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Model of Creative Thinking Process on Analysis of Handwriting by Digital Pen

Kenshin Ikegami, Yukio Ohsawa

Department of Systems Innovation, School of Engineering, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo, Japan, kenchin110100@gmail.com, ohsawa@sys.t.u-tokyo.ac.jp

ABSTRACT

In order to perceive infrequent events as hints for new ideas, it is desired to know and model the process of creating and refining ideas. In this paper, we address this modeling problem experimentally. Firstly, we focus on the relation between thinking time and writing time in handwriting. We observe two types of patterns; one group takes longer time in thinking and shorter in writing, the other takes longer in writing and shorter in thinking. The group having spends longer in writing has shorter time span from one sentence to another than the other group. Backtracking, i.e., the event that participants return back to their former sheet and modify opinions, is observed more often in the group of longer writing than the other group. In addition, participants in this backtracking group gets higher scores for their ideas on sheets than those in the no-backtracking group. We propose a model of creative thinking by applying Operations of Structure of Intellect. It is inferred that the group of longer writing conducts a series of thinking flow, including divergent thinking, convergent thinking and evaluation. In contrast, the group of longer thinking tends to conduct the two different thinking flow: divergent thinking and evaluation; convergent thinking and evaluation. For making creative ideas, we conduct divergent thinking without evaluation and created a large number of ideas. We conclude that the rotations of divergent thinking, convergent thinking and evaluation increase the frequency of "backtracking" and make the ideas more logical ones.

TYPE OF PAPER AND KEYWORDS

Regular research paper: *cognition, handwriting, creative thinking, innovators marketplace, digital pen, data market*

1 INTRODUCTION

In this part, we first explain the importance of modeling creative thinking process for the Market of Data in Section 1.1, and then we introduce how thinking process affects writing process in Section 1.2. Finally, we summarize the contributions of this article in Section 1.3.

1.1 Necessity of Modeling Creative Thinking Process for Data Market

There is large amount of information stored as data in computers all over the world because of the development of information technologies, e.g. social networking service. This large amount of information is called *Big Data*. Although many companies try to

use Big Data for making strategies in businesses including marketing, it does not go well because of the problems that the market of data (note: this differs from data of market) is undeveloped and that there are only a small number of data scientists who deals with Big Data to meet requirements of their clients. Innovators Marketplace on Data Jacket (IMDJ) is an approach to realize the market of data [14]. In IMDJ, participants think about the way to combine and/or use datasets, by communicating each other. Its important point is that the interpretation of data by human(s) is incorporated into the process of knowledge discovery and data mining.

This is especially essential, in case infrequent events should not be removed as noise in the early stages, as they were made by the conventional technique of data mining. Ideas created in IMDJ are put into effect and refined in Action Planning [10]. The ideas of each participant then are scored when they present their ideas to the others. In this way, ideas of how to use datasets should be created and validated in the process of humans' subjective thought, interpretation, and communication. In other words, we have to progress with designing the market of data and with investigating humans' creative thinking process side by side. However, there have been few studies about how people think and what is the best way to think when they combine some datasets and generate ideas.

1.2 Meaning of Handwriting Using Pen and Paper

Some people take notes not by handwriting on a paper but typing on a computer because digital devices like laptops have made remarkable progress. However, there is a difference between learning by handwriting and by typing [7]. Mueller & Oppenheimer [7] analyzed the difference of learning between by handwriting and by typing. In their study, participants viewing TED Talks[1] took notes by handwriting or by typing. After viewing, they were asked two types of questions and their answers were scored: factual-recall questions (e.g. "Approximately how many years ago did the Indus civilization exist?"); conceptual application questions (e.g. "How do Japan and Sweden differ in their approaches to equality within their societies?").

That is to say, factual recall questions tested immediate recall and measured exclusively factual knowledge, and conceptual application questions tested conceptual understanding of whole knowledge. Mueller & Oppenheimer [7] compared the mean scores of the handwriting group and typing group: the mean score of factual-recall questions were not different significantly between the handwriting group and the typing group; the handwriting group got higher scores than the typing group for conceptual-application questions.

From this result, handwriting process increased the human thinking ability, especially memory. Ikeda & Ohsawa [3] analyzed the insight process (which was the analogical thinking to make new ideas) for concept creation using handwriting features. In their study, eight participants, who are engineers of nuclear energy, used the digital pen and took notes about ideas and suggestions in the conference. After the conference, Ikeda & Ohsawa [3] analyzed the relations between insight process and pen speed recorded in the digital pen. As a result, when new created concepts were written in explicit words, the pen speed was getting faster than when unconceptualized tacit ideas were written. That means what to think has an effect on the writing way.

1.3 Contributions of This Paper

In this paper, we propose a model of creative thinking process by analyzing handwriting features for the understanding of human's cognitive process to combine data and create/refine concepts and ideas. Furthermore, we analyze the relations between the handwriting features and the scores of the ideas which are made from the combinations of data, and then we propose a method for creating ideas based on the combinations of data.

2 RELATED WORK

There are two main types of related work: Innovators Marketplace on Data Jackets and Action Planning.

2.1 Innovators Marketplace on Data Jackets

In Innovators Marketplace on Data Jackets (IMDJ), existent data are digested in Data Jackets (DJ). The owner of data or anyone who knows about the data first fills out the title, summary and the format of a dataset in a Data Jacket and publishes it to the public. The owners may be reluctant to publish existent data to the public because there are such problems as ownership and privacy. On the other hand, Data Jackets are easier to publish to the public than the content of data because the provider of Data Jackets can skip confidential variables in writing Data Jackets. Furthermore, by publishing the Data Jackets, other people rather than the provider become enabled to examine how the data could be used, and this is a key point for scoring the use-value of the data.

[1] http://www.ted.com/talks

In IMDJ, correlations among Data Jackets are visualized (using KeyGraph [13] so far). Using this visualization map, participants participate in the workshop, resemble the market of data, where players are divided into two roles as described in Listing 1.

Listing 1: Two roles in IMDJ

(1) Inventors: they create ideas by combining the datasets that are linked in the map.

(2) Consumers: they evaluate, criticize and buy the ideas created by inventors.

In this workshop, participants could express requirements and present data-based solutions, i.e., ideas for satisfying the requirements by use of data, and discuss how to use datasets and score the use-value of data.

2.2 Action Planning

Action Planning is a method for creating strategic scenarios based on simple ideas [10]. The strategic scenario means a series of information about events and actions, which provides candidates of decisions. By communicating current preconditions, causality and relations between elements (In this paper, we defined the word of "element" as the knowledge that is necessary for realizing strategic scenarios), participants discover strategic scenarios as solutions that should be considered for satisfying requirements. To solve a problem and to further refine a solution, items on the sheets of Action Planning give the direction of discussion and the frame of thoughts of the group.

Action Planning mainly consists of three phases, which are presented in Listing 2.

Listing 2: Three phases of Action Planning

(1) Requirement analysis: Participants analyze the requirement of consumers for interpreting latent or potential requirements from given requirements. Then participants devise a solution for satisfying the obtained latent requirement if it differs from the given requirement.

(2) Externalizing elements: Participants externalize concrete elements such as "resources", "stakeholders", "target consumers", "time span" for realizing the solution.

(3) Serializing elements: Participants serialize the externalized elements in time series and examine the validity of the solution.

3 EXPERIMENT I

In this section, we present our first experimental study, Experiment I. Section 3.1, 3.2 and 3.3 shows the details of this experiment and the method of calculation. We explain the analysis method and result of this experiment in Section 3.4.

3.1 Participants

Fifty participants participate in this experiment. They are first or second-year undergraduate students of Arts and Sciences in the University of Tokyo. We divide them into 12 groups with 4 or 5 participants in each group.

3.2 Experimental Content

All the 50 participants had created ideas for making a better society in Innovators Marketplace on Data Jackets (IMDJ) one week before this experiment. We select 12 ideas by a majority vote and assign each group one idea at random. Each group select one clerk and the 12 clerks from 12 groups write down thoughts and opinions of each group on sheets. We use digital pens (made by HITACHI Maxell, DP-201). This digital pen is 160 millimeters in length, 18 millimeters in diameter and 30 grams in weight. The digital pen has a built-in camera and records the XY-coordinates and time when a clerk writes on a specific sheet.

In this experiment, each group digest and write members' ideas on three sheets. The three sheets have different formats corresponding to the way of writing at each step. Participants first exchange their ideas and discussed, e.g. their purposes in the topic. The clerks then write down the ideas and purposes on a sheet, Sheet 1. This sheet is 105 by 148 millimeters, and the content is put in space 49 by 137 millimeters. After filling in Sheet 1, each group conducts Action Planning on Sheet 2, which was 297 by 210 millimeters.

In this experiment, participants conducts two phases of Action Planning: externalizing elements and serializing elements. The items of Sheet 2 are shown in Listing 3.

Listing 3: The items of Sheet 2

```
(1) Elements to be externalized:
    a) Target users of an idea
    b) External collaborators of
       one's working institute
    c) External competitors
    d) Internal collaborators
    e) Internal competitor
    f) Necessary techniques for
       realization
    g) Necessary time for
       realization
    h) Necessary materials for
       realization
    i) Budget
    j) Necessary datasets
(2) Serializing elements in 4
    aspects:
    a) Contents
    b) Budget
    c) Necessary resources
    d) Stakeholders
(3) Goal of realization of the
    solution
```

We show the appearance of Sheet 1 in Figure 1 and that of Sheet 2 in Figure 2. The participants externalize 10 elements as given in Listing 3 (each of the 10 elements was written in the space 35 by 28 millimeters in Figure 2), serialize the elements in 4 aspects as given in Listing 3 (Space for these aspects were 30 by 180 millimeters), decide the goal of realization of ideas (the space was 26 by 180 millimeters) and create strategic scenarios. After filling in Sheet 2 (participants did not have to fill in all the elements), each group writes down ideas and the purposes of the ideas in Sheet 3, which had the same format and size as Sheet 1.

All the 12 groups discuss and write down their thoughts and opinions on Sheet 1, Sheet 2, and Sheet 3 in 75 minutes. Each of the 12 groups has 3 sheets and thus 36 sheets are made in total. Digital pens of 2 groups does not record accurate data due to the misuse of the pen by members. Therefore, we analyze the sheets of the other 10 groups and thus 30 sheets in total.

3.3 Writing Time and Thinking Time

The digital pen records three types of values, XY-coordinates *"x"* and *"y"* and time *"t"* when a clerk writes down anything.

When taking notes, participants may stop writing when they decide what to write and how to express (e.g. recalling about how to spell "KANJI"). Therefore, in

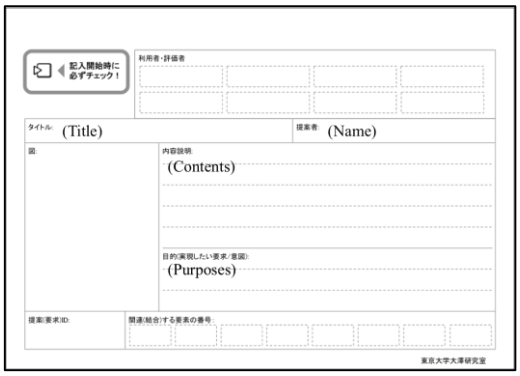

Figure 1: Appearance of Sheet 1

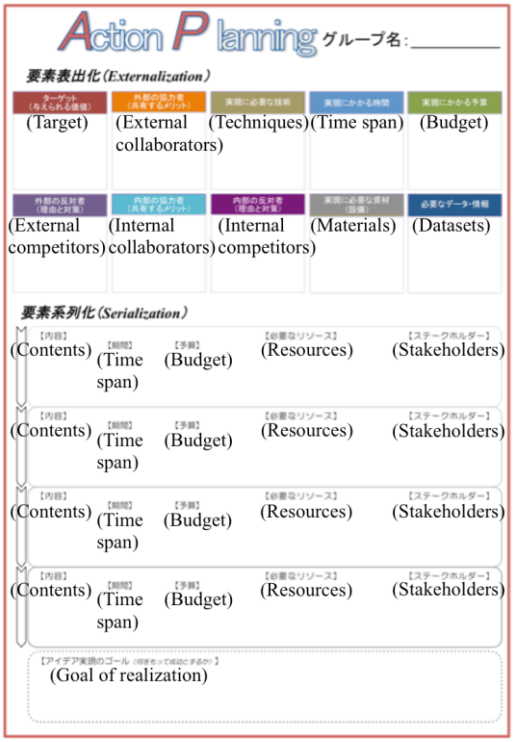

Figure 2: Appearance of Sheet 2

the experiment, we calculate two variables: the writing time *"wt"* and the thinking time *"tt"*. Each of the two variables is derived from following Equation (1) and (2):

$$wt = \sum_i (t_i - t_{i-1}) \ (if\ t_i - t_{i-1} < 5\ seconds) \quad (1)$$

$$tt = \sum_i (t_i - t_{i-1}) \ (if\ t_i - t_{i-1} > 5\ seconds) \quad (2)$$

where $i \in N$, i.e. natural number, and t is the time of that a participant writes. Writing time *"wt"* is the time in which clerks write without pausing more than 5 seconds. Thinking time *"tt"* is the sum of pauses of more than 5 seconds.

In this following, we explain why we use 5-seconds pause as a threshold. In order to decide an appropriate pausing threshold, we record the writing and thinking of participants using different pausing time. Figure 3 presents an experimental result: three types of appearance of one sentence, which is divided by 1-second pausing, by 5 seconds pausing and by 10 seconds pausing.

If we use 1 second as pausing threshold, the sentence was divide into 14 segments. When suing 5 seconds as pausing threshold, the sentence is divided into 5 segments. If 10 seconds are chose as the pausing threshold, the sentence is not divided into any segments and this means that the participator never stop writing. From the experimental result, we consider that participants take over 5 seconds pausing when they think what to write. Therefore, it is suitable to measure writing time and thinking time using 5 seconds as pausing threshold in this research.

In the experiment, we recorded not only the literature length, but also the extra line like in Figure 4.

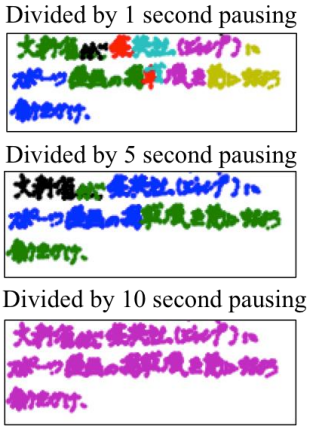

Figure 3: One sentence that is divided by 1 second, 5 seconds and 10 seconds pausing (The colors represent different sections of writing time)

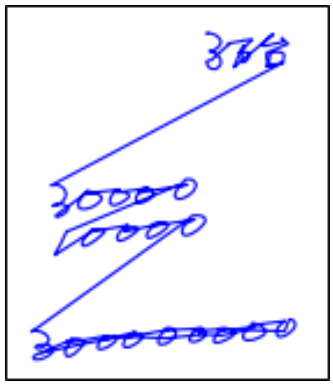

Figure 4: Example of literatures' length that is recorded in digital pen

The literature length means the sequence of points which is recorded in digital pen. We select the summed writing time "*wt*", not the sum of literature length, as the feature of time amount for writing. There are two reasons for this. First, if we select the sum of literature length, it depends on the size of the literature, significantly reflecting a clerk's personality rather than his interest of effort in writing. The second reason is that the literature length may include the movement in the empty spaces between sentences like Figure 4. From these reasons, we select the writing time as the criteria of the amount of writing.

3.4 Analysis of Experiment I

3.4.1 Method

We analyze the relations between writing time "wt" and thinking time "tt" of each sheet (Sheet 1, 2 and 3). We perform the linear regression analysis of the relations between "wt" and "tt" using the following Equation (3).

$$wt_{ij} = \beta_i + \alpha_i tt_{ij} + \varepsilon, \varepsilon \sim N(0, \sigma^2) \qquad (3)$$

Where i is the numbers of sheets (1, 2 or 3), j is the numbers of samples (1~10), α_i and β_i are arbitrary numbers, ε is an error range and σ is the valiance of error range.

3.4.2 Result

Let us show the plots of each of 10 groups of the relations between thinking time "tt" and writing time "wt" of Sheet 1, 2 and 3, in Figure 5. Here we find thinking time "tt_1" and writing time "wt_1" in Sheet 1 has a strong positive correlation (the correlation rate $r = 0.79$, t-value $t = 3.70$, the flexibility $df = 8$, and p-value $p = 0.006 < 0.0$). Linear regression analysis shows following Equation (4).

$$wt_{1j} = 76.26 + 0.13 tt_{1j} + \varepsilon, \varepsilon \sim N(0, \sigma^2) \qquad (4)$$

This analysis shows that the more time participants spend in thinking, the more time participants need in writing. On the other hand, thinking time "tt_2" and writing time "wt_2" in Sheet 2 has an intermediate negative correlation ($r = -0.64$, $t = -2.32, df = 8$, $p = 0.048 < 0.05$). Linear regression analysis shows following Equation (5).

$$wt_{2j} = 611.91 - 0.28 tt_{2j} + \varepsilon, \varepsilon \sim N(0, \sigma^2) \qquad (5)$$

In Sheet 3, the thinking time "tt_3" and writing time "wt_3" have an intermediate positive correlation ($r =$

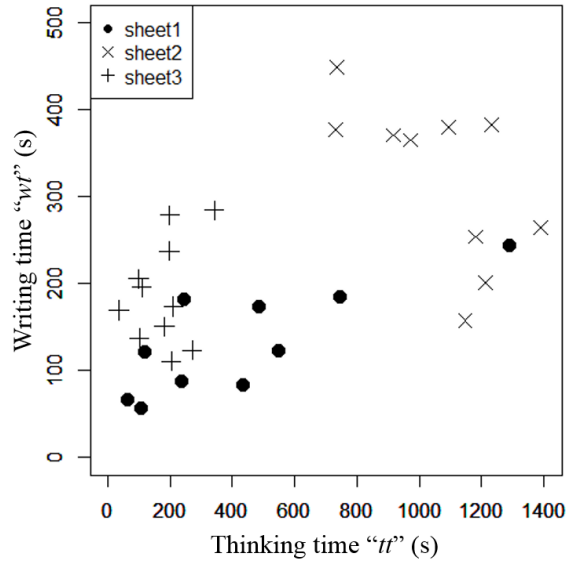

Figure 5: Relations between the thinking time "*tt*" and writing time "*wt*"

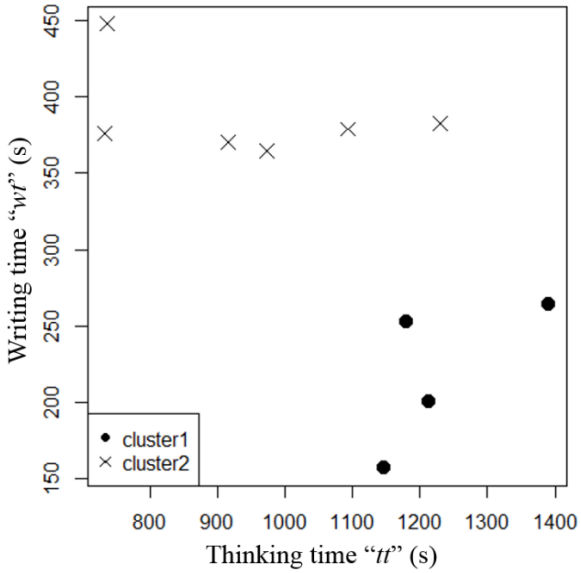

Figure 6: Two clusters of handwriting features in Sheet 2

0.47, $t = 1.52$, $df = 8$, $p = 0.17 > 0.1$), but the positive correlation was not the significance value if we consider its p-value. The p-value is statistically not meaningful because it is over 0.1.

The ways to write in Sheet 1 and in Sheet 2 are the opposite in two senses: On the one hand, there is a positive correlation between thinking time "*tt*" and writing time "*wt*" for Sheet 1; on the other hand, there is a negative correlation between them for Sheet 2. We will discuss the reason in Section 5. We hypothesize that this result is caused by the difference on the ways of the thinking process.

Figure 6 shows that the handwriting features of the 10 groups in Sheet 2 could be divided into two clusters. 4 groups in Cluster 1 tends to spend more time in thinking and less time in writing. On the other hand, the other 6 groups in Cluster 2 tends to spend more time in writing and less time in thinking.

4 EXPERIMENT II

In the last section, as a result of analysis of Experiment I, we conclude that there are two different ways of creative thinking process in Sheet 2, Action Planning. To go into details of this difference, we conduct a further experiment, Experiment II, in this section. Furthermore, the Action Planning sheets, which we use in Experiment I, has two different thinking phase; Externalizing elements and Serializing elements. We hypothesize that the two different thinking phases caused the two types of patterns: one type takes longer time in thinking and shorter time in writing; the other takes longer in writing and shorter in thinking. For this reason, we divide the two different thinking phases into two sheets. In addition, we examine the relationship between the way of thinking and the scores of ideas, which are the quantitative evaluation of ideas.

4.1 Participants

Twenty-nine participants take part in Experiment II. They are undergraduate students in Chiba University. We divide them into 9 groups (Group 6 and Group 7 each had 4 participants and the other groups each had 3 participants).

4.2 Experimental Content

All the 29 participants had created ideas for making the good Olympic in Tokyo one week before Experiment II. Each group select one idea and selected one clerk, who use the digital pen and wrote down thoughts and opinions on sheets, similarly to Experiment I. Each group conduct Action Planning by writing two sheets, Sheet 2-1 and Sheet 2-2.

Sheet 2-1 was 297 by 210 millimeters. Listing 4 gives the items of Sheet 2-1, which participants should think about in the action planning sheet.

Listing 4: The items of Sheet 2-1

```
(1) Requirement analysis:
    a)  Summary of ideas
    b)  Elicited requirements
    c)  Inherit factors
    d)  Potential requirements
    e)  Summary of a conclusive
        solution
```

(2) Externalizing elements:
   a) Target users of the idea
   b) External collaborators of one's working institute
   c) External competitors
   d) Internal collaborators
   e) Internal competitors
   f) Necessary technique for realization
   g) Time span for realization
   h) Necessary materials for realization
   i) Budget
   j) Necessary datasets

The participants think about inherit factors and potential requirements (the requirement analysis is written in a space of 50 by 195 millimeters) and brush up their ideas to conclusive solutions. In addition, they externalize the same 10 elements of ideas as in Sheet 2 of Experiment I. After they finish writing in Sheet 2-1 in a general way, they start writing ideas in Sheet 2-2, which is 297 by 210 millimeters. The items of Sheet 2-2 are described in Listing 5.

Listing 5: The items of Sheet 2-2

(1) Serializing elements in 4 aspects:
   a) Contents
   b) Budget
   c) Necessary resources
   d) Stakeholders

(2) Goal of realization of the solution

(3) Modeling profit flows, i.e. how to make profit by the solution which participants create

The participants serialize the elements, decide the goal of realization of ideas in the same formats as Sheet 2 of Experiment I (the spaces each are 30 by 180 millimeters), and model profit flows (the space was 75 by 180 millimeters) for creating strategic scenarios. Participants does not have to fill in all the elements in Sheet 2-1 and Sheet 2-2. Finally, in this experiment, we divide Sheet 2 of Experiment I into two (sub) sheets: the former externalized elements phase of Sheet 2-1 and the latter serialized elements phase of Sheet 2-2.

All the 9 groups discuss and write down their thoughts and opinions in Sheet 2-1 and Sheet 2-2 in total 130 minutes. We give each group 3 blank papers (297 by 210 millimeters each) for memos, in addition to Sheet 2-1 and Sheet 2-2. Three of 9 groups use them. We show the appearance of Sheet 2-1 and Sheet 2-2 in Figure 7 and Figure 8.

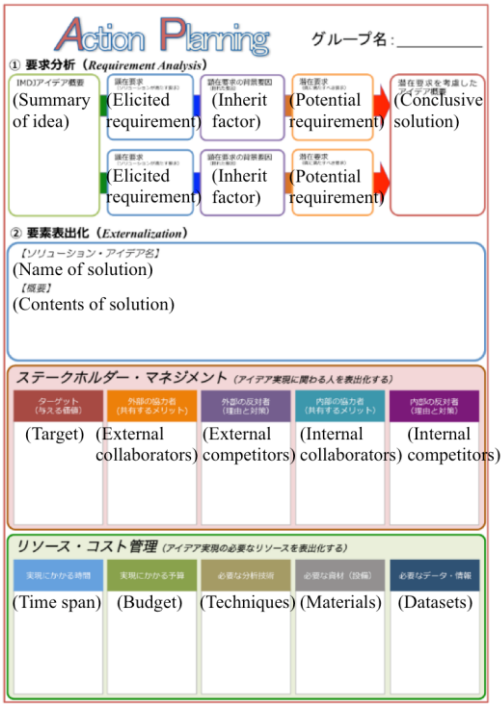

Figure 7: Appearance of Sheet 2-1

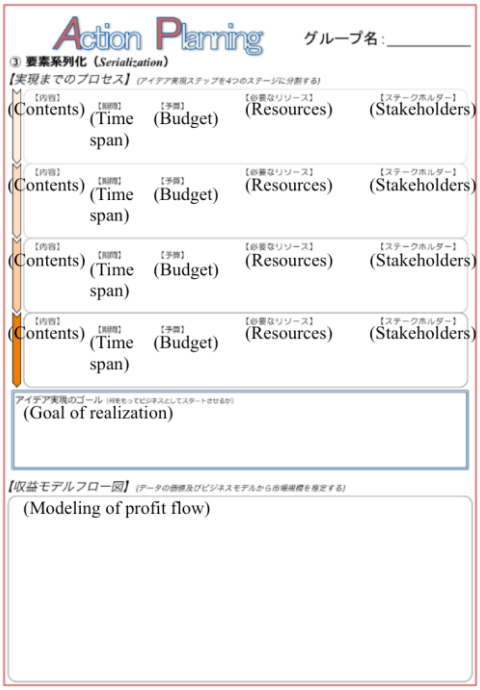

Figure 8: Appearance of Sheet 2-2

After the end of Experiment II, the participants score Sheet 2-1 and Sheet 2-2 of the other groups. We make 16 rating criteria and the participants score each of 16 criteria on a scale of 1 to 5 (very good: 5 points; fairly good: 4 points; neither good nor poor: 3 points;

Table 1: Criteria of rating Sheet 2-1 and Sheet 2-2

No.	Question
1	How well are requirements extracted by requirement analysis?
2	How suitably does the idea solve the requirement?
3	How adequately are the targets listed?
4	How well does the idea solve the targets' requirement?
5	How adequately are outside collaborators listed?
6	How adequately are collaborators inside listed?
7	How adequately are the opponents outside listed?
8	How adequately are the opponents inside listed?
9	How suitable is the time span?
10	How suitable is the estimate?
11	How adequately are the necessary technique listed?
12	How adequately are the necessary materials listed?
13	How adequately are necessary datasets listed?
14	How well is the process of realization elaborated?
15	How well is the model of profit elaborated?
16	How well are the elements consistent with each other?

fairly poor: 2 points; very poor: 1 points). All the participants score the Action Planning sheet of other groups, and recall that Group 6 and Group 7 each have 4 participants and the other groups each have 3 participants. Therefore, 25 participants score Sheet 2-1, Sheet 2-2 of Group 6 and Group 7, and 26 participants score Sheet 2-1 and Sheet 2-2 of the other groups. The 16 rating criteria are shown in Table 1.

4.3 Analysis of Experiment II

In this analysis (called Analysis II), we first calculate the scores of Sheet 2-1 and Sheet 2-2 from the mutual scoring by participants. After that, we examine the relationship between the score and writing time "*wt*" defined in Experiment I.

Table 2: Scores of Sheet 2-1 and Sheet 2-2 of each group

Group	Sheet 2-1		Sheet 2-2	
	Mean	Standard Deviation	Mean	Standard Deviation
1	27.73	3.69	6.23	1.34
2	25.35	4.94	5.62	1.27
3	26.50	3.92	3.85	0.88
4	34.73	4.62	7.15	1.16
5	26.88	3.91	4.54	0.95
6	29.88	3.78	6.84	1.21
7	33.20	4.88	6.80	1.55
8	24.88	5.36	4.77	1.50
9	29.19	3.68	6.65	1.57

4.3.1 Result

We use the mutual scoring of Action Planning sheets by participants. Firstly, we exclude the questions 8, 9 and 16 because their ranges of the score were 1 to 4, not 1 to 5. In addition, the maximum frequency value of Question 6 is 1. Therefore, we exclude it because we expect Question 6 get floor effect, and this meant that there is a biased distribution in the lower side.

Question 1, 2, 3, 4, 5, 7, 10, 11, 12 and 13 have descriptions about quantitative evaluation about Sheet 2-1. On the other hand, Question 14 and 15 has the descriptions about an entry to Sheet 2-2. Therefore, we define the sum of the scores of Question 1, 2, 3, 4, 5, 7, 10, 11, 12 and 13 as the score of an entry to Sheet 2-1. The sum of the scores of Question 14 and 15 is the score of an entry to Sheet 2-2. Moreover, we define the mean of them as the score of an entry to Sheet 2-1 and to Sheet 2-2 of that group. We show their scores of entries to Sheet 2-1 and Sheet 2-2 in Table 2.

To compare the scores of Sheet 2-1 and Sheet 2-2, we standardized them. Following the discussion, we use this standardized scores as the final scores in Sheet 2-1 and Sheet 2-2. In Figure 9, we show the relations between the scores of Sheet 2-1 and Sheet 2-2. In Figure 9, the scores of Sheet 2-1 and of Sheet 2-2 had the positive correlation ($r = 0.77, p = 0.015 < 0.05$). That means that the requirement analysis and externalizing elements affect the result of serializing elements, and vice versa.

Next, we calculate the thinking time "*tt*" and writing time "*wt*" of Sheet 2-1, Sheet 2-2 and memos, in the same way as done with Analysis I. The two times are shown in Figure 10. Figure 10 indicates two clusters of handwriting features in a similar manner to Analysis I; the groups in Cluster 1 take more thinking time than writing time. On the other hand, the groups in Cluster 2 tend to spend more time in writing.

To compare the way of writing, we define the mean writing time "*m_wt*", and the mean thinking time "*m_tt*". The mean writing time "*m_wt*" indicates that the writing time spent in writing one sentence without >5 seconds pausing. The mean thinking time "*m_tt*" expresses the time thinking from one sentence to another sentence. Each of these variables is derived from following Equation (6) and (7).

$$m\_wt = \frac{1}{N_w}\sum_{i}^{N_w}(t_i - t_{i-1}) \quad if\ t_i - t_{i-1} < 5\ sec \tag{6}$$

Where variable: $i \in N$, N_w: the number of writing without 5 seconds pausing.

$$m\_tt = \frac{1}{N_t}\sum_{i}^{N_t}(t_i - t_{i-1}) \quad if\ t_i - t_{i-1} > 5\ sec \tag{7}$$

Where variable:$i \in N$, N_t: the number of thinking with 5 seconds pausing.

Table 3 present the mean writing time "*m_wt*" and the mean thinking time "*m_tt*" of each group. Although each group takes almost the same mean writing time "*m_wt*" ($Mean = 11.54\ sec$, Standard Deviation $SD = 1.76\ sec$), the mean thinking time "*m_tt*" varies widely ($Mean = 66.13\ sec, SD = 22.20\ sec$). When we compare the mean thinking time "*m_tt*" of Cluster 1 ($Mean = 80.10\ sec, SD = 19.22$ sec) with that of Cluster 2 ($Mean = 48.62\ sec, SD = 9.31\ sec$), the mean thinking time "*m_tt*" of Cluster 2 is significantly shorter than that of Cluster 1. This pattern could be also seen in Experiment I (Cluster 1: $Mean = 62.85\ sec, SD = 7.62$ sec. Cluster 2: $Mean = 42.60\ sec, SD = 13.5\ sec$, $p = 0.017 < 0.05$). We show the two clusters and the mean thinking times "*m_tt*" in Figure 11 and the result of two sample t-tests [12] in Table 4. We adopt t-tests because they are a statistical test used to find out if there is a real difference between the means (averages) of two different groups.

Table 3, Table 4 and Figure 11 indicate that the groups in Cluster 2 does not write things without stopping. However, they write short sentences more frequently than the groups in Cluster 1. We discuss this result in Section 5 further.

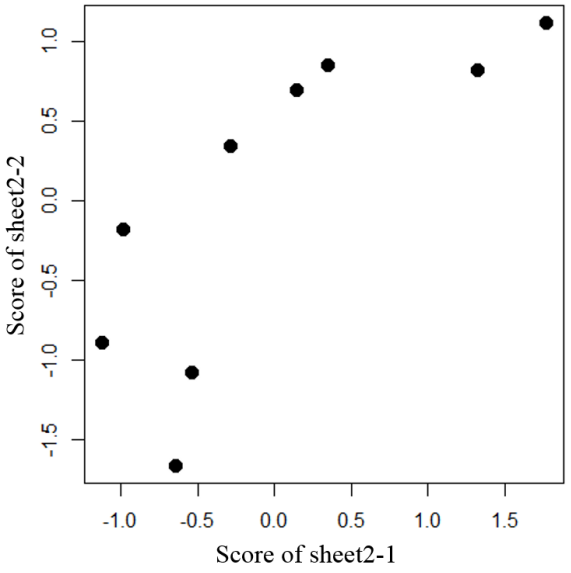

Figure 9: Relations between scores of Sheet 2-1 and Sheet 2-2

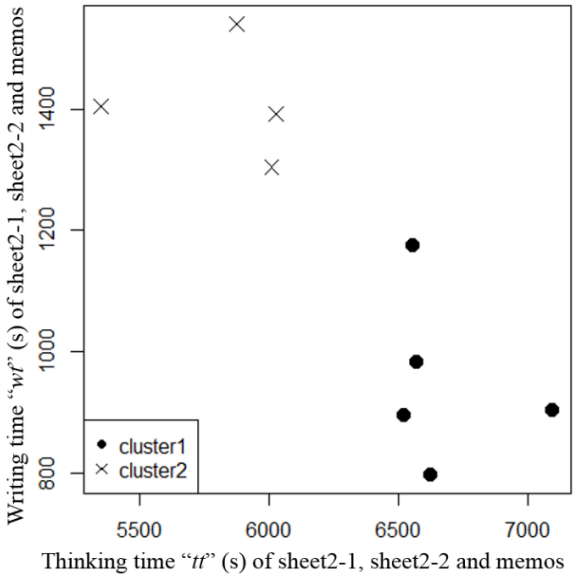

Figure 10: Two clusters of handwriting features in Sheet 2-1, Sheet 2-2 and memos

In writing Sheet 2-2, some groups return back to Sheet 2-1 and write missing elements, then go back to write Sheet 2-2. We define such behavior as "backtracking" in this paper. group2, group4, group6, group7 and group9 of all the 9 groups did this "backtracking". In Figure 11, we show exist-backtracking groups as the red color plot with under bar. The groups conducting "backtracking" except group6 belonged to Cluster 2. From this prospect, in hypothesis, the participants who write sentences frequently tend to conduct "backtracking". The

Table 3: Mean writing time "*m_wt*" and mean thinking "*m_tt*" of each group

Group	*m_wt* (sec)	*m_tt* (sec)
1	11.29	76.41
2	8.87	41.17
3	11.48	84.70
4	13.51	51.97
5	10.04	56.53
6	10.48	73.86
7	13.79	60.28
8	13.70	109.18
9	10.69	41.06
Mean	**11.54**	**66.13**
SD	**1.76**	**22.20**

Table 4: Two sample t-tests between the mean thinking times "*m_tt*" of Cluster 1 and Cluster2

Cluster1		Cluster2		p-value
Mean (sec)	SD (sec)	Mean (sec)	SD (sec)	
80.10	19.22	48.62	9.31	0.021<0.05

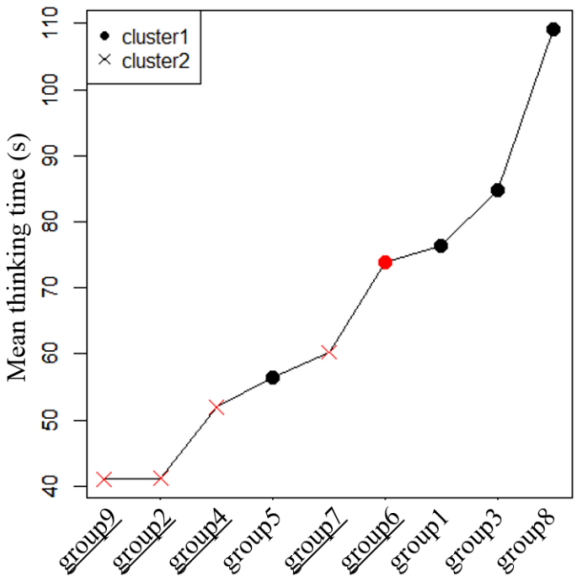

Figure 11: The mean thinking time "*m_tt*" of two clusters

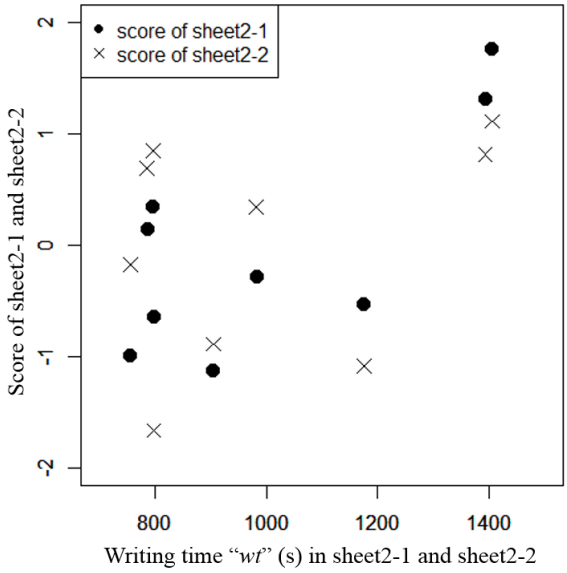

Figure 12: Relationship between the writing time "*wt*" and scores of Sheet 2-1 and Sheet 2-2

Table 5: Mean scores and standard deviation of Sheet 2-1 and Sheet 2-2 between exist-backtracking groups and none-backtracking groups

	Exist backtracking		None backtracking		p-value
	Mean	SD	Mean	SD	
Sheet 2-1	0.52	1.07	-0.65	0.35	0.071<0.1
Sheet 2-2	0.66	0.49	-0.82	0.84	0.029<0.05

relationship between the writing time "*wt*" and scores could be observed by Experiment II. Please note that the scores of idea are not considered in Experiment I, only in experiment II.

Figure 12 shows the relationship between "*wt*" and scores of Sheet 2-1 and Sheet 2-2. In Sheet 2-1, the more time participants spend in writing, the higher scores the group got ($r = 0.73, p = 0.026 < 0.05$). On the other hand, the writing time "*wt*" does not affect the scores of Sheet 2-2 ($cor = 0.34, p = 0.36 > 0.05$). Moreover, the mean scores in Sheet 2-1 and Sheet 2-2 of the groups, which conducts "backtracking", are higher than that of the none-backtracking groups. In Table 5, we show the result of Welch's t-test [12] between that two groups. From Figure 12 and Table 5, it could be said that the amount of writing time "*wt*" affects the scores of Sheet 2-1, and "backtracking" increased the scores of Sheet 2-1 and Sheet 2-2.

5 MODEL OF CREATIVE THINKING PROCESS

Based on the results of Experiment I and II in previous sections, we propose a model of the creative thinking process in this section.

5.1 Results in Analysis I and Analysis II

In Analysis I, by defining the thinking time "*tt*" and writing time "*wt*", we examine the difference of handwriting features between in free writing formats of Sheet 1 and Sheet 3, and in strictly instructed format of Sheet 2 in Action Planning. Action Planning of Sheet 2 instructs participants what to be written down, and this means Action planning has strictly instructed format. In Sheet 1, the more time participants take in thinking, the more time they spend in writing. On the other hand, the thinking time "*tt*" and writing time "*wt*" have the negative correlation in Sheet 2, because there are two clusters which have the different handwriting features. The groups in Cluster 1 take longer time in thinking than the groups in Cluster 2, whereas the groups in Cluster 2 take longer in writing than the groups in Cluster 1.

We then conduct Experiment II and Analysis II for examining the factor of difference between the groups in Cluster 1 and the groups in Cluster 2. Two clusters could be observed similarly to Experiment I. The groups in Cluster 2, which spend more time in writing, tend to write short sentences more frequently than the groups in Cluster I (that means the groups in Cluster 2 tend not to write long sentences without stopping). All of the 4 groups in Cluster 2 do "backtracking", i.e. returning back to write in Sheet 2-1 in the middle of writing in Sheet 2-2, although one of the 5 groups in Cluster 1 do "backtracking". The scores of Sheet 2-1 are affected by the amount of writing time "*wt*", although it does not affect the score of Sheet 2-2. To improve the score of Sheet 2-2, "backtracking" tends to be an important factor.

5.2 Model & Discussion

Figure 13 describes our model of creative thinking process. This model is based on the results of Experiment I and II and the theory of Structure of Intellect [6]. In [6], Guilford explained human intelligence from three sides: Contents, Products, and Operations. Contents are the information to which human applies one's intellect. When we think about Contents, we can generate Products. To generate Contents from Products, we conduct Operations that mean the categories of the way to think. There are 5 factors in Operations: cognition, memory, divergent thinking, convergent thinking, and evaluation.

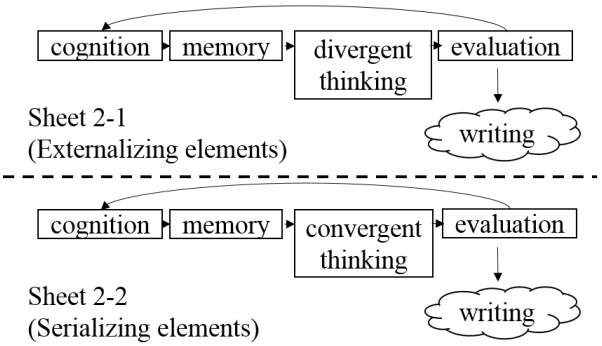

Figure 13: Model of creative thinking process: The thinking flow of Operations in Sheet 2-1 and Sheet 2-2 of Experiment II

When one creates the solution, i.e., the idea of how to use datasets as in Action Planning, one conducts all of the 5 factors of Operations. One has firstly to cognize the information of datasets in Innovators Marketplace on Data Jackets. This process is the cognition of Operations. Participants then have to pull out this cognized information or background in the working memory to think and examine. This corresponds to the memory of Operations. This process enables participants to discuss their knowledge or opinions with other group members. Since the capacity of working memory is said to be around 4 items and can last 10 to 30 seconds [9] and the time span of iconic memory lasts only 0.5 second [2], participants need to do memory rehearsal and retrieval many times.

After cognition and memory, divergent thinking and convergent thinking are conducted in the working memory. Divergent thinking means to remember and recollect pieces of information and knowledge related to the target problem in the working memory widely and in large quantities. This divergent thinking corresponds to Externalization in SECI model [4]. Also, Osborn proposed the method of brainstorming focused on this divergent thinking [1]. In Action Planning, this process is mainly conducted in the phase of Externalizing elements. In contrast to divergent thinking, convergent thinking is the process of reasoning logically from already known information and reaching one solution correctly and rapidly.

The combination of SECI model is equivalent to this process. KJ method suggested by Kawakita can be regarded as a method of applying this thinking process [5]. In Action Planning, convergent thinking is mainly conducted in the phase of Serializing elements. The solutions, created in divergent and convergent thinking, are evaluated in the process of evaluation in Operations. The solutions get more concrete through divergent thinking, convergent thinking and evaluation. Finke's theory about Geneplore model can be interpreted as an explanation of this repetition [8]. He said this cycle was

repeatedly conducted while one creates solutions. As well as the Geneplore model, Ohsawa proposed that four-step spiral was important for Innovators Marketplace on Data Jacket, Sensing external events, Recollection, Scenarization and Co-evolution of scenarios [15]. Two functions are present in the evaluation to be carried out during Action Planning. One is the function to erase the externalized elements. The other is a function of a newly externalized element that has internalized ever.

In Figure 13, we showed the thinking flow of operations in Sheet 2-1 and Sheet 2-2. One flow consisted of cognition, memory, divergent thinking (or convergent thinking) and evaluation. The participants in Experiment II were the almost same ages and used the same format of sheets, and thus we could infer that they spent almost the same time in cognition and memory. From the above, the difference between Cluster 1 and Cluster 2 was caused by divergent thinking, convergent thinking and evaluation. The groups of Cluster 2, which spent a longer time in writing and shorter in thinking in Experiment I and II, had shorter time span from writing one sentence to another.

To sum up, the groups of Cluster 1 conducted fewer divergent thinking, convergent thinking and evaluation than the groups of Cluster 2. However, the participants in Cluster 2 wrote more than those in Cluster 1. From this result, the participants of Cluster 2 conducted more thinking flows than the participants in Cluster 1. The more thinking flows participants conducted, the more "backtracking" they did, and the scores of scenarios were increasing. In that case, what was the main factor of increasing the number of thinking flows? We speculated that fewer numbers of evaluations led to decreasing the thinking time and increasing the number of thinking flows. All of the groups in Cluster 2 did "backtracking" in Sheet 2-2. "Backtracking" was to compensate or revise the ideas which were generated before. That was the same as the evaluation of Operations. The groups in Cluster 2 conducted "backtracking" in the evaluation of Sheet 2-1, when they filled in Sheet 2-2.

On the other hand, the groups in Cluster 1 did not conduct the evaluation of Sheet 2-1 when they filled in Sheet 2-2. From this result, we examined that the participants in Cluster 2 conducted fewer evaluations in Sheet 2-1 than the participants in Cluster 1. The groups in Cluster 1 did not conduct "backtracking" because they did evaluations of Sheet2-1 many times when they were filling in Sheet 2-1. That caused the many thinking flows and "backtracking" of the groups of Cluster 2.

Action Planning was designed for participants to notice the missing elements by serializing elements after externalizing elements [11]. The brain storming was designed to prohibit the evaluation while thinking for better ideas. The groups in Cluster 2 were inferred to keep this rule of divergent thinking. We could conclude that participants did not have to evaluate ideas in externalizing phase but have to do that in serializing phase for effective evaluations, for many thinking flows and for well-organized scenarios.

6 CONCLUSION

We had to progress with designing the market of data and investigating the humans' creative thinking process side by side because the ideas of how to use datasets should be created by the process of human interpretation. In this research, we used the handwriting features to clarify the humans' creative thinking process by the digital pen. In Experiment I and II, two types of groups could be observed: the groups of the first type took longer time in thinking and shorter in writing, which is opposite to the other type of groups. In both types of groups, the time spans taken in writing one sentence were the same, although the time spans taken from writing one sentence to another sentence were the significantly different.

From this result, it was inferred that groups taking less time in thinking evaluated their ideas after the series of divergent thinking and convergent thinking. On the other hand, the groups having spent longer for thinking evaluated their ideas after both of divergent and convergent thinking. Following the steps, divergent thinking, convergent thinking and evaluation could create "backtracking" and improve more valid solutions. The more times "backtracking" were conducted, the more missing elements were complemented. It increases the quality of ideas which are created.

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AUTHOR BIOGRAPHIES

Kenshin Ikegami is a master course student in the Department of Systems Innovation, the School of Engineering, University of Tokyo, Japan. He received BE in Systems Innovation from The University of Tokyo in 2014. He studies about the relationship between the Market of Data and cognitive science under Professor Ohsawa's guidance. Recently he takes notice of natural language process and machine learning method for predict future trends.

Dr. Yukio Ohsawa is a professor of System Innovation in the School of Engineering, University of Tokyo. He received BE, ME, and Ph.D from The University of Tokyo, worked also for the School of Engineering Science in Osaka University), Graduate School of Business Sciences in University of Tsukuba (associate professor, 1999-2005), Japan Science and Technology Corporation (JST researcher, 2000-2003) etc.