Chapter

Toward Clarifying Human Information Processing by Analyzing Big Data: Making Criteria for Individual Traits in Digital Society

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Abstract

The purpose of this research is to solve those problems in education by indicating criteria for individual differences of cognitive mechanism when students interact using digital devices so that teachers would be able to instruct students with appropriate teaching strategies in collaborative learning. From the results of experiments for clarifying information processing by analyzing students' various data (Big Data processing), there was a tendency of an interaction comparing students' performance with the first and the second semesters between visual type and auditory type.

Keywords: individual differences, human information processing, criteria, cognitive schemas, decision-making, personality, prediction of behavior

1. Introduction

About two decades ago, digital instrument has begun to prevail in society, and the arrival of peoples' cognitive revolution has been forecasted [1]. Teachers also have begun to concern with the behavior of learners, so-called digital kids or students, because the latest technologies and information have been introduced one after another at the present field of education. On the other hand, however, it is questionable whether those technologies and information are understood conveniently.

Practically, it seems difficult for teachers to find out teaching strategies with using appropriate digital devices. It is not clear what has changed since the digital transformation of society and what are the causes of the change and their effects, because the individual differences of cognitive mechanism have not been clarified yet.

Accordingly, we have developed the measurements of individual traits concerning with human information processing as a fundamental research so that teachers might be able to understand those students more and instruct them appropriately depending on the criteria for individual traits.

The experiments of this system have been conducted under conditions of presentations either sound voice or written letters. We have collected and analyzed various data, for instance, their replies and response time (decision-making time), after their listening or silent reading.

In the practical experiments of collaborative learning which have formed depending on students' individual traits, they have continuously had interactive communication among team members, even using text message through learning management system (LMS). Consequently, high-stake assessments of students have become significantly higher than those of previous students formed by traditional methods [2]. On the other hand, we have found that there were differences among teams when we have compared their results.

We have checked students' data concerning learning, for instance, their reports, text message among team members for subjects so that we can analyze those data with reaction time (decision-making time), and the so-called Big Data processing and analysis [3]. The purpose of this Big Data analysis is to clarify the cognitive mechanism during learning processes along with the hypothesis from the model of human information processing.

With results of Big Data analysis, we have found that there are two types of traits (visual type and auditory type) and they have proved the relation between those traits of information processing and learning effects in collaborative learning. For instance, members of an unsuccessful team have formed by the similar traits of information processing (three of four members), in contrast, those of a successful team has consisted of different traits.

Therefore, it is supposed that individual traits such as personality and cognitive style in terms of information processing might help teachers to make collective decisions, for example, instruction and forming team members. Consequently, we would like to propose the results of the measurements and analysis as criteria for teaching strategies so that teachers can make their decision for forming interactive team members from the prediction of students' behavior.

2. Previous study

We will need to refer to the previous study when we address to find the method on how to indicate changing cognitive mechanism caused by transforming to digital society. We have become able to communicate each other in real time from distance by exchanging mails, text message, and other social network system instead of audio media like telephone and videoconference system (**Figure 1**).

Figure 1.
Conceptual diagram of paper vs. digital.

It is supposed from reaction time that it is not the same information processing by communication media of sound voice and letters because the different organs perceive and input various kinds of information which are not transformed to the same digital encoding [4]. Though the same grammar, words, and meaning are consisted in one language, they are used by different media: sound voice and letters. From aspects of grammar and meaning, they are similar media; it might make their features clear when they are compared with decision time which is measured from beginning of presenting a short sentence by each media until individual decision-making of participants, like the comparison of familiarity between them in terms of words [5].

With regard to those learning effects, it is reported that comprehension is higher in reading the texts aloud than silent reading [6]. Moreover, it is reported the experiment, whether participants read letters silently changing them into sound or not, has shown that the former cases are better comprehensions than latter ones [7].

There is another question, however, whether this result is always right or not, because there are two kinds of orthographic in Japanese case, which are kana and kanji (a phonogram and an ideogram) [8, 9]. In the case of an ideogram, we understand the meaning as a symbol without changing to sound phonetically. From those reasons, it is assumed that the orthography like Japanese kanji might bring about individual differences of cognitive style regarding to information processing [10].

3. System

3.1 Model of information processing

According to previous study, the model of information processing for one short sentence is devised (**Figure 2**). At first, information about letters consisted of a sentence presented as a subject would be perceived (a: input), and then they would be conveyed and processed with a series of letters or a block of words in order to be comprehended (b: problem solving). Next, the meaning of the information would be decided (c: decision-making); then the result of the decision for meaning would be encoded to perception which would be processing next information continuously (d: feedback control). The procedure from (a) to (b), (b) to (c), (c) to (d) would be repeatedly until the problem of the subject would be solved and selected the answer (h: decision-making) and then output it (i).

While those processing might be continued repeatedly, another feedback control might transfer the meaning of words from (c) to higher brain functions

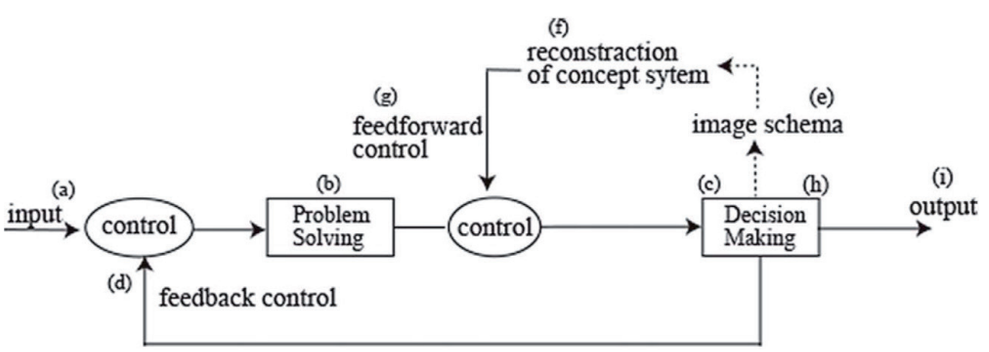

Figure 2.
Model of human information processing system.

by image schema (e) in order to confirm existing meaning or concept of those words or sentences. When those words or sentences are unknown for subjects, they might refer to existing concepts which were constructed by perception of other organs, and then their own new concepts would be reconstructed (f) before decision-making for meaning of words or sentences (c) and adjusted by feed-forward control (g).When you are citing sources, the citations should be set in a numbered format. All the references given in the list of references should be cited in the body of the text. Please set citations in square brackets keeping the below points in mind.

3.2 Hypothesis

There would be two types of traits hypothetically, visual type and auditory type, from the model of information processing. In the case of visual type, information might be mainly processing a circle of (a)→(b)→(c)→(d) repeatedly, and then finally decision-making would be done on (h)→(i) processing. On the other hand, in the case of auditory type, they might add another processing circle of (e)→(f)→(g). In this case, they might be referred to the existed concept which has been constructed by auditory information processing. From those viewpoints.

Hypothesis 1: In the case of auditory type, letters are supposed to be encoded to phonological sound. Consequently, the correlation coefficient between decision time and the number of words or duration of reading aloud (sound voice presentation) might be higher than those of visual type.

Hypothesis 2: The decision time of visual type is faster than those of auditory type because the former ones are supposed to not transform words from letters to sound.

In the next section, we will prove whether those hypotheses are correct or not by experiments.

4. Methods

Questionnaires of personality inventory for a psychological testing (YGPI) have been presented one by one as experimental subjects [Appendices 1 and 2]. YGPI consisted of 120 questionnaires with one short sentence each. Because of making the reliability of the test higher, those questionnaires are presented by reading aloud to subjects in order to fixed interval for selecting answers. It is important for a coefficient of confidence that subjects are brought about replying in time by effort because those regulations make their mental state similar.

For that reason, in the case of testing by paper and pencil, questionnaires of YGPI are not presented by written letters, but sound voice. On the other hand, in the case of testing on display, even presenting them by written letters are controlled the interval of the same condition as sound voice. Accordingly, when we have developed measuring system for cognitive traits of language information processing in terms of written letters, we decided to regulate time of presenting, along with each questionnaire by sound voice.

Participants are required to evaluate their behavior in everyday life whether the questionnaire is the same or not comparing with those of themselves and chose the answer among “yes,” “no,” and “either one” within 3 s after finishing the presentation of a questionnaire. As an instruction of testing, participants are also required to reply quickly without deliberating on making decision in order to prevent from no choice within the time.

4.1 Pilot

4.1.1 Purpose of pilot experiments

The aim of pilot experiments is to find out what have been changed in digital society from cognitive aspects in education. Along with this purpose, experiments and analysis are planned. In the field of education, we are able to choose media, such as sound voice or written letters, using digital materials, for instance, digital textbook and electronic blackboard. Accordingly, we have planned experiments for two kinds of comparison between sheet (paper)/PC and sound voice/letters.

4.1.2 Experiment 1

(1) Subjects: Three kinds of experiments (presenting questionnaires by sound voice and reply on the sheet (OCR), presenting questionnaires by sound voice and reply on display, and presenting questionnaires by written letters and reply on display). (2) Participants: 29 high school students of the first grade (male 13, female 16).

4.1.3 Experiment 2

(1) Subjects: Three kinds of experiments (presenting questionnaires by written letters and reply on the sheet (OCR), presenting questionnaires by written letters and reply on display, and presenting questionnaires by sound voice and reply on display). (2) Participants: 7 university students (male 5, female 2).

4.2 Preliminary experiments

4.2.1 Purpose of preliminary experiments

The purpose of preliminary experiments is to validate reproducibility concerning with the calibration of measuring system, the method of testing, and the results of analysis (comparison between visual type and auditory type).

4.2.2 Subjects of preliminary experiment

Under the same quality and conditions, experiments of presenting questionnaires by sound voice or written letters and replying on display have planned twice with counterbalance of the order.

4.2.3 Participants

Students of the same university, 28 females of freshmen.

4.2.4 Duration

From January to March in 2015.

4.3 Practical experiment

4.3.1 Purpose of practical experiment

The aim of a practical experiment is to examine the validity of criteria for traits of cognitive style in terms of information processing.

4.3.2 Participants

Students of the same university, 98 females of freshmen.

4.3.3 Method

Before starting classes, two kinds of testing, sound voice and letters, have been planned along with the method of preliminary experiments. The members of teams will be decided for collaborative learning depending on their personality which is measured by sound voice experiment. The observations in class will be recorded on their learning process. The interaction on LMS among members of their team will be also observed and recorded. The other data, for instance, results of performance (high-stake assessments) and reports (low-stake assessments), decision time of YGPI, and so on, will be gathered.

4.3.4 Duration

From April in 2015 to March in 2016.

4.4 Methods of analysis

The purpose of these analyses is to make traits of cognitive type in terms of information processing clear by comparing correlation between the number of words and duration of presenting sound voice (**Table 1**) and decision time.

4.4.1 Pilot

Each average of decision time will be calculated for every number of words; those figures will be shown by graphs. Next, different media such as paper, digital, sound voice, and letters have been compared.

4.4.2 Preliminary experiments

Each average of decision time will be calculated for every number of words; those figures will be shown by graphs. Next, it will be compared by the same media between first and second experiment. And then, it will compare the strength of correlations and variance by standard deviations.

The criteria, which are decided by the correlation coefficient between duration of presenting sound voice and decision time (**Table 2**), will decide the type—whether visual or auditory. Then, the decision time will be compared between those two types.

the Number of Words in Questionnaires	1	2	3	4	5	6	7
Frequency (the Number of Qusetionnaires)	1	12	13	27	25	30	12
Avarge Duration of Presenting Sound Voive (sec.)	0.76	1.01	1.38	1.79	2.18	2.49	2.74

Table 1.
The number of words and its frequency and duration.

	Media	Sound (sheet)	Sound (display)	Letters (display)	the Number of Words	Duration of Sound Voice
Comparison	Sound (sheet)	—	0.39	0.15	0.35	0.43
	Sound (display)	0.39	—	0.34	0.49	0.58
	Letters (display)	0.15	0.34	—	0.17	0.18
	the Number of Words	0.35	0.49	0.17	—	0.86
	Duration of Sound Voice	0.43	0.58	0.18	0.86	—

Table 2.
Correlation coefficient (pilot experiments 1).

4.4.3 Practical experiments

After gathering data of 98 participants by measuring decision time, they will be divided into visual or auditory type depending on the criteria which is decided by the preliminary experiment.

And then, whether this criteria of two types are verified or not by comparing results of decision time between preliminary and practical experiments.

Moreover, the results of students' performance practically will be compared by two types between first and second semesters.

5. Results

5.1 Results of pilot

1. Comparison between digital and paper materials

The average of decision time by digital was faster than those of paper (**Figures 3** and **4**), and the correlations with the number of words of digital were stronger than those of paper (**Tables 2** and **3**).

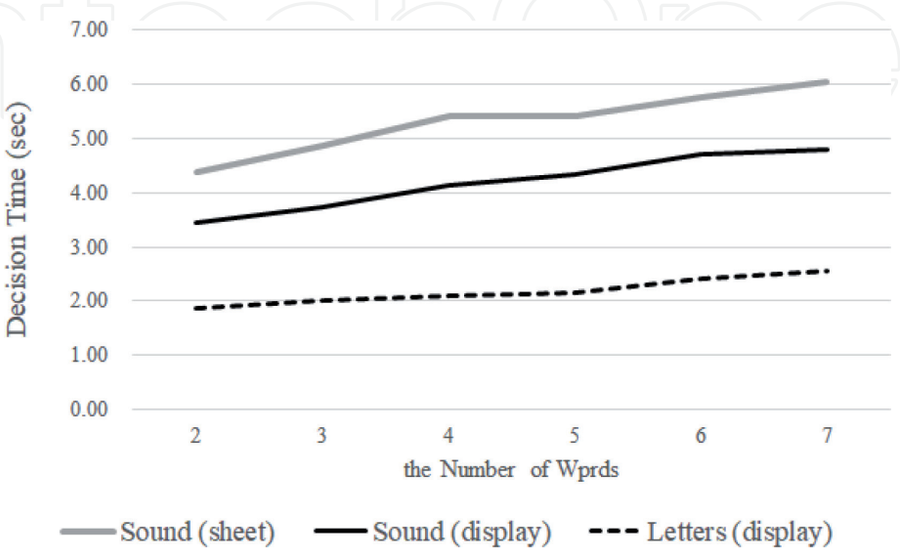

Figure 3.
Comparison of decision time during testing with paper or digital presented questionnaires by sound voice (paper or display) and leteers on display.

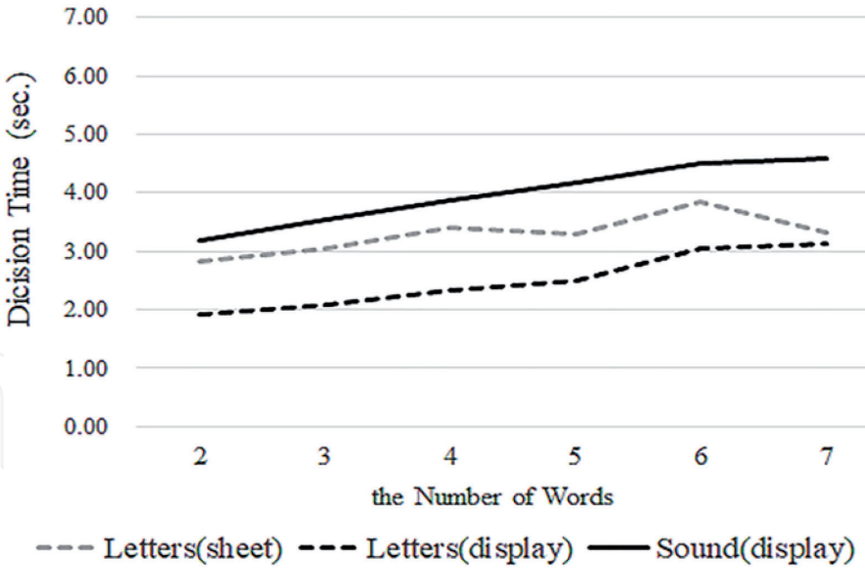

Figure 4.
Comparison of decision time during testing with paper and digital presented quessionnaires by letters on paper or display and sound voice with digital.

Media	Letters (sheet)	Letters (display)	Sound (display)	the Number of Words	Duration of Sound Voice
Letters(sheet)	—	0.17	0.16	0.13	0.16
Letters(display)	0.17	—	0.39	0.31	0.30
Sound(display)	0.16	0.39	—	0.53	0.60

Table 3.
Correlation coefficient (pilot experiments 2).

2. Comparison between sound voice and letters media

The average of decision time of sound voice presentation was longer than those of letters (**Figure 4**).

5.2 Results of preliminary experiment

1. Verifying reproducibility

From the results of presentation by sound voice, there were no differences observed in terms of the average of decision time for each number of words between first and second experiment, in addition to correlation coefficient and dispersion (**Figures 5** and **6**). In the case of letter presentation, the results of comparison between the first and the second experiment were similar to those of sound voice, but the second average of decision time was faster than the first ones (**Figure 6**).

It is supposed the dispersion of decision time of letter presentation is larger and caused individual differences when comparing with sound voice presentation.

2. Comparison between visual and auditory type

There was no difference between visual and auditory type regarding the average of decision time and correlation coefficients (**Figure 7**).

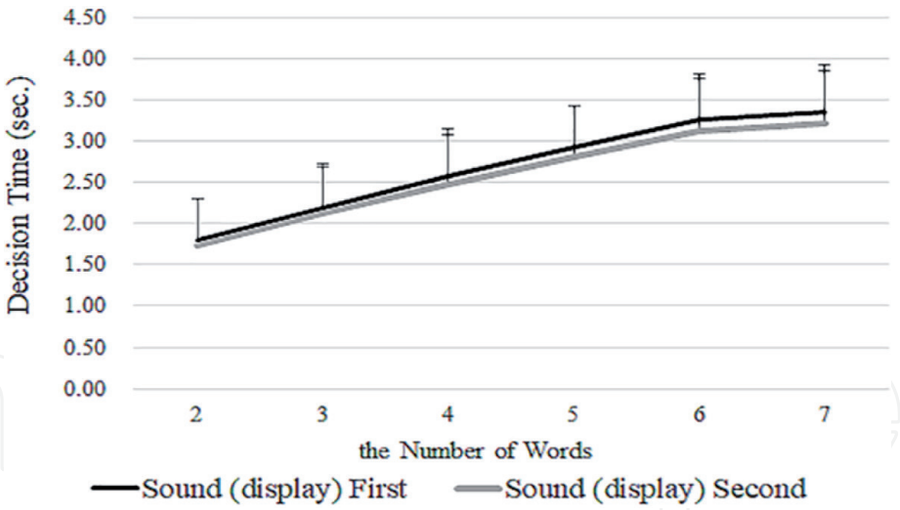

Figure 5.
Comparison of decision time between the first and the second by sound voice.

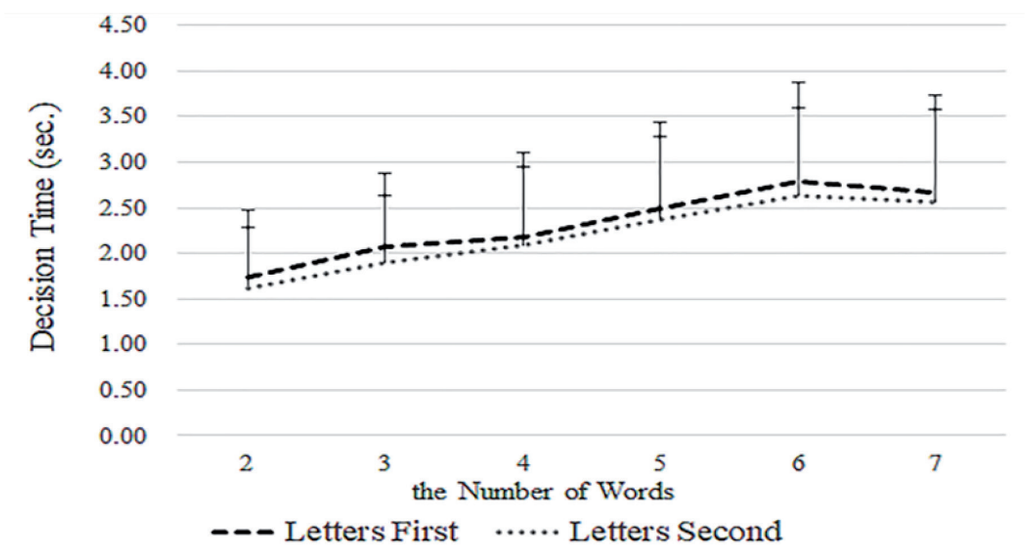

Figure 6.
Comparison of decision time between the first and the second by letters.

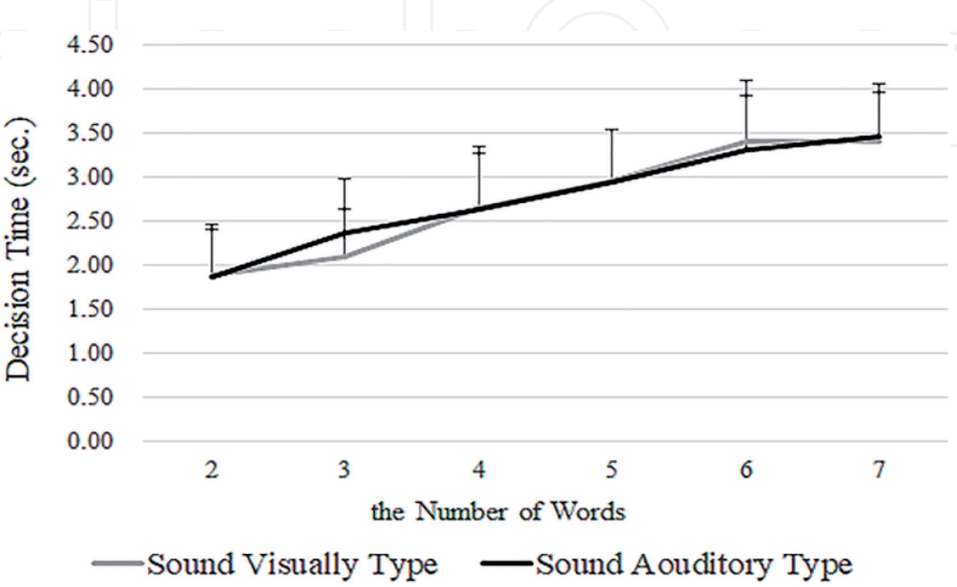

Figure 7.
Comparison of decision time between visual and auditory type by sound voice.

In the presentation of letter case, the average of decision time for visual type was faster than auditory type (**Figure 8**, **Table 4**).

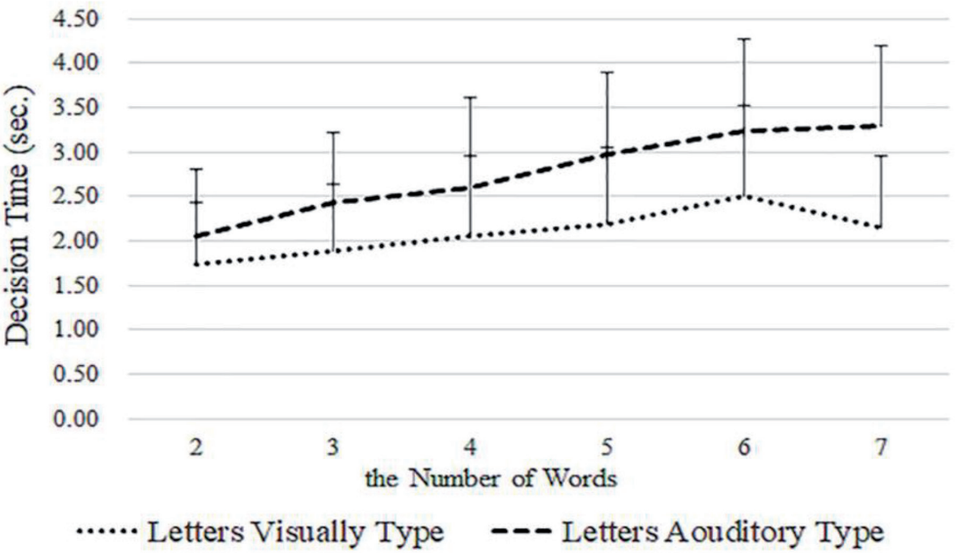

Figure 8.
Comparison of decision time between visual and auditory type presented by letters.

Cognitive Style	Correlation Coefficient
Visual Type	r <0.3
Auditory Type	r >0.5
Intermidiate Type	0.3 =< r <=0.5

Table 4.
Criteria of cognitive style for information processing.

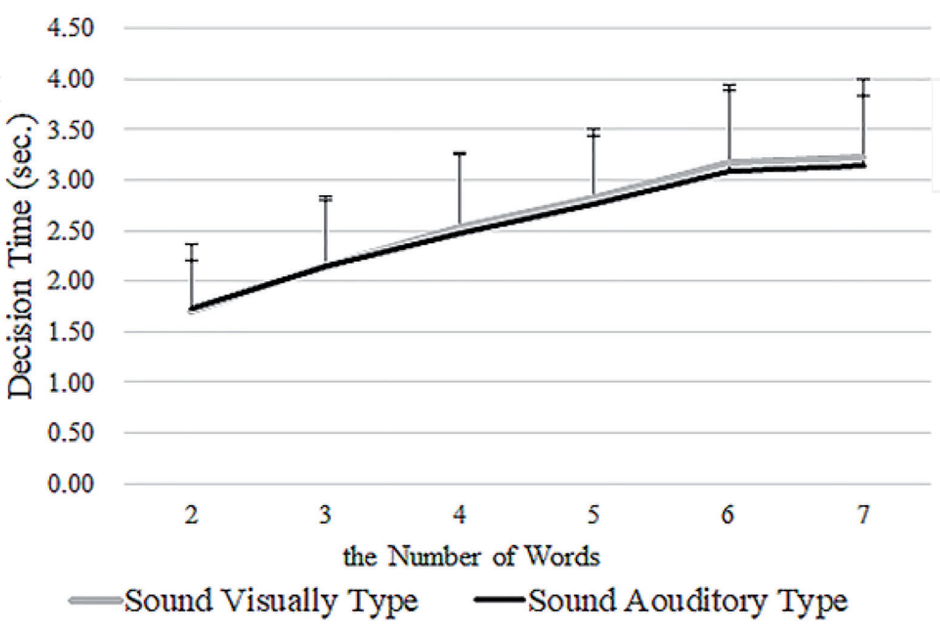

Figure 9.
Comparison of decision time between visual and auditory type presented by sound voice (practical experiment).

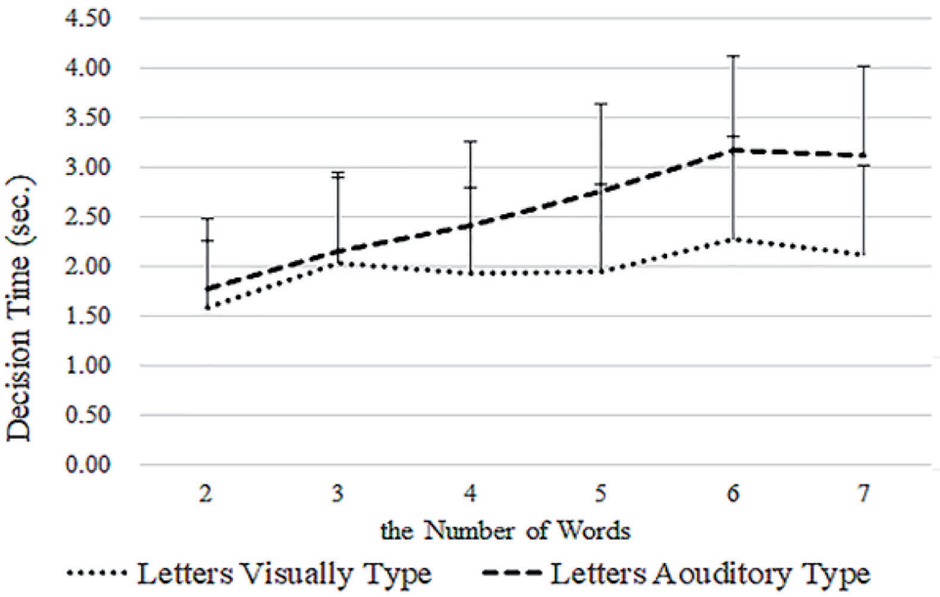

Figure 10.
Comparison of decision time between visual and auditory type presented by letters (practical experiment).

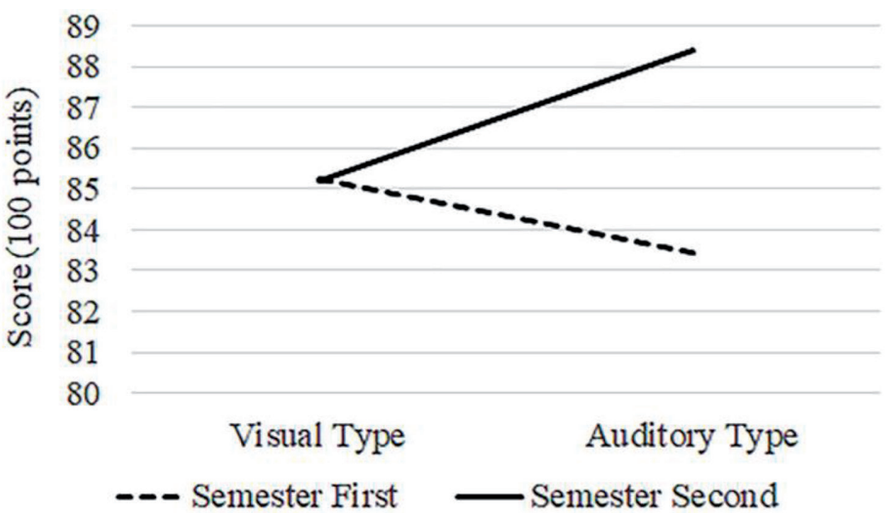

Figure 11.
Comparison of students' performance the first and second semester between visual and auditory type.

Because there were observed similar results between the first and the second experiment, it is supposed the reproducibility of measurements, method of analysis, and the criteria are verified.

5.3 Results of practical experiment

There were 12 students of visual type and 31 students of auditory type, according to the criteria of cognitive type in terms of information processing. There were no differences of the results in sound voice presentation between types regarding to the average of decision time depending on the number of words (**Figure 9**). In contrast, there were differences of the results in letter presentation between two types, regarding the average of decision time and the strength of correlation between decision time and the number of words (**Figure 10**). The tendency of a reciprocation between visual and auditory type concerning with the results of students' performance between the first and the second semester (**Figure 11**) was observed.

6. Discussion

6.1 What has been changed in digital society?

We have implemented the comparative experiments comparing paper and digital materials based on model of information processing (**Figure 2**). The results of measurements of individual decision time by digital materials were observed faster than those of paper. It was supposed to be caused more strongly by time constraints of digital materials than paper ones. In other words, it seems that the periods of time for decision-making were more unrestricted in condition of paper materials than digital ones. In the paper material case, participants were free to fill in their answers on sheets after the next presentation of questionnaire has been begun; on the other hand, in the digital material case, the display has already moved to the next page; then they were not able to reply their previous answer. From this reason, it was supposed the decision time by paper materials is longer than digital ones.

Especially in the presentation of letter case, participants were free to read silent questionnaires on the sheet freely, and then their decision time has become longer than others. In the PC case, each questionnaire is presented on display, and when the next questionnaire is presented, the display is moved to the next page at the same time by automatic migration from the program. From those reasons, in the letter presentation case, participants are not allowed to read previous questionnaires again after the display moved to the next page. It seems that the correlation between decision time and the number of words in digital materials case becomes higher than those of paper.

Through the basis of these results, there is more strict time in the digital material case, and this condition might have effects on decision time. In other words, participants might have been affected on their mental state in the digital material condition because they might feel that they need to decide strictly faster than paper ones. From those results, time bar has been added on display so that participants can feel more comfortable reducing their anxiety.

6.2 Toward clarifying information processing

Preliminary experiments have been conducted to examine the reproducibility for calibration of measurements toward a practical experiment. It is supposed that the reproducibility has been recognized because there were little differences in results regarding to the average of decision time between the first and the second experiments. The correlation coefficient of decision time with period of reading aloud (presented questionnaires by sound voice), comparing between Experiment 1 and Experiment 2, were similar without significantly differences. Concerning with the standard deviation of decision time, the case of letter presentation has been larger than sound voice case. It means that there exist individual differences in traits of cognitive style regarding to information processing.

Accordingly, the criteria of visual and auditory type have been decided provisionally by measurement of decision time depending on correlation coefficients with duration of sound voice presentation time. The results of the examination showed that there were no differences of decision time of sound voice presentation; on the other hand, in the case of letter presentation, the average of decision time for visual type is significantly faster than those of auditory type. Moreover, in the case of auditory type, the correlation coefficients between decision time and duration of sound voice presentation have been higher than visual type. For those results, it is supposed the hypothesis by the model of information processing is examined and proved (**Figure 2**).

6.3 Effects of changing

Those results of preliminary experiments have proved the validity by practical experiments with 98 participants (**Figures 9** and **10**). The indicator of learning effectiveness by high-stake assessment on their performance has shown the tendency of two-factor interaction between visual type and auditory type. From the interpretation on the model of information processing (**Figure 2**), it is supposed that there might be more opportunities for auditory type to reconstruct their concepts from various information when they are learning than visual type.

6.4 Teaching strategies

We have studied about the optimization of forming team members (collective decision-making) by personality (individual decision-making) as teaching strategies [11]. In this case, it is presumed that the learning effect has been improved by interactive communication among team members smoothly, comparing with traditional method of team forming which had decided by order of a student number. On the other hand, when the team members were decided by their personality in order to improve their performance in practical class, there were successful or unsuccessful teams. Looking at cognitive types, the latter has involved the same type of traits (three of four) with regard to the information processing but not personality. From this viewpoint, it is suggested that the method of optimization of forming team members might have been better with criteria for traits of cognitive type in terms of information processing in order to improve learning effectiveness.

7. Conclusion

In this paper, we have conducted experiments toward clarifying human information processing and examined the influence of digital materials in education. Moreover, the criteria for individual differences of information processing have indicated the impact on learning effectiveness. Consequently, the criteria of students' individual traits might help teachers make their plans, such as teaching strategies. It is also supposed that the appropriateness has been proved by the results of analyzing various data concerning with learning, for instance, students' performance, reports, and observation in class. On the whole:

1. What have been changed by digital materials, and what are the causes and how the effects have prevailed?

In education, the materials have been transformed from paper to digital. From the results of our research, it is suggested that the time limitation of digital materials might be strict more strongly than paper and it might have caused their anxiety for learners carrying their mental baggage.

2. There have been increasing opportunities of communication by text media like SNS in real time.

From the results of those experiments, it is assumed that the learning by digital materials with texts might have been caused by clearing individual differences of cognitive style concerning with information processing and effect on learning.

3. From the results of Big Data analyzing, it was assumed that the criteria for traits of cognitive style in terms of information processing by letters might suggest teaching strategies.

A. Appendix 1

the Number of Words	Number	Questionnaires (Letters)	Questionnires (Sound)
2	1	無口である	Mukuch de Aru
	2	感情的である	Kanjyouteki de Aru
	3	心配性である	Sinpaisyo de Aru
3	4	用心深いたちである	Youjijnbukai Tachi de Aru
	5	気が変わりやすい	Ki ga Kawari Yasui
	6	人のあつかいがうまい	Hito no Atukai ga Umai
4	7	自分はいつも逼がわるい	Jibun ha Atsukai ga Umai
	8	たびたび考えこむくせがある	Jibun ha Knagaekom Kuse ga Aru
	9	気持ちを顔にあらわしやすい	Kimochi wo Kao ni Arwasi Yasui
5	10	色々違う仕事がしてみたい	Iroiro Chigau Shigoto ga Shitemitai
	11	新しい友達はなかなかできない	Attarashii Tomodachi ha Nakanaka Ddekinai
	12	色々な世間の活動がしてみたい	Iroirona Seken no Kadudo ga Shite Mitai
6	13	色々な人と知り合いになるのが楽しみである	Iroirona Hito to Shiriai ni Naru noga Tanoshimi de Aru
	14	人は私を十分認めてくれない	Hito ha Watashi wo Jyubun Mitomete Kure Nai
	15	会話の最中にふと考えこむくせがある	Kiwa no Saichu ni Huto Kangaekomu kuse ga Aru
7	16	理由もなく不安になることが時々ある	Wake mo Naku Huan ni Naru Koto ga Tokidok Aru
	17	実行する前に考えなおしてみることが多い	Jikko Suru Mae ni Kangae Naosite Mirukot ga Oi.
	18	なかなか決心がつかず機会を失うことが多い	Nakanak Kessin ga Tuka zu Kikai wo Usinau Koto ga Oi

B. Appendix 2

the Number of Words	Number	questionnaires (in English)
2	1	I am a reticent person.
	2	I am a sentimental person.
	3	I am a worrier.
3	4	I am an extremely cautious person.
	5	I am capricious.
	6	I am good at dealing with people.
4	7	I am always unluky.
	8	I sometimes tend to think deeply.
	9	I am easy to betray my emotion.
5	10	I would like to do various kinds of jobs.
	11	It is difficult for me to make new frinds.
	12	I would like to be extremely acitve in variety of wolrd.
6	13	I am pleasure of meeting with a lot of people.
	14	People would not accept me adequetly.
	15	I am prove to think deeply during converstion.
7	16	Sometimes I become nervous without any reasons.
	17	I have frequetnly reconsidered before a plan.
	18	I have often lost chances because I could not decide immediately.

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