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Dual Loop Theory: Eidetic Feedback Control and Predictive Feedback Control

Keiko Tsujioka

Abstract

We have been studying on human information processing and finding out two types of feedback loop, positive and negative which are used when people understand a sentence. Former one is eidetic feedback control by visual sensory organs with encoding short-term memory (STM). Latter one is predictive feedback control by phonological imagery and schema, which help recall and reconstruction or reformation of concepts concerning with long term memory (LTM). Moreover, those strategies might be related to their behavior or attitudes. We have hypotheses that there are individual differences depending on strategies how two loops are used. Those findings must lead coordinating transformation and learning control for AI doctor or care assistive robots, which are required to interact with various types of people so that they can predict their behavior and attitudes through feedforward control.

Keywords: dual loop theory, eidetic feedback control, predictive feedback control, human information processing, human-machine interaction

1. Introduction

It has been becoming a key factor for artificial intelligent computers, which are composed of modern style machine learning system, how they are able to get involved with human.

Then, in our study, we have conducted experiments over a decade so that we can clarify human information processing, aiming to improve their interaction of AI doctor or support robot with human being by predicting their behavior from finding out their individual cognitive traits [1].

Specifically, we have predicted that their traits concerning with information processing would become clearer by comparing response time to short sentences between presenting with sound voice and letters. Those short sentences which are 120 questionnaires of psychological testing (YGPI) ask subjects whether they are the same or not, comparing with their daily ordinary behavior [2]. In other words, those questionnaires are concerning autobiographical memory [3], which are not effects of their knowledge or academic ability, but personality of 12 factors which divided into two factors, emotional and non-emotional [4–6].

From the results of our previous study, correlation coefficient between individual response time and the criteria of measurement (duration of each reading

questions or the number of words in one question) in the experiment by sound voice (listening) was higher than those of by letters (silent reading). And more, there was greater dispersion of response time among subjects in presenting letters experiment than former ones. From these reasons, we predicted that there would be differentiation of individual traits of information processing for letters than those of sound voice [6, 7].

We have therefore examined response time by silent reading individually and found out that there were persons of Visual type (N = 12 of 98, $r < 0.3$) whose correlation coefficients were much lower than those of Auditory type (N = 31 of 98, $r > 0.5$). In addition to this, the average of response time of Visual type persons was significantly shorter than those of Auditory type [6, 7].

Moreover, we have inspected reaction time of silent reading, especially among Intermediate type (N = 55), and found out there were another pattern of information processing between Emotional and non-Emotional questionnaires [6, 7].

In this paper, we have categorized two types, Eidetic type and Adjusting type, whose correlation coefficients and response time patters were different with each other. From these viewpoints, we had formulated a hypothesis (dual loop theory) and verified them by the experiments of practical collaborative learning in nursing class. One loop might be concerning positive feedback control (PFC) and other one might be negative feedback control (NFC) [8, 9]. Epidemic type persons might have tendency of PFC while they are solving problems. On the other hand, Adjustive type might tend coordinating two cycles (PFC and NFC) [10, 11]. We had revealed differentiations between the two types of behaviors.

Consequently, we would like to propose that the results of this study might help AI computer to learn machinery, thereby analyzing Big Data of various students' results and predicting their individual pattern of behavior so that it can support for personalized education, for instance, optimizing combination for collaborative learning.

2. Methods

2.1 System

Our purpose of this study is to clarify human information processing in order to optimize machine learning for AI computer, which is intended to communicate interactively with human being.

At first, there were problems in collaborative learning of practical nursing class at university and we needed to find the solution. After investigating them in 2014, we have found that there was the main cause of those problems which were failing at a relationship among team members. Then, we have developed the Personalized Education and Learning Support System (PELS) in 2015 [1], which helps instructors and learners to work interactively with each other by optimizing combinations of team members from the viewpoint of personality (**Figure 1**).

The main system of PELS is Big Data processing system (1) (**Figure 2**), [11], which gathers students' various data, for instance. measuring their traits (2), recording their behavior, results of their performance, questionnaires, and so on, and analyzes them (3), then inform them to instructors (4) so that they can make plans for instructions included teaming members for collaborative learning interactively.

The result of students' performances at the first semester (**Figure 3**, upper) has been improving after introducing PELS to nursing classes, comparing the average scores with the conventional form in 2014; on the other hand, it has been dealing from 2015 to 2017 at second semester (**Figure 3**, right). We have supposed that the
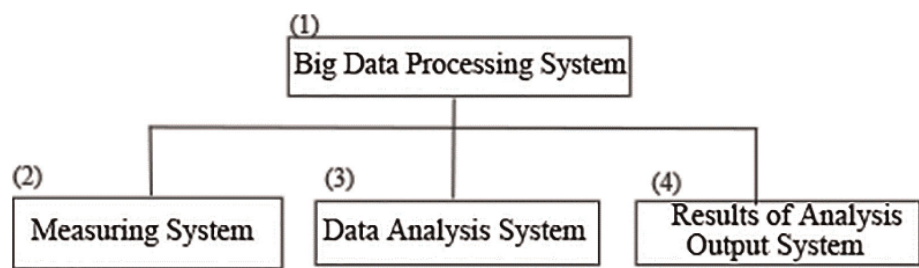
Figure 1.
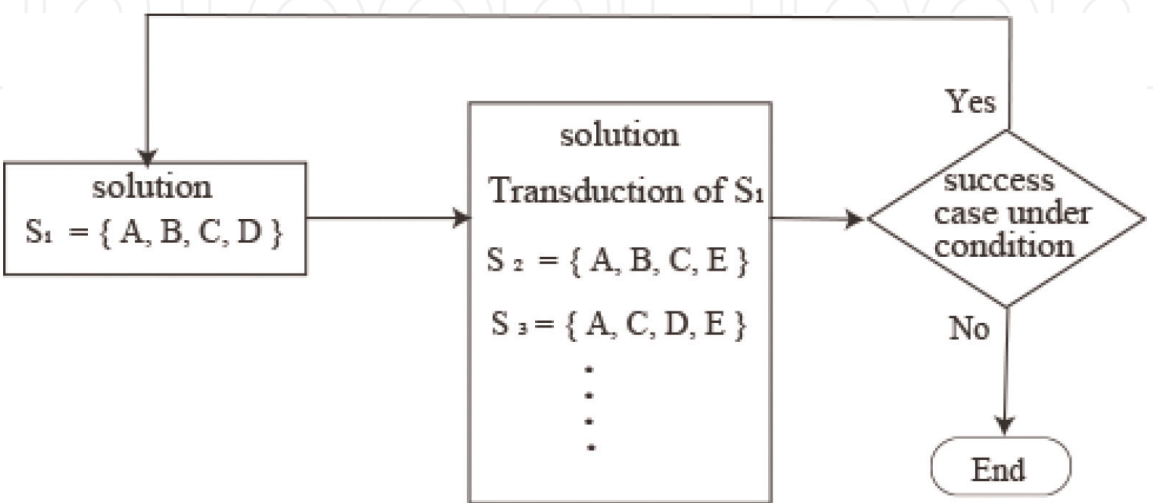*Local search for solution of combinatorial optimization.*

Figure 2.
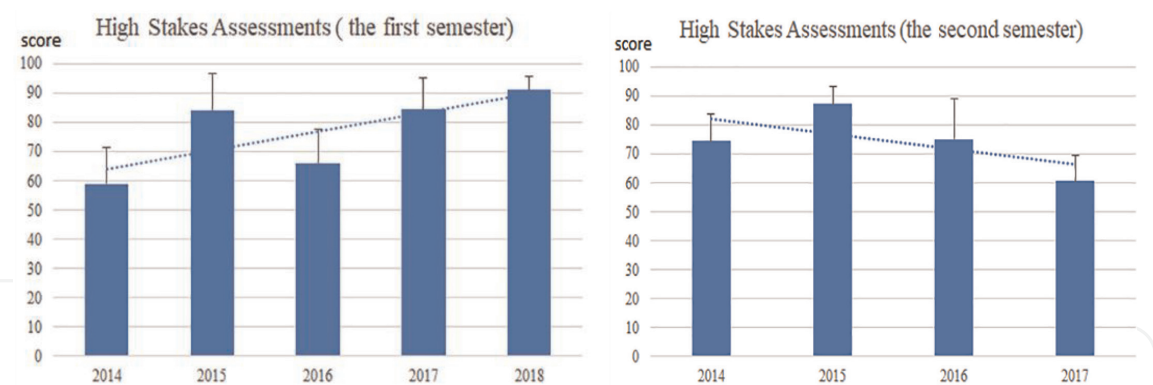*Local search for solution of combinatorial optimization.*

Figure 3.
Changing scores over the years.

reason of those phenomena might be influenced by not only their personality but also their cognitive traits [12], especially concerning with language information processing, because our lifestyle has been changed dramatically in digital society even in educational field [6, 7].

From these reasons, we have been examining PELS from the viewpoints of optimizing combination for teaming members, through comparing performances and individual differences between successful and unsuccessful teams. Combinatorial optimization, however, is considered that it is difficult to find out precise solution because of discrete and non-contiguous data structure; therefore, we have decided to find solution of interactive problems by introducing the method of scaling up [13–15], which needs to be revised in the field of education. As this scaling up method should not change the current education system at their university, we have asked

instructors and students to participate in experimental practical nursing class and agree to investigate their problems and solutions continuously [16].

2.2 Measuring system

Before starting those practical experiments, we had been developing the measuring system for individual traits [12], regarding human information processing. This system is simulated interactive communication between an instructor (A) and a learner (B) with using ICT (a) → (b) → (c) → (d) (**Figure 4**). In the field of educational technology studies, they call this interaction as learning process. When the learner responses to the instructor (A) after the information or instruction for assignments from the instructor (A) conveyed to her or him, the one session of activity has been considered as coming into effect of learning (**Figure 5**).

From this theory of learning processing, we predicted that language information processing might be the same as each other (**Figure 5**, ①). Then, instead of the instruction or assignment, we decided to use questionnaires of YGPI (Yatabe-Guilford Personality Inventory), which is consisted of 120 short sentences and 12 factors (10 of 120 each), and more, they are composed of two main factors, emotional and non-emotional factors. Subjects are required to choose responses to questionnaires among "yes," "no," or "either," comparing with their daily activities or behavior. The system also measures their response time from the start of presenting the questionnaire to subjects' replies (**Figure 5**, ② and ③). Card has
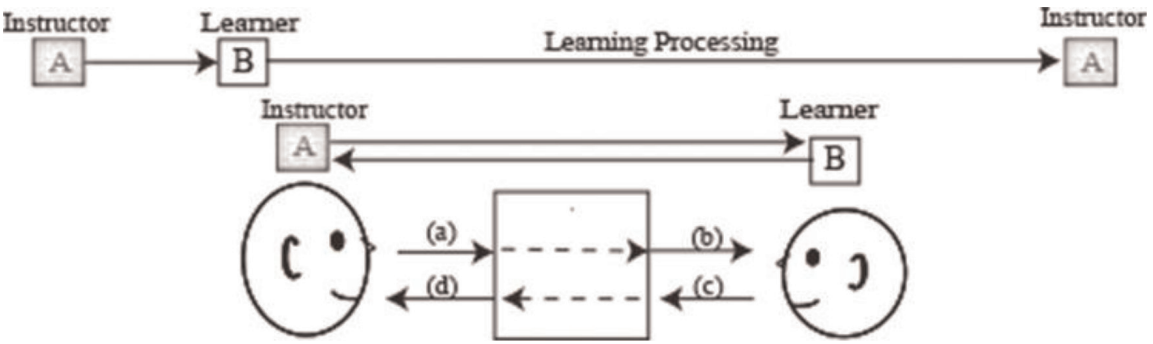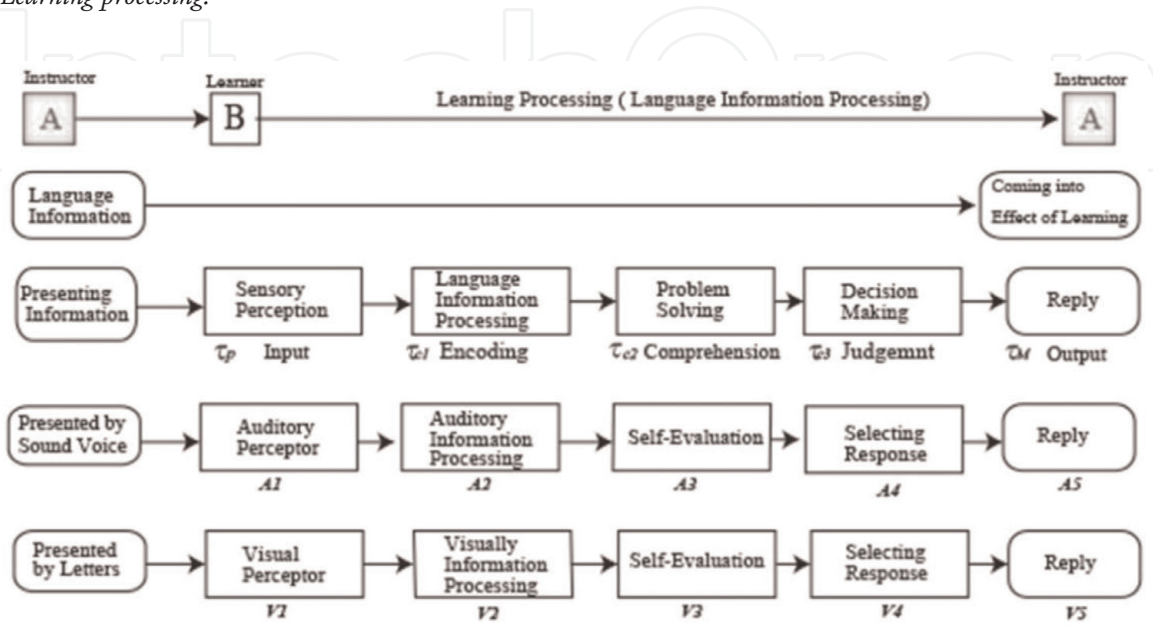

Figure 4.
Learning processing.

Figure 5.
Human information processing.

introduced the theory that the perceptional system (τ_p), cognitive system (τ_c), and motor system (τ_M) are involved in simple reaction time [17, 18].

Learning Processing ＝ Sensory Perception ⟶ Reply (Coming into Effect of Learning)

$$\text{Resonse Time} = (\tau_P) + \tau_{c1} + \tau_{c2} + \tau_{c3} + (\tau_M) \cdots \cdots ①$$

$$\begin{array}{l}\text{Response Time} = (A1) + A2 + A3 + A4 + (A5) \cdots \cdots ② \\ \text{(by Sound Voice)}\end{array}$$

$$\begin{array}{l}\text{Response Time} = (V1) + V2 + V3 + V4 + (V5) \cdots \cdots ③ \\ \text{(by Letters)}\end{array}$$

2.3 Hypothesis

As questionnaires would be the same between those presented by sound voice and letters, differences of their response time should be the same, except the duration of comprehension for problem solving (τ_{c2}) and decision making of intention (τ_{c3}), which are considered working as high-order functions. Hence, response time, which is measured in this study, is not the same as simple reaction time but same as complex reaction time. According to the theory of information processing by Card [17, 18], reaction time for encoding by perceptive organs (τ_{c1}) is correlated with the number of words, because of cycling for processing with each elements of the word.

The results of our exploratory experiments (over 100 subjects aged from 13 to 64) have been shown, however, that the system of encoding might not be the same among subjects. Especially, encoding system [19] for letters might be different individually, and the results of preliminary experiments which have been conducted in the same conditions (age, sex, history of education, and environment of experiments) have imprecated the individual differentiation of cognitive system, included encoding.

From these perspectives, we had introduced the model of human information processing (**Figure 5**) into our research. Specifically, it was predicted that there might be individual differences of information processing, depending on contents of questionnaires, between emotional and non-emotional factors [4] because of the encoding system or image schema system (**Figure 5**; A2, V2) [20], which is concerning with conceptualization. Those might have effects on their comprehension (**Figure 5**; A3, V3) or decision making (**Figure 5**; A4, V4) strongly.

Consequently, the model of information processing had been reviled to **Figure 6** which shows two types of cycle: (4) and (5). Along with previous examinations, the criteria would be decided for discriminating each other by analyzing correlation coefficient between response time and duration of reading (listening) or the
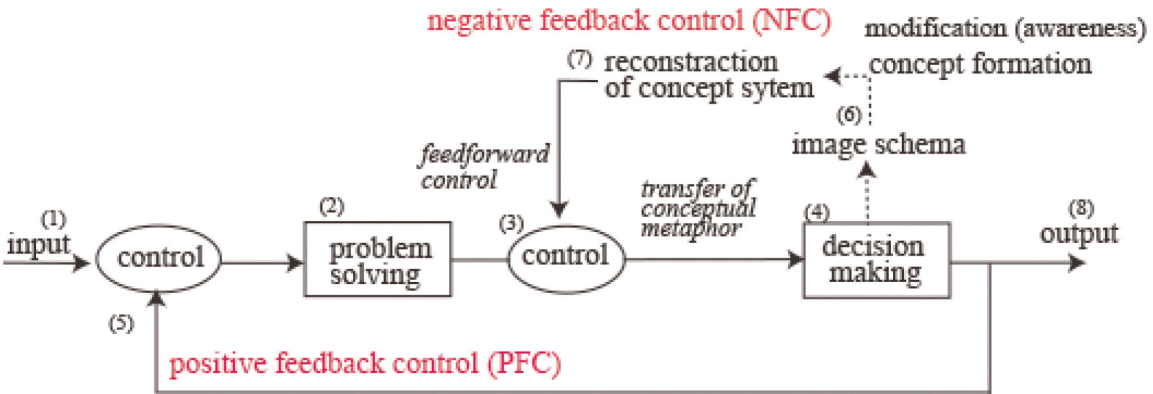

Figure 6.
Model of language information processing system.

number of words, depending on contents; emotional and non-emotional factors. In this chapter, we will examine hypotheses of "dual loop theory" as below.

There might have existed two loops for human information processing: one might be a positive feedback control (PFC) and the other might be a negative feedback control (NFC). Depending on students, which they might choose one during the problem solving would be different and it might be clarified by analyzing the response time, regarding the context of questionnaires.

a. In the case of PFC, Loop of (1)(2)(4)(5), (**Figure 6**), encoded words into symbols might be feedback directly to perceptive organs in order to comprehend the next word along with the context of given each questionnaire. Therefore, this type might have a tendency toward eidetic with short-term memory (STM) to make their decisions in a short time without phonologically silent reading.

b. In the case of NFC, Loop of (1)(2)(4)(6)(7)(3)(4)(8), (**Figure 6**), encoded words into symbols might be feedback control after phonologization with image schema and matching meanings of the words with sound voice by long-term memory (LTM). If there are conflicts between them, s/he might need to modify either one of them; then, the results would be conveyed to the cycle of feedforward control (**Figure 6**; (3)). In this case, they need time to make decision.

c. Most of the students might use both loops to solve problems and make decisions for replies. How they might choose one, depending on questionnaires, would be effects on their performances.

And more over, this tendency might have effects on their personality.

2.4 Methods of experiment

2.4.1 Prototype experiment

2.4.1.1 Purpose

The purpose of prototype experiments is to calibrate the measurement system.

2.4.1.2 Participant

Twenty-eight university students participated in this experiment.

2.4.1.3 Duration

The experiment took place from January to March in 2015.

2.4.1.4 Procedure

The participants were divided into two groups for a counterbalance depending on orders of the way of presentation by sound voice or letters. Prototype experiments are implemented twice to the same participants in the same way and conditions in January and March, for example, the arrangement of laptop displays on the desks and seats in the same room.

2.4.1.5 Data gathering

Each comparative experiment plans to obtain 240 responses and response time per person. Total amount of data should be 6720 for each element.

2.4.2 Practical experiment

2.4.2.1 Purposes

Under the condition of optimized combinations of team members at this time by considering inter personality which is predicted by the result of YGPI and instructors' experiences, the aim is to find out problems remaining in collaborative learning class in order to improve students' performance from another factor.

2.4.2.2 Participants

Ninety-eight new students at university participated in this experiment.

2.4.2.3 Duration

The experiment took place from April in 2015 to March in 2016.

2.4.2.4 Procedure

Beforehand, the instructors had been introduced how to optimize combination of team members in teacher training by using personality types and their experiences. At first, students were explained about the practical experiment and collaborative learning. After obtaining their agreements, they had participated in activities of this experiment, for instance, taking personality testing before starting class, answering questionnaires, collaborative learning in practical nursing class with optimized team members, and so on. Students were required to wear the saddlecloth so that observers and instructors can survey their behavior individually in class.

2.4.2.5 Data gathering

1. The results of performance in class; both low and high stakes assignment;

2. YGPI (response, response time, and evaluation (profile));

3. questionnaires and interviews to instructors and students;

4. interaction among students while they are using LMS (learning management system);

5. record of video in class; and

6. participatory fieldwork.

2.5 Methods of analysis

2.5.1 Quantitative analyses

2.5.1.1 Calibration

The calibration is done by comparing the average of response time to questionnaires by presenting sound voice or letters obtained in prototype experiments in the first and the second time, divided by the number of words.

2.5.1.2 Traits of information processing I

The calibration is done by comparing the average of response time to questionnaires by presenting sound voice or letters obtained in practical experiments in Visual and Auditory types (**Table 1**), divided by the number of words.

2.5.1.3 Traits of information processing II

The calibration is done by comparing scatter diagrams of response time to questionnaires by presenting letters and standard reading time (sound voice) obtained in practical experiments in Eidetic and Adjusting types (**Table 2**), dividing into emotional and non-emotion context (**Table 3**).

2.5.1.4 Evaluation of performance in team

After processing parallel distributions of individual records of performance, low and high stakes assessments, and traits of information processing (**Tables 1** and **2**), a table will be made in order to analyze and evaluate by comparing performances of teams between success and ill-successes team (Team B and Team C).

Traits of Information Processing I	
Visual Type	$r < 0.3$
Auditory Type	$r > 0.5$
Intermidiate Type	$0.3 =< r <=0.5$

Table 1.
Criteria type I.

Traits of Information Processing II	
Eidetic Type	$X = <\mu - \sigma$
Adjusting Type	$X => \mu + \sigma$
Intermidiate Type	$\mu - \sigma < X < \mu + \sigma$

Table 2.
Criteria type II.

Element of Material	Context	Items	Minimum	Maximm	$\overline{X}$	SD
the Number of Characters	Emotional	60	4	20	14.3	4.2
	Non-Emotional	60	4	20	14.2	4.2
the Length of Time for Reading Item	Emotional	60	0.76	3.2	2.0	0.6
	Non-Emotional	60	0.73	3.0	2.0	0.6

Table 3.
Comparison of elements between emotion and non-emotion.

2.5.2 Qualitative analyses

After processing parallel distributions of individual traits of information processing (**Tables 1** and **2**), descriptions of answering questionnaires about psychological testing will be compared between two types of presentation and interpersonal communication in class or practical training (Team B and Team C).

Then, their differences will be discussed in order to clarify the effectiveness of collaborative learning.

3. Results

3.1 Prototype experiment

Twenty-eight participants were the same members as the first and the second implementation on the same seat and the same display for each person. The experiments were conducted by representing counter-balanced by order. The results were obtained by analyzing the average of reaction time divided by number of words in a short sentence (**Figure 7**); both sound voice and letters were not significantly different between the first and the second experiments. The total average (first, second) of sound voice was (=2.69, =2.58) and letters (=2.32, =2.20). The correlation coefficients between response time and the number of words were not significantly different between the first and the second experiments, both representing questionnaires by sound voice and letters (**Table 4**).

From these results, it has been proved with reliability that the level of calibration was high enough to reproduce scientifically, regarding our measuring system. Concerning standard deviation, however, letters ($SD = 0.93$, $SD = 0.85$) was larger than sound voice ($SD = 0.64$, $SD = 0.64$) (**Figure 5**). Specifically, when the number of words was higher, the standard deviation of reaction time to letters became
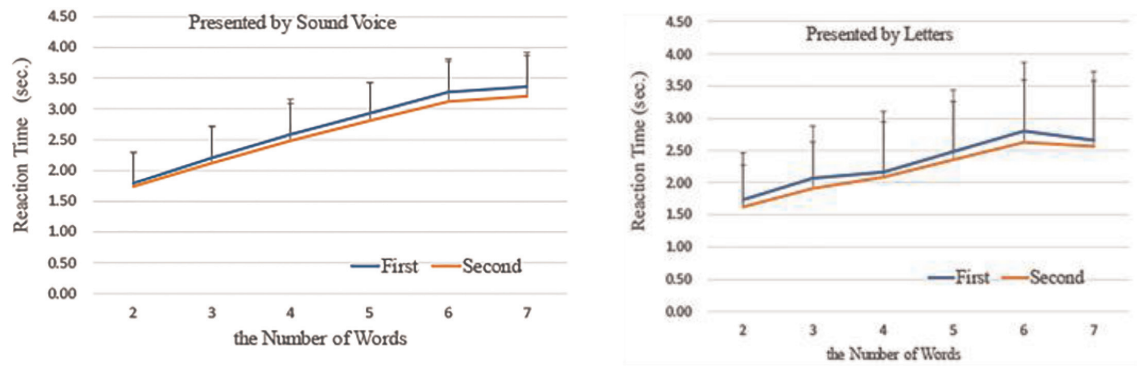

Figure 7.
Comparison of response time between the first and the second experiments (left: presented by sound voice; right: presented by letters).

	Correlation Coefficient					
	Materials of Media					
	Sound Voice			Letters		
	df.	*r*	*t-ratio*	*df.*	*r*	*t-ratio*
First (N=28)	3360	0.70	*n.s.*	3360	0.37	*n.s.*
Second (N=28)	3360	0.68		3360	0.38	

Table 4.
Examination of comparison between the first and the second response time.

larger. This means that there might be individual differences of information processing among students.

3.2 Practical experiment

3.2.1 Quantitative analyses

3.2.1.1 Comparison of traits for information processing I

As we have mentioned in Section 3.1, from the results of prototype experiments, we have proved the reliability and the reproducibility of our measurement system. Then, in a practical experiment, we have used them and gathered data, with the similar way of procedures and conditions applied in the prototype experiments. As the standard deviation of response time presented by letters was larger than those of sound voice, we have checked individual differences of the correlation coefficients between response time and the number of words. Along with the categorization of those correlation coefficients, we have divided students' types as traits of information processing I, Visual type and Auditory type. And then, comparing the average of reaction time between Visual and Auditory type (**Figure 8**), in the case of letters, Visual type (=2.01, $SD = 0.92$, $N = 13$) responded significantly faster than Auditory type (=2.65, $SD = 0.98$, ($N = 31$)) (**Table 5**) ($t = -21.05$, $r < 0.001$).

3.2.1.2 Comparison of traits for information processing II

Figure 9 shows the different patterns of distributed response time (intermediate type of information processing I) between eidetic ($N = 8$ of 11) and adjusting type
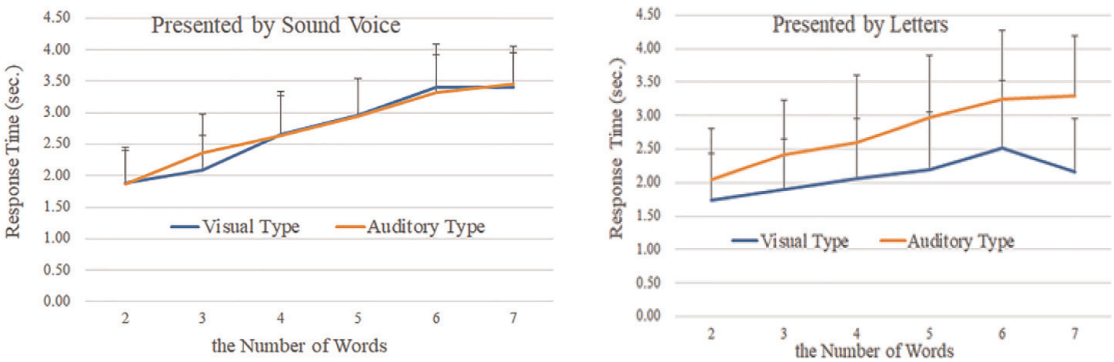

Figure 8.
Comparison of reaction time between Visual and Auditory types (left: presented by sound voice; right presented by letters).
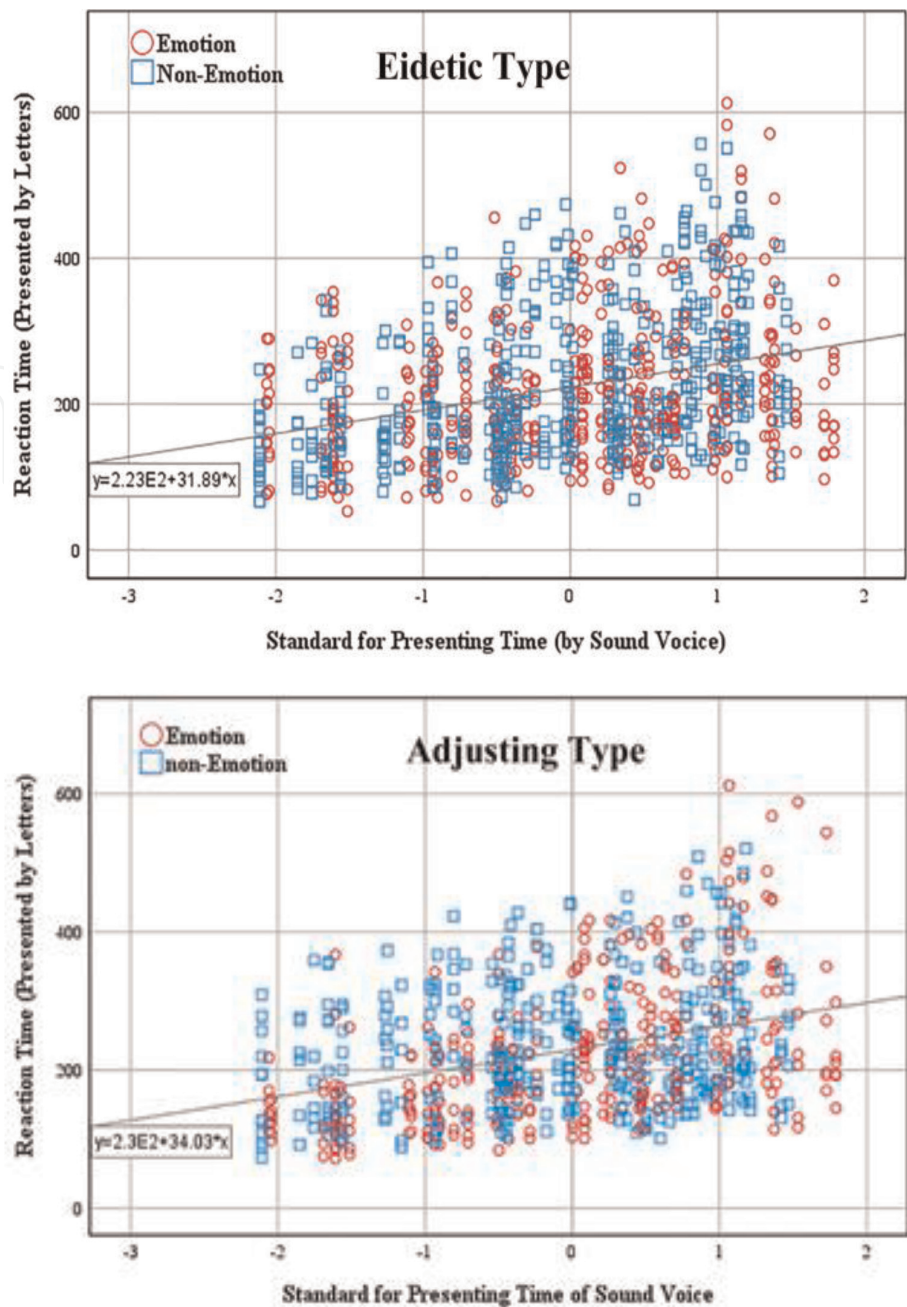
Figure 9.
Comparison of reaction time between emotion and non-emotion (upper: Eidetic type; lower: Adjusting type).

Traits of Information Processin I	Comparison of ReactionTime								
	Materials of Media								
	Sound Voice					Letters			
	$\overline{X}$ (SD)	df.	t-ratio	t - test		$\overline{X}$ (SD)	df.	t-ratio	t - test
Auditory Type (N=31)	2.64 (0.89)	5156	2.12	*		2.65 (0.98)	5154	-21.05	***
Visual Type (N=13)	2.70 (0.82)					2.01 (0.92)			

Table 5.
Results of tests, the significant differences of reaction time between visual and auditory types.

(N = 6 of 10), which were categorized traits by the differences of correlation coefficients between emotional and non-emotional contexts (eidetic type; $X \leq \mu$-σ, Adjusting type; $X \geq \mu + σ$) (**Table 2**). In the case of Adjusting type (N = 10), the average of response time of emotional contexts was significantly faster than those of
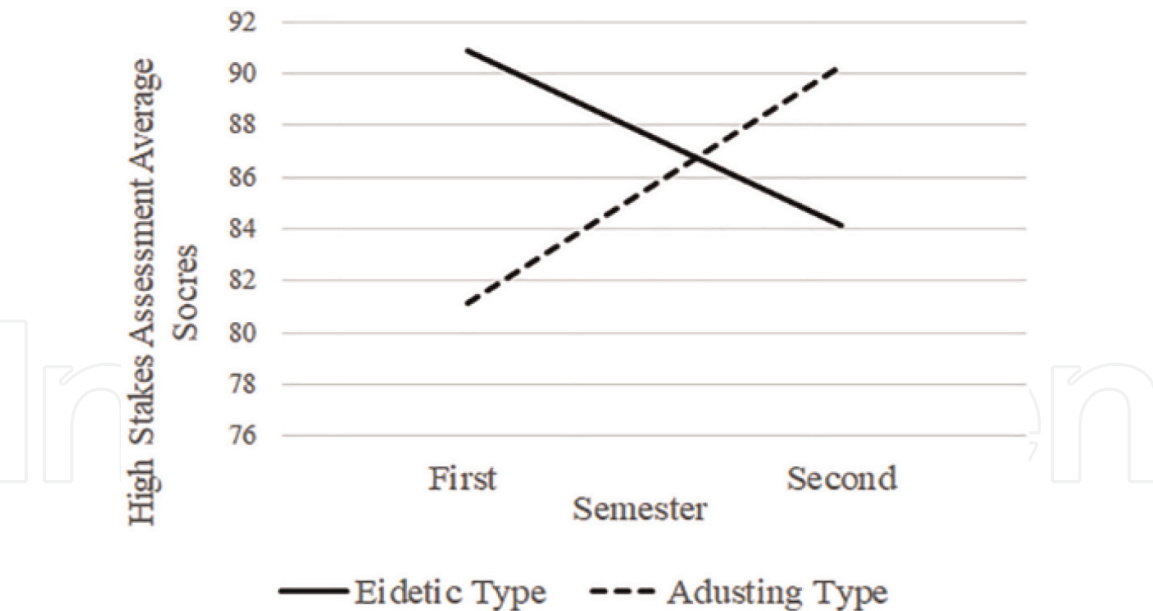
Figure 10.
Comparison of scores first and second semester.

non-emotional contexts. This tendency is found in the patterns of the scatter diagram, which shows distributions of each response time how they diff between emotional and non-emotional contexts. On the other hand, in the case of Eidetic type (N = 11), there are no differences between them.

Figure 10 shows the quantitative interaction between two types of students, comparing their scores between the first and the second semesters (F = 5.3, $p <$ 0.01). The average of Eidetic type in the first semester was better than that of Adjusting type; however, in the second semester, it was reversed.

3.2.1.3 Comparison of team performance

This phenomenon should be examined in detail, checking whether the statistical results are right or not by seeing individual performances practically. Therefore, we have chosen team members whose team was success or ill-success in low- and high-stakes' assessments. In the case of low-stakes assessments, Team B members' records were shown the best improvement among teams, comparing pre-post test scores. On the other hand, in the case of Team C, their records were the worst in class. Those tests conducted in the first semester, and the average of Team C (=77.5) was lower than Team B (=87.3). In the second semester, traits of the whole tendency of teams were the same; however, looking into individual performances, their tendencies were also the same as **Figure 10**. For instance, both scores of eidetic type; SubB-2 and SubC-2 in the second semester were lower than in the first semester, on the other hand, in the case of Adjusting type, SubB-1 and SubC-3, their scores in the second semester, became much better than those of the first semester.

3.2.2 Qualitative analyses

3.2.2.1 Description

In order to check them from another viewpoint practically, their descriptions of answering questionnaires were compared among types of information processing (Appendix 1 and 2).

Appendix 1 shows descriptive answers to the questionnaire about the comparison between auditory and visual presentation of testing. Two of four students, who are visual type, said that it was easier for them to decide responses or image by sound voice than by letters. On the other hand, all three students of Adjusting type have described their responses through self-evaluation by testing.

In Appendix 2, regarding interpersonal communication, which students are required to obtain in practical field for nursing, all three Adjusting type students have described that they think it is important. The others have described about the interactive communication a little more subjectively.

3.2.2.2 Interview

All four members of Team B were interviewed on September 9th in 2018. SubB-2, however, did not appear at the appointment time. After getting appointment again, she appeared for the interview. She said that similar cases have repeatedly happened because it was nothing unusual to make misread message (which caused missing appointment). Concerning interpersonal communication, it has been difficult for her in collaborative working in the practical field and it was the best condition in 2015 with Team B members.

In the case of SubB-1 and SubB-4, they both have talked about their strategies to communicate interactively in collaborative working, even at the specialized treatment department. It seemed that they were able to cope with any persons and cases.

4. Discussion

4.1 Meaning of clarifying human information processing

There are a significant number of studies, which have been conducted about human information processing in the world [17, 18]. Every study is very important for us; on the other hand, most of them are still vague and unclear, because we need to observe real time while it is working, from outside. It should be difficult, however, to see inside of our mind directly. Therefore, we have developed the measurement of individual traits from cognitive aspects so that we can clarify human information processing and predict their behaviors. I would like to make it a meaningful measurement; however, it is still exploratory research and data analysis.

Although there might be a lot of methods to find out the mechanism of human information processing [21, 22], there should be different approaches from each other to achieve a goal, depending on their own purposes. The end of this study is to improve personalized education, however, both the environments in society and educational field have been changing, which must be a lot of elements and always impact on our cognitive system, in other words, on the way of human information processing. This means that we always need to find out the problems which might be courses of ill-success in education.

For instance, in our study case, we have supported collaborative learning in nursing class, which has been introduced for cutting age electronic equipment. It must help students when they start to work at hospital, coping with electronic equipment. On the other hand, they are required to obtain the skill of interactive communication with patients and coworkers. For this reason, the instructors have introduced the method of collaborative learning, which needs to divide students into teams with four members in each. It seems cumbersome to decide the members of teams, if instructors seek for effective learning, because they would be required to predict students' behaviors by analyzing their data, for instance, individual traits

and their needs. Hence, we have begun to support optimizing combination; however, there is no exact solution for it [23]. For those reasons, we have developed the support system or personalized education and learning. This has the measuring system to provide students' data to instructors before starting classes.

As I have mentioned above, however, it has been becoming complicated to combine members of teams. Therefore, if AI doctor or machine would solve this problem by optimizing combination, personalized education and learning would be improved. To achieve this meaningful goal, we need to clarify information processing for interactive communication. This must have synergic effect on AI doctor, care assisting robots and so on, because they need to obtain the ability of interactive communication with people by machine learning.

From these viewpoints, this study and the measuring system for clarifying human information processing must be meaningful to achieve our goal.

4.2 Examination of dual loop theory

We have planned to examine dual loop theory, which I have proposed as hypotheses and implemented experiments, gathered data, and analyzed them. Those ideas were hinted by Card's Model Processor [18], which is a "cognitive model of the user to be employed by the designer in thinking about the human interaction with computer at the interface" and "the Recognize-Act Cycle of the Cognitive Processor," from the view of LTM and STM as a simple reaction time. Although they have introduced this model, they have tried to propose another one (GOES: Goals, Operations, Methods, and Selections) for tasks which can be taken from the half-second level to the two-second level. Approximately, dual loop theory model (**Figure 6**) might be a combination of those two models and we can predict subjects' behavior. Many of such models have been introduced; however, there might be a few to find out individual differences in human information processing.

The idea of this dual loop theory might be similar to the others, however, we seek for finding out individual differences which patters would indicate some types of trait concerning with cognitive behavior.

Although having said that, when the model is examined, we need to use previous studies as references. For instance, by comparing processing between sound voice and letters [24] and cycle reaction time which is proposed by Card [18], we have examined calibration of measuring instrument. From the results of analysis for response time by presenting sound voice have been shown the high level of the calibration from the viewpoints of reliability and the reproducibility (**Figure 7**, left), considering the high correlation coefficient with the number of words which means cycle of response time. On the other hand, in the letter presentation case, it was recognized reproducibility; however, its correlation coefficient with the number of words was not shown high.

From this result, it was predicted that individual differences clearly among students concerning the way of silent reading. Then, categorized types of trait (visual or auditory type) by strengthening of the correlation coefficient between response time and the number of words or duration of reading aloud. There are no differences between the two types of reaction time represented questionnaires by sound voice, but recognized significantly differences by letters (**Figure 8** under **Table 5**). Students of Auditory type have needed time longer than those of Visual type from starting to silent reading to making decision (**Figure 5**). This means that the auditory type might tend to process a word and a sentence with phonologization, using LTM or NFC loop; conversely, the visual type tends to process directly encoding symbol using STM or PFC loop.

From these results of analyses, the hypotheses [a] and [b] have been proved, and next hypothesis [c] should be examined. It was predicted that depending on

the context of sentences, we might process them with different ways, PFC or NFC Loop. One hundred twenty psychological questionnaires were used as a task for one session, but they consisted of mainly two types of contexts, emotion and non-emotion. From the previous studies, when the emotional context is processed, it is considered that we tend to use STM because the effect of emotion on hippocampal-dependent memory consolidation [25, 26]. Then, the categorization of types concerning contexts is performed, Eidetic [27] and Adjusting type, depending on the differentiation of correlation coefficients between emotional or non-emotional contexts (**Table 2**). In the case of adjusting type, the differentiation of response time was clear, and the average of response time to emotional contexts is significantly faster than non-emotional ones. This means that students of Adjusting type might change their strategies to read silently and make decision depending on contexts. In the case of emotional contexts, they might use STM or PFC; on the other hand, in non-emotional contexts, their correlation coefficient is higher and much longer time spent from starting silent reading to making decision [28, 29]. This means that they might read silently with phonologization of words, referring concepts of words meaning by sound voice with image schema. This information processing might help them to reflect on their comprehension is right or not, which is considered negative feedback control (NFC).

From these results, we have proved hypothesis (c); however, we would like to examine more details for this hypothesis.

4.3 Relevance between individual differences and personality

Two teams were selected from the aspect of low stakes assessments (highest and lowest teams, assessing for ability of conceptual metaphor and collaboration), in order to examine more in detail from the aspect of individual differences (**Table 7**). It is easy to compare the improvement performances among students' traits and records or between teams by parallel processing and analyses. The result of the comparison of the average scores between Eidetic and Adjusting types and between first and second semesters has been examined this parallel processing and analyses, which have shown matching with each other.

Moreover, the comparison of those examinations between results of scores and descriptions of students (Appendix 1 and 2) by parallel processing has shown their matching. From this viewpoint, whether those results are matching with the evaluation of personality, regarding the factors of lack of objectivity (O Factor) and lack of cooperativeness (Co Factor) among 12 factors (Appendix 3). Students of Adjusting type (SubB-1, SabB-4, and SubC-3) have taken low scores for both factors; in other words, they are evaluated as objectivity and cooperativeness are strong. On the other hand, students of eidetic type (SubB-3 and SubC2) have taken high score in both factors, comparing with the former students, which means they are subjective and a little bit uncooperative.

Consequently, we might be also able to predict their behavior from traits of information processing. Though the results of our experiments have been proven useful, they are complicated for us. In addition to it, instructors must be busy to prepare other instructions for students. From these reasons, AI machine or doctor which might be able to obtain machine learning is expected and prospected for matching members of team by optimizing combinations.

5. Conclusions

In this chapter, dual loop theory, which consisted of two kinds of feedback control, concerning with human information processing, was proposed (**Figure 6**)

and examined by analyzing the results of experiments. The data were gathered students' response time, using psychological questionnaires (**Figures 4** and **5**) and their records of performances in collaborative learning class and analyzed by the way of parallel distributed processing. The results were as follows:

1. The prototype experiments were conducted by representing counter-balanced by order. The results of analyzing the average of reaction time divided by number of words in a short sentence (**Figure 7**) in both sound voice and letters were not significantly different between the first and the second experiments. Therefore, it has been proved with reliability that the level of calibration was high enough to reproduce scientifically, regarding our measuring system.

2. The response time to questionnaires of sound voice presentation was strongly correlated to the number of words which consist of a short sentence of questionnaires. In presenting letters case, the average of correlation coefficients was weaker and dispersed than those of sound voice (**Figure 7**). From these results, it was supposed that there were individual differences during information processing while students were reading silently. Then, their response time was categorized by the strength of correlation coefficients with the number of words (**Tables 1** and **2**).

It was found out that the average of response time depending on types was different between each other. In the case of Auditory type, the average of response time was significantly longer than those of Visual type (**Table 5** and **Figure 8**).

3. Next, when the sentences were divided into two categories, emotion and non-emotion, there were found different phenomena among students, regarding

Traits of Information Processing II	Reaction Time / second (SD)		t-test		
	Lerres		df.	t-ratio	sigunificant probability
	Emotional	Nonemotional			
Adjusting Type (N=10)	2.27 (0.27)	2.44 (0.32)	1198	2.98	0.003 ***
EideticType (N=11)	2.27 (0.42)	2.35 (0.40)	1317	1.55	0.121

Table 6.
Results of tests, the significant differentiation of reaction time between emotion and non-emotion context for Adjusting type.

Team	Pertici- pant	Traits of information processing		Low Stakes Assessment (Group Work)							High Stakes Assessment		
		I	II	pre test			post test			differ- ence	semester		differ- ence
				Q2	Q3	all	Q2	Q3	all		First	Second	
Team B	SubB-1	inter-mediate	Adjusting	2	0	2	5	5	10	8	79	97	18
	SuaB-2	Visual	Eidetic	0	0	0	5	5	10	10	93	91	-2
	SubB-3	Visual	inter-mediate	0	0	0	5	5	10	10	86	91	5
	SubB-4	inter-mediate	Adjusting	0	0	0	4	4	8	8	91	97	6
Team C	SubC-1	Visual	inter-mediate	5	5	10	5	0	5	-5	65	78	13
	SubC-2	inter-mediate	Eidetic	5	4	9	5	0	5	-4	86	78	-8
	SubC-3	inter-mediate	Adjusting	3	3	6	5	0	5	-1	71	92	21
	SubC-4	Visual	inter-mediate	2	2	4	4	3	7	3	88	92	4

Table 7.
Comparison scores between teams.

traits of information processing type (**Figure 9**). In the case of Adjusting type, the average of response time for emotional contexts was significantly faster than that of non-emotional contexts (**Table 6**).

4. Therefore, the average scores of students' records were compared between Eidetic and Adjusting types. The result has shown the quantitative interaction between them (**Figure 10**).

5. Moreover, we have examined whether those individual differences are connected to other students' performances (**Table 7**, Appendix 1 and 2), and then, checking the verification of the criteria which classified traits both of personality and cognitive features (Appendix 3).

6. Finally, we have discussed on hypotheses (2.3), from three aspects: meaning of clarifying human information processing, the examination of dual loop theory, and the relevance between individual differences and personality. In conclusion, the feature of Adjusting type has been shown their way of information processing by both positive and negative feedback controls, comparing the other type of students, depending on the context. In addition to this result, we have checked their performances, descriptions, and interviews practically.

We need to examine this theory furthermore and optimize the combination of members in order to communicate interactively among students and instructors. Eventually, those results would help the modern style machine learning of artificial intelligent to predict human behavior depending on types and consequently improve their interactive communication with human beings.

In conclusion, dual loop theory would be expected to help us to understand the system of human information processing and predict our behavior according to its patterns. It would be also applicable widely to the machine learning system, for instance, AI doctor and assistive robots which requires the interactive communication with human.
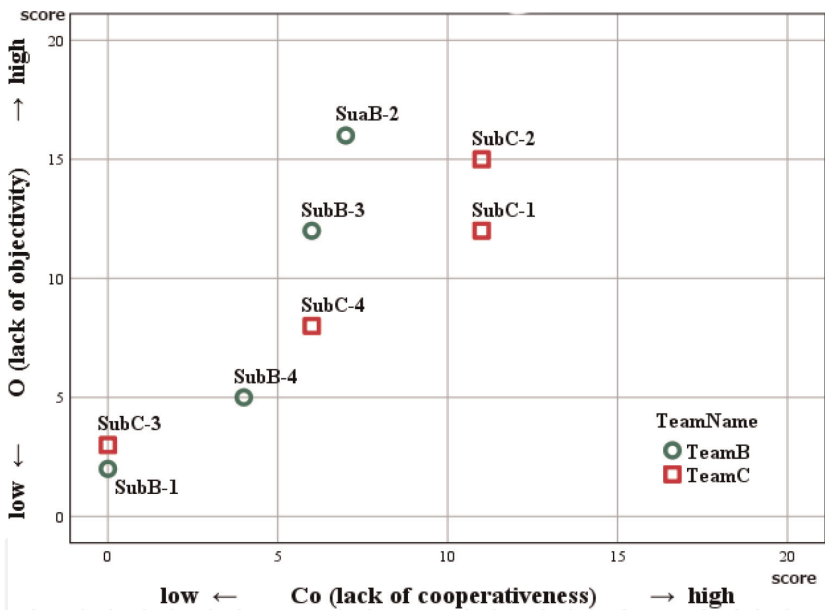
Acknowledgements

Appendix 1

Participant	Traits of Information Processing		Experiments (Comparison of questionnaires between sound voice and letters)
			Are there any changes in your mind?
SubB-1	Mid	Adj	After I had been asked questions which I had never been care about before, I have begun to consider anew about myself.
SuaB-2	Vis	Eid	(no response)
SubB-3	Vis	Mid	I had been able to image easier from questionnaires with representing sound voice than letters, because I had to rearrange them for comprehension in the case of silent reading.
SubB-4	Mid	Adj	I had begun to consider afresh about myself what sort of person I am.
SubC-1	Vis	Mid	It was an opportunity for me to think about myself after I had asked about myself both by sound voice and letters questionnaires.
SubC-2	Mid	Eid	After I had expressed me afresh in words, I had recognized by myself what kind person I am.
SubC-3	Mid	Adj	I thought I need to consider about myself anew.
SubC-4	Vis	Mid	There were nothing especially. I had response to questionnaires easier by sound voice than letters.

Appendix 2

Participant	Traits of Information Processing		Interpersonal Communication
			Are there anything to become aware in practical class or training?
SubB-1	Mid	Adj	It is very important to communicate with patients for care, because it might make an impact on them psychologically and physically.
SuaB-2	Vis	Eid	(no response)
SubB-3	Vis	Mid	There were increased opportunities to compare both good and bad points between me and people sounding me through group working and sessions, and then I have a feeling of myself. And then, I thought I would like to increase my confidence a little bit more.
SubB-4	Mid	Adj	I have recognized again that it is important to communicate with patients in any cases when we would like to convey our ideas in conversation because I think it is easy to change impression depending on our expressions or manners of speaking.
SubC-1	Vis	Mid	After I had aware of nurses, I thought that communication is important.
SubC-2	Mid	Eid	Nurses had changed the manner of speaking depending on patients.
SubC-3	Mid	Adj	I had found that it is important to exchange information with each other so that we are able to perform better practice in class or training.
SubC-4	Vis	Mid	It was more difficult to communicate with patients than I had thought, especially with difficulty to speak. I had aware that we are able to communicate with each other not only by words but also facial expression.

Appendix 3

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