Cognitive Experiment on Generation and Understanding of Associative Representation

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We have proposed a knowledge medium called associative representation to promote the creation of knowledge. In this paper, I investigated how postgraduate students major in information science generate and understand associative representations and found out the following facts. (a) Subjects generated associative representations without difficulty. (b) Ideas were transmitted among subjects who share knowledge using associative representation. (c) The more background knowledge they have, the more they understand an associative representation. The above results suggest that associative representations are easy to understand, and therefore will be useful in the sharing of knowledge, for people who have basic computing skills and knowledge about information science.

Keywords: associative representation, knowledge media, cognitive experiment

連想表現の生成と理解に関する認知実験

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筆者らはこれまでに, 知識の創造を促進するために連想表現と呼ぶ知識メディアを提案してきた. 本稿では, 人間がどのように連想表現を生成し理解するかに関して考察する. 情報科学を専攻する大学院生を対象として実験を行ったところ, 以下の結果を得た. (a) 被験者は連想表現の生成を容易に行えた. (b) 連想表現を用いることにより背景知識を共有する人間の間でアイディアの伝達が行えた. (c) 背景知識の量が多いほど連想表現の理解が容易であった. これらの結果は, 情報科学に関する基本的な知識と技術を有する大人において, 連想表現の生成が容易で, 知識の共有に有効である可能性を示唆している.

キーワード: 連想表現, 知識メディア, 認知実験

1 Introduction

NISHIDA Toyoaki and I have proposed a knowledge medium called *associative representation* in which nodes are connected by links that have direction and are capable of many-to-many mapping in order to promote the creation of knowledge[1].

We have set several hypotheses that "associative representation is (a) easy to generate and manipulate by computers, (b) easy to generate and understand by humans, and therefore, (c) useful to extract and integrate information from a wide variety of information sources and to share knowledge among people."

To investigate the above hypotheses, we have developed a system called CoMeMo and verified several cases so far[1, 2, 3]. For example, we developed an application which extracts and reorganizes information from WWW pages and newspaper articles, and a shared-card information system called InfoCommon to support community information sharing.

As a next step, I investigate how people generate, and understand the semantics of associative representation using CoMeMo.

In what follows, I first give an overview of associative representation. We then describe two experiments using CoMeMo.

2 Associative Representation

Associative representation is a knowledge medium in which nodes are connected by links which have direction and are capable of many-to-many mapping.

The basic entities of the associative representation are the *unit* and the *association*. A unit is either a *concept* or an *external datum* (e.g., image, audio files). A concept has a label. An external datum has a label and an URL. A *key unit* is a

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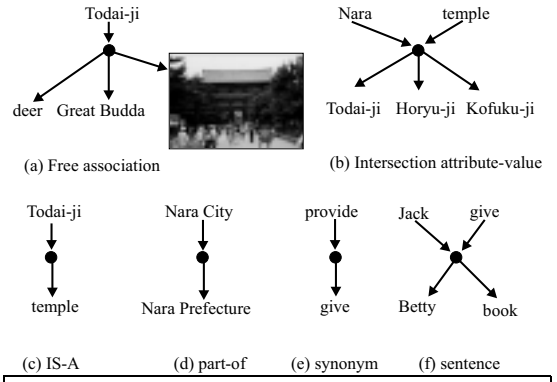

(a) Free Association: deer, the Great Budda, and a photo of Todai-ji are triggered by Todai-ji.
(b) Intersection, attribute-value: Todai-ji, Horyu-ji, and Kofuku-ji are temples in Nara.
(c) IS-A: Todai-ji is a temple.
(d) Part-of: Nara City is a part of Nara Prefecture.
(e) Synonym: 'Provide' and 'give' are synonymous.
(f) Sentence: Jack gives Betty a book.

Figure 1: Examples of various types of associative representation.

node from which a given link originates. A node at which a given link terminates is called a *value unit*.

An association is a single link which connects one or many key units with one or many value units which represent memories triggered by the given key units. A key unit for one association may, of course, be a value unit for another, and vice-versa.

In the diagrams in this paper a dot represents an association and an arrow connected to a dot represents the direction in which the association flows (e.g., Figure 1). Text and occasional images represent units.

In addition, I use the notation shown below for convenience. "association = key-unit(& key-unit)* –> value-unit(, value-unit)*." For example: "Nara & temple –> Todai-ji, Horyu-ji, Kofuku-ji." to represent the association in Figure 1(b).

An associative representation can be seen as a special kind of semantic network, with an open semantic structure. Furthermore, associative representation is based on many-to-many mappings, unlike typical semantic networks which are based on one-to-one mappings.

As Woods[4] pointed out, links in semantic networks may have various meanings. Figure 1 shows some sample associations that represent various meanings. The kind of relation that is made between objects is left up to the user. The semantics of the relations in an associative representation need not be explicitly stated, but users may include semantic descriptions on labels. By keeping the semantic relations largely implicit, the method of representation can be made compact and robust.

3 Experiment 1

The aim was to investigate how people generate an associative representation from ideas, and how people understand associative representations generated by others.

3.1 Method

Subjects One Ph. D. and four second-year M. Eng. students, and one faculty staff member from the Artificial Intelligence Laboratory at Nara Institute of Science and Technology.

Procedure

1. The subjects were taught how to generate associative representations (students only).
2. Each subject then generated an associative representation flowing from the keyword 'agent', which is, in one meaning, a research topic in the laboratory (students only).
3. They were shown the associations generated by the other subjects and asked the following questions.
   - Do you understand these representations ?
   - Can you identify who made it?
   - If you can, how?

   They were then instructed to:
   - Say anything that you felt about this experiment (students only).
4. The same as 3 (for the staff subject only).

3.2 Results and Discussion

3.2.1 Generation

All concepts were originally written in Japanese. Example screens generated by subjects are shown in Figures 2, 3, 4, 5 and 6.

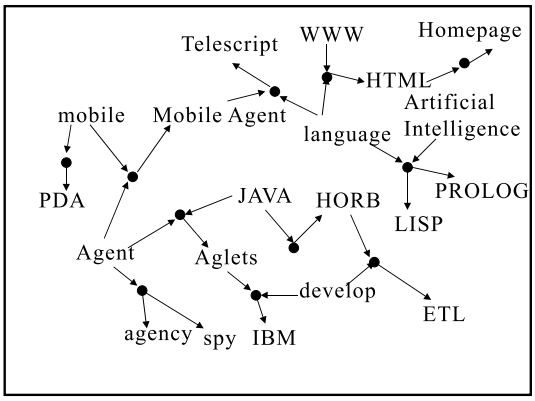

Figure 2: A screen generated by subject A.

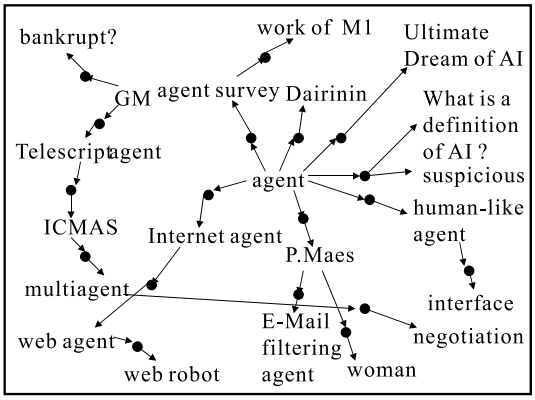

Figure 3: A screen generated by subject B.

I describe the screens generated by Subject C, D and E who had no prior experience on generating associative representations.

Subject C recalled his research topic 'real world agent', or 'intelligent robot' and then wrote the names of all of the robots, and of the research staff and students in charge of each. 'Utchan' is the nickname of a person in the laboratory who is popular for his shy and romantic character. 'Captain' is the nickname of another student in the

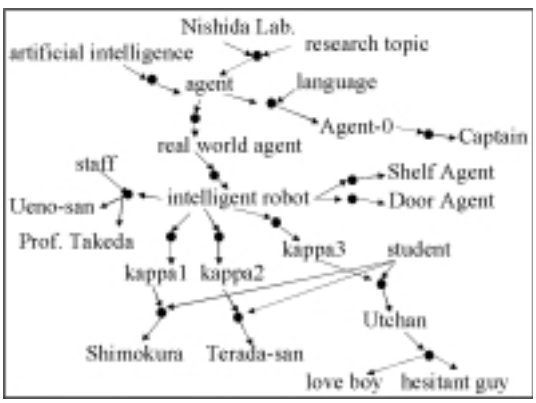

Figure 4: A screen generated by subject C.

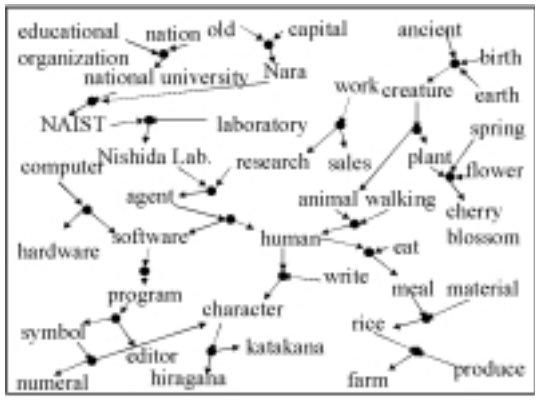

Figure 5: A screen generated by subject D.

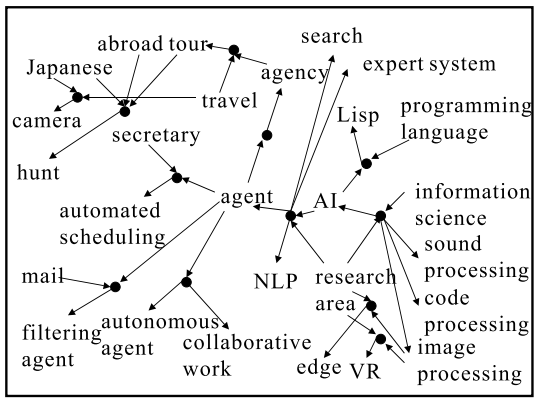

Figure 6: A screen generated by subject E.

laboratory. In general, subject C's associations with 'agent' concern only the small world of the laboratory.

The associative representation created by subject D was totally different. This subject did not recall any research topic. Most of the concepts start from 'software' and 'human' and the generated concepts are not apparently related to 'agent'.

Subject E's associations were with other aspects of 'agent'. There are three main groups of nodes. One is to do with 'travel' and 'agency' and the other two are to do with 'agent' in a computer science and language sense, and 'research' and 'area' in information science, respectively.

All subjects generated their associative representations within 30 minutes. I take this to mean that adults who have basic computing skills and knowledge about information science can generate associative representations by free association, without difficulty.

Summaries of generated concepts and associations are shown in Tables 1 and 2. Most of the concepts were expressed as nouns or noun phrases (98%) and I found that subjects tended to use nouns to describe items they recalled when using

Table 1: Generated concepts.

Subject	noun	verb	adverb	other	Total
A	20.0	0.0	0.0	0.0	20.0
B	16.0	1.0	1.0	3.0	21.0
C	23.0	0.0	0.0	0.0	23.0
D	38.0	2.0	1.0	0.0	41.0
E	25.0	1.0	1.0	0.0	27.0
Mean	24.4	0.8	0.6	0.6	26.4

Table 2: Generated associations.

Subject	1 to 1	1 to many	many to 1	many to many	Total
A	4.0	1.0	6.0	1.0	12.0
B	18.0	2.0	0.0	0.0	20.0
C	9.0	2.0	5.0	0.0	16.0
D	1.0	7.0	12.0	0.0	20.0
E	0.0	0.0	10.0	2.0	12.0
Mean	6.4	2.4	6.6	0.6	16.0

the CoMeMo. There were many kinds of associations and it is difficult to determine their common or major features. One common feature was that few many-to-many mappings were created. This may be because the generation of many-to-many relations is too much of a load on people, or because they are not easy to see on the CoMeMo.

Figure 7 is a graph of a statistical analysis of those concepts that were commonly entered, namely, 'language', 'agency', 'artificial intelligence (AI)', and 'Lisp'. Here, I can see some similarity in the associative representations produced by our five subjects. Subject D's results do not appear on the graph because they were too distant from the others.

3.2.2 Understanding

Each subject understood the meaning of the associative representation generated by the others. For example, all other subjects correctly identified the maker of subject C's screen. I thus surmise that ideas can in fact be propagated, using associative representation, among subjects who share knowledge of each other.

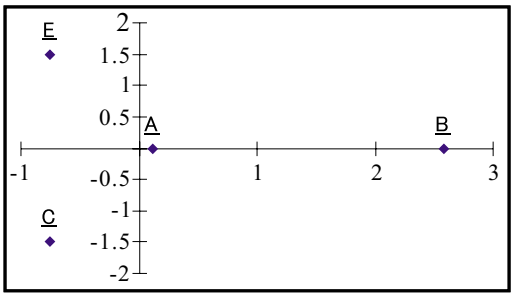

Figure 7: Graph resulting from statistical analysis.

All subjects, except for its originator, laughed when they saw subject C's screen. Four out of five student subjects said that they had some fun during the experiment. The staff subject said, "I can learn something of their knowledge level concerning research topics", "I may want to ask for a report from subject A[1] ", "I want to talk to subject D, because s/he may be an interesting person", and so on. I think that transmitting ideas between groups using associative representation leads to better knowledge of people and therefore facilitates human communication.

4 Experiment 2

The aim was to investigate how people generate associative representations from various information sources such as ideas and research memoranda and articles, and how people perceive the semantics of an associative representation.

4.1 Method

Subjects Postgraduate students in the same laboratory as Experiment 1, consisting of three Ph. D. students (hereafter D), five second-year M. Eng. students (hereafter M2), and four 1st-year M. Eng. students (hereafter M1). The first-year M. Eng. students were all newcomers at the time of the experiment because the Institute only has postgraduate students.

Procedure

1. Five test screens (Test 1 to Test 5) were prepared using the CoMeMo by me and the other staff.
2. The subjects were shown each of these screens and asked the following questions.
   - Do you understand the content of the screen ? (Q1-1st)
   - State the meaning of each circles[2] (Q2).
3. They were asked the same question as Q1 (Q1-2nd).

Test Screens

[1] The associative representation generated by subject A partly concerned a survey of agent languages.

[2] I did not explain associations and therefore used the term 'circle.'

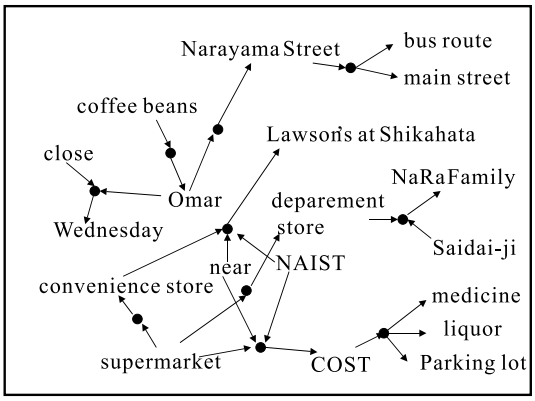

Figure 8: Test 1 (Generated from information on shops).

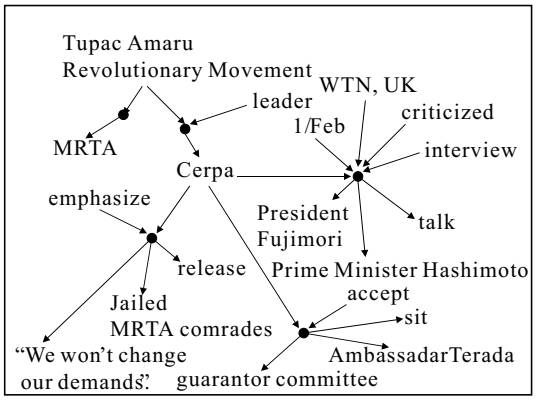

Figure 9: Test 2 (Generated from a newspaper article).

- Test 1: information on shops around the Institute. See Figure 8 for the resulting screen, and Table 3 for the process used.
- Test 2: description of the occupation of the Japanese Ambassador's Residence in Peru in 1997 (the Peru Incident) generated from a newspaper article. See Figure 13 for a transaction of the original newspaper article, Figure 9 for the resulting screen, and Table 4 for the process used.

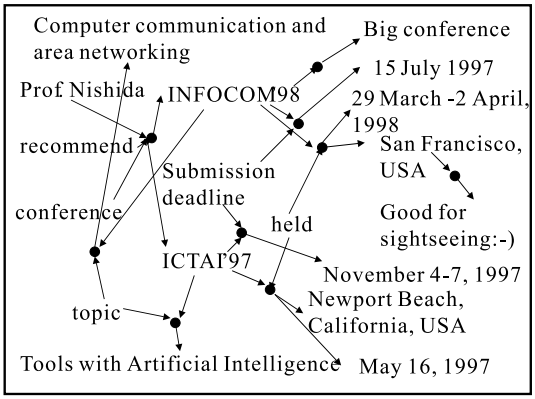

Figure 10: Test 3 (Generated from information on CFPs).

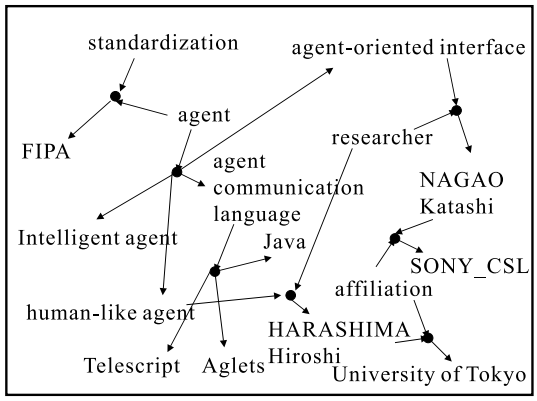

Figure 11: Test 4 (Generated from research memoranda about agents).

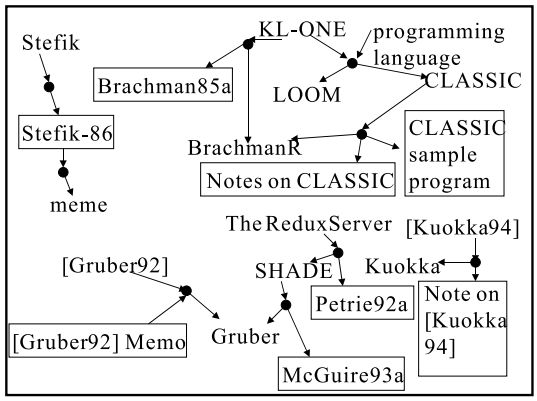

Figure 12: Test Screen 5 (Generated from research memoranda about knowledge medium).

- Test 3: information on CFPs (calls for papers) announced in the laboratory. (Figure 10).
- Test 4: research memoranda about agents possessed by one of the staff (Figure 11).
- Test 5: research memoranda about knowledge media possessed by one of the staff. (Figure 12)

In Tests 1, 2, 3 and 4, written concepts were in Japanese. They were in English in Test 5.

4.2 Results and Discussion

4.2.1 Generation

I was well trained on generating associative representations and generally thought it an easy task. I describe the parts on which I found difficult to generate.

Table 3: Process of generating Test 1.

no.	Article	Generated Associations
1.	A suparmarket near NAIST(the Institute) is COST.	(1)"NAIST & near & supermarket –> COST."
2.	At COST, Medicine and liquor is sold, and COST has parking lots.	(2)"COST –> medicine, liquor, parking lot."
3.	By supermarkets, convenience stores are reminded.	(3)"supermarket –> convenience store."
4.	The convenience store nearest NAIST is Lawson's (a famous convenience store in Japan) at Shikahata (a place)"	(4)"NAIST & near & convenience store –> Lawson's at Shikahata."
5.	Supermarkets remind me of department stores.	(5)"supermarket –> department store."
6.	Department stores remind me of NaRa Family (a department store) in Saidai-ji (a place)	(6)"Saidai-ji & department store –> NaRa Family."
7.	I buy coffee beans at Omar (a shop).	(7)"coffee beans –> Omar."
8.	Omar closes every Wednesday.	(8)"Omar & close –> Wednesday."
9.	Omar besides at the Narayama Street (a street)	(9)"Omar –> Narayama Street."
10.	The Narayama Street is a bus route and the main street around here.	(10)Narayama Street –> bus route, main street."

Test 1 The table 3 shows generating process in Test 1. All ideas except for no.4 and 6, were easily expressed using associative representation. I focus on the process at no.4 and 6.

At no.4, I wondered how to express the first idea, which was an image of Lawson's (a chain store as one of the most famous convenience stores in Japan) which besides a crossroads at Shikahata (a place), because there are several Lawson's around there. I then created a concept 'Lawson's at Shikahata' as a value of an association to distinguish the store from other Lawson's.

At no.6, the first idea occurred was "department stores remind me of NaRa Family (a department store) in Saidai-ji (a place)." Naturally, there are two choices: (1) generating one association: "department store -> NaRa Family in Saidai-ji." (2) generating two associations: "department store -> NaRa Family." and "NaRa Family -> Saidai-ji." The first one corresponds to the case of no.4, however, it was not taken. In this case, NaRa Family is the biggest department store in Nara prefecture and there is no department store which has the same name, and therefore it need not to distinguish the NaRa Family from other stores. The second one is also natural, but it was not written either. I thought that "entity-attribute-value" relation was more compact and informative than "free recall" relation and generated an association "Saidai-ji & department store –> NaRa Family."

The above cases show the difficulty when there is supplementary explanation of the value units.

Test 2 At first, I tried to express every word in the newspaper article and noticed that it was very difficult to convert complicated sentences into associative representations. I then changed the strategy and selected only important words to summarize the article.

> Cerpa, the leader of the Tupac Amaru Revolutionary Movement (MRTA), which is occupying the official residence of the Japanese ambassador to Peru in Lima, criticized talks between Prime Minister Hashimoto and President Fujimori in Toronto, Canada, in a radio interview with the English television station WTN on the 1st of February. Cerpa said "We have a purpose and will not change our demands." He again emphasized that the MRTA has no intention of with drawing their demand for the release of jailed MRTA comrades. He also clarified his acceptance of Terada, Japan's ambassador to Mexico, sitting in on the meetings of the guarantor committee.

Figure 13: Original newspaper article.

The first sentence was too complicated and I divided it into three parts. Some important words were picked up and associations were generated using them. Although there was no problem in the first two parts, the last part was not an easy task. It is natural to assign 'subject' and 'verb' as key units and 'object' as value units. Ornamentation parts could be assigned as key units. In this case, I could not distinguish ornamentation parts from the verb and objects, and therefore the generated association became misleading.

The subject of the second sentence 'The subject' was turned into 'Cerpa' and unified with it. Likewise, some words were changed to simplify associative representation.

From this study, I found that it is difficult to express complicated sentences like those in newspaper articles as associative representations, especially when ornamentation is attached to more concrete words. Summarized articles may be of greater utility.

4.2.2 Understanding

Comprehensibility Table 5 shows the restoration rate of associative representations in Q2.

Table 4: Process of generating Test 2.

no.	Article	Generated Associations
1.	Cerpa, the leader of the Tupac Amaru Revolutionary Movement (MRTA), which is occupying the official residence of the Japanese ambassador to Peru in Lima, criticized talks between Prime Minister Hashimoto and President Fujimori in Toronto, Canada, in a radio interview with the English television station WTN on the 1st of February.	(1) Tupac Amaru Revolution Movement → MRTA.; (2) Tupac Amaru Revolution Movement & leader → Cerpa.; (3) Cerpa & 1/Feb & WTN, UK & criticized & interview → Prime Minister Hashimoto, President Fujimori, talk.
2.	Cerpa said "We have a purpose and will not change our demands." He again emphasized that the MRTA has no intention of withdrawing their demand for the release of jailed MRTA comrades.	(4) Cerpa & emphasize → "We will not change our demands", release, Jailed MRTA comrades.
3.	He also clarified his acceptance of Terada, Japan's ambassador to Mexico, sitting in on the meetings of the guarantor committee.	(5) Cerpa & accept → Terada Ambassador Mexico, sit, guarantor committee.

Table 5: Restoration rate.

Subject	Test 1	Test 2	Test 3	Test 4	Test 5	Mean
D	100%	66%	100%	100%	97%	93%
M2	100%	56%	80%	100%	56%	78%
M1	60%	70%	40%	93%	44%	61%
Mean	87%	64%	73%	98%	66%	78%

I evaluate that the subjects understood associative representation as a result that (1) all subjects answered the outline in Test 1 without being explained the meaning of associative representation and (2) the restoration rate was 78% on average(Table 5).

Background Knowledge To understand the meaning of test screens, I assume the following knowledge is needed. Test 1: local information around NAIST, Test 2: peru case in 1997, Test 3: call for papers, Test 4: Japanese AI researchers, and Test 5: research information about knowledge media in AI.

Overall, material was construed correctly according to the percentages D(93%) > M2(78%) > M1(61%) as shown in Table 5. This suggests that the more background knowledge subjects have, the more they understand an associative representation. I think the difference between the results for Tests 2 and 5 strengthens this finding. Test 2 restoration rates were M1(70%) > D(66%) > M2(56%), while for Test 5 they were D(97%) > M2(56%) > M1(44%). Knowledge about research topics is not needed to understand Test 2 but it is needed to understand Test 5.

I analyze that the more human background knowledge people have, the more people understand associative representation.

Degree of Understanding Table 6 shows the degree of understanding of the theme in Q1.

Table 6: Understanding of theme.

Subject	Test	Test 1	Test 2	Test 3	Test 4	Test 5	Mean
D	1*st*	3.7	3.3	4.0	2.7	3.3	3.4
	2*nd*	4.0	3.3	4.0	3.3	3.0	3.5
M2	1*st*	3.2	3.6	2.0	3.0	1.2	2.6
	2*nd*	4.0	3.0	3.2	4.0	1.0	3.0
M1	1*st*	3.2	3.6	2.0	3.0	1.2	2.6
	2*nd*	3.5	4.0	4.0	4.0	1.0	3.3
Mean	1*st*	3.4	3.5	2.7	2.9	1.9	2.9
	2*nd*	3.8	3.4	3.7	3.8	1.7	3.3

5 : very comprehensible 4 : comprehensible
3 : intermediate
2 : not very comprehensible 1 : cannot understand

The interesting result is that in Test 2, the degree of understanding decreases after the restoration process. This suggests that associative representation is easy to understand as a first glance, or, people think they understand, however, understanding is not very deep.

Other Finding The subjects restored the meaning of associations by referring units they can understand when they didn't understand the unit's labels. This tendency was apparent in Test 3 in which the structure of associations were coherent (e.g. conference names, their venues, periods and so on). I analyze that the context helps human understanding of associative representation.

5 Related Work and Discussion

The work reported in this paper is a part of the CoMeMo project which aims to support people to articulate and utilize information in everyday life using an information representation called associative representation. I focused on how people generate and associative representation using the CoMeMo. CoMeMo project is a part of the

Knowledgeable Community Project which aims to develop a computational framework of collecting, accumulating, systematizing, sharing, and creating knowledge by human-computer interaction.

Sumi's work using concept maps[6] is related to our approach in terms of sharing ideas among groups without using well-defined information representation. The major difference is that associative representation has direction and many-to-many mapping while his system has no link, which focuses on positioning according to the similarity of each node.

I have found that students in the laboratory generated associative representation to describe their free association without difficulty. These are all adults (ages 22-33) who have basic computing skills and knowledge about knowledge representation. In Moriyama's experiments[5], high school students also generated associative representation concerning knowledge about Japanese history.

However, the result of Test 2 in Experiment 2 suggests that it is difficult to describe complicated sentences such as newspaper articles using current associative representation.

To cope with these problems, we have three choices:

(a) to use external-datum to describe complicated sentences

(b) to concentrate important terms in the original sentences (i.e. summarizing sentences)

(c) to introduce other kind of notations to describe complicated sentences

If choosing (a), it need not change systems at all, however, this may reduce the effectiveness the system. (c) is the right choice to improve ability of the representation, however, it decrease the easiness, the biggest merit of the representation. (b) may be the best choice at this moment, however, it needs more effort to create summary. The choice is open for future.

From the experiments, I have found that subjects in the laboratory understand associative representation concerning the topic they have knowledge, ideas can be transmitted using associative representation among subjects who share knowledge, and the more background knowledge subjects have, the more they understand associative representation.

These results suggest that people who have basic computing skills and knowledge and information science can understand associative representation and exchange ideas using associative representation.

6 Conclusions

I investigated how postgraduate students major in information science generate and understand associative representations and found out the following facts. (a) Subjects generated associative representations without difficulty. (b) Ideas were transmitted among subjects who share knowledge using associative representation. (c) The more background knowledge they have, the more they understand an associative representation. The above results suggest that associative representations are easy to understand, and therefore will be useful in the sharing of knowledge, for people who have basic computing skills and knowledge about information science.

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