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Design and Development of a Conjunctive Word-Learning Support System for Conjunctive Expressions with Different-Meaning Commutativity and its Experimental Use

Kengo IWAI[a], Fonteles Furtado PEDRO GABRIEL[b], Yu OGATA[c], Yusuke HAYASHI[d], Tsukasa HIRASHIMA[e]

[a,b,c,d,e]*Graduate School of Engineering, Hiroshima University, Japan*

*iwai@lel.hiroshima-u.ac.jp

Abstract: Conjunctive words connect two sentences logically. This property is divided into same-meaning and different-meaning commutativity. The former emphasizes a meaning that is explicitly represented in the sentences that already exist, but the latter adds a meaning beyond what is explicitly represented in them. Doing exercises to learn how to use both the former and the latter is important because conjunctive words play an important role in reading and writing effective sentences. Exercises to learn the former are easy, as there is only one correct answer to a fill-in-the-blank problem. On the other hand, to demonstrate mastery of the latter, the exercises must be difficult because various correct answers with different meanings exist. In this study, we designed and developed a conjunctive word learning support system for performing conjunctive word exercises to master different-meaning commutativity. In this system, the learner is provided with an exercise that entails assembling a sentence structure composed of two sentences and a conjunctive word and a conjunctive logical structure composed of two explicit situations and an implicit situation. The system also automatically diagnoses the learner's performance on the exercises and gives feedback based on the diagnosis results. Furthermore, we carried out an experiment to verify the validity of this system, and the results suggest that the system is effective for helping students to master this aspect of language.

Keywords: Conjunctive word, different-meaning commutativity, automatic diagnosis

1. Introduction

Connective words play an important role in both reading and writing (Aidinlou & Mehr, 2012; Manan & Raslee, 2018), and they are sometimes called "discourse markers" or "linking words" (Fox Tree, 2010; Yale Center, 2012). Connective words are especially important in Japanese-language learning because they play an important role in reading and writing effective sentences and are one of the most important elements of the language (Ichikawa, 1978; Baba, 2005; Yamamuro, 2008). Therefore, we focus on the role of connective words in Japanese-language learning. The role of conjunctive words is to logically connect the contexts that exist before and after them. Furthermore, if the context is understood semantically, the conjunctive word is not always required. In this case, the conjunctive word does not add a new meaning to the existing context. In fact, a conventional exercise on conjunctive words is to choose a conjunctive word that represents a connection/relationship. Whether the relationship is appropriate for the context is determined only by the sentences before and after the conjunctive word.

On the other hand, many studies have pointed out that an important role of conjunctive words is to give the reader a hint to make the future context easier to discern during the process of reading comprehension (Ujiie, 1973; Itou & Abe, 1991; Ishiguro, 2008). These words also play a role in establishing the context beforehand. In other words, conjunctive words indicate meaning in the process of reading comprehension and description, although the reason for the choice of conjunctive words is

obvious after all contexts become clear. At times, the meaning of the sentences is changed by the choice of conjunctive words. In this study, we define this property of conjunctive words as "different-meaning commutativity." This definition is described in Chapter 2.

In this study, we designed and developed a conjunctive word-learning support system for mastering different-meaning commutativity. The implementation of such an exercise was not easy because it needed to target the implication that was changed by switching conjunctive words. In this study, the information structure of a conjunctive expression is understood as consisting of a sentence structure and a conjunctive logical structure. Furthermore, the sentence structure consists of three elements of two sentences and a conjunctive word that connects the sentences. The conjunctive logical structure consists of three elements of two explicit situations that the sentences that comprise the sentence structure explicitly express and an implied situation suggested by the conjunctive words. In correspondence with these two structures, we articulate a framework in which a conjunctive expression with different-meaning commutativity and its meanings constitute a mutual dependence between a conjunctive word and an implied situation model. As an exercise based on this model, we designed an activity that entailed assembling and manipulating the sentence and conjunctive logical structures and developed an environment in which the system could diagnose students' performance and give feedback on the results of the activity (Ogata et al., 2015). Furthermore, to verify the validity of this system, an experiment using it and an evaluation of the results were performed.

2. Different-Meaning Commutativity

A conjunctive word provides a logical connection between the sentences before and after it. This is called a "conjunctive expression." A conjunctive expression consists of two sentences and a conjunctive word that connects them. In addition, this expression holds even if the conjunctive words in the conjunctive expression change. This property is often called "commutativity" (Itou & Abe, 1991). Due to this property, the meaning does not change or the meaning changes as the conjunctive expression changes. We call commutativity that does not change the meaning "same-meaning commutativity" and commutativity that changes the meaning "different-meaning commutativity." In this study, we focus on conjunctive expressions that reflect different-meaning commutativity. The following is an example of this type of commutativity (Ishiguro, 2008):

(Conjunctive expression 1) "I practiced hard every day and participated in the tournament, so I came in fourth out of twenty people."

(Conjunctive expression 2) "I practiced hard every day and participated in the tournament, but I came in fourth out of twenty people."

In these two conjunctive expressions, the two clauses before and after the conjunctive word are the same. Therefore, the meanings explicitly expressed are common to both. However, the meanings implied by the conjunctive expressions are different because of the difference in the conjunctive word. In conjunctive expression 1, the expression implies that coming in fourth out of twenty people is a reasonable result of practicing hard every day. On the other hand, in conjunctive expression 2, the expression implies that coming in fourth out of twenty people is a disappointing result after practicing hard every day. Thus, different-meaning commutativity entails a change in meaning when the conjunctive word is changed.

The importance of different-meaning commutativity has been pointed out in many studies. According to one interpretation, the conjunctive word is not meant to represent pure or objective logic, and conjunctive expressions include the subjective intentions of a writer as their premise (Ujiie, 1973). Through them, the individual logic of the writer is expressed. The importance of the role of conjunctive words has also been pointed out by scholars. Such words aid in the recognition of speakers and impart the subjective situational understanding of writers (Kawabata, 2009). In addition, another function of conjunctive words is to help the reader understand what a writer is implying (Ishiguro, 2008). This is regarded as a creative aspect of conjunctive words, and the implication appears logical if the subjectivity of writers is accepted by readers. On the other hand, it has been noted that exercises to examine conjunctive expressions with different-meaning commutativity have not been conducted

before (Ishiguro, 2008). Therefore, it is important to provide support for mastering the use of conjunctive expressions that involve commutativity.

3. Modeling a Conjunctive Expression with Different-Meaning Commutativity

3.1 Mutual Dependence between Conjunctive Words and the Implied Situation Model

The mutual dependence between conjunctive words and the implied situation model is a framework for representing the different-meaning commutativity model. The model represents the mutual dependence between the conjunctive word and the implied situation. A diagram of this model is shown in Fig.1. The conjunctive expression consists of two sentences, with a conjunctive word placed between them. In addition, such sentences are composed of a front sentence and a back sentence. This is called "sentence structure." In addition, the meaning of the sentence structure consists of an explicit situation and an implicit situation. The explicit situation represents an obvious connection between the front and back sentences. The implicit situation represents a situation implied by connecting the sentences with the conjunctive word. This is called a "conjunctive logical structure."

Figure 1. Mutual dependence between conjunctive words and the implicit situation model

3.2 Different-Meaning Commutativity Model

The different-meaning commutativity model is a principle that explains the essential content of the conjunctive word exercise in this study. Based on the diagram of Fig. 1, Fig. 2 shows a conjunctive expression with different-meaning commutativity. Its distinguishing characteristic is that two conjunctive expressions are given, and they respectively imply different meanings. The two expressions consist of two identical sentences with a different conjunctive word connecting them. The two sentences and the two conjunctive words are the components used to assemble these two conjunctive expressions, since the two conjunctive expressions are composed of the same two sentences and a different conjunctive word. These are called "sentence expression elements." In Fig. 2, the meaning of each sentence is comprised of its explicit and implicit meanings. The explicit meaning is indicated explicitly in a sentence, and the implicit meaning is implied by the conjunctive word. Furthermore, the explicit meaning is represented by the same two sentences as the sentence expression elements, and the implicit meaning is represented by a different sentence. The meaning of the sentence is comprised of the two sentences that represent the explicit meaning and the sentence that represents the implicit meaning. Furthermore, the meaning of two-sentence structures in relation to different-meaning commutativity is inferred from two sentences that respectively represent the same explicit meaning and two sentences that represent a different implicit meaning for each conjunctive word. These are called "conjunctive logical expression elements." Fig. 3 shows an example of two conjunctive expressions with different-meaning commutativity. This example is the same as the example in the introduction and is represented by this model expression. In this study, we designed a conjunctive word exercise by assembling a pair of sentence and conjunctive logical structures from the sentence expression and conjunctive logical expression elements. This design of the exercises is described in the next chapter.

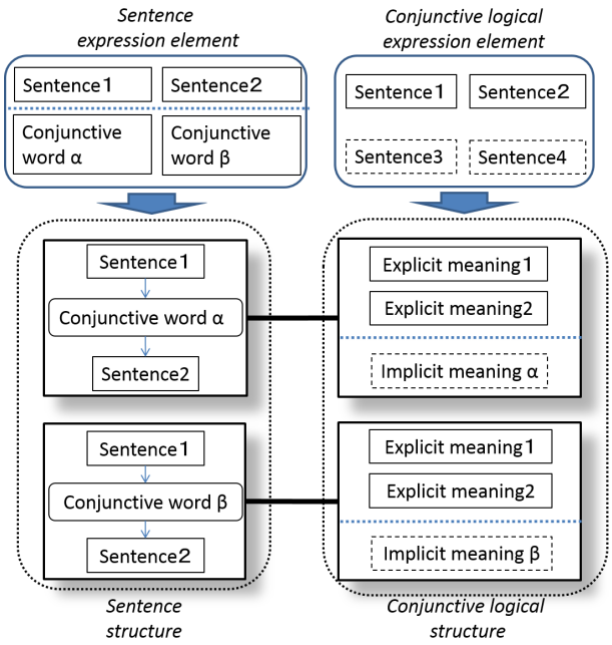

Figure 2. Definition of a different-meaning commutativity model

Figure 3. Example of a different-meaning commutativity model

4. Design and Development of a Conjunctive Word-Learning Support System

4.1 Learning Assignment Setting

In this study, this conjunctive word-learning support system includes providing the sentence expression elements and the conjunctive logical expression elements to learners. This system allows the learners to assemble the information structure of the conjunctive expression with different-meaning commutativity as a conjunctive word-learning assignment. By using the pairs in Figs. 2 and 3, a sentence expression

element list and a conjunctive logical expression element list, as shown in Fig. 4, can be prepared. By applying this system to the diagram of the sentence and conjunctive logical structures in Fig. 1, reconstructing Figs. 2 and 3 can be made into an assignment. In this type of assignment, although the relationship between the sentence and conjunctive logical structures is a many-to-many relationship, designing such an information structure and using it as an assembly activity can form the basis of a system that allows learners' level of mastery to be diagnosed automatically. This approach is called the "open information structure approach" (Hirashima & Hayashi, 2018). Furthermore, it has been confirmed that a system designed using this approach promotes the learning of information structures such as arithmetic word problems and concept maps (Hirashima, 2015, 2016). Therefore, we designed and developed a conjunctive word-learning support system based on this approach.

In order to diagnose students' level of mastery automatically with this system, we prepared sentences that included an explicit meaning (explicit sentences) and conjunctive words, and sentences that included an implicit meaning (implicit sentences) that could be indicated by their combination. By asking learners to combine the elements, this system provided them with assignments that helped them recognize conjunctive expressions that indicated different-meaning commutativity. In each assignment, two explicit sentences that could become the front and back sentences in the sentence structure were presented, as were two conjunctive words that could be inserted between them to construct sentences that made sense. Depending on the elements, if the conjunctive word was changed, the implicit sentence could change and vice versa. In this study, one of the goals of this conjunctive word exercise was to help learners understand different-meaning commutativity.

Furthermore, the variations in combinations increased by changing the type of target conjunctive word. The conjunctive words included in the assignment created using this system included resultative and adversative types to represent logical connections (Inoue & Hirashima, 2011). In the case of resultative and adversative conjunctive words, the following exercises, in which six sentences and two conjunctive words are presented, can be used to assess learners' mastery.

(1) Prepare a pair of explicit sentences that can be used as the front and back sentences.
(Examples: "I wanted to see my friend" and "I went to the station")
(2) Select two conjunctive words that can connect explicit sentences.
(Examples: "so" and "but")
(3) Consider concrete examples of implicit sentences when the explicit sentences are connected by the conjunctive word and create a conjunctive logical structure.
(Examples: "My friend is at the station" and "My friend isn't at the station")
(4) Prepare sentences that are the opposite of the front and back sentences.
(Examples: "I didn't want to see my friend" and "I didn't go to the station")

The elements created based on this procedure are both elements of the sentence and conjunctive logical structures. From the examples above, it can be seen that the learner's answer should correspond to a sentence and conjunctive logical structure that can be formed by the combining six sentences and two conjunctive words. In this procedure, multiple sentences can be composed. Fig. 5 shows the combinations that can be given as answers when the assignment is designed this way. The combinations of answers can be organized in a tree structure. The sentence structure includes 60 ways (6 sentences × 2 conjunctive words × 5 sentences = 60 ways), the conjunctive logical structure includes 120 ways (6 sentences × 5 sentences × 4 sentences); thus, there are 7,200 total ways to answer (60 × 120). Therefore, the flexibility of the system is maintained because the number of potential combinations of answers is huge.

The types of exercises in this system are classified into (1) free-assembly exercises, (2) transition-assembly exercises, and (3) partial-assembly exercises. The free-assembly exercise requires learners to assemble the entire sentence and conjunctive logical structures. The transition-assembly exercise requires learners to change part of the sentence and conjunctive logical structures from a state in which all the components have been assembled in advance and then reassemble the other parts accordingly. In the partial-assembly exercise, some of the components of the sentence and conjunctive logical structures are decided in advance, and the remaining parts are assembled by learners. This exercise is divided into 5 components because there are multiple patterns of predetermined parts. Therefore, the parts assembled in each exercise are different.

Figure 4. Sentence expression and conjunctive logical expression element lists

Figure 5. Instance of mutual dependence between a conjunctive word and an implicit situation

4.2 Immediate Feedback

Another important element in formulating conjunctive word exercises to address conjunctive expressions with different-meaning commutativity is immediate feedback. There are several types of feedback in learning (Hirashima, 2017), and we utilize true-false feedback. A correct pattern is a combination that does not cause a contradiction in the combination of the prepared sentence expression and conjunctive logical expression element lists. There are 48 correct combinations (6 front sentences × 2 conjunctive words × 4 back sentences = 48) among these combinations. Even though there are 5 back sentences, we count them as 4. The reason is that the combination of a positive and a negative sentence is excluded because it is an unnatural construction (example: “I wanted to see my friend, so I didn’t want to see my friend”). The correct pattern can be created from the 48 combinations above, excluding cases of unnatural sentences and those in which there is no implicit sentence in the expression element list. An unnatural sentence like “I want to see my friends, so they are at the station” would be excluded. In the assignment corresponding to this example, 32 patterns are correct. However, there are cases in which implicit statements are not uniquely determined. In such cases, the implicit sentence “cannot be decided” was judged as the correct answer (example: “My friend is at the station, but I didn’t go to the station”).

4.3 Interface of the Conjunctive Word-Learning Support System

An interface from this system is shown in Fig. 6 (translated from Japanese to English). The upper-left is a blank space where the sentence structure is assembled, the upper-right is a blank space where the conjunctive logical structure is assembled, and the lower half shows the options available to the learner. At this stage, the learner assembles the sentence and conjunctive logical structures at the top using the options at the bottom of the screen.

The sentence structure is constructed by moving the front sentence, the conjunctive word, and the back sentence from the lower-left card group to the upper-left blank. The conjunctive logical structure is constructed by moving explicit and implicit sentences from the bottom-right card group to the upper-right blank. After that, the result is shown by pressing the answer button.

Figure 6. Interface of the conjunctive word-learning support system

5. Experimental Use of the Learning Support System

5.1 Procedure for Practical Use of the Learning Support System

The purpose of this experiment is to verify the following two items:
1) This system can be used by children in a primary school setting.
2) Use of this system positively affects primary school students' mastery of the use of conjunctive words.

The flow of the experiment is as follows:
(1) Pre-test
(2) Class: A teacher has test subjects recognize the implicit situation in a textbook with a description of different-meaning commutativity.
(3) Description of system
(4) Exercise 1 (16 minutes): Types 2 and 3 (5 questions for each assignment)
(5) Exercise 2 (10 minutes): Type 1
(6) Post-test and questionnaire

The test subjects were 39 fourth-grade students at an elementary school. Exercise1 and exercise2 were based on the words “friends” and “station.”

5.2 Log Data and Questionnaire

In order to verify that this system could be used by primary school students in practice, we analyzed the log data of this system and the questionnaire. The results of the questionnaire suggested that these types of assignments were difficult for some of the children because the proportion of negative responses to questions about their difficulty was high. On the other hand, the other questions yielded mostly positive opinions, and the exercises and system in this study were generally well-accepted. Therefore, the results suggest that the children understood the significance of the exercises and engaged in them with interest even though they recognized that they were difficult. Moreover, 32 out of 39 subjects filled out the comments section in the free-writing portion of the questionnaire, and many of their responses were “I want to use this system again” or “I enjoyed this system.”

An analysis of the results of the system log shows that the children answered an average of 1.95 times per minute during the first 5 minutes and 1.58 times per minute during the last 5 minutes of the 26-minute exercise. Therefore, we believe that students were continuously engaging in the learning activity because the system was used constantly from the beginning to the end. Moreover, we believe that the learners answered while thinking about the validity of the combinations of a conjunctive word and an implied situation within this framework. This is because the rate of correct answers given by the learners was higher than the rate of correct answers among all the combinations that the learners could choose in this exercise. Based on these observations, we believe that the children actively engaged with these exercises and gave them careful consideration when choosing their answers.

5.3 Pre-Test and Post-Test Comparison

In the pre-test and post-test that were conducted before and after the class, the same three questions were given in the form shown in Fig.7 (translated from Japanese to English). These tests were different from the assignment given using the system that we described, and they were given to investigate whether the children could find more combinations of conjunctive words and implied situations. During these tests, the test subjects were given adequate time to allow them to record all possible combinations.

Fig. 8 shows the results of the pre- and post-tests. The results are analyzed by dividing assignments into one category for the resultative and adversative and another for other conjunctive words. The recall rate (the number of correct answers in the learner’s responses divided by the number of all possible correct answers) and the precision rate (the number of correct answers given by the learner divided by the total of all learners’ responses) were determined for both assignments. The analysis results for the resultative and adversative conjunctive words show that the average recall rate increased from 64.7% to 73.7%. Furthermore, when an analysis of the variance was performed, a significant difference was confirmed ($p = 0.00661$), and the effect size was large ($d = 0.81$). The average of the precision rate decreased from 94.6% to 93.6%; thus, no significant difference was confirmed. On the other hand, the analysis results of the other conjunctive word assignments show that the average recall rate increased from 47.3% to 51.9%. Furthermore, when an analysis of the variance was performed, no significant difference was confirmed. The average precision rate decreased from 44.6% to 38.3%, indicating a significant difference ($p = 2.91E-05$).

The analysis of the assignment for the resultative and adversative conjunctive words suggests that more correct combinations were chosen in this exercise. The reason is that the recall rate significantly increased without changing the precision rate, although a few mistakes were still included. Therefore, this result suggests a meaningful learning effect on students’ mastery of conjunctive words of the resultative and adversative types. The analysis results of the other conjunctive word assignments did not suggest that there was a significant learning effect in the numerical sense. This is because the recall rate increased but was not significant, and the precision rate decreased significantly. However, the increase in the recall rate and the decrease in the precision rate suggest a tendency to use conjunctive words in various ways. Therefore, it is believed that this exercise affected the learners’ awareness and understanding of conjunctive words in general. At the same time, the results also suggest that it would be necessary to do similar exercises for each conjunctive word.

Figure 7. Format of the pre-test and post-test

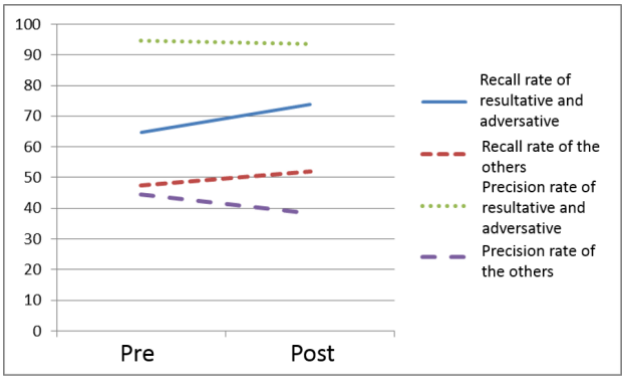

Figure 8. Results of the pre-test and post-test

6. Concluding Remarks

In this study, we discussed the significance of different-meaning commutativity and its modeling based on previous research. Based on the model, we proposed a conjunctive word exercise focused on different-meaning commutativity and developed a system for administering it. Furthermore, we performed an evaluative experiment to verify the validity of this system. From these results, one can see that the positive learning effect on students' mastery of different-meaning commutativity for conjunctive words of the resultative and adversative types was verified. In the future, we would like to create guidelines for assignments focusing on other types of conjunctive words, discuss more advanced methods of gathering feedback, and verify the usefulness of learning activities through a detailed analysis of learners' responses.

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