Visually-Structured Written Notation Based on Sign Language for the Deaf and Hard-of-Hearing

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Abstract: Deaf and hard-of-hearing (DHH) students often face challenges in comprehending highly specialized texts due to the long time needed to understand their content. This may be due to factors such as the complexity of Japanese syntax, which differs from Japanese sign language. This study describes the results of a questionnaire on the notation method that we proposed based on sign language for DHH individuals. The results revealed that DHH individuals who use sign language correctly answered most questions on sentence structure when using the proposed notation methods than when using Japanese sentences.

1 INTRODUCTION

In a study in which subjects were tested on their reading comprehension of texts, the results demonstrated that there were issues in comprehending both the structures and meanings of sentences (Arai et al., 2017). Furthermore, it has been highlighted that deaf and hard-of-hearing (DHH) individuals face challenges in acquiring spoken language. One study reported that variance in vocabulary and delays in grammar were observed when comparing children with hearing and DHH children (Takahashi et al., 2017). One of the characteristics of language is linearity, and speech sounds can be represented by one-dimensional time-series data. For DHH children, difficulty with the reception and expression of speech is due to the challenges in processing such linear data.

Meanwhile, the sign language used by DHH individuals uses a three-dimensional space. For example, it can use directions and locations in space to represent objects of action, and "timelines" in space to indicate the present, past, future, or a specific time (Engberg-Pedersen, 1995). Using space to represent abstract linguistic concepts (subject and object) and nonverbal expressions, such as pointing and facial expressions to perform grammatical functions can clarify the structure of sentences (Valli et al., 2011).

It is important to consider that, for some DHH individuals, the spoken language is their first language owing to the use of hearing, whereas others require visual linguistic input (Marschark and Knoors, 2012). Thus, by employing spatial cues akin to sign language, complex sentences may be better comprehended by DHH individuals who use visual language.

The number of DHH individuals who attend higher education institutions, such as universities, and work in more specialized fields, has been increasing. To continue learning throughout their lives, including reskilling for work, support methods are needed for DHH individuals. DHH computing professionals in the United States are highly interested in reading assistance tools (Alonzo et al., 2022).

If automatic translation from Japanese as a written language to sign language notation becomes possible, it will be easy for DHH individuals to read specialized texts. Therefore, this study examines the notation method structured using characteristics of sign language and describes the results of a questionnaire on the type of notation method that would be easy for DHH individuals to comprehend the text.

2 PRIOR RESEARCH

2.1 Studies on Notating Sign Language

Sign language lacks a notation method, and several

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such methods have been proposed to address this. One method uses symbols to represent the details of the finger and hand movements that express words and sentences. It is advantageous because it allows users to express words and actions by only looking at the notation, even if they have never seen it before; however, the descriptions of each word are lengthy, and grammar is complicated (Hanke, 2004). A method of using English words to textualize words that appear in signed sentences has also been proposed. The written notation for Japanese sign language, sIGNDEX, uses romanized Japanese (*rōmaji*) to represent words and their own (textual) symbols to notate facial expressions and other nonhand movements (Hara et al., 2007). Both of these methods are used to analyze sign language and are not used in typical settings, as they require memorizing numerous symbols unique to each method.

2.2 Studies on the Visual Representation of Sentence Structure

Visualizing the sentence structure of Japanese requires considering which unit of text to base the visualization on; that is, the entire text, paragraphs, chunks, and words. Graphic organizers can be used to visualize entire texts (Minaabad, 2017), and the dependency analyzer CaboCha can be used to segment texts into chunks, making it possible to visualize the dependency structure (Kudo and Matsumoto, 2002). However, as these tools cannot grasp the semantic structure of a sentence, for example, which part is subject and which is the object, they are not easily adaptable to sign language.

Other examples of diagramming entire texts that have been proposed include methods of illustrating a text's logical structure using a graph representation (Hasida, 2017). A graph document is a noncontiguous type of text that represents the relationships between textual information as explicit spatial attributes. Unlike continuous text, such as written text, this type of noncontinuous text, in which textual information is presented simultaneously in a graph, has been found to facilitate the comprehension of content (Larkin and Simon, 1987).

Based on a study of college students, simultaneously presenting information by arranging it in space, similar to that in illustrations, promotes the comprehension of entire texts. Additionally, an important part of promoting comprehension is the relation of the textual data to entire graphic elements, such as by drawing boxes around it or arrows pointing to it (Suzuki and Awazu, 2010).

For DHH individuals, it is appropriate to present information in a form similar to the spatial arrangement used in sign languages. Thus far, there have been notations for sign language research and translation, but no system has been proposed for DHH to read. Therefore, in this study, we examine a novel notation method for DHH.

3 SENTENCE STRUCTURE AND PROPOSED NOTATION METHOD

3.1 Comprehending Sentence Structure

In English, word order provides clues for understanding the structure of a sentence, such as identifying the subject and object. However, in Japanese, except for predicates at the end of sentences, word order can be swapped using particles. Alternatively, it is not possible to identify subjects and objects from word order, and because DHH individuals face challenges in acquiring spoken Japanese, it is difficult to understand Japanese sentence structure.

When hearing individuals communicate with DHH, they often use signed or manually coded Japanese. When sign words are expressed in Japanese word order and particles are omitted, it is difficult for those with hearing impairment to understand the meaning and structure of the sentence (Chonan, 2001).

In contrast, unique languages developed by deaf people, such as American sign language (ASL) and Japanese sign language (JSL), make it possible to visually describe sentence structure using space, pointing, and facial and other nonhand expressions (Valli et al., 2011)

With short texts, DHH individuals can occasionally comprehend the meanings of sentences by extrapolating from experience, regardless of whether Japanese, manually coded Japanese or JSL are used. However, for specialized texts, it is often more difficult to achieve this, which makes it necessary to have a correct understanding of the sentence structure.

3.2 Characteristics of Sentences in Specialized Texts

When actual DHH students were tested on their understanding of sentences containing a variety of technical terms, it was found that certain features of

the language made it difficult for them to understand Japanese sentences correctly; that is, we observed that:

- The subject and object could not be inferred from word order.
- The subject and object could not be inferred from the particle alone.
- Grammatical roles did not necessarily coincide with semantic roles.

The following points were considered to be reasons for the difficulty in understanding the structure of sentences in specialized texts:

- The subject is omitted in numerous sentences.
- There are many long phrases and clauses.
- There are long or many clauses, or clauses modifying the subject.

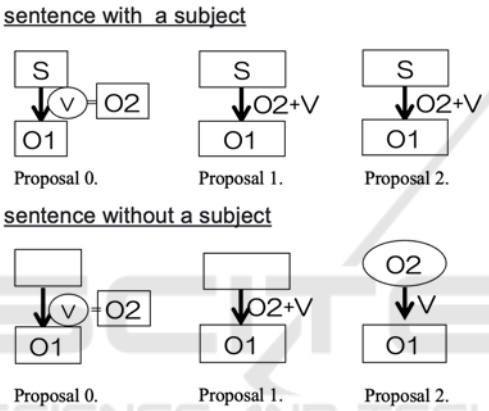

Figure 1: Example of notated rule with our proposed method（S: subject, V: verb, O1: indirect object, O2: direct object).

In this study, we attempt to notate technical sentences with these characteristics using the proposed notation method.

3.3 Proposed Notation Method

In this study, we propose a notation method that focuses on the relationship between words and phrases to make it easy for DHH individuals to understand the structure of sentences. Therefore, we used Japanese labels for the individual signed words. One of the features of sign language is the use of space, which enables the clarification of subjects and objects or expresses two things simultaneously, which is difficult to conduct in spoken language.

We intended our notation method to recreate this feature on a flat surface and to represent the relationship between words diagrammatically.

In the experiment, we tested three proposals (Figure 1), based on a notation method (Tamura and Shiraishi 2015), that consider the spatial characteristics of sign languages. Each proposed method had different symbols surrounding the predicate and object and different notations when the subject was omitted.

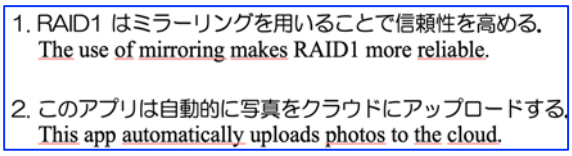

Figure 2: Sentences to notate in Question 3.

4 EXPERIMENTAL METHOD

A total of 10 DHH students participated in the experiment. Students were presented with Japanese sentences written normally and/or diagrammed using different notation methods. The participants were then asked to respond to the questionnaire.

The sentences we used and diagrammed were taken verbatim, or partially revised, from past problems on exams, such as the Fundamental Information Technology Engineer Examination (Information-Technology Promotion Agency).

In Questionnaire 1, writing examples of Proposals 0, 1, and 2, were presented in nine sentences. Participants ranked the three proposals based on the following points.

- Ease of understanding the meanings of sentences.
- Ease to grasp the subject and object of a sentence.

From the results of Questionnaire 1, the proposal with the lowest rank sum was selected as the proposal for each participant.

In Questionnaire 2, we presented sentences notated with their selected proposal and asked participants to identify the subjects and objects of all sentences and provide a subjective rating (on a 6-point scale from 1: ‘strongly disagree’ to 6: ‘strongly agree’).

In Questionnaire 3, we instructed participants to use their preferred notation method to notate the specialized sentences. In total, participants were presented with two sentences (Figure 2).

5 RESULTS AND DISCUSSION

In Questionnaire 1, two participants chose Proposal 0, one chose Proposal 1, and seven chose Proposal 2. The free responses suggested that, in general, writing sentences using our notation method was effective to a certain extent based on the following responses:

- The words in the sentences were boxed in order, which made it easy to understand the meanings.
- At a glance, it was easy to understand what I could not understand simply by reading the text.
- It was visually easy to understand when the text was boxed or circled.

However, participants highlighted issues with the rules of the notation method. These included

- I do not like writing predicates next to arrows (Figure 3, Proposal 1).
- The fewer boxes there are, the easier it is to read, as opposed to a large number of boxes and circles (Figure 4).
- Since I read these from top to bottom, it feels slightly off to have the first box blank (Figures 5, Proposal 0, and Proposal 1).
- I mainly chose the ones that are circled or squared, as it is easy to understand those that emphasize the object.

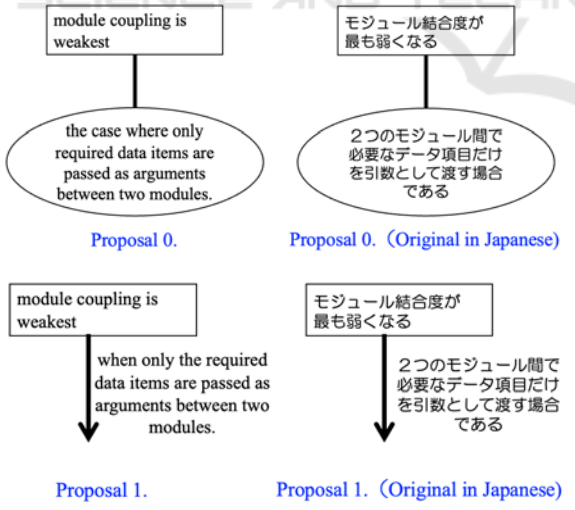

Figure 3: Example where the predicate could be written next to an arrow (Proposal 1).

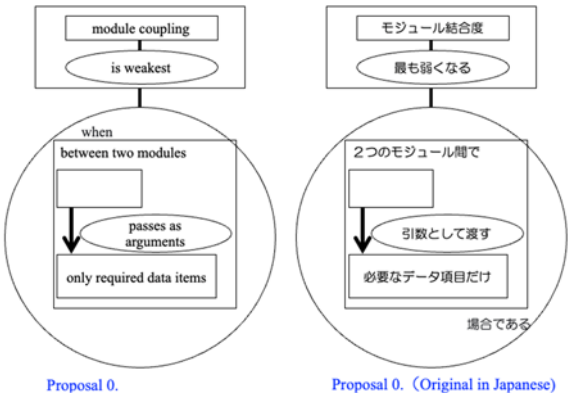

Figure 4: Examples with many enclosing boxes and circles.

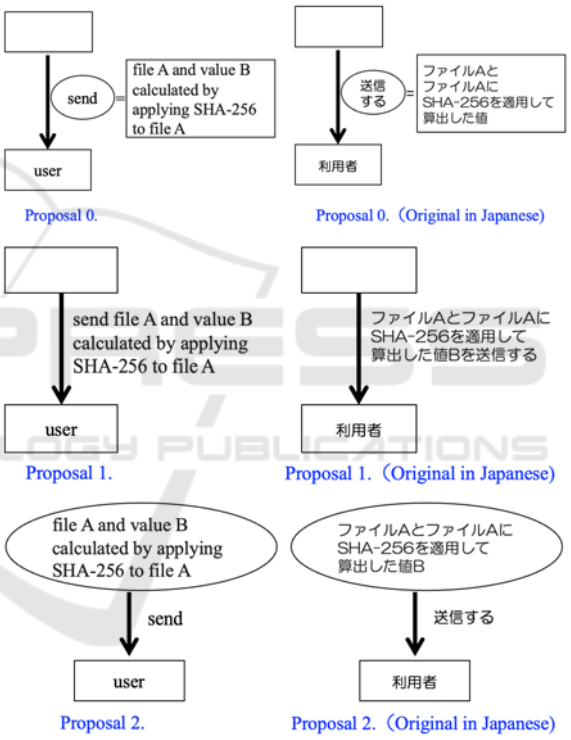

Figure 5: Sentence where the first box is blank because the subject is omitted (Proposal 0, Proposal 1).

In Questionnaire 2, we asked eight respondents to provide subjective ratings (on a scale from 1–6) regarding the ease of knowing what the subject and object were and understanding the meanings of the sentences. We also instructed them to identify the subjects and objects of the sentences. Figure 6 shows the percentage of correct answers for the subjects and objects. An example of a sentence where many respondents wrongly identified the grammatical object is shown in Figure 7.

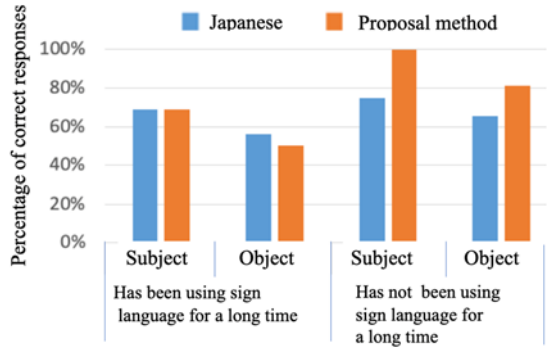

Figure 6: Percentage of correct responses for the subject and object when the sentences were written normally and diagrammed with our notation methods.

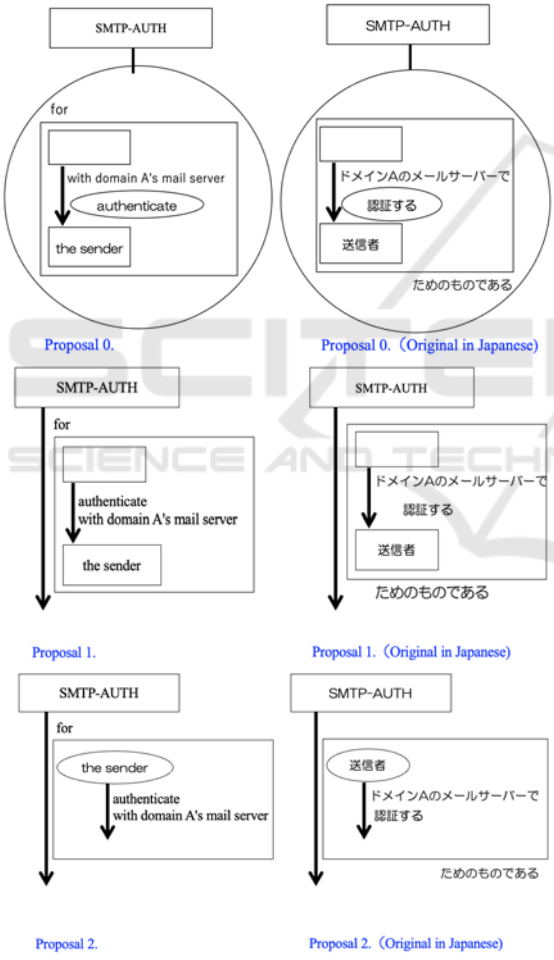

Figure 7: Sentence where most of the respondents wrongly identified the grammatical object.

Table 1: Percentage of correct responses for each respondent when diagramming the sentences using our notation method.

ID	Has not been using sign language for a long time	ID	Has been using sign language for a long time
ID_S1	79%	ID_L1	100%
ID_S2	71%	ID_L2	86%
ID_S3	71%	ID_L3	100%
ID_S4	100%	ID_L4	57%
Mean	80%	Mean	85%

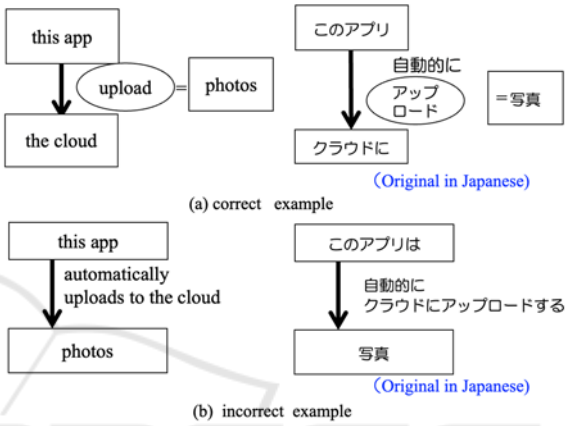

Figure 8: Example responces in Questionnaire 3.

The respondents were classified as having a short sign language history and long sign language history based on whether they started using sign language after entering university or had used it before. The results demonstrate that there was no difference in the percentages of correct responses between sentences written in Japanese and sentences are written using our notation method for respondents with a short sign language history. However, the percentage of correct responses tended to be high for respondents with a long sign language history when our notation method was used.

In Questionnaire 3, we instructed the participants to notate the sentences in our notation method. The percentage of correct responses for the eight respondents in Questionnaire 3 is listed in Table 1. Long-term users of sign language had a higher correct response rate than non-long-time users of sign language.

Figure 8 shows example responses in Questionnaire 3. In the correct and incorrect response examples, the direct and indirect objects were placed in opposite directions.

In sign languages, there are verbs called agreement verbs. The orientation or location of some verbs includes information about the subject and object of

the verb (Valli et al., 2011). Our notation method recreates these spatial sign language expressions. The limited number of respondents notwithstanding, the high accuracy rate among those with a long sign language history may indicate the proposed notation method's effectiveness for DHH individuals.

In addition, we found that it was difficult to estimate the different notation method proposals solely based on subjective ratings because the results of the subjective evaluation did not coincide with the percentage of correct answers.

6 CONCLUSIONS

A questionnaire was conducted on the notation method for visually structuring sentences for DHH individuals based on examples of writing sentences with specialized content. The results indicate the following:

- DHH individuals who are long-term users of sign language can correctly identify subjects and objects at a higher rate in sentences using our notation method than in sentences written normally in Japanese.
- The percentage of correct responses was also high when the sentences were notated using the proposed notation method.

Alternatively, it is expected that when the participants are accustomed to using spatial expressions in sign language, they can easily use the proposed notation method to understand the sentence structure even if it is used for the first time.

While the free responses to the questionnaire indicated that diagramming sentences with boxes and circles around the words was effective to a certain extent, they also pointed out the following issues:

- Excessive boxes and circles may cause low subjective evaluation.
- Writing the predicate section next to the arrow was rated poorly.
- The method of indicating the absence of a subject using a blank square tended to have a low subjective evaluation.

This study has two limitations. The first limitation was the number of participants, because verification using numerous DHHs is required.

The second aspect concerns the scope of the applicable text. Ambiguity in written expressions, not only in Japanese, is caused by the existence of a structure in the language. In a notation method such as the proposed method, which attempts to describe "structure" visually, there are sentences that are difficult to express visually. We found examples of both cases where the cause is the sentence itself (e.g., the sentence itself can be interpreted in several manners), where the cause is the notation. Our notation method offers adjustable granularity of text chunks.

In the future, we will continue to examine notation methods that make sentence structures easy for DHH individuals to understand by conducting surveys with numerous sentences.

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