeter, Fluke Inc., U.S.A.)

Using an ice box and potassium, the body thermo sensing system can be calibrated to 0.00. Figure 4.4 illustrates this property.

The trigger signal is measured by the pulse, and then outputted to the measuring systems for heart rate and blood pressure. For the experiment a signal-outputting system is developed with the analog low-pass filter with a cutoff frequency of 400 Hz. Signals are converted digitally (resolution 14bit at 0.5Vpp, sampling frequency 1kHz), and transmitted to a data logger (NR-2000, Keyense Inc., Japan).

The signal is then transmitted to a PC and is processed with the software Matlab (MathWorks Inc., USA). The trigger signal is also sent to the eye movement recording system (ST-661, NAC Inc., Japan), which simultaneously measures pupil size, blink frequency, and eye location based on the two-dimensional coordinates of the left and right eyeballs. Subjects' conversations are recorded online via the VEA. Their voices are picked up by the microphone inside the MR magnet, while they hear the experimenter's voice and audio stimulation through the air-transmitted headphones. Voices from conversations are sampled by VEA (ST 2.0) and all signals are recorded digitally. The entire systems measures, with a frequency of 1k Hz, physiological conditions and timing information of brain activity. Subjects press a button whenever they felt excitement from the stimulation.

Figure 4.5 shows the devices used in the physiology system.

(1)and (2) show the gantry of the magnetic resonance system.

(3) shows the monitoring system of head-body position inside the gantry.

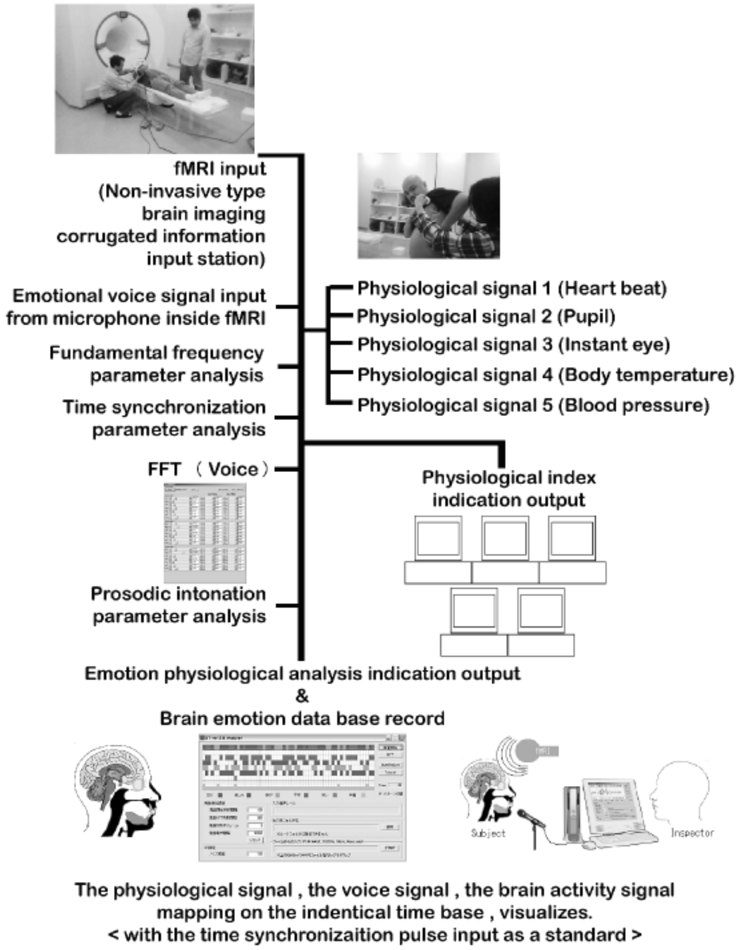

Figure 4.2: Structural Diagram for the Analytical System for Cerebral Physiological Signals of Emotions

(4) and (5) show the MRI control system.
(6)shows the overall signal system.
(7) shows the body temperature analyzer (multimeter for the thermocouple).
(8) shows the sensor used in the thermocouple measurement of ice and water.
(9) shows sample data from a thermocouple measurement.
(10)shows the monitoring system for eye movement, blink, and pupil size.
(11) shows sample data from the heart rate monitoring system.
(12) shows the data processing system for heart rate.
(13) shows the images of the 3-dimensional function of magnetic imaging between tasks.
(14) shows pupil size, which is related to eye movement, and the instant of an eye-blink.
(15) shows the sensor system used to measure blood pressure and heart rate.

Table 4.1 shows the sensitivity (acuity) of each system.

Figure 4.6portrays the analytical system for cerebral physiological signals for emotions.

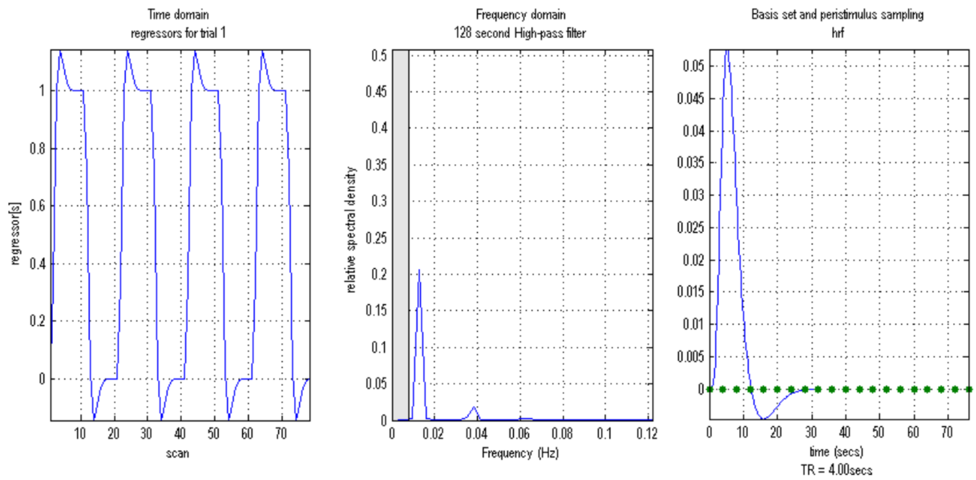

Figure 4.3: Analytical Properties of the fMRI (source: NICT)

4.5 Physiological Parameters

This system utilizes the VEA and feeling judgment parameters, proposed in this essay. Parameters centering on F0 and on the "excitement" of VEA and other emotions are selected. Parameters and VEA are displayed simultaneously; brain images and other physiological indicators are measured and displayed simultaneously. This experiment utilizes the diverse range of physiological parameters indicated below. All of these physiological parameters are evaluated with parameters such as VEA and F0. The purpose of the experiment is, in addition to subject's "passive feeling evaluation", to accomplish an objective ¡active feeling¿ measurement and verify it. For the purpose of investigating emotional brain activity, there are studies utilizing functional magnetic resonance imaging scanner (fMRI), like the measured values of physiological parameters. Indeed, physiological parameters and VEA do not define feelings and emotions quantitatively. However, as a preliminary means (equipment and sensor) to quantitative definition, this system proves meaningful. Particularly, this thesis presumes a relationship between F0 and emotions, and its measurements are taken separately from the VEA. Measurements of physiological parameters and studies in fMRI are done in collaboration with the ¡Brain Information Group¿ of Kansai Advanced Research Center, Communications Research Laboratory.

1. Body temperature: showing homeostasis as a function of vital activity.
2. Blood pressure: governed by the autonomic nervous system and the hormone system.
3. Heart rate: governed by the autonomic nervous system, related to emotions.
4. Pupil size: governed by the autonomic nervous system, has a positive correlation to feelings. Also reflects level of consciousness.
5. Blink frequency: increases with stress and fatigue, reflects imbalance of the autonomic nervous system.
6. Eye movement: affected by psychological state such as consciousness level or attention.

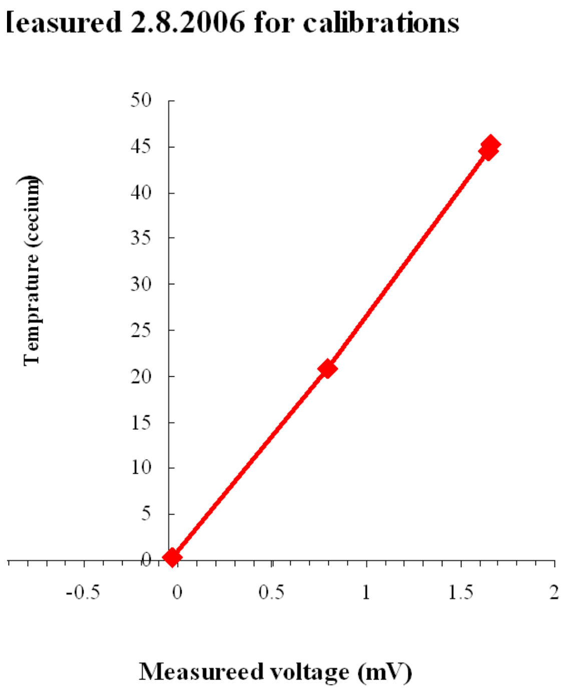

Figure 4.4: Property of a Real-time Measuring System Using Thermocouples.

7. Blood Oxygenation Level Dependent imaging (BOLD): reflects neuronal activity at various loci in the brain.

4.6 Preliminary Tests

Unanswered questions regarding the execution of the experiment are listed below. Preliminary tests are conducted to see whether or not they will pose as problems in the actual experiment. The implementation plan described in Chapter 3.1 (p.21) is followed.

Question 1: Whether or not the experiment system would function properly
Question 2: Whether emotions would be portrayed through physiological indicators
→ video stimulation of horror
→ video stimulation of relaxation
Question 3: Whether the unique test environment of fMRI can be normalized
Question 4: The possibility of using sound as stimulation
Question 5: The possibility of an experiment involving conversation

4.6.1 Checking the Experiment System's Operation and Physiological Indicators

As a part of the preliminary tests, the hardware is checked for proper connection and functioning. Here, however, we do not deal with vocal delivery (since for this purpose a head position-securing device is required, and a means to reducing noise created by fMRI is necessary). At the same time, tests are also conducted on the whether the presented video stimulation arouses emotion, and whether changes in physiological indicators are detected.

Figure 4.5: Equipment for the Physiological Analysis System (in collaboration with NICT).

Experimental Conditions Items to be tested for

Measurement of brain activity via the fMRI, body temperature, blood pressure, heart rate, pupil size, blinking, eyeball movement, and subjective reports. Due to the constriction caused when measuring blood pressure, this measurement is taken at the initial and final stages of the experiment.

Stimulation Samples

Video stimulation that is soundless and which can be used inside the fMRI is selected. Video durations, considering the property of haemodynamic response, are made into 20-seond videos, followed by 20-second intervals of blank footage. There is a total of 8 video stimuli (4 of excitement stimulation, 4 of control), all soundless and lasting 20 seconds each. After the first 20 seconds of blank footage, one of the above video stimulation is shown at random. Following that is another 20-second interval of blank footage. This is repeated for 8 times.

The contents of the excitement-stimulating footage are as follows:

1. Scary footage (including horror and bizarre things)
2. Shocking footage (homemade videos showing accidents, etc.)
3. Humorous footage (from homemade videos)
4. General 'exciting' footage, such as fighting scenes from science fiction movies, etc.

Contents of the control footage include footage that do not provoke interest, such as street scenes, and footage that does not arouse excitement, such as flower gardens.

Table 4.1: 生理指標センサー精度 （資料提供 NICT，2006）

Sensor	Method	Sensitivity（Accurate）	Manufacture
Heart rate: SpO2 Analysis	Measurement of opposite to the time between pulses number	1000Hz	Invivo Research Inc.
Blood pressure	BP monitor	mmHg	Invivo Research Inc.
Body temperature	Heat electrical potential	0.01 Celcium	Fluke Inc.
Pupil size,	Infrared reflection	1mm, 200Hz	NAC Inc.
Eye movement	Infrared reflection	1mm, 200Hz	NAC Inc.
Blink frequency	Infrared reflection	1mm, 200Hz	NAC Inc.
Voice	F0，Intonation analysis Non-language scansion	Real time Recognition rate 70～80%	A.G.I.Inc. (ST.2.0)
Brain	Blood oxygen level dependent (BOLD)effect	1x1x1 mm	Siemens

Environmental Conditions

Videos are shown via a projector. During the experiment the lights are turned off in the fMRI laboratory.

Laboratory Equipment The 3T fMRI control system (Trio, Siemens Inc., Germany), trigger pulse control application presentation (Neurobehavioral Systems Inc., U.S.A.), measuring system for heart rate and blood pressure （Magnitude, Invivo Research Inc., U.S.A.）, eyeball measuring system (ST-661，NAC Inc., Japan), sensor system for body temperature (handmade).

Experimental Procedure The experimental method is described below.

1. The subject's blood pressure is measured.
2. Once the heart rate meter and thermometer are put on the subject, the subject enters the fMRI gantry. The lights inside the room are switched off.
3. Adjustments to the positioning of the eyeball measuring system are made.
4. All those other than the subject leave the room.
5. Using the fMRI, the positioning of the brain scan is adjusted.
6. The experiment begins. Video stimulation is shown.

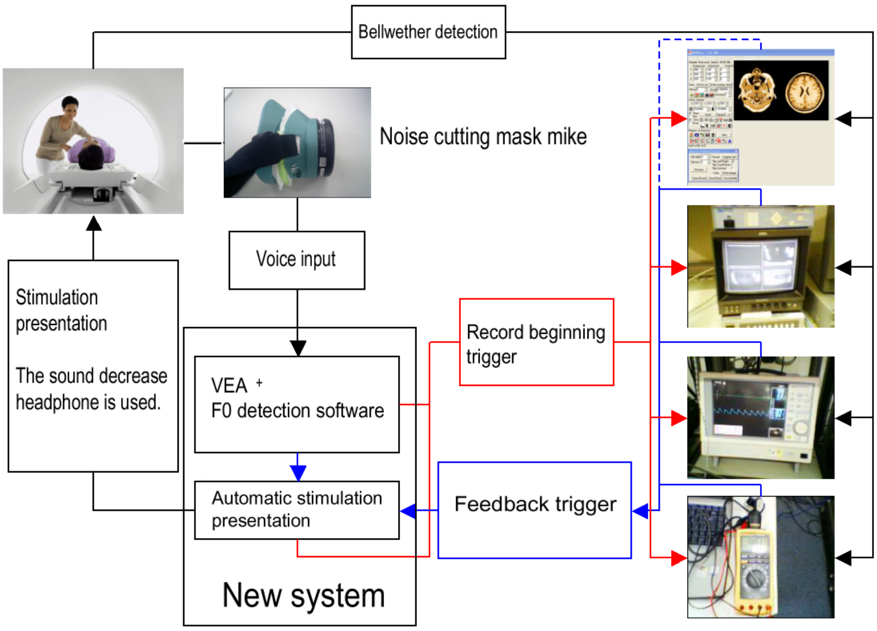

Figure 4.6: A Diagram of the Analytical System for Cerebral Physiological Signals of Emotions

7. (20-second blank footage + 20-second stimulation) x 8 = 5 minutes and 20 seconds later the experiment is over. Images of the brain's structure are taken with the fMRI.

8. The lights are turned on and the subject's blood pressure is measured.

9. The subject is asked to give subjective feedback.

Detailing of Test Samples Number of subjects: 2

Collected data: fMRI imagery, heart rate, body temperature, eyeball movement (of 1 subject. One of the subjects was wearing contact lens, and since the rim of the lenses were easily confused with the outer region of the eye, valid data could not be obtained.)

Stimulation used: excitement-stimulating footage, control footage Attributes of the stimulation footage and their order:
Time (seconds) Video content
0- 20 blank footage
20- 40 excitement-stimulating footage (surprise)
40- 60 blank footage
60- 80 control footage (street scene)
80-100 blank footage
100-120 excitement-stimulating footage (humor)
120-140 blank footage
140-160 control footage (flower garden)
160-180 blank footage
180-200 excitement-stimulating footage (horror)
200-220 blank footage
220-240 control footage (street scene)
240-260 blank footage

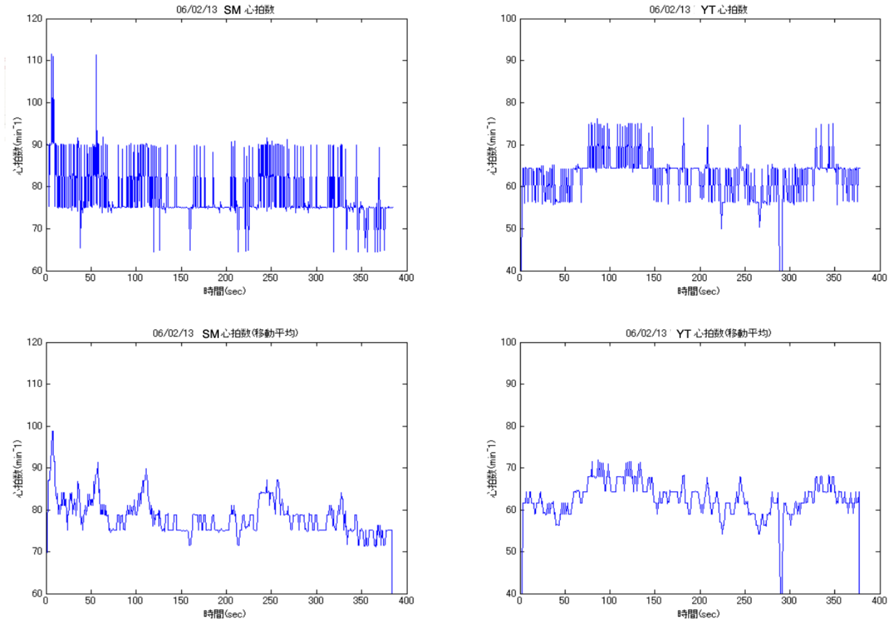

Figure 4.7: Graphs of heart rates and their moving averages (in collaboration with NICT)

260-280 excitement-stimulating footage (humor)
280-300 blank footage
300-320 control footage (flower garden)

Experiment Results Heart rates increased by 5-10 beats/minute after the first initial 5-10 second period of video stimulation.

Particularly with the stimulation which provoked a strong emotion (anger), there was an evident change in heart rate. Increasing heart rate continued through the 20-second interval of blank footage. When stimulation consisted of less exciting elements (such as calmness), heart rate was decreased by 5-10. With strong excitement stimulation, one of the subjects (YT) displayed increased pupil size and eye-blink frequency, which lasted through the following interval. For both subjects, body temperature remained consistent for the most part of the experiment. An analysis of brain activity done simultaneously from physiological indicators was carried out by the statistical software, SPM (London, Great Britain, free software: http://www.fil.ion.ucl.ac.uk/spm/). Figure 4.7 displays data related to heart rate, body temperature, blinking and pupil size. Figure 4.8 depicts the change in body temperature of one of the subjects, SM. The sharp rise and fall in the graph result from the attachment and removal of the device; no significant change is detected. Figure 4.10 illustrates the subject SM's brain image and activity.

Figure 4.9depicts the change in body temperature of one of the subjects, YT. The sharp rise and fall in the graph result from the attachment and removal of the device; no significant change is detected.

In Figure 4.10, brain activity restricted to the superior temporal gyrus STS, frontal cortex, and the language area (Broca's area) can be seen.

In Figure 4.11, activity can be seen in the anterior frontal, amygdale, frontal eye field, and

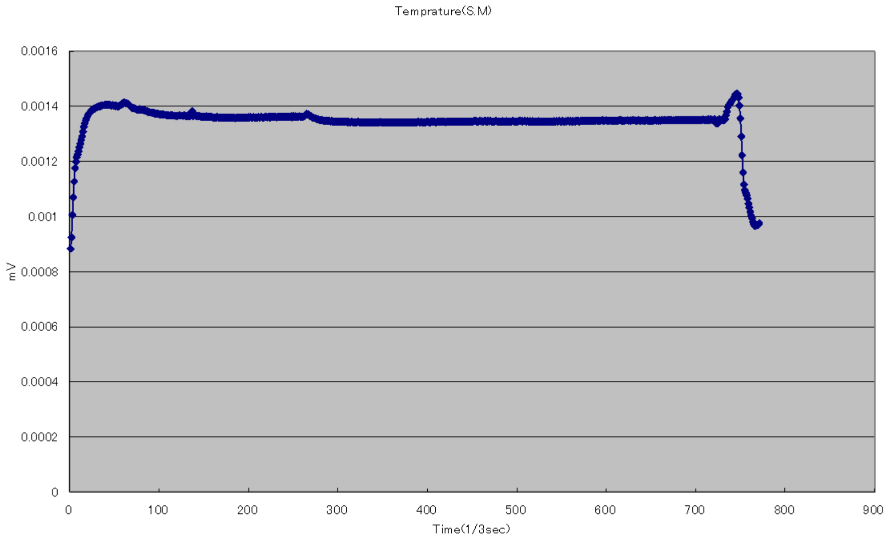

Figure 4.8: Body temperature of subject SM (in collaboration with NICT)

medial prefrontal regions (matching previous research results on feelings in monkeys). IT can be inferred that these regions are connected with the A10 nerve, and correspond with past feelings of fear and the activation site of the adrenergic system. Results are consistent with Chapter 1.2.4（p.6）, Chapter 1.2.4（p.7）and 1.2.4（p.7）. Overall test results from the above showed that the experimental system functioned properly as a whole. However, as pointed out in Chapter 1.2.4（p.7）, the following problems were detected with the pupillometer.

1. Blinking actions are necessary for the position adjustments of eyeball movement.

2. Adjustment is not possible with eyeglasses or contact lenses (rims of the lenses and reflection are mistakenly recognized as the whites of the eyes).

Because the self-made body temperature measuring device measures relative temperature, ice is used to lower the temperature of one to 0 degrees. Additionally, the presentation program is completed and it became possible to conduct measurements with synchronizing signals. (However, collected data do not reflect the triggers).

Among the excitement-stimulating videos, horror footage created changes in heart rate and blinking. However, with the same footage, one subject felt fear and the other subject felt anger, with decreased heart rate and increased heart rate respectively. Also, changes in heart rate were detected during control footages of relaxation, such as the flower garden. With regards to body temperature, no significant change was detected. As noted in Chapter 1.2.4（p.6）, subject SM developed early acclimatization, and correlations in heart rate and blood pressure were relatively less significant from the second stimulation onwards. But by combining brain and physiological indicators, analysis can still be possible.

4.6.2 The Normalization of the Unique Test Environment of fMRI

The experiment is carried out in the very unique environment of fMRI. Specifically,

1. It is a powerful magnetic field; the carrying of any metals or magnetic materials is very dangerous.

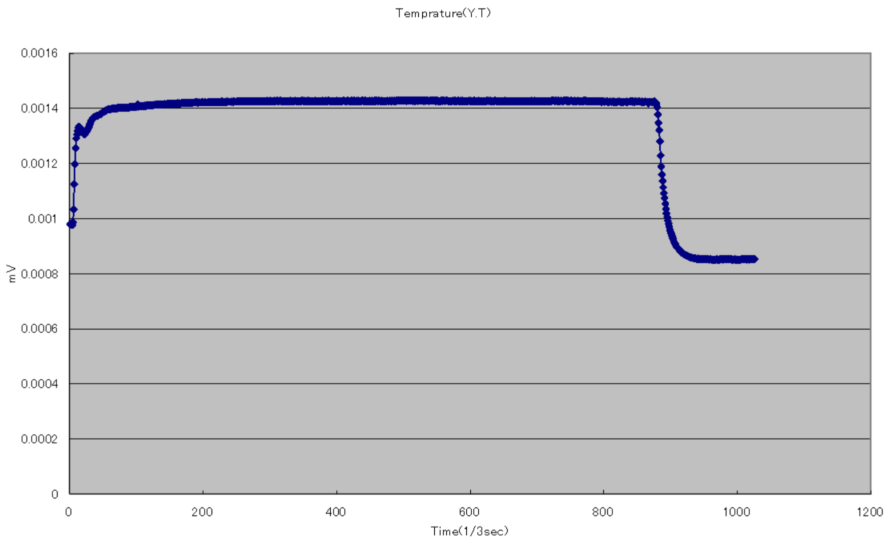

Figure 4.9: Body temperature of subject YT (in collaboration with NICT)

2. The intense noise can lead to mood disturbance.

3. The interior of the gantry is a very small, confined space, and may bring about feelings of pressure and discomfort. Questions relating to environmental influences as such remain unanswered. For this purpose, whether or not the same experiment can be done in a non-fMRI environment, without such influences, is examined.

Experimental Conditions Items to be tested for

Heart rate, subjective feedback of the subject

(Since the fMRI is equipped with the thermometer, manometer, and eyeball measurement system, they are not used for this experiment).

Stimulation Samples

The same stimulation videos used for fMRI are utilized.

Environmental Conditions

Videos are shown via projectors. Subjects are asked to lie down (same as the fMRI). Subject is the only person in the room (same as the fMRI).

Experimental Procedure

1. The subject is asked to put on a heart rate meter (POLAR F4), and to lie down on the bed.

2. The lights in the room are turned off. Persons other than the subject exit the room.

3. The experiment begins. The stimulation videos indicated in the test samples are shown. (20-second blank footage + 20-second stimulation) x 8 = 5 minutes and 20 seconds later the experiment is over.

Experiment Details Video stimulation: the same footage used in the preliminary test for fMRI is used.

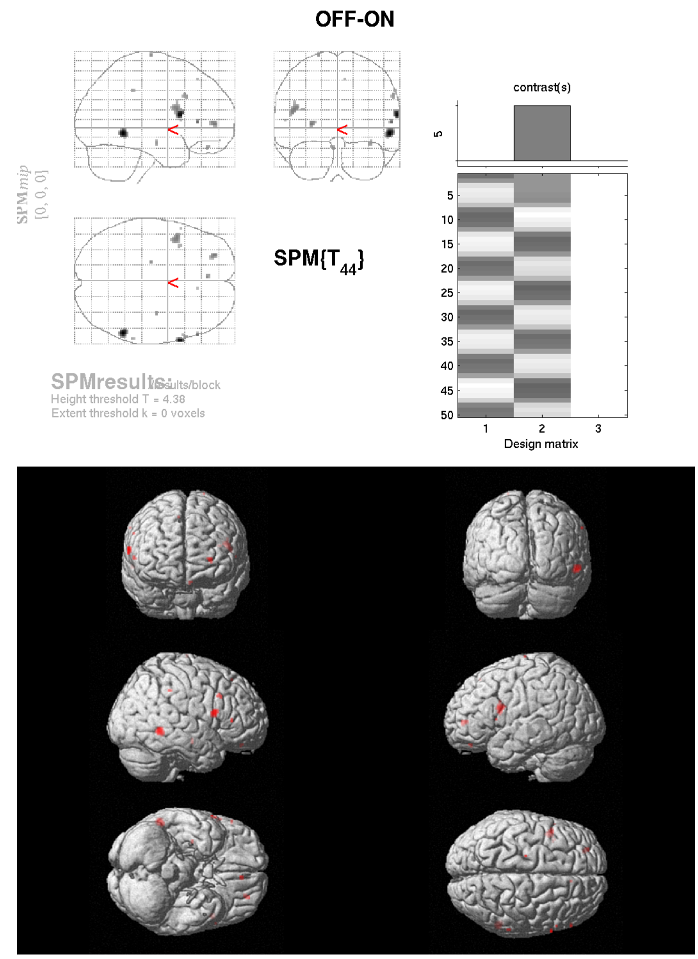

Figure 4.10: fMRI Brain Image of Subject SM (in collaboration with NICT)

Participants: 3 (the same participants in the preliminary test for fMRI, in addition to the video editor).

Experiment Results Like the test done with the fMRI, of the excitement-stimulating videos, the horror footage showed a change in heart rate. Also, of the control footages of relaxation, such as the garden, showed a change in heart rate. Results seen in heart rate display the same trends as the fMRI test; for the least part it can be concluded that there is no influence on heart rate from magnetic fields, noises, or feelings of pressure. Additionally, in the case of the video editor, no change in heart rate can be seen with horror footage, likely due to the effect of habituation. However with relaxation footage such as that of the flower garden, there was a decrease in heart rate. It is possible that the effect of habituation is little in relation to relaxation footage.

4.6.3 Discussing the Experimental Probability of Using Voice as Stimulation

The questions posed here are the possibility of using sound stimulation to reduce noise, and whether emotions can be aroused via sound stimulation, and seen through physiological indicators. Hence, tests are done on fMRI and sound environment.

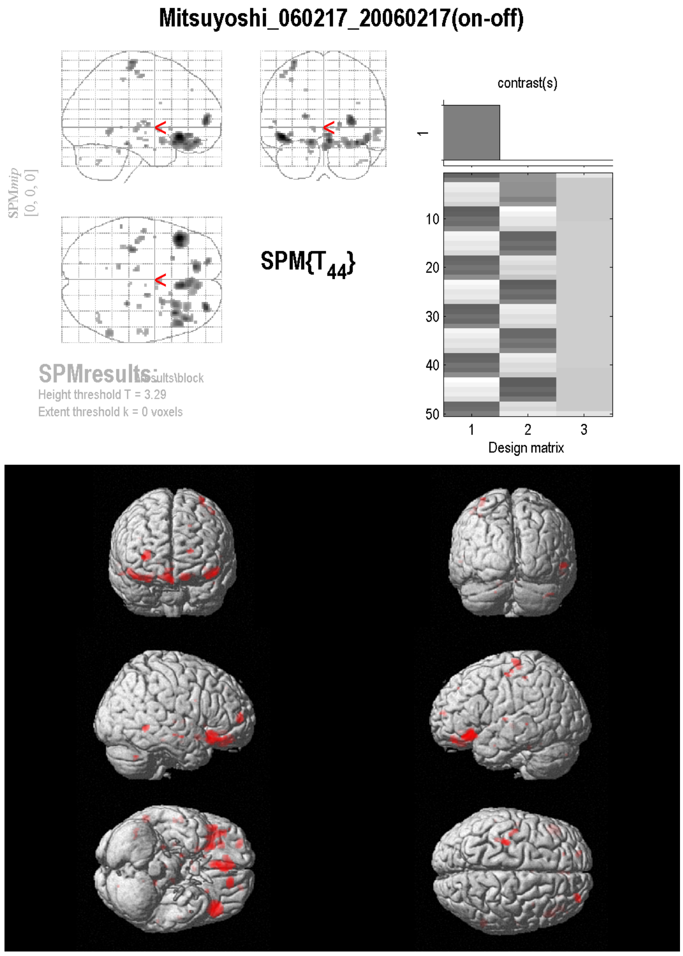

Figure 4.11: fMRI Brain Image 2 of Subject SM, assessment of the amygdala (in collaboration with NICT)

Experimental Conditions Items to be tested for

Measurement of brain activity via the fMRI, body temperature, blood pressure, heart rate and subjective reports.

Due to the constriction caused when measuring blood pressure, this measurement is taken at the initial and final stages of the experiment. With regards to testing eyeball movement, since the issue with eyeglasses and contact lenses has not been resolved, it is not measured here.

Stimulation Samples

20-second voice samples (of anger, normality) x 4 - verified by consistent subjective evaluations of 6 different individuals After the first 20-second interval of blank audio, one of the above samples is played at random, followed by another 20-second blank interval, and another playing of voice by random selection. Total repetition is 8 times. Voice samples include both "natural speech," excerpts from natural conversations, and "acting speech," lines and emotions performed from written lines. Anger is used as excitement voice and normality is used as control voice, and incorporated into the 20-second stimulation voices.

Environmental Conditions

Audio stimulation is given to subjects via air-transmitted headphones. The lights in the fMRI laboratory are turned off during the experiment.

Laboratory Equipment The 3T fMRI control system (Trio, Siemens Inc., Germany), trigger pulse control application presentation (Neurobehavioral Systems Inc., U.S.A.), measuring system for heart rate and blood pressure (Magnitude, Invivo Research Inc., U.S.A.), sensor system for body temperature (handmade), and air-transmitted headphones.

Experimental Procedure

1. The subject's blood pressure is measured.
2. Once the heart rate meter and thermometer are put on the subject, the subject enters the fMRI gantry. The lights inside the room are switched off.
3. All those other than the subject exit the room.
4. Using the fMRI, the positioning of the brain scan is adjusted.
5. The experiment begins. Voice stimulation is played.
6. (20-second blank audio + 20-second stimulation) x 8 = 5 minutes and 20 seconds later the experiment is over. Images of the brain's structure are taken with the fMRI.
7. The lights are turned on and the subject's blood pressure is measured.
8. The subject is asked to give subjective feedback.

Experiment Details Number of subjects: 1
Collected data: fMRI image, heart rate, body temperature
Stimulation used: excitement voice (anger), control voice (calm)

Attributes of the stimulation voices and their order:
Time (seconds) Audio content
0- 20 soundless
20- 40 excitement voice (acting speech)
40- 60 blank audio
60- 80 control voice (acting speech)
80-100 blank audio
100-120 excitement voice (acting speech)
120-140 blank audio
140-160 control voice (acting speech)
160-180 blank audio
180-200 excitement voice (natural speech)
200-220 blank audio
220-240 control voice (acting speech)
240-260 blank audio
260-280 excitement voice (acting speech)
280-300 blank audio
300-320 control voice (natural speech)

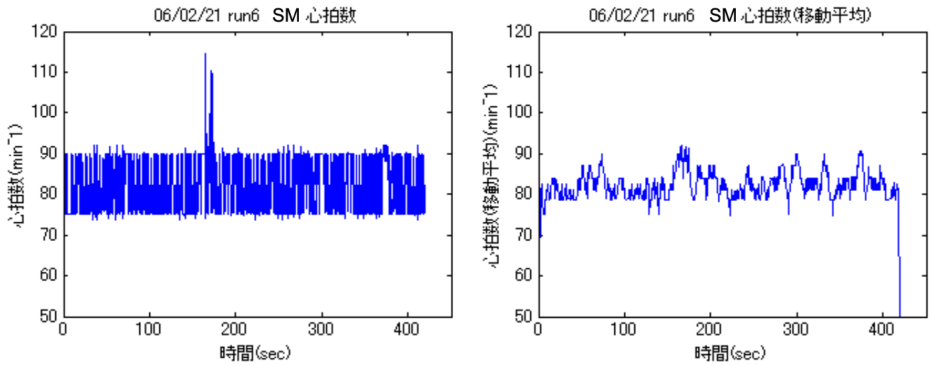

Figure 4.12: 4.12 Heart Rate Under Voice Stimulation (in collaboration with NICT)

Experiment Results Figure 4.12 displays measured heart rate.

With the use of air-transmitted headphones, an experiment using voice stimulation was achieved. Normal voices (without any particular feelings) did not have any influence on the subject. In most cases of angry voices, no change was detected in physiological indicators. However, in one particular case where anger was aroused in the subject as a result of hearing an angry voice (according to subjective feedback received from the subject following the experiment), there was an increase in heart rate. Collected data show that feelings were aroused in an excitement voice of natural speech, indicating that natural speech may be more suitable to our purpose than acting speech. Regarding this issue, there is a need to increase the number of participants in the experiment and to verify it. Even when our voice stimulations have consistent subjective evaluations from 6 different individuals, they may not necessarily be voices that evoke feelings. Also, because responses to the same stimulation can vary greatly between individuals, it is necessary to collect subjective evaluations and cognitive results individually.

4.6.4 Probability of Experiment Involving Audio Speech

The question remains: When noise is controlled and the head is fixed in a constant position in the fMRI environment, is the experimentation environment involving speech considered established? Whether or not conversations can be used as stimulation samples, is also included in the environmental problem. Here, tests both inside and outside of the fMRI are conducted to see if conversations can be used for the experiment (at the same time, it is also to test whether VEA, with objective logic, is able to conduct quantification of feelings).

Experimental Conditions Items to be tested for Items to be tested for

Measurement of brain activity via the fMRI, body temperature, blood pressure, heart rate, voice, VEA and subjective reports.

Due to the constriction caused when measuring blood pressure, this measurement is taken at the initial and final stages of the experiment. With regards to testing eyeball movement, since the issue with eyeglasses and contact lenses has not been resolved, it is not measured here.

Stimulation Samples

Microphone conversation with someone outside

Environmental Conditions

Conversations are carried out via air-transmitted headphones and a nonmagnetic microphone, between the experimenter and the subject. The lights in the fMRI laboratory are turned off during the experiment.

Laboratory Equipment The 3T fMRI control system (Trio, Siemens Inc., Germany)
Trigger pulse control application presentation (Neurobehavioral Systems Inc., U.S.A.)
Measuring system for heart rate and blood pressure (Magnitude, Invivo Research Inc., U.S.A.)
Sensor system for body temperature (handmade)
Air-transmitted headphones
Nonmagnetic microphone
Voice-recording PC
VEA system (A.G.I. Inc., Japan)

Experimental Procedure

1. The subject's blood pressure is measured.

2. Once the heart rate meter and thermometer are put on the subject, the subject enters the fMRI gantry. The lights inside the room are switched off.

3. All those other than the subject exit the room.

4. Using the fMRI, the positioning of the brain scan is adjusted.

5. The experiment begins. A conversation between the experimenter and the subject is carried out.

6. Like the video stimulation tests, the experiment lasts for 5 minutes and 20 seconds. Images of the brain's structure are taken with the fMRI.

7. The lights are turned on and the subject's blood pressure is measured.

8. The subject is asked to give subjective feedback.

Experiment Results The experiment is carried out with two subjects. Figure 4.13 displays the subject SM's heart rate information. Figure 4.14 displays results of feeling recognition from voice. The colors represent different emotions: red is anger, yellow is delight, blue is sadness, green is normality, orange is humor, and gray is excitement. The top layer depicts the feeling of first priority, those below it are multiple feelings that are included within. The first 80-second interval consisted of conversation regarding the experiment, the next 80-second interval related to enjoyable instances during the experiment, and from 140-second onwards, conservation revolved around topics regarding the opposite sex, such as appearance and voice. During conversations regarding physical appearance of the opposite sex, increase in heart rate (Figure 4.13) was shown, likely pointing to subjects' excitement. Conversations evolved around fun topics after the first 80 seconds, and the depiction of yellow (delight) in feeling recognition technology (Figure 4.14) show that it is possible to detect delight in noisy environments as well. However, as influenced by noise, orange and red appear constantly throughout. These results are considered to responses to the noise frequencies.

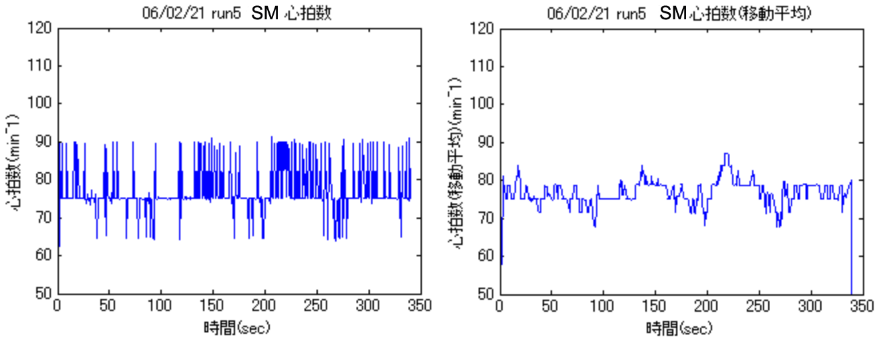

Figure 4.13: Heart Rate Obtained from the Conversation Experiment (in collaboration with NICT)

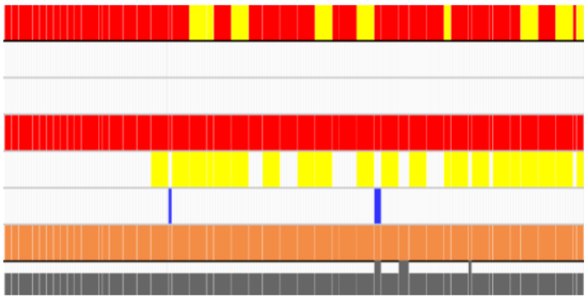

Figure 4.14: VEA Feeling Recognition Results Obtained from the Conversation Experiment

4.6.5 Results

Using air-transmitted headphones and a nonmagnetic microphone, conversations between the experimenter and subject were successfully carried out amidst the noise created by fMRI. Additionally, real-time analysis of voices was performed by inputting them into the computer and using the software for feeling recognition. Recognition results showed that, although most feelings detected were anger resulting from the noise, the recognition of delight was possible (according to subjective feedback from the subject, and the experimenter who conducted and listened to the conversation). However, the false recognition of humor and anger due to the noise is problematic. Head movement during conversations did not allow analysis of fMRI. Additionally, it is difficult to confirm, in real-time, emotions that are aroused during the conversation, or to control conversations so that the targeted emotions are provoked.

4.6.6 A Summary of the Preliminary Tests

Experiment results are described below.

1. A system that can simultaneously measure brain information and physiological indicators is created.

2. The following are proven possible: the provocation of emotions via video display, the provocation of emotions via audio, and conversations taking place between inside and outside of the fMRI.

3. Stimulation samples that arouse emotions are created.
4. Change is confirmed in physiological indicators due to the following simulation:
   (a) Horror stimulation - changes in heart rate, blinking (in one subject)
   (b) Relaxation stimulation - decrease in heart rate
      i. The physiological indicators listed above that change under stimulation may not be dependent on environmental factors such as noise, magnetic field, or psychological pressure from within the gantry.
   (c) The noise within the fMRI is reflected in frequency analyses of anger and humor of the VEA. Additionally, delight was able to be recognized separately from the above.

4.6.7 Issues and Problems

1. To conduct conversation experiments of higher accuracy than the preliminary tests, the fixation of the head and reduction of the noise level of fMRI, as mentioned in Chapter 4.6.4 (p.78), are necessary.
2. It is difficult to arouse targeted emotions in another person through conversation. It is also dependent on the individuals participating in the conversation. Therefore it is ideal to build a system where the appropriate topic is chosen bidirectional and automatically, and presented.
3. Blood pressure was measured before and after the experiment. However, real-time measurement was not conducted. Moreover, it is unknown that whether real-time measurements, due to the constriction of the upper arm, will have an effect on blood flow, heart rate, mind, and emotional provocation. This will be an issue of future investigation.
4. Effects of video stimulation vary greatly depending on whether subjects are seeing it for the first time. How originality is kept becomes an issue.
5. Even when the exact same stimulation is given, there is no guarantee that the emotions aroused are consistent. This is true for the previous issue of originality as well. Not only external stimulation needs to be kept consistent, the relation between subjects' internal conditions and external stimulation needs to be controlled.
6. There is a need to confirm whether experiment results can be applied generally; the overall number of participants to be increased.

4.7 Problems and Solutions of Experiments in Conversation Form with the fMRI

4.7.1 Problems

1. The fMRI is effective for measuring activity in the center of emotions - limbic cortex, amygdala, hypothalamus, hippocampus and cerebellum. However, in conversations the subjects' head have to be steadied.
2. The fMRI has an extremely high noise level "comparable to an approaching jet plane", and vocal analysis is difficult under this circumstance.

With the above conditions, analysis of feelings or conversation taking place within the fMRI was impossible. From there, this experiment was achieved by securing the subject's head with Styrofoam and a nylon belt, and by creating a noise-insulating masked microphone set for conversations specifically. Styrofoam is heated and formed to shape of the head to create a holding fixture to the gantry bed inside the fMRI, and a nylon belt is used to secure the subject's head from above the eyebrows. The masked-microphone, and noise filter to 80 decibels, all contributed to the achievement of the subject's voice analysis during the operation of fMRI. The following method describes how the problem of noise inside the fMRI gantry, equivalent to noise level of a jet plane, is solved.

4.7.2 Solutions to the Problems

With regards to noise, to reduce the noise created by the magnetic coil inside the fMRI requires the development of a noise-free MRI. In the actual experiment, however, as long as fundamental frequencies of voice can be detected, there is no issue. Additionally, brain images need to be captured during conversation while the detection of fundamental frequencies is taking place. For this purpose, a method is created to secure the head for brain image capture and to detect fundamental frequencies, all within the fMRI gantry.

4.7.3 Solving the Noise Issue

Initially, to solve the noise issue of fMRI, I created a nonmagnetic microphone cover to reduce noise by 80 decibels. At first, I created a microphone cover by wrapping the following in 8 total layers: (natural) sponge, paper towels, paraffin-covered cardboard, and shock absorber sheets, in the respective order. Figure 4.15 shows a test product made in the early stage. A nonmagnetic microphone made especially for the fMRI is inserted into the cover, and noise tests are performed. Figure 4.16 shows a comparison between audio inputs to the microphone within the fMRI gantry before and after noise control. At this stage, noise reduction was successful to a great extent; however, voice is muffled, and depending on the subject, fitting of the mask and difficulty of mouth movement can be issues. As a result, a commercial gas mask was used to achieve the same level of noise reduction, while at the same time supporting the freedom to speak (refer to Figure 4.17).

Noise Insulation Mask Main unit TOYO SAFETY Gas Mask No.1880-1, Nationally approved TN 242 (2005) GM

The filter portion of gas masks is hard and made of plastic, and the portion touching the mouth is made of rubber. Silicon is injected into the rubber part, molded, and paper towels inserted for insulation. Figure 4.17 illustrates the mouthpiece portion. Additionally, 5 pieces of paper towels and a sponge are layered between the (plastic) filter portion and the rubber portion of the gas mask, and the microphone is mounted into the center opening for better seal. The materials are shown in Figure 4.18. As a result, noise insulation is guaranteed and the reduction of 80 decibels was achieved. With the rubber portion alone, noise was able to intrude easily. It is deduced that noise reduction results were achieved due to the weight of the silicon and the layering of different materials. Breathing is through the nose. Together with the headphones, it became possible to carry out conversations in the fMRI with the outside, without minding the noise. Figure 4.19 shows the entire masked microphone.

However, in the case of the gas mask, because of the seal, human voice is muffled and volume is increased. Amplifier gain adjustments are performed to adjust human voice (refer to Figure 4.20).

Figure 4.15: Test production of a nonmagnetic microphone cover for noise reduction within the gantry

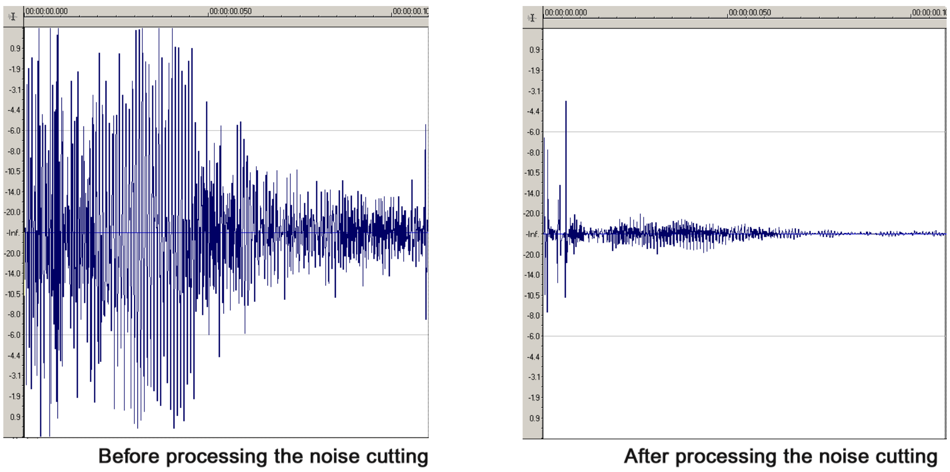

Figure 4.16: Noise Reduction Effects in the Gantry (Wave Patterns of Noise)

With the above methods, noise is reduced (to 80 dB), the head is secured, and conversation experiments are conducted. Before VEA is used to test samples directly, I conducted the verification of voice analysis via fundamental frequencies. Figure 4.21 compares results from: before taking noise measures, after gain adjustments, and after taking noise measures with masking. Fundamental frequency is on the horizontal axis, and the vertical axis compares maximum amplitudes.

From this graph, it can be seen that, although masking is ineffective for low frequencies, it proves effective for the others. Additionally, gain adjustments have contributed greatly to the reduction of noise. The reason that masking is ineffective for low frequencies is attributed to its layered structure. This is possibly caused by the difference in impedance between the filter and the rubber portion with the relatively heavier silicon filling in the mouthpiece. However, when the following test is done on fundamental frequencies, such effects cannot be seen. This is attributed to the achievement of vocal analysis via free conversation within the fMRI.

Figure 4.17: Workmanship of the mouthpiece (for speaking with greater ease)

Figure 4.18: Mitsuyoshi-style's masked microphone, disassembled.

4.7.4 Method Used in Securing the Head

In this experiment, there is a need to compare emotions to brain activity. Additionally, to analyze emotional activity from brain images, an analysis of the limbic system is required, particularly the amygdala, as indicated by many researchers in the field of neuroscience - noted in Appendix B.1（p.121）. Here, fMRI is utilized. Although MEG and brain wave measuring are also effective, MEG cannot analyze deeper regions such as the amygdala, and brain waves can only pick up general information. Also, while the experiment uses subjects' normal state as control (C) and their excited state as stimulation (E), it needs to be ensured that subjects' mental conditions are not affected by the means of securing their heads. For this reason, subjects are treated with extra care when securing their heads, to prevent any head-related transfer of influences from movement in the jaw or body during conversation. Figure 4.22 is a cushion used to gently secure the subject's head. The back of the subject's head is secured with Styrofoam made to fit his or her head shape. Since Styrofoam is nonmagnetic, there is no effect on the MRI. From this, I was able to create a close-fitting, secure cushion, to reduce subject's pain in the back of the head, and make prolonged testing (several hours) possible. In picture1, the head-securing gauge attached to the gantry bed is replicated, showing a concave shape. A piece

Figure 4.19: In completed state

of heated Styrofoam is placed between the head of the subject, who is wearing the nonmagnetic, sound-insulating headphones, and the gauge. When the Styrofoam has cooled down after two minutes, it is complete. Picture2 shows the Styrofoam that is placed within the gauge. Picture3 shows the finished Styrofoam. With this, it is possible to stabilize the subject's head to the gauge of the gantry bed without any pain. Figure 4.23 shows how the subject is stabilized on the gantry bed of the fMRI. A nonmagnetic, reinforced nylon belt is used to secure the subject's head and the Styrofoam to the gauge. The belt is placed over the subject's eyebrows, and fastened without causing the subject any pain. By securing the noise-insulating headphones, masked microphone and Styrofoam with the belt from the beginning, left-right movement of the head is restrained. Then, top-bottom movement of the head is controlled by securing the head to the bed. With these steps, it is possible to carry out brain imaging and detection of the hemoglobin movement in the brain without letting any body movements, such as moving jaws during conversation, influence the brain.

4.8 Emotional Detection of the Subject

Since feeling labels are determined by human subjectivity, VEA used subjectivity in making the decision tree to construct the decision logic. However, as the origin of emotions is regarded to be at the center of the brain, without cognitive influences in the subject's introspection, there are instances where the subject is not aware of emotions in the brain. At the same time, when the subject is aware of his or her excitement, it is difficult to conduct evaluations without affecting the excitement. As shown in Figure 4.1, while the ideal method is to measure physiological reactions and complex hormone reactions in real-time, since there is no such technique tests are conducted on physiological reactions and vocal chords. In this case, introspectively labeled feelings are not taken into account. Instead, excitement is taken as emotion , and vocal tract information, affected by intention, is eliminated. By doing so, it is preferable to collect vocal chord information via fundamental frequencies directly. Hence, it is necessary to be able to measure emotions directly from vocal chords, instead of subject's introspection.

Figure 4.20: Amplifier gain adjustment (in collaboration with NICT)

4.8.1 Detecting Emotions from Fundamental Frequency Detection

There is a need to analyze emotions from fundamental frequencies, for direct detection of excitement from the relation between fundamental frequency and power, rather than the VEA system which uses the C5.0 decision tree to reflect subject's introspection.

Detection of fundamental frequency follows the VEA method, implementing both Cepstrum and the proposed method. By doing so, I can determine which method is applicable to fMRI, and by comparing variations and discrepancies, confirm the condition of emotion.

By measuring emotions from Δ power and $F0$, it is assumed that level of excitement and its comparison with physiological indicators can be found in the relationship between variations in fundamental frequency and power, which was not uncovered in the comparison of parameters in VEA.

Henceforth, by observing these conditions, VEA's decision logic and decision tree, and the parameter threshold can be improved for use in subjective emotion, and physical observation of subjectivity and introspection will become possible

4.8.2 Experiment for Fundamental Frequency Detection

Figure 3.7 show results of conducting fundamental frequency detection in the noise environment of the fMRI gantry. The viewer is capable of simultaneous display of the fundamental frequency detection proposed in this paper, and the fundamental frequency detection of the commonly used Cepstrum technique. By using this, following the implementation plan explained in Chapter 3.1（p.21）, I found the difference in detection of feeling speech, during the conversation experiment conducted in the fMRI.

As reference for fundamental frequency detection in activated fMRI, Figure 4.24 shows F0 of each of the feeling conditions during speech in the fMRI.

The waves shown in green are wave patterns of speech. The right hand side shows fundamental frequency measured by the proposed method of this paper; the red line shows rise and fall of power. Fundamental frequency from Cepstrum is displayed on the left hand side. As

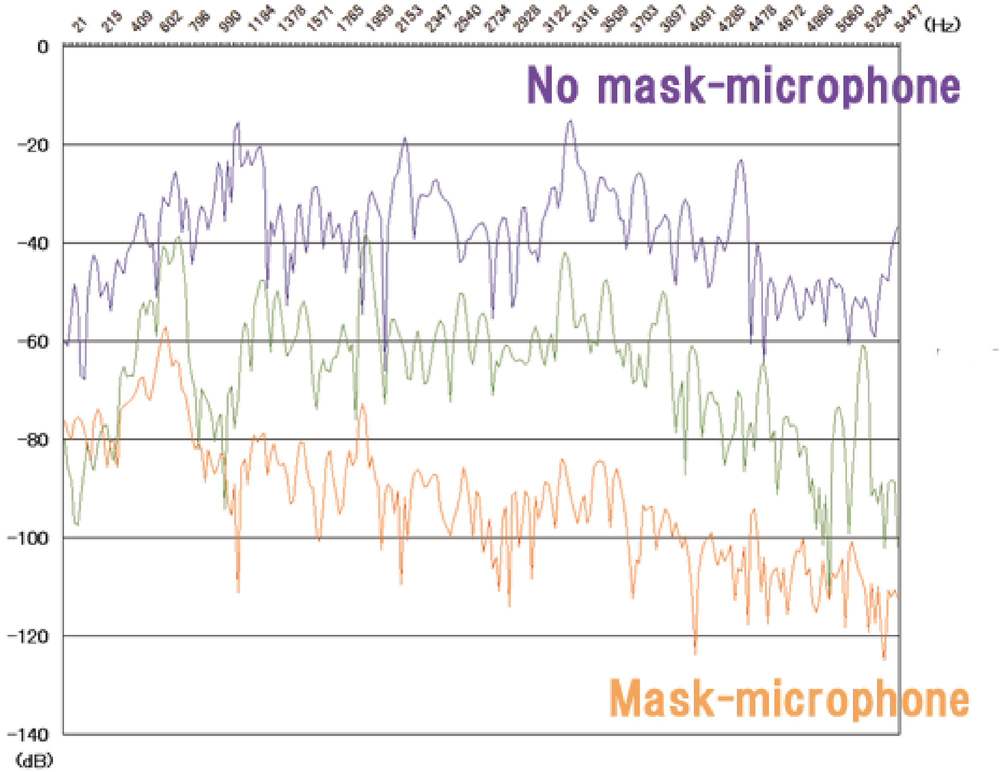

Figure 4.21: Noise Reduction Effects in the Gantry (FFT comparison, reduction of 80 dB (1/100 million)) (in collaboration with NICT)

can be seen from Figure 4.24 and Figure 3.7, in the proposed method the continuity of F0 is apparent. On the other hand, F0 of Cepstrum shows greater inconsistency. However, where fundamental frequency is used to find emotional condition in fMRI experiments, this inconsistency may become an indicator, hence both are presented here.

Additionally, from the comparison of the two, fundamental frequencies that are robust and those that are not become evident. However, because conditions of the vocal chord cannot be detected from daily life conditions, there is no comprehensive method for measuring fundamental frequencies from voice. Hence, continued verification will be performed by using the association between brain activity and physiological indicators, and a comparison and differences in these two methods.

The different conditions are numbered and described below.

Figure 4.22: Making of the cushion for head stabilization (NICT)

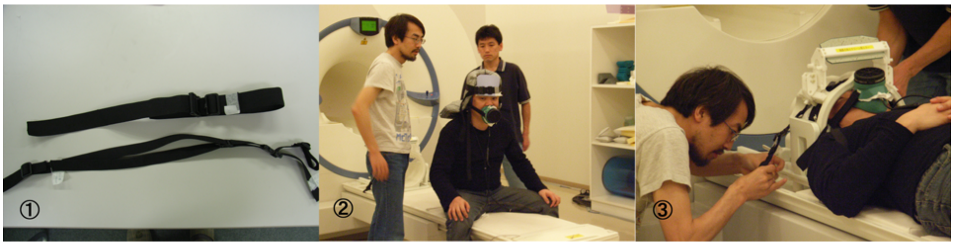

Figure 4.23: Belt used for head stabilization

1. Calm (apology speech): subject makes excuses to another person, slight accentuation is seen
2. Calm (canned speech): subject explains something to another person
3. Excitement (acting speech): subject is speaking in pretended excitement
4. Excitement (natural speech): subject is speaking in natural excitement

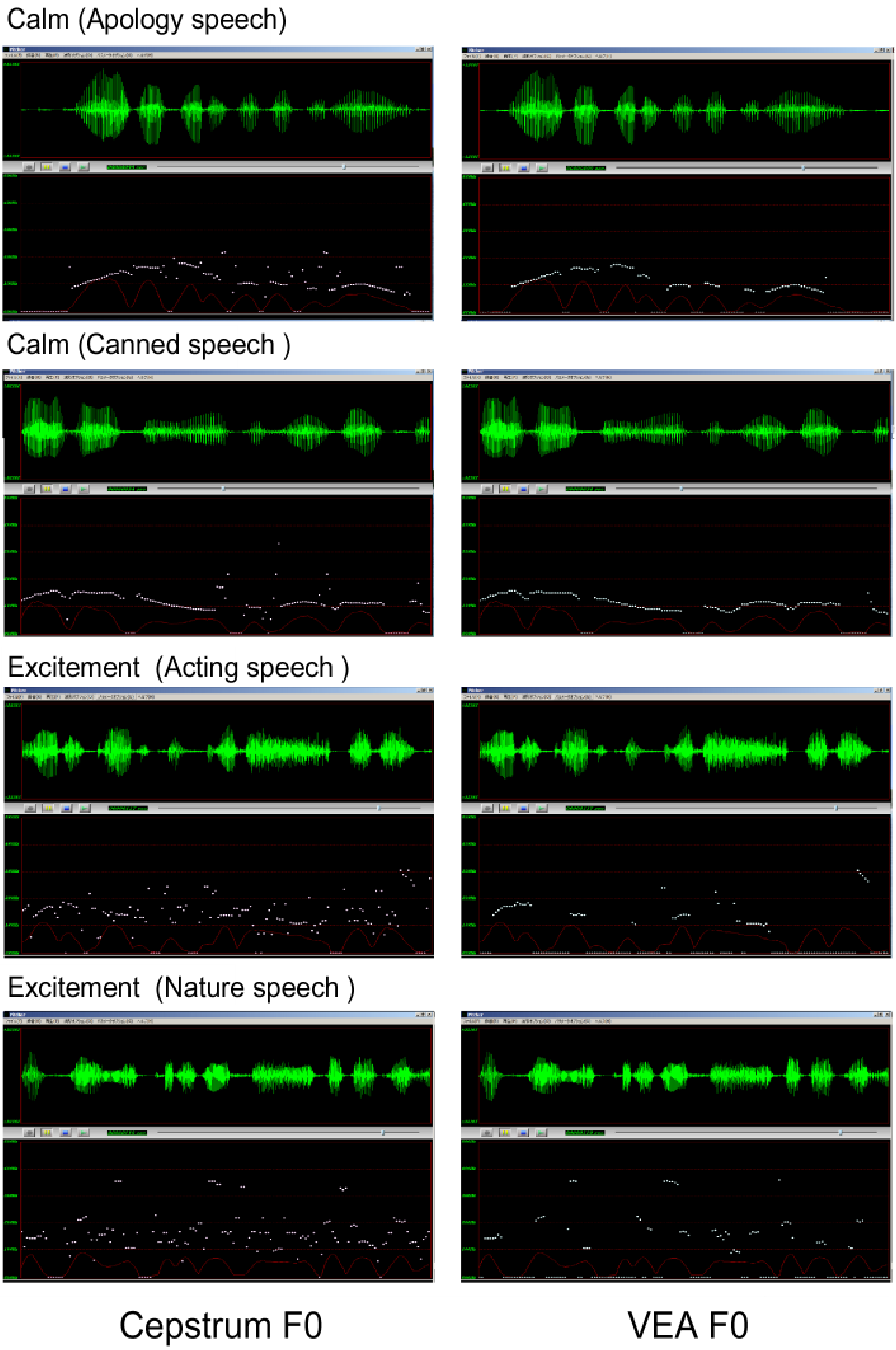

Figure 4.24: Fundamental frequency detection of normality and excitement in activated fMRI

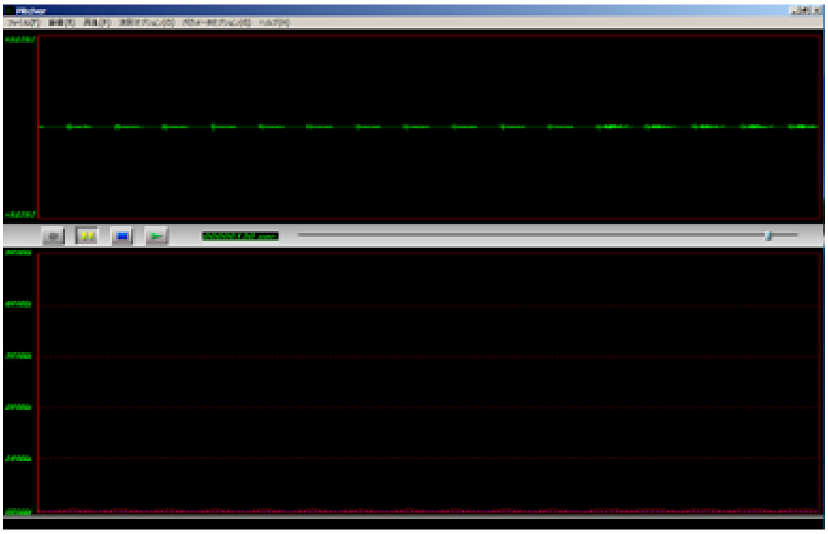

Figure 4.25: Effects of noise reduction measures on fundamental frequency in activated fMRI

From the comparison in Figure 4.24, similar to Figure 3.7, Cepstrum shows a difference in excitement, in what can be seen as errors of fluctuation in fundamental frequency when compared to the proposed method. In fundamental frequencies of the proposed method, however, they are not erratic dispersion, but evident differences in elevation.

Also, in regards to excitement, when comparing fundamental frequencies of normal and excited conditions, the variation in elevation is evident.

The drastic change and fluctuations in fundamental frequencies of the proposed method, among all conversational speech during the 30-minute experiment, utterances at this frequency is confirmed by both the subject and evaluator, introspectively and subjectively, to be excitement, and is checked against speech conditions before and after. Again Cepstrum, like shown in Figure 図 4.24, when compared with the proposed method, erratic fluctuations in fundamental frequency can be seen.

Figure 4.24 shows influence on F0 based only on noise in the fMRI.

It can be seen here that in the upper wave patterns, like results in Figure 4.21, small, constant wave patterns are shown as reduced noise. However, this is not seen in the lower part. This is due to the elimination of noise to F0. In addition, in both Cepstrum and the proposed method, impedance of noise was not observed. Here the detection of fundamental frequency and $A-K-D$ in fMRI is achieved, and the functioning of VEA within the fMRI is confirmed.

4.9 Confirmation of System Operation through the Conversation Experiment

To resolve the fundamental problem of feelings, there needs to be a system that can analyze, based on law and theoretical knowledge, the cause and effect relationship between physiology (such as the brain and heart rate) and cognition (introspective, subjective). For that purpose I conducted verification on the comparative method for cognition and feeling labels, explained in Chapter ref 音声感情認識, ensuring its capabilities. Consequently, it is necessary to build an analytical system via VEA, to find the relations between physiology and emotions. However, for physiological influences of hormones, DNA, neurotransmitters, and the immune system

Table 4.2: Sensor Data of Physiological Indicators (Subject YT) (in collaboration with NICT)

Physiological index	Excite	Ang	Fear	Joy	Sorrow
Heart rate	++++	+++	0	++	−
Blood pressure	0	0	0	0	0
Body thurmo	0	0	0	0	0
pupil size	++	0	+++	0	-
eye movement	*	*	*	*	*
Blink	+++	0	-	0	0
Voice	++++	+++	0	++++	+
fMRI	+++	+++	+−	+	−

that cannot be verified through methods of engineering, they can be inferred from law and theoretical knowledge based on the feeling of mechanism mentioned in Chapter 2.2. I verified the operation of the system that can compare physiological reactions (heart beat, brain activity, etc.) excluding hormones, DNA, neurotransmitters, and the immune system.

Conversation experiment Using the masked microphone created in March of 2006, tests of emotional conversation were conducted on subjects YT and SM, with more meticulous stabilization of the head. The experiment consisted of 2.5 minutes each of anger- and delight-stimulation conversation, totaling 5 minutes per session. Each subject was tested for two sessions. Conversational speech was recorded and simultaneous VEA analysis was performed.

Confirmation of system operation via mutual conversation A mutual conversation between 2 subjects is analyzed using the method below.

1. The conversation is separated into 2 lines of chronological sequence. Patterns in fundamental frequency are extracted from each of those two lines. Frequency analysis is done separately. Any matching components in frequency property are searched for.

2. The conversation is regrouped into one chronological sequence. Frequency analysis is conducted within the sequence, and any continuous features that summarize the relationship are extracted. Whether each subject's speech is in alignment or deviation to the continuance, is found by analyzing each conversational element and utterance. In other words, phase synchronization is analyzed from the continuance of frequency property.

3. Patterns in anger and delight are extracted from VEA, and examined for any correlation with the continuance described above.

4. To examine the correlation physiologically, comparisons with heart rate and brain activity are performed.

4.9.1 Results

In Table 4.2, a +sign indicates a strong reaction, and the number of + signs corresponds to the level. 0 indicates no reaction, and an inverse reaction is indicated by -. The * indicates that there was no measurement. With Voice, when the judgment of ST2.0 matches the inspector's subjectivity, the number of + signs is used in correspondence to its level. And 0 indicates no

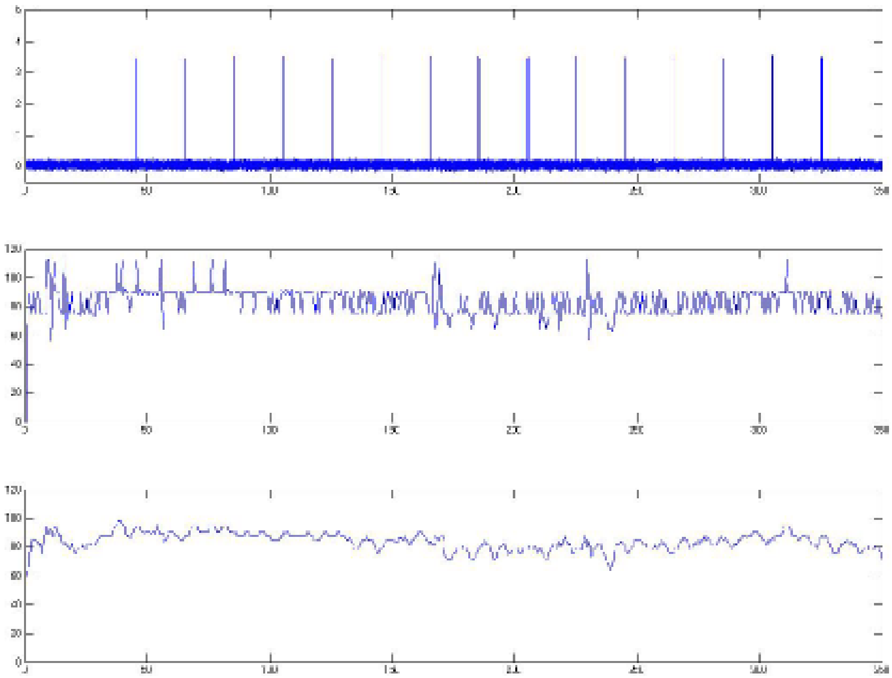

Figure 4.26: Sample data from the system for emotional physiological brain signal analysis (Subject TM)

reaction, - indicates a reverse reaction. For fMRI, whenever a reaction is confirmed in the limbic system, cerebellum, or hypothalamus, the number of + signs used corresponds to the level for each part. When a reaction is confirmed in the prefrontal region of the brain, the number of - signs is used in correspondence to its level. Figure 4.26 portrays sample data from the system for emotional physiological brain signal analysis. With this, the verification of the physiological analysis system connected to the proper operation of VEA, was made possible. Hence, the system for VEA and physiological reaction comparison is able to operate, and although the number of participants is few, the cause and effect relationship between the brain, heart rate, and VEA is confirmed.

4.10 General Discussion

Although humans are able to infer another person's feelings from facial expression, situation, and voice, without the help of characteristic facial expressions, guesses made from natural expressions rarely match the other person's introspection - chances are poorer than random guess. Also, with machine recognition, because image processing techniques remain undeveloped, the focus of research on feelings here is through voice. On the other hand, aside from feelings, humans also have primitive emotions. Based on past research, emotions are found to occur from the primitive center of the brain. From there, the topic of research is focused on feelings and emotions based on voice.

Human vocal chords are assumed to be strongly influenced by emotional reactions of the brain, which are affected by brain and oral structure, and the connection status of nerves. Additionally, vocal chords are also affected by influences of agents and triggers on introspective feelings. The above, the "validation of the influence emotions and feelings have on vocal chords," is set as part of my hypothesis.

In comparison to emotional excitement, feelings of "anger," "@delight," and "sadness" have "individual differences in feeling labeling due to cognition influences of physical reactions and environmental situations." This is also incorporated into my thesis.

The concept that feelings are labels assigned from human subjectivity and introspection is examined through "human-human" and "human-machine" comparisons. By analyzing voice parameters, I proved that emotions are revealed in fundamental frequencies and that they are the fundamental elements affecting all feeling labels. I also verified scientifically that fundamental frequency parameters of emotions are firm standards in the analysis of feelings and emotions from voice. From this, it is possible to consider the fundamental problem of feelings, based on the relationship of the two reactions of the mind - emotions which are physiologically driven, and feelings which are labeled from cognitive influence.

To verify the fundamental problems of feelings, in the "validation of the influence emotions and feelings have on vocal chords" and the "individual differences in feeling labeling due to cognition influences of physical reactions and environmental situations" using the analytical system for feeling labels and emotions based on voice, I build the following: emotional analysis based on fundamental frequencies of vocal chords, vocal evaluation system that allows the evaluator to naturally label feelings from voice, emotional analysis (VEA) automatic labeling system based on machine voice reflecting human subjectivity, system which can display VEA decision results and evaluate them in real-time, parameter comparison tool for verification of emotional influence on fundamental frequency.

The information gained from detection of fundamental frequency via the VEA system is described below. In regards to the estimation of fundamental frequency used in VEA, erratic fluctuations can be seen from Cepstrum. On the other hand, the proposed method leads in automatic error detection, and errors are few. This shows that the estimation of fundamental frequencies made by proposed method is more readily quantified. When looking at automated and real-time analysis, the proposed method succeeded in speculating fundamental frequencies through VEA.

The following describes the decision logic used in the VEA system. If feelings are labels, it is only natural that the decision logic is made in reference to subjective human labels. VEA's feeling element parameters utilize a decision tree structure that reflects human subjectivity. The VEA display system is real-time, like conscious excitement of previous emotion, analyzes conscious feeling labels, and displays feeling judgment simultaneously with phonation. The system's judgment results are recorded and used for real-time evaluation by the speaker and the observer. With this, the feeling elements of anger, delight, sadness and calm are detected from voice analysis, and the creation and capability test of the automatic feeling label system based on the decision tree reflecting human subjectivity were accomplished. Additionally, detection of 3 levels of excitement emotion was achieved through fundamental frequency.

These systems were used to compare human feelings and emotions to the system. In regards to the fundamental problem of feelings the cognitive influence of feeling labels is the main issue. My hypothesis assumes that emotions are physiological reactions centered on the brain, and feelings are labels based on cognitive influence. Also, emotions have less individual differences, even from a third person's subjective perspective, and make stable criteria. However, feeling labels are considered to be uncertain when used in comparison as human subjectivity.

In the experiment, there is a need to compare emotions, feeling labels, and the subject or a third person's subjectivity. The system performance is comparatively tested based on a third person's subjective perspective. As a result, an average of 73% excitement emotions was confirmed (83% yes and 62% no). In a comparison with other feeling labels (37%) from the same experiment, comparing subjective emotions based on multiple third party results, it is nearly twice the difference. From this, it can be concluded that emotions are more stable criteria than feeling labels, even when looking at subjective perspective.

However, to measure subjective evaluations of passive emotions, subjects (third party) are asked to evaluate excitement based on 3 levels. Subjective evaluations of excitement were drastically different from system output. On top of that, the number of N/A responses increased. This means that subjective evaluation is not possible in this case. In other words, even if humans can determine the existence of excitement emotion, but it is difficult to create criteria based on categories of level. Nonetheless, when subjects evaluated feeling labels from VEA display, uniformity was 62%. Results were that human ability to recognize feelings from nonverbal prosodic information was a 55% baseline score.

From the comparison between the subject's (third party) feeling labeling, and the evaluation conducted from VEA display, it proves that the evaluator is affected by cognitive influence of the VEA display.

Additionally, because subjective perspective other than that of the subject cannot be used as criteria for recognition rates, the subject's speech feelings (subject's subjectivity) and the VEA system were compared. As a result, it is proven that VEA judgments have a comparable capability to that of human subjectivity. From the comparison between the system and human subjectivity, the system can detect emotion of excitement and feelings and perform more accurate detection on emotions, but among third party evaluators, there was less than 20% congruence in feeling evaluations. Also, from a comparison between the display system of feeling labeling decision, and human subjectivity that was easily affected by passive cognitive influence, it is confirmed that "feelings are first recognized through labeling (cognition confirmation influence)", showing uncertainty in human subjectivity.

From this, Schechter-Singer's Two-Factor Theory that says "feelings are first recognized through labeling (cognition confirmation influence)" is verified. On the other hand, it is proven that elements of emotion are related to all separative elements of feeling, based a comparison of parameters.

Based on a comparison between the decision based on feeling labeling that is easily affected by cognitive influence and active feelings of the subject, and the verification of cognitive influence from the VEA display, the Schachter-Singer Two-Factor theory is in the least proven in the evaluator (third party). With regard to the emotional detection of excitement, even in an experiment with no cognitive influence, effectiveness is almost double that of feeling labels. The influence of emotion parameters on separation of each feeling, comparing subjective evaluation of emotions and VEA, in the case of the third party where there is no cognitive influence, a reliable 73% consistency is shown, proving it to be stable criteria.

However, there is still much unknown to the mechanism of human feelings. There is also a complex relationship between the brain and neurotransmitters, and the influence of secretory substances. The purpose, in terms of engineering, is to devise and provide a device to researches for better understanding of the mechanism of human emotions and physiological reactions. Since subjects cannot introspect excitement in real-time, it was necessary to establish the methods for: fundamental frequency detection to inspect vocal chord conditions, which are directly influenced by emotions due to brain and oral structure, confirmation of the ignition regions in the brain that are related to emotions, direct verification of emotional "excitement" (physiological reaction) through physiological indicators, and simultaneous examination of emotions from fundamental frequency.

As the system for clarification of the physiological mechanism of feelings, using emotion parameters, a method that allowed measurement of emotions by comparing VEA and physiological indicators (physical reaction) was created, and I attempted emotional measurement via brain activity, physiological signals and VEA.

To make in-depth research of the feeling mechanism via the brain and emotions possible, with advanced imaging technique of the brain (fMRI), and a wide range of physiological states, it is proven that research of human feelings can be done. Additionally, a feeling recognition experiment in free conversation, that has not been done successfully in fMRI, was achieved.

In this experiment it is proven that real-time, free conversation analysis within the fMRI was possible, with the linkage between fMRI and the system for emotional physiological brain signal analysis, a self-made masked microphone with good noise insulation, blocking out noise from fMRI operation, reduction of noise within the fMRI from 130 dB to 80 dB (1/100 million), robust detection of fundamental frequency, securing the head with a self-made nylon belt, and by controlling movement of the head during conversation.

With this, the system for emotional physiological brain signal analysis is linked with the VEA system, the overall system does not need the subject's subjective evaluation ¡passive feeling evaluation¿, and a real-time analysis of the condition of active emotions via physiological indicators excluding hormones, immune system, and DNA was made possible.

Moreover, the system was able to verify emotional ignition via brain activity, heart rate, and vocal chord information caused by visual and audio-visual stimulation.

4.11 Future Issues

Research in emotions and feelings, due to the development in sensor technology allowing real-time observation of brain activity in high accuracy, has just begun. On the other hand, human subjectivity has 20 to 40 percent of uncertainty, and is prone to cognitive influence of physical reactions and the environment. It can also be said that cognitively labeled feelings from human subjectivity is ambiguous. Hence, measurements of feelings based on human subjectivity, are debated among a consensus of 60 to 80 percent. If the construction of an emotional speech database of 2000 people can be done by IEEE, the degree of consistency between subjectivity and physical reaction found for every feeling, results can be used to standardize the test samples of emotional speech. There is also the need to standardize the material based on regional, gender, and age differences.

At the same time, for standardized audio samples, it is necessary to know what types of physiological reactions are displayed by humans. There is also a need to record the speaker's brain condition, physiological substances, physical reactions, hormones, and DNA.

Some experiments in molecular biology are likely to reveal sympathetic vibration and resonance as linkage between cells. There is a need to examine the relationship between sympathetic vibration and resonance at the cellular level, and the transmittance and sequence of feelings and emotions by examining Appendix C（p.133）, Appendix C.2.1（p.137）, Appendix C.2.2（p.139）. and Appendix C.2.3（p.141）

Under current circumstances, because real-time measurement of hormones, secretory substances and neurotransmitters remains undeveloped, heart rate and vocal chord information (fundamental frequency detection) in useful in examining physiological reactions. In the future, there will be full-fledged participation in physiological experiments. Moreover, it will be possible to infer conditions of the mind and brain to a certain degree, through the use of handy devices such as cellular phones, from vocal chord information and so forth. In this sense, application to medical care, QOL, automobiles, airplanes, and search are possible.

The detection technique of fundamental frequency, and attainment of clear fundamental frequency in 130 dB of noise should be, in a broad sense, not only contributive to research in feelings, but also to the fields of sound and throat research. However, because there may pose ethical issues in the examination of vocal chord vibration and fundamental frequency of living subjects, there needs to be a detailed comparison between parameters gained from fundamental frequencies and physiological parameters. Furthermore, the detailed clarification of the physical cause-effect relationship between VEA based on human subjectivity and actual physiological indicators, will be a future issue.

Chapter 5

Conclusion

This paper assumes that feelings are labels assigned from human subjectivity and introspection. There are physiologically driven emotions (physiological reactions) and cognitively influenced feeling labels (cognition labels); my hypothesis says that these two mind reactions are the basis of the fundamental problem of feelings. Emotions originate from the limbic system of the brain, serving as stable guidelines that do not do waver among different people's subjective perspectives, and that they can be detected through voice from decision logic of fundamental frequency and power. On the other hand, feelings are cognitive labels; they are affected by individual differences in subjectivity and cognitive influence, and cannot become good guidelines in comparison to emotions. However, elements of emotions, through the brain and oral structure of and emotional speech, hormones, neurotransmitters, homeostasis, have overall influence on feelings, and can serve as guidelines for feelings.

To confirm this hypothesis, I proved the difficulty in feeling recognition from face and movement, and investigated cognitive influences of emotions and feelings by comparing human subjectivity and introspection.

By looking at the structure of human emotional phonation from influences of the brain, hormones, and neurotransmitters, the mechanism of emotional speech is used to construct a nonverbal, Vocal Emotional Analysis (VEA) system.

With parameters used for feeling analysis of the voice and the decision tree that reflects human subjectivity, the results from cognitive comparison of separated state of feelings and emotions show that, in emotional parameters, fundamental frequency is related to power, and that emotional parameters have an overall influence on the separation of feeling labels of "anger," "delight," "sadness," and '@calm." Also, it is discovered that parameters derived from the logarithm of fundamental frequency and parameters of excitement have a mutual influence on the separation of feeling labels.

The consistency of subjectivities in humans, the comparison of subjectivity and VEA, and the comparison of introspection and VEA are divided into feelings and emotions and evaluated separately. Results showed that, congruence in human subjectivies did not exceed 20 percent. Also, in a comparison of the subject's introspection based on VEA and the third party's subjective perspective, there is higher consistency in subject's introspection and VEA, over feeling recognition standards based on human prosody alone and the consistency between human subjectivity and VEA. Also, the cognitive influence of VEA display feeling labels on human subjective evaluation is proven. Human subjective evaluations showed only high consistencies in excitement emotion.

From the above results, the following is confirmed and the hypothesis is proven: cognitive influence is proven from a comparison between VEA and humans; feelings are labels assigned from human subjectivity and introspection; emotions (excitement) are reliable standards for both VEA and human subjectivity; in voice, elements of emotion are included in all feeling labels; both feeling and emotion parameters are strongly influenced by fundamental frequencies which are vocal chord information.

Feelings, as labels assigned from human subjectivity and instrospection, take strong influence from emotions, and subjectivity can be swayed by excitement which is detected in the vocal chords, and labeling displays due to the effect of cognitive influence.

Then, to find whether emotions, having big influence on feeling labels, have physiological drives (brain, physiological reactions), I decided to create a system where emotions can be simultaneously compared with physiological indicators and VEA. With the VEA system, which has robust standards for emotion (fundamental frequency) and standards that reflect human subject, I was able to conduct a noise reduction of 80 dB in the 130 dB noise environment of fMRI, create a technique for obtaining clean fundmental frequencies, set VEA as the criteria for physiological reactions of emotions, and build a system where real-time measurements of brain activity, heart rate, blood pressure, body temperature, eyeball movement (including blinking), and vocal chords (fundamental frequencies, power) was possible.

The operating experiment of the system, by video presentation, was able to verify the ignition of emotions indicated in neuroscience via the fMRI, with only two participants. With this, it showed that the system could be applied to the physiological analysis of the fundamental problem of feelings. Additionally, in the conversation experiment conducted during fMRI operation, human subjectivity and subject's introspective labels proved consistent. The fundamental frequency properties of fluctuation and difference of elevation were found through voices of excitement. However, since this paper is a engineering experiment of the system, from this experiment alone, the physiological drive of emotions (creation of emotions from physiological reactions) cannot be verified. There needs to be much future analysis from clinical cases conducted by medical researchers using the system proposed in this thesis.

From the above, it is proven that the VEA can serve as reliable standards when measuring human subjectivity that has the tendency to fluctuate; it can be used in the comparative study of feelings, physiological drive of emotions, and cognitive labels, and in physiological analysis, it is effective for analysis of emotions and feelings via fundamental frequency.

Appendix A

Reference Material (Psychological)

A.1 Details on the Psychological Studies of Feelings

In present day, there are few researchers that regard concepts of feelings unnecessary to the behavioral sciences. This is because "fear" and "unrest" cannot be clearly differentiated through behavioral observation. However, both "fear" and "unrest" are emotions, or mental conditions similar to that of ; "unrest," feelings of presentiment or prediction not expressed in actions, does not appear in behaviors.

For example, supposing that an experiment in which "subjects are asked to press a button whenever they feel 'fear' or 'unrest'" is conducted, the thought experiment is described below.

Suppose that upon a stimulus or some similar input, subjects feel a change in mental condition. In response to that stimulus/input, subjects judge (perceive/verify) instantaneously the change that is taking place within themselves, define the feeling (introspect), and press the button. This introspection is the subject actively sensing changes in the mind. Here, the first action that takes place is the final act of pressing the button, the complicated mechanism of systematic introspection is hard to express through action. Obviously, the question that then surfaces is that of the complicated mechanism. When explaining the mind and emotions scientifically, it is necessary to explain the mechanisms of "introspection" and "subjectivity," where they come from, and how they take place, in a reproducible (quantifiable) manner. Furthermore, the mind and emotions are difficult topics even from the philosophical aspect. Looking back again at the thought experiment, it must be proven that "introspection" does not appear in behaviors. Or to prove that it is not shown in changes of facial expressions or physiological signals. If "introspection" is shown, there is a need for "subjective" evaluative criteria to define its representation, which will not be quantitative. Subjectivity is a passive evaluation. However, when this "subjectivity" is attempted to be quantified statistically, by verifying feelings as "introspection" through facial expressions, it becomes necessary to judge what the expression is from the subject's "introspection" or an observer's "subjective" view.

Nonetheless, when this verification of "introspection" is shown through changes of physiological signals, it is at least possible to verify the subject's "introspection" in physical quantities. Also, if it is possible detect quantitative changes, it is likely to see changes in feelings. When considering the possible methods of examining human "introspection," it is ideal to measure changes in "introspection" against fixed standards, in continuous quantities such as distance and weight. As a result, it will be possible to analyze the angle and cycle if fluctuations or radical changes are detected in "introspection" and its mechanism of action. For that purpose, fixed standards and a method for measuring sequential change are necessary.

On the other hand, recent analysis done with the neural network and stochastic model are attempting to look at the difficult mechanism of "introspection" stochastically as a system outputted based on law, and to recreate it. However, the stochastic concept itself is uncertain. It is difficult to measure change conditions of "introspection" in quantitative, continuous quantities such as distance and weight. Moreover, if the uncertain stochastic model is used as a means of correction based on law, it becomes impossible to deny the probability of association for "introspection." In scientific terms, it is difficult to reach a conclusion here.

In this thesis, the main purpose is to construct a system where "introspection" can be analyzed via scientific method, and the first step is to find the fixed standards (which will be the parameters). As the object of this study, in finding out whether there is a mechanism to "introspection," what exactly "introspection" is, it is necessary to narrow down "introspection." Here, by looking at "introspection" as active, conscious feelings, from the perspective of passive feeling evaluation - how one identifies others' feelings, how one detects emotional change - I thought of how I would, with machines, measure and analyze the relationships among "introspection," the brain, physiology, and active feelings, and the relationships among "subjectivity," the subject, and a third person's evaluation. Without using the neural network and the stochastic model, I use a logical decision method with machine-based analysis, to physically examine the human method of feeling identification. My hypothesis is based on past experimental results on feelings, neuroscience, and clinical trials, physiological traits such as hormones, and brain and bodily structure. I examine the feeling problem from the relationship between passive feelings and active feelings, the relationship between the subject and the observer, and cognitive influence. Then, I devise a method to make comparisons with physiological indicators possible, and to analyze the relationships among active feelings, physiological phenomena, decision logic, and parameters. I create the means to clarify the emotional mechanism from an analysis of the active and passive elements of "introspection," and a comparison of quantitative data, and the logical rules of systemized "introspection."

By doing so, it becomes possible to provide to researchers who are analyzing the relationship between emotions and "introspection," the mechanism of emotions, or its origins, the quantitative measurement methods and the means to make comparison possible, based on the reconstructed logic of the mechanism of "introspection."

Past research of feelings in psychology are shown below.

1. The resonance and sympathy of emotion: Phenomena such as "emotional contagion," "co-action," "motor mimicry," which are not related to complex cognitive activity, can be seen in children at development stages. These are not results of complex cognitive activities related to others' inner processes. (Saarni et al.1998)[141]

2. Anger, sadness, and fear: Infants are sensitive to pleasure-unpleasure from an early stage. However, this does not prove that they are able to clearly identify anger, sadness and fear [141].Put together by the author, Figure A.1 shows the development process of children's emotions from the perspective of developmental psychology.

   Figure A.1 shows children's development process of emotions.

3. Specific patterns of emotional experience are organized by personality formation.

   Izard1993[142]Magai1996[143] Tomkins1995[144]

4. Certain types of emotional conditions have perceptional and cognitive biases of others' emotional expression. Forgas2000[145] Forgas2001 [146]Izard1991[45] Magai1995[147] Tomkins1995[144] Emotional bias brings about deviation. This may also be connected to paranoia.

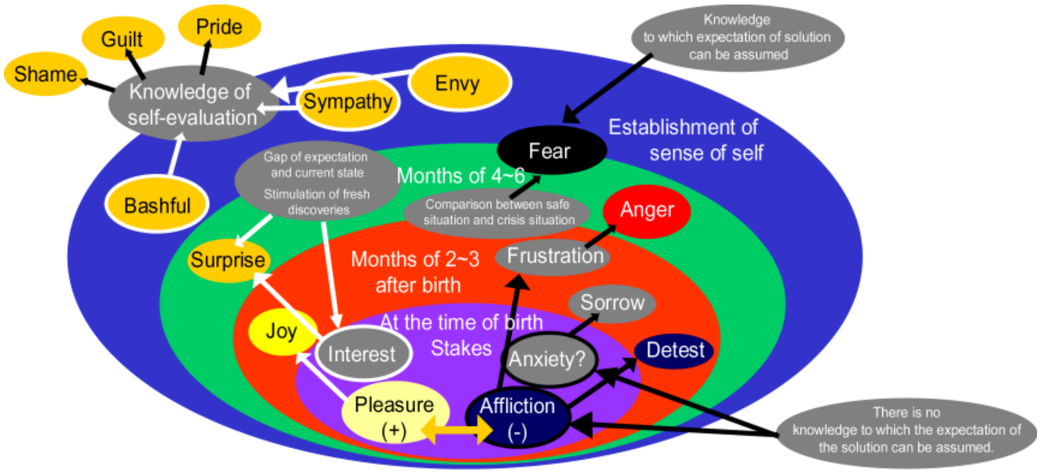

Figure A.1: Children's development process of emotions （made from [5][6]）

5. Certain types of emotional conditions affect cognitive processes such as memory, thought, and problem-solving. Bower1988 [148]Isen1984[149] Mathews1993 [150] Malatesta& Wilson1988 [151]

6. Consequently, it is related to the onset of exclusive, hostile behaviors. Forgas2000[145] Forgas2001[146]

7. Therefore it has a strong influence on the precision of memory, learning, recall, creativity and problem-solving.
Isen1984[149]Nasby1982[152]

8. Human beings begin performing emotional resonance from childhood. It can be predicted that emotional communication of excitement elements is performed, since "particularly, expressions of emotional excitement (anger, happiness) surpass those of sadness and pain."Denham1986[153]

9. Resonance of emotional bias conveys bias to the cognitive subject as well, hence evoking behavior. "Resonance of emotions" Malatesta& Wilson1988 [151] Haviland& Walker-Andrews 1992 [154] Keltner&Haidt2001 [155]

10. Sensing another person's emotions is to estimate his or her personality and intentions, and to apply unique behavioral patterns to him or her. Keltner1996 [156] Keltner& Haidt 2001 [155]

A summary of psychological research on emotions Emotions occur not randomly but from specific relationships. Additionally, the resonance and influence of emotions have great influence on human behavior, thought, and memory. These researches reinforce a part of the author's hypothesis in 2.2.1（p.15）. Also, the internal influence of emotional scripting during the upbringing process forms a portion of the personality. This signifies that emotions play an important role in the intellectual processes such as memory, learning, and problem-solving, sensitivity, and the formation of personality.

A.2 The History of Feelings Models

In regards to the visualization of the relations of feelings, research based on subjective evaluations has been done by Wundt, Plutchik, and Ogaeri. In Wundt's model, the axes of nervousness and relaxation do not portray much significance. Plutchik's model is simple and easily comprehensible, but current neuroscience and physiology are able to provide more detailed analysis, and what he regards as the most fundamental emotion is also analyzed in greater depth. Consequently, a dynamic, transitional reproduction of Plutchik's model of the relationship between emotions and feelings, cannot be done based on physiology. Ogaeri's model focuses on one-dimensional elements, restricting it to the positive-negative dimension. However, the focus on the color spectrum can be evaluated.

The following describes modeling based on previous research in feelings.

The Feelings Models

1. Plutchik (1962)

   Plutchik hypothesized that the 8 emotions of "receptiveness, surprise, fear, sadness, disgust, expectation, anger, and happiness" cannot be analyzed further.

   Apart from humans, emotions can be seen in dogs and cats. Therefore, emotions should not be considered as mere physiological reactions, but as adaptive behavior to the environment.

   To explain that theory Plutchik created a 3D model of emotions utilizing a 3D color model of perception.

   Plutchik used the color correlation theory to illustrate the emotions in a ring. Like the complementary colors of color correlation, "happiness" and "sadness," "receptiveness" and "disgust" are considered to be contrasting feelings. Also, each emotion is considered to have differences in intensity levels in the 3D model of emotions. For instance, in the emotion of "sadness," there are differences in intensity such as "grief," "sadness," and "reverie." To decide the intensity of emotions, synonyms for different emotions are collected, and numerically evaluated by 30 college students with a measure of magnitude.

   Figure A.2 shows the 3D model made by Plutchik.

   Using this diagram, Plutchik explained the following:

   (a) first of all there are pure emotions,
   (b) pure emotions are unique in physiological basis and behavior,
   (c) they exist in bipolar pairs,
   (d) and have levels of intensity

   The uppermost items, such as receptiveness and fear, are pure emotions. In terms of colors, as primary colors, these emotions cannot coexist. Then, for each emotion, like opposing colors, there is an opposing emotion. Going down the diagram, there are feelings such as repulsion and rejection. This shows that the level of intensity decreases as you go down the diagram. The pure emotions bind to create mixed emotions. Other feelings models are described below.

2. Wundt's "Three Dimensional Theory of Feelings" (Wundt, 1920)

   The classification of feelings is given in a three-dimensional hypothesis, of "excitement-calm," "pleasure-unpleasure," "nervousness-relaxation."

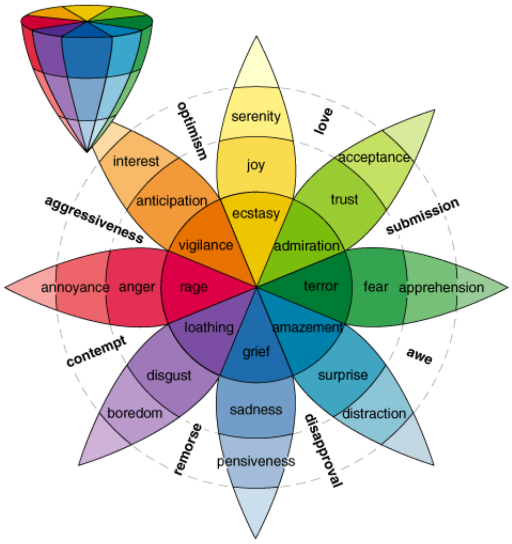

Figure A.2: Plutchik's 3D color model of feelings（Plutchik，1962）

3. Ogaeri's "Spectrum of Feelings Theory"

   Ogaeri divided feelings into these 7 categories, "love, joy, happiness, 0, sadness, anger, hate" and reasoned that they correspond to the light spectrum (red, orange, yellow, green, blue, indigo, violet). The emotion of 0 is a "neutral feeling," showing a state of weak movement in feelings.

A.3 The Labels of Feelings in Detail

Psychologists and researchers disagree on categories of feelings, and have failed to reach a conclusion [157]. In regards to this research, it is essential to determine which feelings will be the object of this study. All elements and feelings of the mind are researched as thoroughly as possible, then listed, and categorized according to the author's "introspection." The focus is narrowed down to fundamental ideas and those that are cross-sectionally related.

To verify this, words that are related to feelings, mental conditions, emotions, and corresponding behaviors are extracted from the dictionary of psychology and Japanese dictionary [158][157]. Then, similar expressions are put together, and organized and replaced by the most frequently used ones. As reference, types of feelings are listed below.

1. Survival-reproduction (propagation): a constant, instinctive desire, it is the basis of thought-decisions in communication; it brings forth the feelings and emotions of risk avoidance based on life sustainment. Moreover, it is the most primitive desire forming the base of emotions that determines pleasure-unpleasure

2. thirst: emotion that has fundamental influence over all feelings, emotions, and motivations that arise from life sustainment. It creates the pressure to fulfill all wishes, and is the source of creation, the self, and wishes. It is the root of human desire.

3. Wish: a more moderate feeling compared to that of thirst.

4. Despair: when there is no avoidance of crisis or chance of resolution, a feeling that is giving up all. Brings forth every sort of negative behavior (suicidal, homicidal, hate).

5. Excitement: a basic, certain emotion that is invoked since early childhood, creating strong feelings and desires. It is an extremely powerful emotion that affects all distribution of feelings, and has fundamental influence. It is the energy drive of behaviors and motivations. Although the self desires a synergetic condition from it, it is controlled by the self when in excess. It is also considered to be the most susceptible to hormonal influence.

6. Stillness (tranquility): a basic emotional state; an emotional state where involvement in everything is static. It represents a state of mind that that is opposite to excitement; it is self-control or awakening from excitement, or calmness resulting from hormonal change. It is a condition of zero excitement.

7. Pleasure: an emotional state, a positive emotion invoked since early childhood, a stimulus-response element innate pleasantness. Shows strong reaction due to instinctive influence. It has a strong effect on thought and memory; it is the drive behind intention, and makes up motivation.

8. Unpleasure: an emotional state, a negative emotion invoked since early childhood, a stimulus-response element of innate unpleasantness. Shows strong reaction due to instinctive influence. Particularly has instinctive influence on memory and thought. Creates emotional tendency to oppose and deceive, but can be self-controlled from results of social learning. Apart from smell and physiological repulsion, it is influenced by the prefrontal region of the brain.

9. Like (receptiveness, affection): a positive, receptive emotion related to pleasure, which is determined by pleasure-unpleasure based on instincts of reproduction and survival. It is reinforced by empathy and envy, synchronized with reason (morale); goodwill is created in aesthetics, positive elements and affirmation of learning, strengthening altruism.

10. Stability: an emotional state where the situation or condition constantly remains in the region of pleasure, can sometimes be triggered by physical condition.

11. Pleasurable sensation: emotion arising from mainly bodily condition when feeling pleasure. Adjoined to pain and suffering, it can also happen when transitioning takes place from agony or exercise such as that of "runner's high." Is also the (habitual) trigger for euphoria and ecstasy. Situation and environment can also become triggers.

12. Dislike (disgust): a negative, rejecting emotion related to unpleasure, which is determined by pleasure-unpleasure based on instincts of reproduction and survival. A broad feeling linked to anxiety and sadness, has the power to move towards the entire dimension of unpleasure excluding self-harm. There is physiological dislike (an emotion) and situational dislike (a feeling).

13. Agony: an emotion created when intense unpleasure or pain is felt, mainly under bodily condition or mental situation, also triggered by the situation or environment.

14. Anxiety: an emotion of prediction, arising from an emotional state that results from the situation being unstable in the region of unpleasure; can sometimes be triggered by bodily condition. It is an emotional related to fear, occurring from the prediction of a dangerous or negative matter in an unstable state. Because it is hardly shown in behavior,

behavioral science cannot be used to tell anxiety and fear apart. It is the feeling element that creates various feelings and affects the entire region of unpleasure. Moreover, it is attributed as the cause of most psychological disorders, and is linked to elements of fear, confusion, discomfort, and indecision, all of which impede rational judgment. (Opposition and isolation are affected by rational judgment and social judgment by the self). When this stimulation is too strong, it may lead to evasion, self-harm, harm to others, and mental disorders. It is the most important emotional state in clinical practice. It is linked to excitement, and has strong tendencies to trigger feelings (cognitive verification) of anger and sadness (in this case they are cognitively influenced so are not considered as pure emotions).

15. Love: a broad feeling label formed from the emotion of like, also an emotional state. Because it is created both in both physical and situational environment, there is the instinct created from the reproductive element, and that which triggers the nurturing of children. The feeling of adorableness. It is an important factor of cooperative reception, while being the fundamental element of tenacity. It plays a very active role in sexual love, thirst, narcissism, and altruism; however, it easily induces confusion, stagnation and obsession, creating reversal.

16. Happiness: an emotion of pleasure arising from pleasurable sensation and like, also triggered by situational environment. Easily influenced by cognition, can also turn to fear in some individuals. Although often regarded as being close to pure emotion, it is shown to be influenced by the indicated environment in our comparative subjective experiment as well as by Schachter.

17. Delight: although affected by the situation and environment, it is a strong state of pleasure that restores the body condition.

18. Comfort: emotion of pleasure arising from stability and like, also affects bodily condition through receptiveness and affection.

19. Ease of mind: an emotion that arises from an emotional state that results from the situation being stable in the region of pleasure; can sometimes be triggered by bodily condition.

20. Anger: a type of excitement that arises from pain, unpleasure, and anxiety, along with distaste, in both bodily and environmental condition. When there is a physical trigger, it can be responsive and reflexive. An active feeling that is let out in excitement and is related in essence to the emotion of excitement. Although often connected to frustration, it is closely related to indecision and opposition, and represents a mind condition that has the power to move towards the offensive dimension of distaste and destruction. It is regarded as an emotion in psychology. If frustration can be regarded as an emotion, despite of cognitive influence, anger can also be considered as an emotion. However, experimentally it is hard to clearly differentiate happiness and anger in human "subjectivity" and "introspection." In some cases it can incite great creativity, and can phase transition to pleasure. Often, following the influence of cognitive verification, anger and happiness are felt from excitement. When the reason for excitement is the dissatisfaction of desire, where disgust is felt it can also be said that there is anger. It also has a cross-phase with sadness.

21. Bitterness: a strong emotion arising from agony, close to being a reaction. Also influenced by the situation and environment through bodily reactions. It is reflex response

to avoid it. It is also used as a generic term for sentiments such as anxiety, disgust, and sadness.

22. Affliction: a strong emotion related to survival, it is a bodily reaction and situational label arising from agony and disgust, and parallels anger. An important emotion that is confirmed to be present since early childhood. Appears easily when feeling loss, obsession, unpleasure, dissatisfaction, and hardship. Also showing in physical conditions, disease and injury, and mental stress, it is a strong element that has an effect on all factors of unpleasure.

23. Sadness: an emotion that is triggered by states of unpleasure such as anxiety and disgust, occurring in all sorts of conditions. Also triggering melancholy and sorrow, it easily coexists with agony; emotion that parallels anger.

24. Fear: an emotion that results from extreme anxiety, can arise from all types of situations. Also a trigger of fright and terror. A feeling that has the power to move towards avoidance. Easily shows in behavior. Unlike anxiety, it does not appear in early childhood, hence it cannot be defined as a certain emotion. Meanwhile, similar to anxiety, it is the base of all feelings of unpleasure, and is more behavioral. Religion attempts to overcome this anxiety and fear through obedience to absolute existence. Behavioral science cannot clearly differentiate the two.

25. Beloved: arising and centering on love, a condition of affirming and wanting the other person. In some cases happiness and comfort have an influence.

26. Joy: a strong state of happiness.

27. Wanting: triggered by delight and happiness, a state of desire where someone must have something, also induced by the situation and environment.

28. Amazing: feeling arising from delight and bitterness, can be easily felt in situations of inversion, and emphasis.

29. Enjoyable: state where condition of comfort continues for a relatively longer period.

30. Reassured: centered on ease of mind, state where comfort is predicted or felt.

31. Unforgivable: a strong, negative state arising from unpleasure disgust, and anger.

32. Melancholy: a lonely state arising from sadness; can also be triggered by fear. Mainly in cases where anxiety and desire go unfulfilled, it occurs in the entire region of unpleasure, and is affected by the self and knowledge information. A mental state that can also be caused by sympathy, its element of depression is a strong intellectual human feeling. When influenced by the self, it can develop sympathy. And in strong sadness, it undergoes a phase transition to become anger. It has been verified in numerous experiments that in this case, excitement (emotion) has a strong influence.

33. Afraid: state of fear

34. Confusion: a cross-state between stability and instability, it can also occur under extended periods of stability or instability, it has the power to change the situation when seeking change.

35. Sorrowful: a condition of mental pain, coming from agony and sadness

36. Harsh: condition where bitterness and affliction continue

37. Envy: arising from want and joy, an envious state where happiness and guilty conscience are felt at the same time.

38. Splendid: state or situation created from joy and loveliness.

39. Proud: condition created from state of superiority in loveliness and enjoyableness.

40. Kind: situation arising from reassurance and enjoyableness.

41. Reprehensible: created from sad and afraid, a hateful state where resentment and shamefulness coexist

42. Regrettable: an unforgivable situation where elements of reprehension take effect in a state of unachieved desire, an intension feeling that easily links to jealousy

43. Detestable: mental state where the heart aches from an unforgivable situation

44. Unbearable: mental state where the heart aches, a harsh situation

45. Horrendous (horrible): where harsh conditions continue, and horribleness is felt

46. Perplexity: where state of confusion does not improve

47. Righteousness: a proud situation of good things that often parallels benevolence.

48. Superiority: a self-awareness of supremacy that occurs in a proud situation, can also trigger feelings of pride.

49. Beautifulness: a feeling towards nice objects or enjoyable, lovely conditions or states to be proud of

50. Sustenance: a feeling that tries to maintain the pride or warmth in an enjoyable situation, can have other drives depending on the person.

51. Boredom: a feeling that arises under an extended, enjoyable and warm state in a stable situation of ease of mind, there are also instances where negative stimulation (thrill) are sought for. Also similar to aristocratic leisure, because it occurs in absolutely safe conditions, most of the time a full-fledged situational reversal is not desired.

52. Elegance: a feeling that is of the same nature to boredom and parallels it.

53. Dependence: thought is paralyzed, a state where all is given up in an attempt to get absolute safety. It is a mental state centered on dependence on others' kindness, one's own wishes are stable and being satisfied, thinking is slow, and where safety is confirmed and trusted, dependence and respect intensifies.

54. Threat: state where safety is being threatened

55. Shame: a guilty state that takes place when something wrong, indecisive, or guilty is done, but it arises from panic and agitation. It can easily reverse to attack. In masses, it also links to combat, and has a strong influence.

56. Regret: a sentiment that occurs in regrettable situations, when one's own ability is not sufficient, or when one causes a reprehensible situation.

57. Inferiority: a sentiment that arises from a reprehensible state when one is aware of his or her own inexperience or failures.

58. Self-will: a state that occurs from a mental state of regret towards a reprehensible condition.

59. Self-respect: in a regrettable situation, there is a tendency to flaunt oneself to protect one's reputation, also connected to extroversion; however, it is easily linked to hatred and the harming of others. It is a rather immature and simple but powerful feeling. It also arises from pride and narcissism.

60. Rejection: s condition of complete denial under an unforgivable or regrettable situation

61. Jealousy: in a regrettable situation, where hateful feelings are not so strong, it reflects the state of intense regret resulting from non-acquisition or non-achievement, creating great frustration. It has a big influence on complexes and love and hate, and is created when there is a remarkable distance between reality and wishes; it has a strong influence on behavioral judgment. Jealousy induces disgust towards others. Of the same nature as adoration, it has a strong element of obsession, and like hatred it can easily cross-phase. Because it is a feeling not found in early in infants, it is considered to be a result of the victory of the ego in a rivalry between the ego and the superego.

62. Animosity: a feeling of strongest hate, it comes with attack, influences anger, and is prone to act. Although it is directly linked to desire, because it is not observed in infants, it is gained through knowledge and sociality. Hence, it is as strong as an emotion, but assumed to be influenced by knowledge and the ego. It brings forth a negative intention, wish or judgment towards the other person, and with doubt or indication it can lead to confrontation (attack). Also, it can easily be linked and integrated with jealousy, creating an inversed love-hate feeling.

63. Hostility: a mental state of opposition in a hateful situation, centered on hatred. It arises when one's point of view or wishes are rejected, when being controlled, and under circumstances of attack, also intensifying fixation and the intent to harm others.

64. Ugliness: another form of expressing disgust arising from affliction and hate.

65. Exclusion: excluding behavior coming from an unbearable situation or disgust and hate, it is a feeling originating from affliction and anger, strongly influenced by disgust, and intensifies when the situation, environment, or intention are turned away from oneself.

66. Avoidance: an act of escape in an unbearable situation that cannot be removed

67. Servile: giving in to pressure in an unbearable situation, occurring from its link to shame, induced when stimulation is nonexistent and the situation is stable and the mind at ease, a feeling that is accompanied by interest to seek change.

68. Fear: a state that arises under a scary situation that is unbearable

69. Bewilderment: a panic state in an extreme situation:

70. Euphoria: a situation where situations of extreme happiness continue to occur

71. Envious: a state where envy is fixated and conscious to the self

72. Thankfulness: a mental state that arises from realization of self-benefit in a situation of envy

73. Shyness: a mental state where, in a wonderful or envious situation, reward or evaluation of one's own hard work is great.

74. Respect: one of the mental states towards circumstances of happiness, loveliness and wonderfulness, parallels shyness, it is similar to piety or respect arising from altruism. In part where it is held back internally, it is influenced by introversion.

75. Kindliness: a lenient mental state or behavior towards another person, arising from loving or wonderful situation easiness

76. Benevolence: an affectionate mental state or behavior towards another person, arising from loving or wonderful situation

77. Sacrifice: an extreme act of altruism arising from righteousness and benevolence, centered on respect and justice. Mental state that operates when self-sacrifice can bring smooth overall progress and eliminate elements of obstacles, intensifying self-harm.

78. Acclaim: a comparative result from righteousness and superiority.

79. Conceit: mental state that arises from superiority and beautifulness, centering on superiority, rational assessment of the situation cannot be made, when all of one's own assertions are fulfilled or results are as desired, under the circumstances that negative feeling elements are not created, dominance and independence strengthens.

80. Demand: mental state that pursues things such as beauty or the continuation of peace, although the object of pursuit varies greatly from person to person, it is connected to beauty and preservation.

81. Communal: the establishment of group rules in the pursuit of preservation or continuation, a mental state of respect, but does not reach the state of demand due to tedium. It is centered on responsibility, strongly induced when inconsistencies with personal morale are verified, also intensifying justice and cooperation.

82. Sloth: centered on boredom, also triggered in some instances of elegance.

83. Dejection: situation that arises from elegance or boredom at the origin of dependence, a sense of entrapment that comes from the structure of dependence, not to the point of depression.

84. Panic: a state of paranoid schizophrenia that occurs when the situation of confusion cannot be pulled together by oneself.

85. Repent (guilt): a state of negative self reflection arising from shame and regret, a sense of redemption arising through reflection. Although it relates to subordination and self-harm, it has the tendency to jump to attack in justice due to self-preservation and justification. It also tends to constantly link to justice.

86. Gloomy: a mental state of negative premonition arising from regret and inferiority, denying the present condition, the non-existence of morale, and a feeling of growing irritation over an extended period when collapse is being predicted.

87. Self-reproach: a warning for self-improvement arising from inferiority, in a state of continuation due to self-will, when the reason of frustration is one's own responsibility, it arises from instances of reflection and determination.

88. Obstinacy: centered on self-will, a state where strong ego is formed due to self-respect.

89. Rejection: centered on self-respect, excluding behavior or intention when feelings towards the other person are lost.

90. Unfeeling: centered on intolerance, a state of looking down on the other person due to jealousy or unfeeling.

91. Punishment: a direct act of warning due to jealousy or hatred

92. Attack: a direct act of rejection due to hatred or antagonism

93. Narrow-hearted: a mental state of self-preservation and self-justification arising from antagonism and ugly mind.

94. Fright: a mental state of self-rejection from ugliness, a mental state of exclusion and inferiority.

95. Clandestine: a mental state of concealment to avoid reality when exclusion is not possible

96. Sophistry: excuses in situations of servility when reality cannot be avoided

97. Escape: a servile situation towards fear, directly connected to behavioral factors of survival in crisis prevention and anxiety, a defensive state under extreme danger that can easily become acts of fear. In connection to avoidance of reality in a depressed state, it can also link to suicide.

98. Adoration: a condition where reasoning and judgment are paralyzed under intense intoxication and envy, through a new religion or love in brainwashing or sexual attraction, arising in a condition that is lacking intellectual and judgmental ability, it is also considered to have a strong influence on bodily reactions.

99. Expectation: a mental state that arises from envy and thankfulness, a condition that is desiring a happy state, it is an emotion existent from early childhood, and links to interest. As a strong emotion that creates want, it develops from surprise and joy, and also affects palpitation. It is also related to surprise, disappointment and loss.

100. Humility: centered on thankfulness, a condition of controlling one's own desires due to the effect of shyness.

101. Forgiving: centered on benevolence and kindliness, mental state or behavior arising from feeling something is wonderful in a relaxed condition

102. Mercy: mental state or behavior of higher altruism arising from respect and kindliness

103. Praise: mental state of evaluating something splendid, arising from respect and shyness

104. Abnormal behavior: condition or behavior arising from bodily reaction that cannot be controlled by reason

105. Depression: the final state of negation, stagnation and becoming depressed, becoming extreme pessimism and self-harm once surpassing this. Because anxiety arising from reason and knowledge has a large effect, it often happens in intellectual people. Losing willpower, in a state that perceives all conditions in the negative, it can eventually lead to a deadlock (suicide), but in complete decline of motivation suicide cannot be done.

106. Manic: a 'high' state of dispersed emotional change just before paranoid schizophrenia, and is accompanied by a sense of surge and elation. It is large affected by excitement, as an index for direct subjective evaluation, it is valid in physiological indication. Although fundamentally not influenced by constraints of intellect, it often occurs when having given responses to ideas or difficult problems.

107. Motivation: having the power of bipolar direction from the state of depression, also with the most direct relation to reproduction and survival, it links easily to excitement and is physical and positive energy of the instinct.

108. Admiration: a state of interest in the situation or environment

109. Assurance: faith coming from admiration

110. Responsibility: based on faith, a similar mental state to that of communal self-reproach, it is also regarded as a sense of duty or responsibility. It is centered on sympathy and conviction, synchronized with reason (morale), it is a state that arises from creation of beauty (aesthetics) or love, strengthening obligation. .

111. Confidence: having the power of bipolar direction from the state of depression, from verification of the resulting influence of the situation or environment, it is a stable mental state that becomes definite with the achievement of responsibility.

112. Decay: a state of thought suspension coming from the paralysis of dependence

113. Nihility: state of thought suspension coming from the paralysis of adoration, intoxication and derangement.

114. Interest: a mental state that arises from expectation and adoration of an object, usually towards someone on one's mind, it is a state of the mind that also triggers excitement and is close to emotion. It can happen under any circumstances, and has a strong influence on the whole. It is also one of the most important feelings, triggering obsession and want.

115. Curiosity: a condition where one's object of interest becomes dull and interest is lost, feeling inclination to something else, arising from recognizing novel things, strong impressions or excitement. It has a close connection to acquisition instinct, becoming a stubborn state under stagnation. It is also an instinct governing motivation. It brings forth scientists' pursuits and thirst for knowledge. In artists it brings forth the will to create. Centering on want, when influenced by positive feeling elements, ambition and motivation are strengthened.

116. Blessedness: situation where someone lovely and wonderful is obtained, and the wonderful condition continues for an extended period of time, a mental state when feeling continuity and the continuance pleasure such as stability and ease of mind. Felt when in delight, joy, rejoice, gratification, fun, and ease of mind.

117. Revolt (objection): a mental state of revolt when the objective is not achieved, behavior of regret and non-forgiveness, strongly induced when one's assertion is not permitted, and attack intensifies. Also, rebellion occurs from instances of being dominated, or long periods of stagnation, further intensifying attack.

118. Conflict: a direct act of attack in hateful, unforgivable instances

119. Comfort: situation of lovingness and fun, where both mind and body are magnificently stable, and fitting to society and the environment

120. Obsession: a trigger of depression that affects both mind and body, in a state where interest is fixed, it is similar to a type of jealousy in a state of wanting and fixation. It is an extremely strong phenomenon occurring through stagnation, and is close to depression. Although it may appear in most phenomena, it usually occurs in a state of fixation over unachieved and pending realities, and has an influence on the spirit of inquiry. Obsession has a close connection to want. It is a feeling close to a strong emotion, creating knowledge and want.

121. Rigidity: a state of obstinacy and self-reproach

122. Worry: a mental state of gloom where predictions of the future are not good

123. Desolate (helpless): sentiment caused in a continuance of weak anxiety

124. Suffocating (entrapment): a unhappy state of elevated depression, a feeling of being in a state unable to move one's body

125. Lonely (alone): predicting isolation that is linked to sadness, a temporary sense of loneliness

126. Irritated (unbearable + disgust + unpleasure): an irritation when not achieving the objective

127. Creepy (anxiety + disgust + unpleasure) a feeling of insecure premonition or physiological disgust

128. Eerie (anxiety + fear): a feeling when verifying or predicting a condition that is different from the usual

129. Frustrating (a state of frustration): a long reaction of light irritation when the objective is not fulfilled

130. Uncertainty (confusion): a wonderment towards the feeling of being unable to know oneself

131. Humbling (servile): a prolonged sense that arises from inferiority and self-depreciation

132. Hesitation (confusion): exposed when attempting to restrain radical behavior, related to embarrassment and shyness

133. Embarrassed (shame): another name for shame, becomes shame in strong levels, but usually of the same type as shyness

134. Annoying (unpleasure): under subtle gloom, a thought towards state of anxiety and frustration

135. Isolation: although a result of exclusion, it is a condition related to survival element in separation from the mother at young age. To avoid isolation, one becomes gregarious and cooperative. When combined with despair, it triggers self-harm and impulses of suicide.

136. Serious: a state resulting from rigidity, often leads to depression when one becomes too serious.

137. Bright: a sense of refreshment resulting from pleasure, it has a sense of openness resulting from happiness

138. Showy: sense of appreciation for beautiful things based on style, coming with public acknowledgment comfort is felt

139. Sincerity: mental state and behavior coming from self-respect and justice, linked to confidence

140. Enthusiasm: energy arising from one's own desire and ambition, it is an increase of motivation

141. Justice: a proactive feeling that results from righteousness, conceit, and demand through self-love and achievement, it is accompanied by aggression, following, and dominance. It can easily convert to other active feelings, instantly leading to the harming of others due to shame. It can also be said that in those that such restraint is ineffective, the ego is strong. Therefore, the sense of justice can easily become obsolete in those other than the subject, easily treated as hypocritical. As a result, taking it as shame (e.g. negation of control), it becomes acts of attack. Although it is a feeling arising from intelligence, in academic conferences, debates, and professionals that engage in adequately rational activities (control of superego), it is accompanied by immature behavior (attacks of faulty control of emotions). In the history of mankind, it is the feeling concept most used in war and principles of dispute (trial), also having a strong implication of monotheist religion. In the contradiction that the absolution judgment of good and evil cannot be done by anyone, assuming another person as evil based on one's own righteousness, the notion of asserting one's own properness can also be regarded as the inability of rational control (rational conversion) under the influence of desire. Hence, it is easily synchronized with the tendencies to pursue good and evil in values beyond human understanding such as religion.

142. Elation: a type of enthusiasm arising from justice and demand, increasing pleasantness

143. Nobleness: arrogance is recognized by the public, a state where comfort level rises

144. Arrogance: a state arising from self-love that is dominated by vanity and centered on self-esteem, boast and desire intensify.

145. Gentleness: mental state arising from mercy and forgiving

146. Nurturing: desire arising from social behaviors of gregariousness and altruism

147. Altruism: a general, mind condition arising from broad love relations such as adoration and envy, linked to respect

148. Cooperation: a mental state arising from humility and praise that tries to bring harmony with the other person

149. Justification: an assertion of self-preservation that arises from fright and narrow-heartedness

150. Impudence: an assertion of justifiability that links with pretense and conflict

151. Contempt: an expression of disdain that arises from narrow-heartedness and attack

152. Barbarity: a determined state of conflict arising from contempt

153. Compulsion: a state of strong rejection where a trick is being plotted

154. Destruction (extermination): an act of destroying the other person unfeelingly under absolutely unforgivable circumstances

155. Self-love: a stubborn, self-affirmative state where all but oneself is disregarded

156. Dominance (self-love + justice + conceit): a final act arising from self-love and accompanied by superiority, self-respect and justice. In mass it brings attack or war.

157. Gregariousness: a wish of gathering or social desire, arising from the attempt to obtain (or maintain) ease of mind, or arising from love, nurturing, altruism, mercy, and cultivation. The family is one such archetype.

158. Surprise: because it happens under all kinds of circumstances, there is no particular connection with other feelings. However, the state of surprise is a basic, direct reflexive response that is linked with excitement. It is invoked under some change of the mind. There is also the possibility of other feelings being determined by the surrounding environment due to the recognition of surprise. Although it does not take place with any particular patterns due to its occurrence under any sudden change in feelings as a whole, it occurs in infants when sensing a gap between expectations and reality.

159. Openness: although it occurs in any situation, this refers to the state of self-emancipation under frustration. It can occur both consciously and psychologically. It is verified just before the state of trance or mania, similar to comprehension, as self-emancipation from extreme stress or frustration (learning). It has a close connection to excitement.

160. Empathy: a feeling created at first arising from ease of mind, also connected to friendship. Although it can easily develop into righteousness, in most cases it opposes social relations. It is also similar to partiality.

161. Self-depreciation (servile): like servility, it is a mental state of losing self-confidence from continued negation and rejection, and although being opposite in position to boast, like boast it occurs in resistance to fear of something. When the impact of this element is strong, it is easy to be inclined towards making mechanical responses and judgments. All feelings are suspended, creating stagnation. In other words, on a lighter level it brings subordination, but when such negation has gone too far it becomes obsession, inferiority and depression. Beyond that it splits in two directions, going towards attack on its opposite side, or leading to trauma in a state of complex. When the cause of self-depreciation is the escape from anxiety or fear, a reversed state of self-reliance and control arises once one becomes aware that such causes have been resolved. However, when those results are not shown strong feelings of guilt arise. It is a feeling for the purpose of self-escape.

162. Disappointment (discouragement): expectations end up in failure, centered on stagnation, occurring in instances of openness from frustration or when results are not as desired, it is a feeling without the occurrence of negative feeling elements.

163. Nervousness (frustration): regarded by Wundt as an important emotion of the divergence of feelings. Surely, nervousness is a trigger of stress and frustration. Yet, when the solidification of feelings is regarded as a bodily reaction for the purpose of escaping life-threatening crises, it no longer remains a feeling. Nervousness occurs in all types of feelings, especially in instances of great fear and disgust, or extended periods of frustration. However, when linked to hostility, it leads to attack or punishment.

164. Acquisition (a result of motivation): it is invoked when results or material objects desired instinctively cannot be attained, or when one wants to reproduce the instances of strong impression or excitement. It can also be referred to as the collector's instinct, a strong desire. It also governs motivation. In scientists it creates the thirst for knowledge, curiosity, and behaviors of data collection. In artists it creates the will to create. In a state where the desires of longing and aspiration are fulfilled, it becomes complete state of pleasure, relating to satisfaction.

165. Agitation (perplexity): arising from anxiety, it is an emotion that works powerfully in a situation that has no hope of resolution. This is a response that occurs in the stage preceding perplexity. One becomes confused in the consideration of crisis avoidance, coagulating (a state of suspension), or falling into a state of paranoid schizophrenia. It also appears easily in physiological indicators, and can be found in divisive phenomena as the state of panic. Although it does not occur intentionally, it can be acted out. Because it is expressed in all types of feelings, it cannot be specified.

166. Creation (motivation): although whether it is a feeling is unknown, accompanied by impulse, and not being related to logic, it has a strong element of emotion. While it has a strong mutual influence on curiosity, it is at the source of impulse for the desire of new results. When in the invoked state a creative personality is created, but it easily decays the ego and superego. Because it is an element of creating something new, it has a tendency to seek out states of dissatisfaction and indecision towards the interior and exterior. For that reason, it has an inherent element of the negation of the status quo, and considerably lacks the overall balance in feelings. At a point of stagnation it invokes the overthrow of the status quo, but easily cross-phases into obsession. Hence, it results in the maintenance of the status quo until results are given.

167. Boast (arrogance + conceit): a strong feeling in the direction of dominance, highly unidirectional, it is behavior in the state of confidence, justice, nobleness and arrogance. It continues until one becomes satisfied by the respect from others. When satisfaction from information or results is not achieved, the self-contradiction becomes unbearable, and there are the tendencies towards self-harm and harm of others. Control needs the stimulation of praise and affirmation from others, but linked with reproductive instincts, it has a complicated nature. In some instances it occurs as a revolt of anxiety towards something.

168. Reception (like): opposite state of refusal and negation, becomes toleration in an intense state. Since it is a general state, it does not appear under specific conditions, but it is connects easily to like.

169. Negation (dislike): behaviors or conditions of disgust; opposite state of reception, becomes refusal in an intense state. It is created by the revolt and disgust arising from ego (danger, unpleasure, opposition, physiological disgust, etc.). Since it is a general state, it does not appear under specific conditions.

170. Remorse (regret): another name for regret and repentance, a feeling that links strongly to redemption and shame when recognizing one's own contradictions or mistakes; also leading to self-depreciation when intense. Assumed to be under the influence of the ego and superego.

171. Disdain (contempt + self-respect): a feeling linked to boast that is created when feeling elbowroom towards the other person under a safe situation, a slight degree of contempt. Is easily led to presentations of contempt and haughtiness. .

172. Impatience (unbearable + perplexity): although it occurs in all kinds of situations, responses from the survival factors of crisis avoidance, anxiety elements, and indecision and tedium strongly stimulate behavior. In some instances, behaviors generate aggression for no apparent reason, tying to conflict.

173. Attachment (love + obsession): state of adoration. Links to persistence.

174. Lethargy (nihility): occurs easily when achieving, giving up, or losing a purpose. A state close to nihility. A state of desire depletion. Also a temporary state of suspension. It also occurs when exceeding the critical state of irresolution of a wish or problem. At the same time it is similar to an afterimage of achievement following extreme training, sports, or learning. Absentmindedness is a similar state.

175. Loss (unpleasure): a trigger of the sad and reprehensible regions, a sentiment felt in extreme fatigue, in the loss of possessions of material objects or status, in the loss of belongingness from family or a lover, and in failure.

176. Palpitation (perplexity): a mental state that occurs in front of the opposite sex and persons of envy, expressed strongly in heart rate and pupils. Commonly expressed as heart "thumping."

177. Puzzled (perplexity): feeling arising from a contradicting situation, a state that occurs in all types of feelings.

178. Consolation (empathy): a diplomatic act of compassion, easily occurs when one is in a safe condition

179. Disappointing (regret): a state of low regret

180. Renunciation (avoidance): a state of giving up the resolution for a problem

181. Toleration (benevolence): a great, inclusive feeling of acceptance, arising from reception. Linked with philanthropy and altruism.

182. Sentimental (bitterness): in an intoxicated state of sadness.

183. Sense of accomplishment (motivation + satisfaction): a sentiment of satisfaction, in opposition are non-attainment and dissatisfaction.

184. Desire to belong (gregarious + dependence): a feeling of identification related to gregariousness, has a close connection with dependence. It is a desire of the mind to gain one's own evaluation from the group that one belongs to; it also connects to the pretense of portraying a larger self.

185. Pretense (narrow-heartedness): a state close to boast, accompanied by intimidation, it can be verified through phenomena such as "loud laughter." The "roar" of intimidation found in animals can be found in some instances as a rational response in the communal life of humans as "laughter."

186. Intimidation (attack): a state of confronting danger, or in instances of pretense and boast, often appears in occasions of educational behavior. An act of revolt.

187. Projection (empathy): a state of agreement to gain identification with the other person, also linked to sympathy. Mental activity for self-persuasion. Equivalent to the projection of subjectivity referred to in psychology, the act of switching places with the other person.

188. Guidance (nurturing): an extremely strong desire of upbringing in paternal cases, although similar to a feeling of instruction arising from pride and sense of self-display, this feeling emerges when there is no survival element or love. It also triggers boast.

189. Sickening (unpleasure): synonymous with bad feelings, arising from physiological disgust, a feeling of disharmony. Has the instinctive pressure of rejecting all.

190. Self-love (love): shows a self-centered state of love towards the self. Changes largely under the influence of boast.

191. Triumph (conceit): feeling arising from ease of mind and achievement, to feel proud.

192. Guilty (envy + reprehensible): is reprehension under the triggers of shame, regret, and inferiority, and becomes envy when triggered by want and joy. The mental state that occurs in the advantageous state of having surpassed one's own expectations when faced with one's present conditions, what should be done, and those results. Has a contrasting nature to boast. Also related to shame.

193. Obedience (fear + subordination): although indicating the state of keeping up with a strong presence, or obeying in fear of attack, this is the subject's response to a concern. In other words, this is also the final resort in a situation without hope of resolution, it differs from the subject's response of true nature.

194. Subordination (dependence): a state of pursuing further unification beyond obedience. A state of giving up self-judgment, giving new standards of value to the superego, it is a method at attempted self-control. It has a secondary purpose; can also occur in other situations.

195. Following (dependence): behavior of projection related to unification with the other person, arising from empathy and envy.

196. Vigilance (anxiety + gloomy): a combined feeling related to nervousness and doubt, triggered by anxiety.

197. Sympathy (empathy + sad): formed for the first time for another person, a sentiment controlled by empathy similar to that of dependence, can easily lead to unification with the other person, creating gregarious and sacrificial behavior.

198. Self-important (confidence + arrogance + superiority): an expression of a lower dimension of superiority, has a childish aspect.

199. Trust (adoration + confidence): a mental state arising for the first time from toleration. Can occur both towards oneself and someone else.

200. Independence (exclusion + self-respect): an aspiration of self-reliance that is created both introversive and extroversive.

201. Duty (responsibility): representation of responsibility primarily influenced by belonging and subordination.

202. Collection (interest + obsession): behaviors associated with obsession, such as collection, that satisfy desires arising from non-attainment and non-possession. Beyond this selfishness intensifies, becoming materialistic desire, and creates even more irritation of non-attainment and non-possession.

203. Ecstasy (euphoria): state of euphoria

204. Courage (justice + elation): act of representation arising from pride and righteousness. What is not shown in behavior cannot be referred to as courage.

205. Defense (flight + attack + conflict + revolt): immediately influenced by irritation and sense of danger, it is a direct response under dangerous situations and in life maintenance. A type of offensive sentiment created through feelings arising from anxiety - disgust, fear, vigilance and doubt. Also the opposite of sacrifice, and easily converts.

206. Harming others (attack, revolt, conflict): behavior arising from anxiety and avoidance of danger, it is a strong intention from fear, shame and disgust, and has an important orientation as the driving force of conversation. Although it is a direct response in dangerous, life-threatening situations, it has a large personality difference with defense.

207. Self-harm (depression behavior): an act of avoidance arising from despair, isolation, agony, and shame, can become intense masochistic behavior. Because animals and infants do not commit suicide, disorder is caused when there is strong influence to shame and superego from intelligence. Beyond this it will become self-destruction or stagnation (complete D condensation), and can be a life-threatening crisis becoming the final stage.

208. Aspiration (motivation): centered on motivation, a state with the power to influence all positive feelings. It is perceived as the direct portrayal of desire, the driving force of thought and reasoning.

209. Suspicion (lost + unforgivable): centered on doubt, when there are discrepancies with one's own opinion or when the other person's deception is exposed, a state created when the emotional synchronization with the other person is in discord, intensifying disgust.

210. Ill-tempered (love + animosity + self-will): centered on love and animosity, when dissatisfied, trying to get someone's attention, under the verification of safety, it is a state arising from slight animosity, intensifying self-respect, harming others, and dominance.

211. Chivalrous spirit (empathy + justice): centered on respect and justice, a mental state that arises from one's own interpretation that danger and courage is needed along self-sacrifice in a cooperative relationship, intensifying attack and harming others.

212. Spirit of inquiry (curious + motivation): centered on obsession, a mental state that arises when one's own interest or curiosity are being stimulated, intensifying advancement and collection, it becomes the driving force of problem pursuing thought until one is satisfied.

213. Competitive spirit (motivation): centered on desire, a mental state that arises when the existence of a rival is confirmed, achievement, harming others, and dominance intensify.

214. Ambition (conceit + arrogance + dominance): centered on self-respect, a mental state that occurs when seeking the elevation of one's own position, it is a result of the influence of desire being reflected in sociality.

215. Self-confidence (responsibility): centered on the sense of responsibility, a mental state arising from situations accompanied by responsibility.

216. Speculation (expectation): centered on trust and want, a mental state arising when pursuing individual property through outside help, intensifying dependence and expectations.

217. Immediate presence (type of amazing): state arising when wanting to feel stimulation, also accompanied by surprise, excitement is intensified.

218. Feeling out of place (unpleasure + expulsion): centered on unpleasure, preceding physiological disgust, it is the state arising from the expulsive feeling when visuals or traces of information do not match, intensifying disgust.

219. Expulsion (physical exclusion): when the feeling of trying to expel a strange object or excretion affects the pleasure center of the mind and emotions.

220. Sense of danger (anxiety + hostility): arising from anxiety and hostility, centered on nervousness, when there is no hope of solution, at odds with morale, it is a state arising from the prediction of damage to the self, intensifying defense and attack.

221. Affinity (type of empathy): centered on altruism and empathy, in accord with morale, it is a state arising when the situation and environment are proximate, intensifying belonging, dependence, trust, and respect.

222. Sense of damage (inferiority + self-depreciation): centered on inferiority, self-depreciation, and sentimentality, it is a state that arises when sensing attack, rebellion, disaffection, intensifying attack and the desire to be cooperative.

223. Acute feeling (agony coming from the situation/environment): centered on remorse and sentimentality, a state where no negative feeling elements have arisen under having a strong impression or having learnt remorse, and want is intensified. Mainly affects memory.

From the above list, based on results of previous research, the relationship among feelings, the brain, and physiology is brought to light, organized, and since it is necessary to create a visualization of the collective relationships, Appendix C.2 (p.135) Figure C.2shows its visualization.

A.4 Other Research on Problems of Cognition

In regards to the cognitive problem of feelings, the controversy between Zajonc [159] [160][161]and Lazarus [162][163] [164]in the early 1980s is famous. Lazarus states that, “certain types of cognitive activity precede the initiation of emotions as necessary and sufficient conditions,” while Zajonc counters that, “cognition and emotions are independent systems, although being sufficient conditions they are not necessary conditions.” However, a conclusion has not been reached.

Appendix B

Reference Material (Physiological)

B.1 Research on Feelings and Secretory Substances

Genes have an influence on brain activity. In fact, there is a close connection between the secretion rate of chemical substances that affect brain activity and genes as well. Here, to find the relationship between feelings and the substances secreted by organisms, while taking James-Lange theory into consideration, I use studies of genes, chemical substances in the brain, and the mind [7][8], and studies of emotions and hormones [9], to speculate the mechanism of feelings from a different perspective than that of psychological research. However, the functions of secretory substances as physiological indicators, for the most part remain uncertain, and their connections with the mind and feelings are complex due to subtle environmental, time, and circulatory influences. For this purpose, since there is a lack in direct evidence, I refer to all facts that have come up in my research below.

1. Substances related to feelings

   5-hydroxyindoleacetic acid

2. Substances related to ambition

   Serotonin/dopamine

3. Substances related to violence

   Adrenaline/male hormones

4. Substances related to unrest

   (a) Chemical substances that have an influence on unrest

   Influencing unrest (including for both healthy persons and patients with panic disorder)

      i. Noradrenalin
      ii. CRH (pituitary glands)
      iii. Serotonin
      iv. GABA (gamma-aminobutyric acid)
      v. Cholecystokinin (hormone)
      vi. Benzodiazepine

   (b) Chemical substances that have an influence on panic disorder

i. Carbon dioxide
ii. Lactic acid
iii. Caffeine
iv. Female hormones

The following describes physiological research on emotions and feelings in detail and their mechanisms.

Adrenaline/male hormones

1. 1. Violent people are said to have more adrenaline (hormone) and male hormones.

Dopamine (DA)

1. In moderate quantities it is related to ambition, in excessive quantities it leads to paranoia and symptoms of hallucination. When it is in shortage it leads to Parkinson's disease.

2. In Parkinson's disease, patients lose ambition, and tremble when touching objects. When given dopamine, the trembling ceases.

3. Dopamine is made from a substance called L-DOPA

4. Dopamine is located in the substantia nigra and the striatum. The substantia nigra is linked to exercise; the striatum is linked with ambition.

5. Reward prediction experiment on mice: mice are stimulated with electrodes. Following the stimulation the mice are given food. When such rewards are being predicted, dopamine is secreted.

6. The locus ceruleus is located next to the substantia nigra.

Stimulants such as amphetamine are known to increase the effect (excitement) of dopamine.

Vasopressin (VP) In experiments with animals, vasopressin increases when gaining the dominant position in conflicts. Under stress, vasopressin is secreted alongside CRH. It is the ACTH released reinforcement of CRH. It also affects fear, as well as daily rhythm and homeostasis.

Opioid peptide An endogenous opioid (pain-relieving substance) of the brain, it is often found in the hypothalamus and locus ceruleus. From reactions of increasing or subsiding pain threshold, an euphoric mood similar to that of morphine affects the amygdala. It is also the source of adaptation to difficult situations, and transfers harsh situations to pleasure; an example of this is "runner's high," which is a feeling of happiness occurring from strenuous exercise.

Enkephalin (enk) Enkephalin is an opioid peptide, consisting of the Met-enk and Leu-enk forms. It is located in the dorsal grey matter of the spinal cord. It has the effect of pain-relief. Also found in the catecholamine neuron.

CRH (pituitary gland) A main transmission pathway of ACTH secretion for the hypothalamus, CRH is a stress substance composed of 41 amino acids, and relates to the CRH-ACTH (pituitary gland) - cortisol (adrenal cortex). In response to a stressor, this peptide is secreted as a ACTH secretion hormone, which reacts in the brain, and induces feelings of unrest. Under this influence, composure is lost, and breathing and heart rate increase. The effect of this substance on emotions is confirmed with the prescription of CRH anti-substances.

ACTH (pituitary gland, brain) It is an adrenocortical-stimulating hormone and POMC peptide. From animal experiments, responding to a stressor, it is shown to take part in feeding, sexual behavior, attack, defense, stereotypical actions, learning and memory, pain sensitivity, body temperature adjustment and neuroendocrine adjustment.

Noradrenalin (NA)

1. It is a neurotransmitter of excitement, coming from the locus ceruleus - nucleus creating autonomic seizure that is located in the bridge of the brain stem, which is composed of the interbrain (thalamus, hypothalamus), midbrain, and medulla oblongata. .

2. The locus ceruleus is at the center of unrest/fear. This is proven in three animal experiments.

    (a) When applying electric stimulus to the locus ceruleus of monkeys, unrest and fear is detected, and autonomic nervous symptoms similar to that of human panic are provoked.
    (b) Firstly, cats are put where they can move freely. When threatened by dogs or loud noises, the nerve cells in the locus ceruleus are stimulated and electrical activity is detected.
    (c) When the locus ceruleus of cats are damaged, the same experiment (B) does not demonstrate comparable reactions of unrest and fear.

3. There a receptor for receiving and sensing noradrenalin (β receptor), and a receptor for detecting the release of noradrenalin, and controlling the amount of noradrenalin synthesis (α 2 receptor).

4. The intake of medicine (such as Yohimbine) with an effect on noradrenalin cells can lead to panic disorder (since Yohimbine inhibits the functioning of the α 2 receptor, an excessive response of noradrenalin nerve cells in the locus ceruleus is provoked).

Acetylcholine (Ach) A neuroendocrine substance noted for its relation to Alzheimer's disease. It is regarded to have an influence on depressive tendencies.

5-hydroxyindoleacetic acid

1. By measuring the level of 5-hydroxyindoleacetic acid in spinal fluid, it is possible to find whether the body is reacting to sadness or happiness.

2. 5-hydroxyindoleacetic acid is made when serotonin is broken down by the MAO enzyme.

Serotonin Serotonin preceding the 5-hydroxyindoleacetic acid is described below.

1. Originates in the raphe nucleus (located between midbrain and medulla oblongata).

2. The substance that enhances serotonin release stirs up unrest, while the substance that suppresses its release works as an anxiolytic.

3. Sends nerve fibers directly to the locus ceruleus, and suppresses the activity of noradrenalin.

4. Serotonin has more than 10 types of receptors, including ones that work positively and ones that work negatively.

5. Medication related to serotonin

   (a) Fenfluramine, an appetite suppressant drug, promotes the release of serotonin, and often induces panic attacks in patients with panic disorder.

   (b) Meta-chlorophenylpiperazine stimulates serotonergic receptors directly, causing severe panic attacks in patients with panic disorder, and inducing strong anxiety in healthy subjects. In patients with obsessive-compulsive disorder, obsessive-compulsive symptoms may worsen temporarily. Giving this to patients with generalized anxiety disorder may induce reactions of anger and increased anxiety.

   (c) Clomipramine is used for the treatment of obsessive-compulsive disorder and panic disorder. It prevents serotonin that is released into the synapse from being taken back in by the nerve terminal. When given in large quantities, conditions may worsen; therapeutic effect is achieved when given in small doses over an extended period of time.

   (d) SSRI are used as selective reuptake inhibitors of serotonin. Similar to the clomipramine, it only works on serotonin.

   (e) Buspirone is used as an anxiolytic. It reacts on receptors that control the release of serotonin, weakening the excitation of serotonergic neurons, and suppresses the release of serotonin.

1. Those depressed have low levels of 5-hydroxyindoleacetic acid and serotonin. When they are cured of depression, 5-hydroxyindoleacetic acid returns to the normal level.

2. When the level of serotonin is low, one becomes fearful of being harmed, pessimistic, shy, timid, and tired. Contrastingly, when the level of serotonin is high, one becomes calm and collected, optimistic, and energetic.

3. Psychopaths (criminals who do not feel guilt from killing) tend to have a low level of 5-hydroxyindoleacetic acid and a high level of serotonin. The activity level of MAO, which breaks down serotonin, is low.

4. In a state of unrest there is a poor flow of serotonin. By blocking the presynaptic receptor, the flow improves.

5. Anxiety is eased when stimulation is applied to the postsynapse (the medication Prozac).

GABA (Gamma-aminobutyric acid) In anxiety, when the same thought keeps coming to mind, the neural circuit is in a loop and neurotransmission does not stop.

1. Neurotransmission stops in reaction to chloride; GABA controls chloride.
2. The nerves that stop neurotransmission are called inhibitory nerves, and GABA is the substance that comes out from inhibitor nerves. When this substance reaches the GABA receptors, chloride is released. .

1. Inhibitory neurotransmitter located in the cerebral cortex, cerebellum, hippocampus, and brain stem.
2. There are two receptors, A and B. The GABA-A receptor has an influence on anxiety, it is also bound to benzodiazepine.
3. Chemical substances related to GABA
   (a) Benzodiazepine: when bound to anxiolytic benzodiazepine receptors, the bind of GABA and GABA-A receptors are activated, and as a result, chloride ions flow into cells and nerve cells react. This cellular reaction induces sedative, hypnotic, anxiolytic and anticonvulsant effects.
   (b) β-carboline: an anxiety-inducing substance that works through the benzodiazepine receptor that produces anxiety (an inverse agonist). Drug administration experiments are conducted on 5 male subjects at German pharmaceutical company Schering's research institute. It has been verified that benzodiazepine anxiolytics can suppress anxiety that has been aroused.
   (c) Flumazenil: medication for treating the side effects of benzodiazepine (dazed, drowsiness). No subjective symptoms are noted when given to healthy subjects, however, 80% of patients with panic disorder experience panic attacks with it. There are two possible mechanisms.
      i. Patients with panic disorder are born with benzodiazepine anxiolytic substances in their brain, and flumazenil inhibits this effect, causing an attack.
      ii. The benzodiazepine receptor sensitivity is altered in patients with panic disorder, and an attack occurs.

Benzodiazepine

1. Binds to the GABA receptors, and encourages the flow of chloride.

Cholecystokinin (CCK)

1. A hormone of the gastrointestinal system, it makes the gallbladder contract and causes the release of pancreatic juice from the pancreas.
2. It is found in the cerebral cortex, amygdaloid nucleus, hippocampus, substantia nigra (which produces dopamine), raphe nucleus (which produces serotonin), solitary nucleus of medulla oblongata (which produces noradrenalin), and the area postrema (which is related to sense of pain).
3. An experiment with cholecystokinin-4 (CCK-4 hereafter) is described below.

4. CCK-4 is given to 10 healthy subjects. Panic attacks occurred in 7 of the subjects and the remaining 3 experienced anxiety.

5. Benzodiazepine anxiolytics were able to suppress the anxiety.

6. Prolactin (hormone associated with lactation) in the blood and cortisol (adrenocortical hormone) increase (subjects are observed for 15 minutes after injection. The levels of lactic acid, glucose, and catecholamine remain normal). The nerve center that controls the secretion of prolactin and cortisol are located in the hypothalamus of the brain - the neurohypophysial system - and has a close connection with stress responses.

There are type A and type B receptors for cholecystokinin. Since pentagastrin, which induces panic attacks like the CCK-4, only reacts to the type B receptor, the B receptor is considered to have a connection to panic attacks. The A receptor is considered to suppress the functioning of the B receptor and to contribute to the relief of anxiety.

Type A: the digestive tract, solitary nucleus, the area postrema.

Type B: cerebral cortex, amygdaloid nucleus, hippocampus.

Carbon dioxideCO_2

1. Has an effect on panic disorder.

2. Anxiety and nervousness result from hyperventilating (overdoing repeated deep breathing). Panic attacks occur when patients with panic disorder hyperventilate.

The most likely mechanism is that in hyperventilation, oxygen level in the blood increases → blood becomes alkaline → alkaline blood contracts blood vessels in the brain → a variety of symptoms occur in brain tissues that have insufficient oxygen → brain cells that have insufficient oxygen rely on glycogen for energy supply, lactic acid increases → blood becomes alkaline, cells become acidic, the neurons of the respiratory center in the medulla oblongata are stimulated and lead to hyperventilation → resulting in a vicious cycle.

Lactic acid

1. Administering lactic acid to subjects with panic disorder will cause panic attacks.

2. There is no explication on its mechanism.

Caffeine

1. An overdose in caffeine will cause caffeine intoxication. Its characteristic is strong anxiety, in some cases there is no differentiation between caffeine intoxication and panic attack. It is established to also occur among healthy subjects.

2. Tolerance to caffeine's effect develops. Patients of panic disorder and anxiety disorder are particularly sensitive to caffeine; caffeine can also trigger panic attack.

Female hormones

1. Estrogen: has the effect of enhancing noradrenalin activity; can cause panic disorder.

2. Progesterone: it is said to have an anxiolytic effect, however, because it stimulates respiration, extended use will lower the concentration of carbon dioxide in the blood. As a result, the brain becomes more sensitive for carbon dioxide, and panic disorders related to carbon dioxide occur at a higher rate.

Figure B.1illustrates the relationships between various biological substances and anxiety. Anxiety indicates that certain neurotransmission in the brain has not ceased. Human feelings and emotions are related to the moving of substances in the brain.

Experiments of drug administration show that diazepam (a sedative) is effective when anxiety does not cease, this research the underlying principles of anxiety are clarified thoroughly. Clomipramine (a sedative) is effective (serotonergic receptor) for obsessive-compulsive disorder. SSRI (prozac) can be effective for self-injurious actions, and tic. Methylphenidate and amphetamine: effective for ADHD, attention-deficit hyperactivity disorder (acquired).

Dopamine, serotonin, and noradrenalin, the three monoamines make physical consideration of the human mood possible.

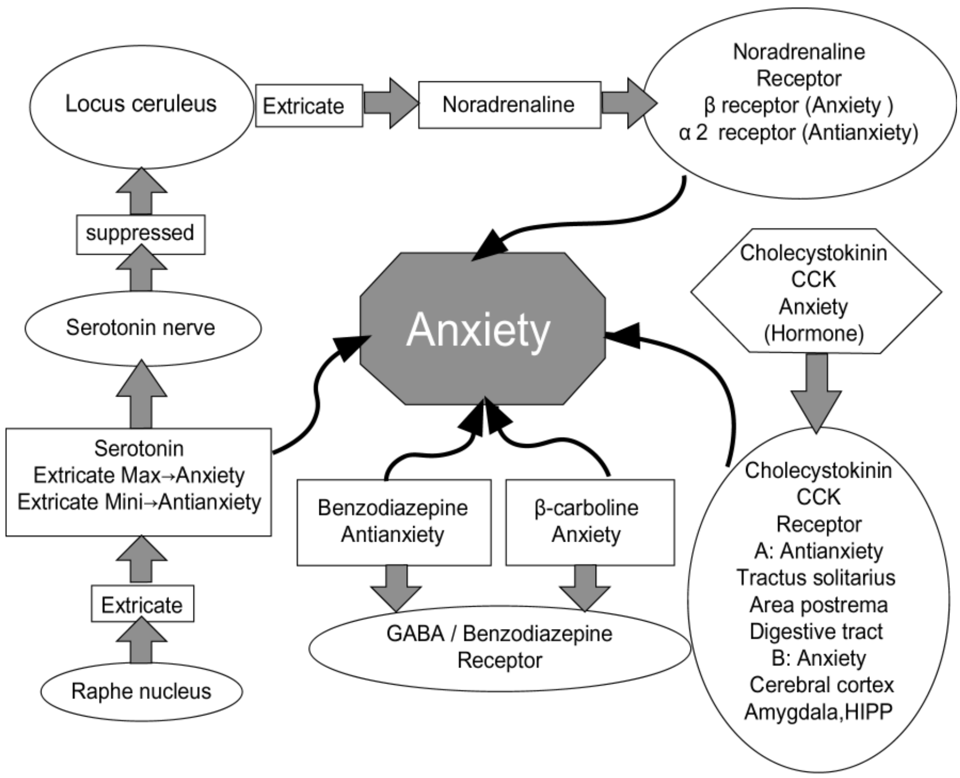

Figure B.1: The relationship among anxiety, chemical substances, hormones, receptors, and areas of the brain (Koichi Shibasaki, made from [7][8])

Table B.1shows the relationship between emotional physiology and biological substances (secretion) of human and animals.

表 B.1 The relational table of emotional physiology and biological substances (secretion) of humans and animals (made from [9][7][8].Referred to in Chapter C.1 (p.133) Figure C.1, Chapter C.2 (p.135) Figure C.2, Chapter 2.4.3 (p.17) Figure 2.4)

matter	excitement	stress	anxiety	disgust	agonism	fear	depression	pleasure-unpleasure	stability	euphoria	expectation	heart rate	pupil	sympathetic	sweat	body temperature	blood pressure	cycle	immune
CRH (pituitary glands)	arousal	○ ACTH ○	◎	-	◎	-	◎	-	-	-	○	◎	-	-	-	-	◎	biorhythms	-
Neuropeptide Y (NPY)	calm	○ CRH ◎	○ ×	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-
Cortisol	-	○	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vasopressin (VP)	-	○ homeostatic	-	-	◎	◎	-	-	-	-	-	-	-	active immune functions	-	-	◎	biorhythms	-
ACTH	-	○	-	-	◎ ×	-	-	-	-	-	-	-	-	-	-	×	-	-	-
Cholecystokinin (CCK-4)	front ◎	-	○ ◎ strong	-	-	○ ◎ strong	○	-	-	-	-	-	-	-	○	-	-	-	-
Cholecystokinin (CCK-8)	all ◎ front ×	-	-	-	-	-	-	-	○	-	-	-	-	-	-	-	-	-	-
Melatonin	calm	○ ×	-	×	◎?	-	-	happiness	○	-	-	×	-	forgetting repression	-	-	-	biorhythms season	active immune functions
Opioid peptide (endorphin)	-	-	NA ×	-	-	NA ×	-	pleasure	-	○	-	-	-	motion pleasure	-	-	-	-	NK-active immune functions
β-endorphin(β-End)	-	CRH ×	-	-	-	-	-	-	-	-	-	◎	-	-	-	-	◎	-	-
Acetylcholine (ACh)	-	CRH ◎	-	○	-	-	◎	-	-	-	-	-	-	-	-	-	-	-	-
Noradrenalin (NA)	◎	CRH ◎ △	◎	-	◎	◎	◎	-	-	-	-	◎	expansion	tension memory	-	-	-	-	-

matter	excitement	stress	anxiety	disgust	agonism	fear	depression	pleasure-unpleasure	stability	euphoria	expectation	heart rate	pupil	sympathetic	sweat	body temperature	blood pressure	cycle	immune
Adrenaline	-	CRH ◎ △	◎	-	◎	◎	-	-	-	-	-	◎	expansion	tension	-	-	-	-	-
Dopamine(DA)	◎	CRH ◎		-	◎?	-	low ◎	-	-	-	-	-	-	memory	-	-	-	-	-
Serotonin (5-HT)	-	CRH ◎	◎ ×	-	low ◎?	◎	◎	-	-	-	-	-	-	-	-	-	-	-	-
Angiotensin (Ang-)	-	CRH ◎	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Galanin	-	CRH ◎	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Somatostatin (SRIF)	-	CRH ×	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
α-MSH	-	CRH ×	-	-	-	-	-	-	-	-	-	-	-	-	-	×	-	-	-
GABA	-	CRH ×	NA ×	-	-	NA ×	-	-	-	-	-	-	-	-	-	-	-	-	-
Benzodiazepine (BZD)	-	×	◎	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diazepam	-	-	NA ×	-	-	NA ×	-	-	-	-	-	-	-	-	-	-	-	-	-
Ethanol	-	-	NA ×	-	-	NA ×	-	-	-	-	-	-	-	-	-	-	-	-	-
Enkephalin(enk)	-	-	-	-	-	-	-	-	-	○	-	-	-	-	-	-	-	-	-
β-carboline	-	-	○ ◎	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Isoprenaline	-	-	◎	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Yohimbine	-	-	◎	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fenfluramine	-	-	◎	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sodium lactate	-	-	◎	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO_2	-	-	◎ strong	-	-	◎ strong	-	-	-	-	-	-	-	-	-	-	-	-	-
Caffeine	arousal	-	◎	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Galanin	-	-	×?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxytocin	×	×	×?	-	-	-	-	-	-	-	-	-	-	-	-	-	-	maternal behavior	-
FMRF Amide	-	-	×	-	◎?	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Testosterone	-	-	×	-	◎ strong	-	-	-	-	-	-	-	-	-	-	-	-	-	-

matter	excitement	stress	anxiety	disgust	agonism	fear	depression	pleasure-unpleasure	stability	euphoria	expectation	heart rate	pupil	sympathetic	sweat	body temperature	blood pressure	cycle	immune
Androgen	-	-	×	-	◎	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Estrogen	-	-	×	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Progesterone	-	-	-	-	×	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Corticoid	-	-	-	-	-	-	○	-	-	-	-	-	-	-	-	-	-	-	-

○ shows synthesis/secretion, ○× shows secretion and suppression, ◎ shows acceleration, CRH ◎ is CRH synthesis/secretion acceleration, front ◎ is acceleration in the prefrontal cortex, all ◎ is acceleration in the entire brain, front × is suppression in the prefrontal cortex, low ◎ is decrease then acceleration, × is suppression, ○ homeostatic is maintaining homeostasis through secretion, CRH × is CRH synthesis/secretion suppression, ◎× is control, △ is adjustment, NK is natural killer cells, ? is reported information, - is not indicated in literature [9].
As seen in the Table, the many '-' signs show that many of the relations among the mind, feelings, and secretory substances remain unknown. The CCK system, 5-HT, GABA, and DA interact in complex ways and seem to act to emotions. Additionally, sex hormones seem to have a close relation with attack. These secretions and substances are controlled by cranial nerve activity, and the limbic system, emotions, and memory work together intimately [9].

B.1.1 Animal Experiments of the Brain and Attack-Defense

It is illegal to apply electric shock to a living person's brain for the purpose of analyzing emotions. The best way is to use results from animal experiments with chemical substances and electric shock as predictions, and to verify them against human brain images and hormones. Research is done on animal testing [9]. Table B.2 and Table B.3are relational tables for emotions and areas of the brains in animals.

Table B.2: Relational table for attack and regions of the brain, in animals （made from [9]）

Region	Agonism (turf)	Agonism (competitive)	Agonism (carnivorous)	Agonism (stimulative)	Agonism (fear)	Agonism (maternal)	Agonism (reproductive)
Amygdala （外部底部）	×	-	×	×	-	×	×
Amygdala （中央内側部）	-	-	-	-	○	-	○
Lateral hippocampus	○	-	-	-	-	-	-
Ventral hippocampus	-	-	-	-	-	○	○
Septal region	-	×	-	-	×	×	×
Central white and gray matter	-	○	-	-	-	-	-
Hypothalamus	-	-	-	-	-	○	○
Hypothalamus (dorsal)	-	-	-	-	×	-	-
Hypothalamus (dorsomedial)	-	-	-	○	-	-	-
Hypothalamus (posterior)	-	-	-	○	-	-	-
Hypothalamus (lateral)	-	-	○	-	-	-	-
Hypothalamus (ventromedial)	-	-	×	×	×	-	-
Hypothalamus (ventrolateral)	-	○	-	-	-	-	-
Caudate nucleus (cephalic)	-	×	-	-	-	-	-
Anterior cingulate gyrus	-	-	-	○	-	-	-
Posterior cingulate gyrus	-	-	-	×	-	-	×
Fornix (fimbria)	-	-	-	-	○	-	-

○ is induction and × is suppression

Table B.3: Relational table for 3 stages of defense and regions of the brain, in animals（made from [9]）

Region	Stage 1 Anxiety (crisis)	Stage 2 Fear (avoidance)	Stage 3 Outrage
Amygdala	○	-	-
Septal hippocampal system	○	○	-
Periaqueductal gray matter	-	○	○
Medial hypothalamus	-	○	-
Raphe nucleus	-	○	-

Appendix C

Reference Material: Hypothesis

C.1 Using the Hypothesis to Create a Dynamic Vector of Emotions

Functions of human secretion of hormones and other substances in the most part remain explained by science. However, there is much evidence leading to the link between hormone secretion and human emotions.

Using information found from major physiochemical substances and their corresponding reactions explained in Chapters 1.2.2 (p.4) , Chapters 1.2.3 (p.5) , Chapters 1.2.4 (p.5) ,and Appendix B.1 (p.121) a visual interpretation of a dynamic vector was created to demonstrate the relationship between physiological indicators and emotions. Nevertheless, as shown in Appendix Chapters B.1 (p.121) , due to the fact that uncertainties between physiological indicators and hormones remain, and that the influence of microenvironment, time, and cyclical relations come into play, the proposed model portrays dynamics from currently attained information.

Figure. C.1 illustrates the dynamic vector of relationships between physiological indicators and emotions, drawn from literature review.

The instinctive factors of survival and reproduction are placed in the center of the figure.

This structure is based on the primitive behavioral principles of living organisms. The study of physiology relates the origin of emotions to the instincts of self preservation and preservation of the species. The same is said in the study of neuroscience. According to Joseph LeDoux [165] ,in the evolution of the brain that brings about emotions and actions, all animals, including humans, are motivated by the basic needs of food and shelter for self-protection (survival) and breeding (reproduction). The nervous system and the conscious mind serve to perform those functions, and when in function, emotional feelings are created.

Therefore, the underlying principle of this study is that emotions originate from the desires to survive and reproduce. Pleasure-unpleasure are also taken to be effects of these desires. When brain reactions, biological substances and hormones, situation judgments take place under the needs of survival and reproduction, emotions are created. The corresponding fig of Appendix C.1 (p.133) portrays a series of radiating concentric circles. Going outwards from the innermost circle, this shows that humans as humans are influenced by factors of the cognitive external environment and situations, stimuli such as stress, uncertainty and happiness accumulate. The concentric circles consist of feelings, emotions, as well as mental conditions. The farther in you go of the circle, the closer you get to emotions; the colored section depicts all that are termed similar to emotions.

In the same publication, Joseph LeDoux says, “anybody feels love and hate, fear, anger and pleasure. What is the one thing that makes it possible to call them all emotions? In-

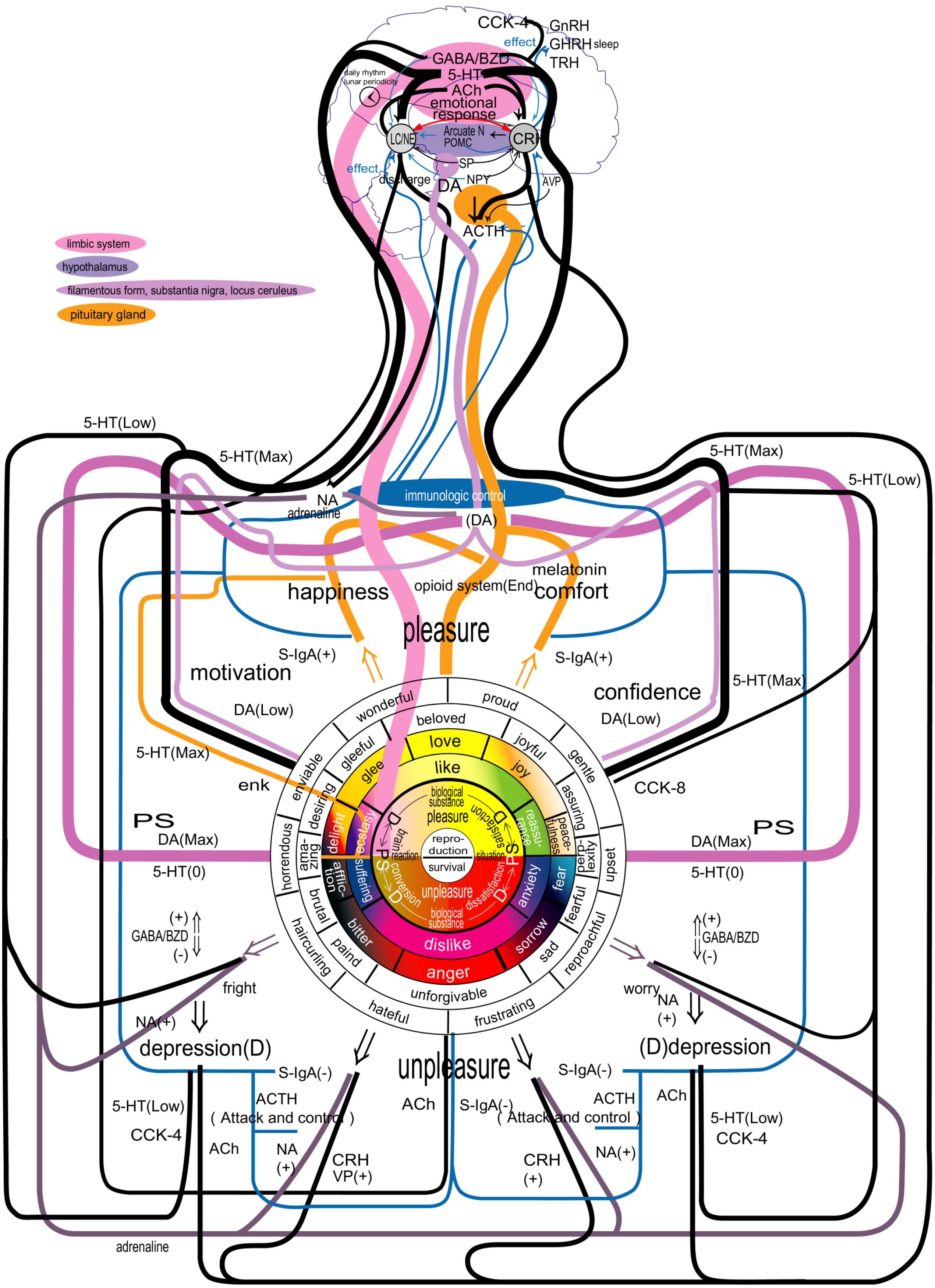

Figure C.1: The Hypothetical Dynamic Vector of the Brain, Secretory Substances, and Neurotransmitters stinct(subjectivity and feeling) is not the only thing." In other words, LeDoux attempted measure these emotions in a scientific approach, rather than instinct. I agree with LeDoux's opinion; this study utilizes physiological indicators other than human subjective claim, and is based on the analysis of brain, heart rate, and vocal chord activity data collected during conversational speech. However, even though I attempt to analyze emotions in ways other than instinct and subjective claim, I have to first determine the basis of emotions.

The figure in Appendix C.1 (p.133) is created from relationships between physiological responses, brain functions, hormones, and biological and chemical substances, to serve as a guide in the examination of all the different aspects of emotions. The center of the concentric circle consists of primal desires, while the left side of the circle is made up of feelings that are influenced by chemical substances in the brain, and take place in the brain. The right side of the figure consists of feelings that are situation-induced. Additionally, under certain circumstances the left and right side react simultaneously and the brain is at unrest. When this happens, opioid peptide comes into play and suffering can transform into pleasure Chapters B.1 (p.122) . In the figure of the concentric circle, the area near the center may rotate clockwise or counter-clockwise under the influence of hormones. Inside the colorless section are feelings generated from primitive desire; sentiments felt by the subject are on the inside, while adjectives describing resulting impressions are organized into two white lines on the outside.

C.2 Solving the Fundamental Problem of Emotions

Based on the hypothesis of the dynamic vector of emotion in Appendix C.1 (p.133) , I simulated a dynamic model. This model centered on Cannon-Bard's theory, and using comparisons between the model of emotions/physiology and human subjectivity, I was able to capture the phenomena of James-Lange's theory and the Two-Factor Theory, hereby conducting an analysis of the mechanisms of emotions. Using the dynamic vector, I then created an analytical system for (brain) physiological signs for emotions. The figure is explained as follows.

Figure C.2 shows the correspondence to the fundamental problem of emotions. The hypothesis of the dynamic vector of emotions explained in Appendix C.1 (p.133) is derived from clinical and medical results conducted on relations between the brain/secretory substances and feelings. The same dynamic vector model is then utilized to visualize the perceptional cognitive influence.

As explained in the green sections of the figure, emotional labels and cognitive situational perceptions affect feelings in the brain as they are then restructured. By comparing the restructured, subjective view and the dynamic vector displayed in Figure C.1 (p.133) , it is possible to build a verification system for the fundamental problem of emotions.

Naturally, this chart can be used to analyze relative associations of emotions by rotating it a little at a time. However, in the case of patients or users with significant deviation (based on the threshold value or on doctor's opinion), there is a possibility of the PS condition, D condition, or abnormal personality traits. Additionally, in communication taking place between machine and human, this chart can be used by the machine to infer conditions of the human mind. Furthermore, by changing elements of the chart, it is possible to use it as a means of mind evaluation that is applicable to all types of situations. Not only as relative standards for clinical practice, this model can be used in accordance with engineering to provide an absolute standard for analysis.

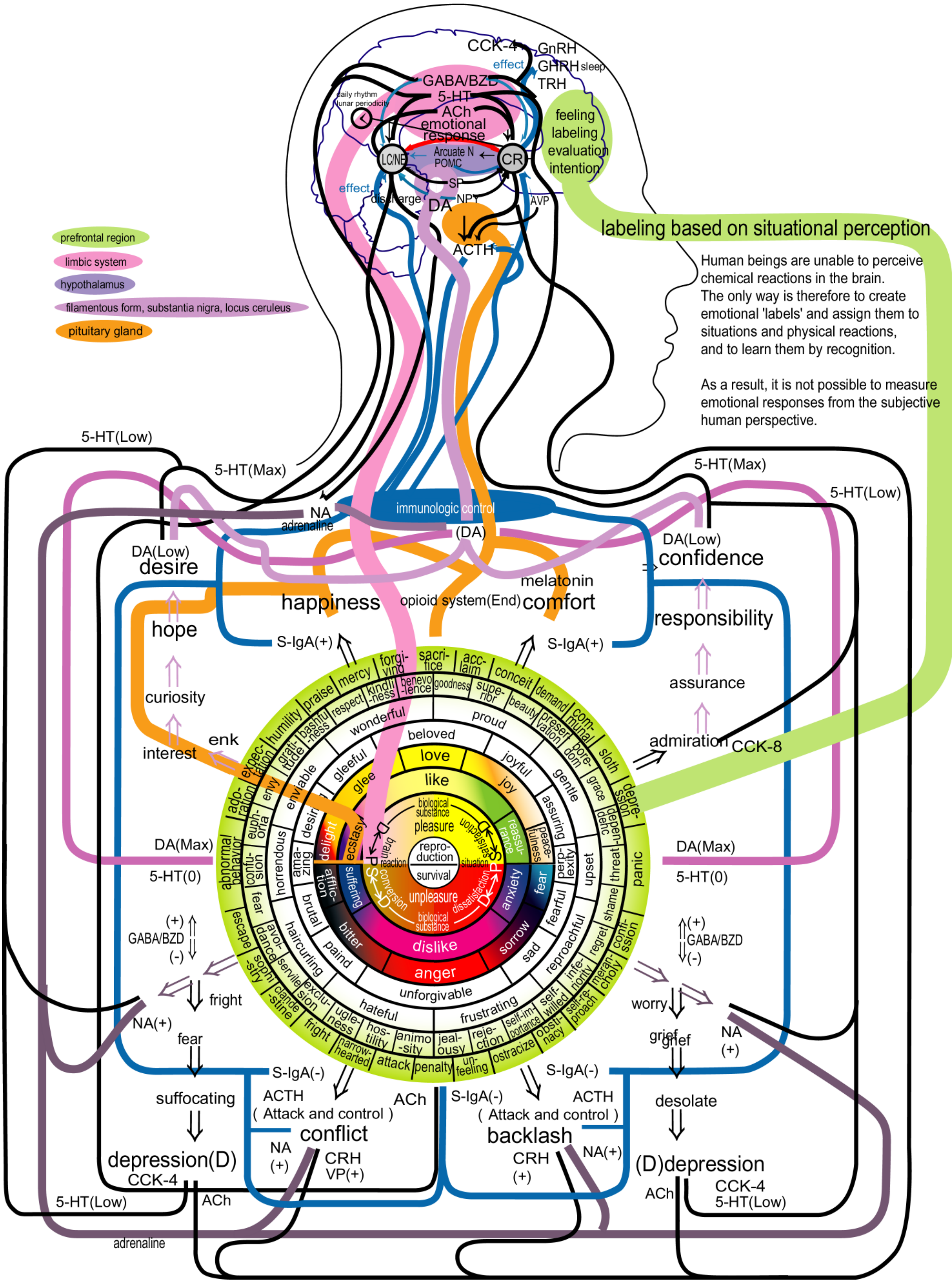

Figure C.2: The Hypothetical Dynamic Vector of Feelings and Cognitive Influences (Labels)

C.2.1 Emergence of Stimuli Sequences in the Brain (Emotion) through Stochastic Waves and Probability

Our approach is to first determine whether the brain is a (mathematically) probable , parallel neural net that portrays deviation. If so, our method is to capture and portray the series of "ignitions" of reactions in the human brain. Meanwhile, if the human brain is not probability (in which case the ratio of emotions to ignitions is 1 to 1) I measure the fluctuation of physiological indicator parameters, and focus on the homeostasis of hormones, the brain and DNA.

Based on prior research and using the following methods, I make the assumption that stochastic waves (the model of quantum mechanics) can be applied to the understanding of stimuli sequences in the brain.

1. By looking at neural activity, brain transmitter substances and ion exchange, I find the transition states of ignitions, and the probability of emotion detection to ignition in each region of the brain. Then, with an analysis of the quantum effect, I derive the probability distribution of its density.

2. In the case where quantum effect is confirmed, I predict a random subject's "emotions in the brain" from the deviation of stochastic waves (state), and verify our prediction using a measuring device.

3. From results gained from previous steps, I find the total deviation of stochastic waves while taking into account the feedback influence (interference) of factors including hormones and neural activity in the brain.

Figure C.3 displays the understanding of stimuli sequences in the brain using our hypothesis.

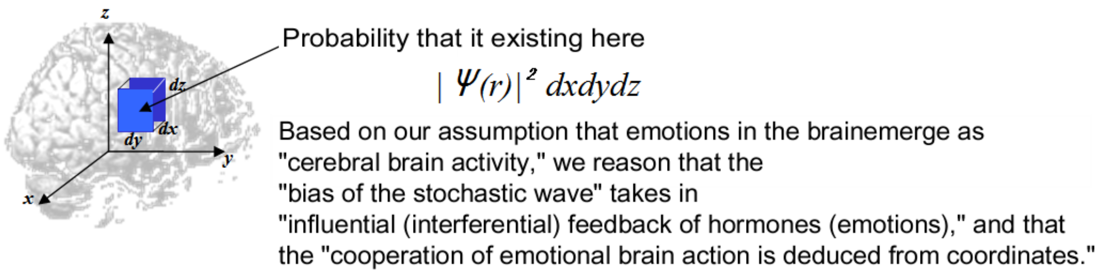

Figure C.3: Applying the Hypothesis to Examine Stimuli Sequences in the Brain

It is widely accepted that the behaviors of cranial (brain) nerves are probability. However, in reality, sensors measuring brain activity such as the fMRI do not have resolution at the nerve-cellular level. Moreover, current fMRI technology picks up additional brain activity outside the targeted area. Consequently, it is not possible to draw a definite conclusion whether reactions and emotions take place in the brain at a 1 to 1 ration. When exploring systems of probability with uncertainty elements involved, a common interpretation is that of quantum mechanics of electronic engineering.

The quantum effect confirms cause-effect relations among brain, intention and emotions when using methods that employ stochastic waves and wave intensity to recreate neural activity in the brain. Likewise, in situations where the relation between emotions and regional ignition of the brain is probability, or where neural activity of the brain is probability, the quantum effect also proves valid.

Quantum mechanics interpret photons and electrons (the wave nature of light) as clouds, and the state of particles are substantiated. The probability of substantiation is calculated using this interpretation by looking at emotions, memory and reactions that occur as regional activity in the brain.

On neural activity in the brain, I derive an equation for stochastic waves (referring to [166]) in dealing with ion exchange and ignition of nerve cells as electrons (hereby referred to as mind quantization). Wavelength λ and vibration frequency ν are linked by relation to momentum p and energy E of mental quantization, in reference to Einstein's theory.

Where the of mental quantization is m, based on the relation between energy and momentum, the equation

$$E = \frac{p^2}{2m} \tag{C.1}$$

can be used for free electrons. Using this correlation on Einstein's equation

$$E = h\nu \tag{C.2}$$

and applying

$$p = \frac{h}{\lambda} \tag{C.3}$$

$$h = 6.6 \times 10^{-34} J \cdot s (\text{Planck's constant}) \tag{C.4}$$

the relation between wavelength λ and vibration frequency ν

$$h\nu = \frac{1}{2m}\left(\frac{h}{\lambda}\right)^2 \tag{C.5}$$

is defined.

The function that expresses amplitude of the substantiated stochastic wave is the wave function. The wave function $\Psi(x, t)$

$$\hbar = \frac{h}{2\pi} \tag{C.6}$$

$$i\hbar\frac{\partial}{\partial t}\Psi(x,t) = -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2}\Psi(x,t) \tag{C.7}$$

satisfying the conditions of the one-dimensional Schrodinger equation, is applied to the three-dimensional sphere of the brain, and the standardization of the wave function is given

$$\int |\Psi(x,y,z)|^2 dV = \int |\Psi(x,y,z)|^2 dxdydz = 1 \tag{C.8}$$

when the above is fulfilled

$$|\Psi(x,y,z)|^2 = \Psi^*(x,y,z)\Psi(x,y,z) \tag{C.9}$$

is true, $\Psi^*(x,y,z)$ and $\Psi(x,y,z)$ become a complex conjugate. Under this condition, the integral range of mental quantization becomes the entire brain region （refer to fig. C.3）. This is the rudimentary explanation using quantum mechanics without taking in to account the factor of time.

Although the concept of stochastic waves appears to be obscure, it is able to capture the timing of the substantiation (particulation) of certain reactions, emotions or feelings at a fixed state. In the method described above, it is preferable to have hardware that carries out smooth partial differentiation or calculations of matrix vectors. However, in some economic models, learning models of probability and sum of probability is not equal to one. In these models, the methods that deal with accidents and surprises have yet to be established. Even in cases where the brain is established as a probability model, it is hard to assume that the sum of the probabilities is one （refer to Equation C.8） and that brain reactions represent a closed system. Moreover, taking into account the amount of stimuli and chemical substances that are delivered to the brain, we can predict an influence on feedback with time. Also, since nonlinear expressions cannot be generalized, it can be easily foreseen that a wide range of relative expressions will arise from experimental results. Because probability is a method that is used to explain uncertain things, it is hard to come up with a clear conclusion.

C.2.2 Emergence of Stimuli Sequences in the Brain (Emotion) when Cerebral Nerves Are Not Displaying Probability

In the case that the relations between cerebral nerves and emotions are not probability, I look at it as a closed system given that there are proven correlations between neurons and emotions. I turn our focus to the homeostasis of human emotions (where emotions are stabilized and kept calm) in a healthy condition. Assuming the brain is a closed system, I measure fluctuations of various physiological parameters of the brain, and set up a procedure to compare healthy and unhealthy conditions that are assessed by the doctor as so. We then set up a procedure to find the relative expressions between emotions and the brain, and between emotions and physiology, basing on the assumption that I can find abnormalities of emotions in the brain (deviation of stimuli sequences of excitement or unrest).

The significance in the comparison between healthy and unhealthy subjects is that, on one hand, healthy subjects should be maintaining physiological homeostasis, while unhealthy subjects may not be able to, or are left in an unbalanced state for some reason. Thus, in an attempt to find mental health condition from emotional sequences, I measure emotional homeostasis based on physiological indicators of the brain. However, in the case such as synesthetes (who simultaneously sense taste and sight), for persons who are able to maintain a unique state of homeostasis even when they have differing senses, I regard them as healthy.

As a way to find the clear relation between the brain and emotions, there is a method in which I can find intuitively the cause-effect link in brain transmitters, ion exchange and DNA through the state of homeostasis or collapse of the closed system.

In the intuitive approach, I use fractionation operators that are able to express simultaneously the relation between continuous quantities and separation numbers, in equal and unequal fractions. The following section explains divided quantity symbol “quantity fractionation operator $\underline{\text{♀}}$”.

The number of divisions is expressed as x, and in expressing continuous quantities of behavioral results in capital letters, when divided equally

$$2Y = A \tag{C.10}$$

$$A \div 2 = Y \underline{\text{♀}} Y \tag{C.11}$$

and when divided unequally

$$A_1 + A_2 + A_3 + ... + A_{...x} = A \tag{C.12}$$

$$A \div x = A_1 \underline{\text{♀}} A_2 \underline{\text{♀}} A_3 \underline{\text{♀}} ... \underline{\text{♀}} A_{...x} \tag{C.13}$$

is written. This is used to express transitions of physical quantities. The distribution of division, the number of times (behavior and behavioral quantity), and division results (quantity) can be illustrated all together, depending on the operator and operand.

For instance, suppose we cut a fish. According to contemporary calculation methods, we can only find the number of divisions; however, with the method described above, we can find the weight of the fish, the number of pieces and the quantities of each, all the same time. We utilize the ability of this approach to examine relative, continuous relationships in closed systems all in one go, and use it to determine what is healthy (homeostasis or closed system) and unhealthy (unbalance, or open system). Equation C.13expresses addition (summation). As long as the sum stays constant, homeostatic state of the closed system can be preserved.

On the other hand, we can use $\underline{♀}$to express a spring sequence. In that case we indicate the spring coefficient above the quantity fractionation operator, and use $E$to represent overall energy of the sequence, considering E_1, E_2, $E_3 \cdots E_{...y}$as (potential) quantities of each value. The following illustrates this method.

Setting x as the connectivity number of the spring, respective spring coefficients as k, and $a \Leftrightarrow b$ as the range of dynamic alterations,

$$E_1 + E_2 + E_3 + ... + E_{...y} = E \tag{C.14}$$

$$E \div y = E_1 \underline{♀}^{k_1}_{a_1 b_1} E_2 \underline{♀}^{k_2}_{a_2 b_2} E_3 \underline{♀}^{k_3}_{a_3 b_3} \cdots \underline{♀}^{k_y}_{a_y b_y} E_{...y} (E_1 \underline{♀} E_y) \tag{C.15}$$

is derived.

This method is used to determine intuitively the relationship between ion exchange and the exchange of transmitter substances, under the assumption that the brain is a closed system. Theoretically, in the case where mental, sympathetic vibration (PS $\Leftrightarrow$ D move) takes place during communication/simulations (of resonance or synchronism) with others, it is possible to apply the sympathetic resonant trait of springs to a three-dimensional model. This is also effective in explaining relative relations by recording traits of a sequence or wave consecutively. For instance, I can also illustrate this by setting the influence of exchange transmittance to k, and age-related degradation and DNA variation as $t_1 \Leftrightarrow t_2$. From the time barin transition (limit) I can verify the physiological homeostasis of a closed system, by observing its preservation of balance against fluctuations. On the other hand, if the system remains deviated for an extended period of time, I can conclude that it is unhealthy and abnormal (open system, unbalanced). We also take into account chemical substances and hormonal influences as quantities of the closed system (circuit). If homeostasis is lost under the influence of these input, I consider the system as having become unhealthy. We calculate the degree from threshold values of time and quantity.

Time t is an important factor in finding relative relations, and with the passing of time $\underline{♀}$ needs to be revised from future experimental results.

For practical convenience, in utilizing our quantity fractionation operator, I assume that

$$\div 2 = \frac{1}{2} \neq 0.5 \tag{C.16}$$

and $\div x$ is behavioral operator, not as a quantity. Since this method is simply used to record quantities, in computer science terms it is necessary to use non-digital terminology (such as Quantal) to portray continuous quantities.

With this method, a computing machine for calculating continuous quantities automatically based on time t is needed in order to tackle the massive calculations of neural network simulations. Under current situations, application exceeding the focus of a certain area of brain activity (such as a 1 cubic millimeter region) is difficult.

C.2.3 The Possibility of Cerebral Nerves Being Both Probability and Non-Probability

It is also conceivable to look at the relationship between emotions and the neural circuit/tissues of the brain as alternating between probability and non-probability conditions. For a description technique that is valid for both the probability model and the relative model, I convert existing probability $|\Psi(x, y, z)|^2 dxdydz$ to a coefficient and insert it into Equation C.15. In this case I provide that the overall sum corresponds to a closed system, by standardizing the wave function and ensuring that the probability sum is a quantity of 1. This allows us to grasp the limited degree of freedom of the brain using quantum mechanics. However, when I try to compare it to the mean field of the many-body problem of nonrelativistic theory which has unlimited degree of freedom, only in very special cases does it possess any physical meaning. Hence no generalizations can be made. From another approach I use the exchange of operators as a coefficient and use its mapping to find correlations. As such I can consider the operator (e.g. Hamiltonian) using alternative quantities and energy, and apply it with continuous quantities. We can also draw the same connection to DNA, or apply probability to behaviors/intentions algebraically.

When implemented through computing machines, it is feasible to ontologically compress the massive amounts of nerve cell network calculations by reflecting human intention through the Quantal model.

C.3 Solving the Problems of Psychological Research of Dynamic Model

Locus ceruleus, raphe nucleus, and substantia nigra appearing in Chapter B.1 (p.122) are located in the innermost region of the brain. They generate emotions from the brain stem and amygdala (limbic system), and in the hypothalamus they convert emotion to action and in doing so create desire. Moreover, through memory in the hippocampus, they influence emotions (such as fear and unrest) [46][77]. This means that the measurement of the mechanisms and separation of emotions and actions is possible by confirming coordinates in brain activity. Hence, this makes answering the full range of issues raised in psychological studies referred to in Chapter 1.4 (p.9) possible.

C.3.1 Cannon-Bard's Explanation of the Dynamic Model of Emotions

Chemical substances of the nervous system that are related to emotions are created in the innermost regions of the brain, closest to the human body [43]. While emotions are located in the innermost parts of the brain, will and reason are related to the cerebral cortex and particularly in the prefrontal region of the brain. This has also been proven by Morris who received the Nobel Prize in 1949 [46]. We can apply this to psychology by assuming the prefrontal region is manipulated by reason and the superego, and the innermost of the brain is controlled by id (instinct). Additionally, I can apply what is pointed out by Cannon-Bard in Chapter 1.2.1 (p.4) , which reasons that I can analyze emotions and its suppression through confirming coordinates of activity in the brain.

C.3.2 Cannon-Bard and James-Lange's Explanation of the Dynamic Model of Emotions

If mental energy can be portrayed through chemical substances or electric signals resulting thereof, James-Lange's theory from Chapter 1.2.1 (p.3) is applicable. It becomes possible to verify Cannon-Bard and James-Lange's theories through emotional mechanisms. Simulation of the mechanisms and comparisons with the brain will allow verification of the relationships.

C.4 A Three-Dimensional Interpretation of the Emotional Model

Based on the two dimensional Figure 2.4 the Axis of Pleasure-Unpleasure is placed perpendicular to the Axis of Paranoid Schizophrenia, and is represented as the originating source of emotions. Using 'excitement' and 'calmness' as the third-dimensional axis, a circulatory system where they also act on influence from hormones or the conscious self is created. Moreover, from the state of excitement, change in emotions takes place, and system creates an effect on "pleasure-unpleasure."

The change taking place in the circulatory system due to emotions, in which the region between PS (paranoid schizophrenia) and D (depression) oscillate, is referred to as the PS ⇔ D Move. The PS ⇔ D Move is the origin of human thought and intention. From there, the mental conditions that are created: unrest (fear), anger, sadness, dislike, happiness, affliction, bitterness, delight, glee, reassurance and so forth, are considered sentiments closest to emotions. This is made into a three-dimensional, movable model in Figure C.4. In this model, the two-dimensional emotional map of Figure 2.4 moves up and down as a whole due to emotions.

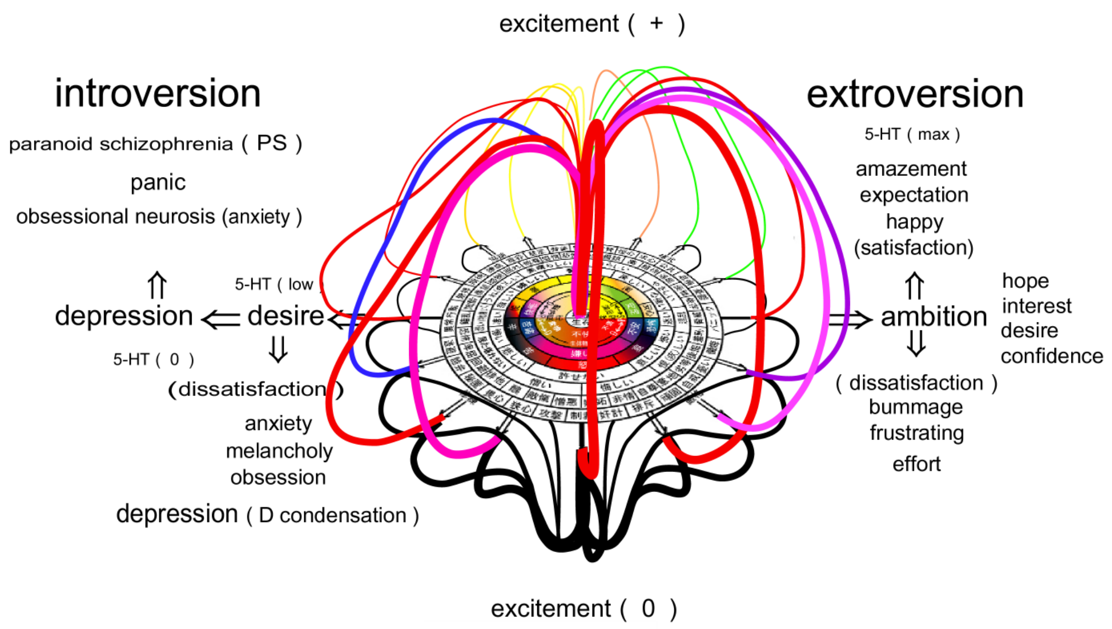

Figure C.4: A Three-Dimensional Model of the Author's Mental Conditions

Additionally, there are introvert and extrovert axes. For the purpose of explanation, there is an illustration similar to lines of magnetic force; however, there is no relation between magnetism and emotions. Here, hormonal and circulatory influence are portrayed on the horizontal and vertical axes, and resulting reactions of excitement are illustrated in lines. This model, created to achieve better understanding, is based on introspection of changes in my own feelings. Based on levels of excitement, introversion and extroversion, the divergence and placement of emotions move dynamically. Penetrating the center of the model is a control rod that manages the upper and lower vectors. Human emotions are both induced and self-emergent, while mediated by hormonal influence. This model is created as a homeostatic state of emotions, circulating and operating on its own. It is based on introspection, psychology, clinical science and constructed to serve as a principle for the quantitative research of emotions.

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