Recognition of the Coherence Relation between *Te*-linked Clauses

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Abstract
This paper describes a method for recognizing coherence relations between clauses which are linked by *te* in Japanese — a translational equivalent of English *and*. We consider that the coherence relations are categories each of which has a prototype structure as well as the relationships among them. By utilizing this organization of the relations, we can infer an appropriate relation from the semantic structures of the clauses between which that relation holds. We carried out an experiment and obtained the correct recognition ratio of 82% for the 280 sentences.

1 Introduction
One of the basic requirements for understanding discourse is recognizing how each clause coheres with its predecessor. Our linguistic and pragmatic competence enables us to read in conceivable relations even when two clauses are copresent without any overt cues, i.e., in parataxis.

There has been a variety of definitions for coherence relations (see (Hovy and Maier, 1993) for a survey). However, the definitions are rather vague and they are often recognized to be underspecified (Moore and Pollack, 1992; Fukumoto and Tsujii, 1994). This paper attempts to explicate how such coherence relations arise between segments of discourse. We focus on *te*-linkage in Japanese — a translational equivalent of English *and*-linkage, since mere parataxis ranges over too widely to capture the underlying principles on the coherence relations.

We consider that coherence relations are categories each of which has its prototypical instances and marginal ones. As with all instances of categorizations, the prototypical cases of each relation are clearly distinguishable from one another. In some cases, however, it is often hard to make clear argument for a relation being one rather than another. In addition, these relations themselves are hierarchically organized according to their specificity. By considering the prototype of each relation, we can infer an appropriate relation from the semantic structures of the segments between which that relation holds.

2 Categorization of *Te*-linkage
Traditionally, *te*-constructions have been divided into three categories according to the function of *te*: (i) as a non-productive derivational suffix; (ii) as a linker joining a main verb with a so-called auxiliary to form a complex predicate; and (iii) as a linker connecting two phrases or clauses. Since the derivatives and the auxiliaries are relatively fixed compared with the third category, we concentrate on the third category in this paper.

Japanese *te*, like English *and*, is used to express a diverse range of coherence relations as shown below.

1. **Circumstance**
   ```
   itami-wo koraete hasiri-tuzuketa.
   pain-ACC endure-te run-continue-PAST
   "Enduring pain, (I) kept running."
   ```

2. **Additive**
   ```
   zyoon-wa akarukute kinben-da.
   Joan-TOP be-cheerful-re diligent COPULA-PRES
   "Joan is cheerful and diligent."
   ```

3. **Temporal Sequence**
   ```
   gogo-wa tegami-wo kaite, ronbun-wo yonda.
   afternoon-TOP letter-ACC write-te thesis-ACC read-PAST
   "In the afternoon, (I) wrote letters and read the thesis."
   ```

4. **Cause-Effect**
   ```
   taihuu-ga kite, ie-ga hakai-sareta.
   typhoon-NOM come-te houses-NOM destroy-PASSIVE-PAST
   "A typhoon came, and houses were destroyed."
   ```

   The examples are borrowed from (Hasegawa, 1996).
which the second predicate is a so-called auxiliary. 

In formal writing such as newspaper editorials, the notion of "togetherness" can be divided into two categories according to the temporal properties of re-linkage. One in parallel and the other in series. In cases where the first clause denotes a state and the second an event, since we have a tendency to focus on a changing event rather than stable state. Thus, the Circumstance relation composes this category. The cases where the first clause denotes some manner of event are also contained in this category, since a manner accompanies an event.

We presume that the inherent meaning of *te* is "togetherness." The only relations that fit with this meaning are possible to arise within *te*-linkage. The notion of "togetherness" can be divided into two categories according to the temporal properties of relations. One in parallel and the other in series. In the former, two events occur simultaneously or two states hold at the same time, while in the latter, two events occur successively.

These two categories are further divided into smaller categories according to the event structures of conjuncts. The category of sequential relations contains both Cause-Effect and Temporal Sequence. When two events which are linked solely by temporal sequentiality are expressed via *te*-linkage, the conjuncts must share an agitative subject. Thus, causation and one person's volitional acts are sufficient to be recognized as togetherness.

On the other hand, in order for the category of parallel occurrence of events to be compatible with *te*-linkage, they must be homogeneous in some sense. One such example is the case where a thing has two different properties (Additive) and another is the cases where two different things have similar properties or are engaged in similar events (Contrast). As for the Additive relation, the subject of the second conjunct is often omitted since it is the same as that of the first. In addition, both predicates of the conjuncts are static — adjectives or stative verbs — because they have no temporal boundaries as opposed to events and can easily hold at the same time within one person. As for the Contrast relation, the subjects of the conjuncts must be different from each other and hence both of them are explicitly mentioned (often marked with the contrastive *wa*). In general, the similarities of the predicates appear as the syntactic parallelism as the example (6) shows.

The other sub-category of the parallel occurrence of events is "accompaniment," where the second clause is equivalent to *I sat down* and *The door opened* are presented paratactically in Japanese, the interpreter naturally reads in a Temporal Sequence relation, just as in English. But this relation is not an available interpretation when the clauses are linked by *te*. That is, among the relations potentially implicated by *te*, the only one that is possible is re-linkage. The other sub-category of the parallel occurrence is "accompaniment," where the second clause is equivalent to *I sat down* and *The door opened* are presented paratactically in Japanese, the interpreter naturally reads in a Temporal Sequence relation, just as in English. But this relation is not an available interpretation when the clauses are linked by *te*. That is, among the relations potentially implicated by *te*, the only one that is possible is re-linkage. The other sub-category of the parallel occurrence is "accompaniment," where the second clause is equivalent to *I sat down* and *The door opened* are presented paratactically in Japanese, the interpreter naturally reads in a Temporal Sequence relation, just as in English. But this relation is not an available interpretation when the clauses are linked by *te*. That is, among the relations potentially implicated by *te*, the only one that is possible is re-linkage. The other sub-category of the parallel occurrence is "accompaniment," where the second clause is equivalent to *I sat down* and *The door opened* are presented paratactically in Japanese, the interpreter naturally reads in a Temporal Sequence relation, just as in English. But this relation is not an available interpretation when the clauses are linked by *te*. That is, among the relations potentially implicated by *te*, the only one that is possible is re-linkage. The other sub-category of the parallel occurrence is "accompaniment," where the second clause is equivalent to *I sat down* and *The door opened* are presented paratactically in Japanese, the interpreter naturally reads in a Temporal Sequence relation, just as in English. But this relation is not an available interpretation when the clauses are linked by *te*. That is, among the relations potentially implicated by *te*, the only one that is possible is re-linkage. The other sub-category of the parallel occurrence is "accompaniment," where the second clause is equivalent to *I sat down* and *The door opened* are presented paratactically in Japanese, the interpreter naturally reads in a Temporal Sequence relation, just as in English. But this relation is not an available interpretation when the clauses are linked by *te*. That is, among the relations potentially implicated by *te*, the only one that is possible is re-linkage. The other sub-category of the parallel occurrence is "accompaniment," where the second clause is equivalent to *I sat down* and *The door opened* are presented paratactically in Japanese, the interpreter naturally reads in a Temporal Sequence relation, just as in English. But this relation is not an available interpretation when the clauses are linked by *te*. That is, among the relations potentially implicated by...
"since (I) want to meet (you)"

(18b) expresses the reason why the speaker came to the hearer — "he wish to meet the hearer caused him/her to come." Thus, this relation associates the two extremes i.e., parallelism and sequentiality.

Finally, the Concession is closely related to both Cause and Contrast. In the Concession relation, the first clause implies something and the second clause denies it. The implied states or events are often those to be caused by the events or states denoted by the first clause, and then denied and contrast with the second clause.

The whole organization is shown in Figure 1. Note that this organization of the relations are viewed from the perspective of te-linkage. The different organizations may emerge via the other linkages.

4 Recognizing the Coherence Relations

4.1 Overview

Theoretically, it is more likely that when we have heard/read the first clause and te, we narrow down the possible relations by inferring the content of the second clause. For example, if the first clause denotes an action, we will infer what is caused by the action or another action which may follow the action — that is, Cause or Temporal Sequence will be expected. On the other hand, if the first clause denotes a state, Circumstance or Additive will be expected. In practice, however, we have both clauses at hand. Therefore, we adopt the following algorithm:

STEP1 Assume part of semantic structures of the conjuncts by reverse linking

STEP2 Unify them with a verb's semantic structures

STEP3 Infer the most feasible relation between them

In STEP1, part of the semantic structure of each clause is abductively assumed by applying linking rules backward. The linking rules are regular ways of

\[
(\forall w, e, g, p) go(e, y, p) \wedge location(e) \wedge goal(g) \\
\supset pp("w - ni", g) \wedge place(g)
\]

\[
(\forall w, e, g, p) go(e, y, p) \wedge possess(e) \wedge goal(g) \\
\supset pp("w - ni", g) \wedge thing(g)
\]

\[
(\forall w, s, y, p) be(s, y, l) \wedge location(e) \wedge at(l, p) \\
\supset pp("w - ni", p) \wedge place(p)
\]

\[
(\forall w, e, c, z) act(e, z, y) \supset pp("w - ga", z) \wedge animate(z)
\]

\[
(\forall w, e, g, p) go(e, y, p) \wedge location(e) \wedge goal(g) \\
\supset pp("w - ni", g) \wedge place(g)
\]

\[
(\forall w, e, x, z) act(e, x, y) \supset pp("w - o", y)
\]

\[
(\forall w, e, s, y) become(e, y, s) \supset pp("w - ga", y)
\]

\[
(\forall w, e, s, y) become(e, y, s) \supset pp("w - o", y)
\]

\[
(\forall w, e, x, y) act(e, x, y) \wedge become(e, y, s) \\
\supset pp("w - o", y)
\]

Figure 2: Examples of the linking rules

\[
(\forall s, y, z, l) be(s, y, l) \wedge at(l, z) \supset State(s)
\]

\[
(\forall e, x, y) act(e, x, y) \supset TransAct(e)
\]

\[
(\forall e, y, p) go(e, y, p) \wedge path(p) \supset Move(e)
\]

\[
(\forall e, y, s, l, z) become(e, y, s) \wedge be(s, y, l) \wedge at(l, z) \\
\supset Achievement(e)
\]

\[
(\forall e, e_1, e_2, z, y) act(e_1, e_2, z, y) \wedge cause(e, e_1, e_2) \\
\wedge become(e_2, y, s) \wedge be(s, y, l) \wedge at(l, z) \\
\supset Accomplishment(e)
\]

\[
(\forall s) State(s) \wedge thing(y) \wedge place(z) \supset verb("aru", e)
\]

\[
(\forall s) State(s) \wedge animate(y) \wedge place(z) \supset verb("iru", e)
\]

\[
(\forall e) Move(e) \wedge manner1 \supset verb("hashiru", e)
\]

\[
(\forall e) Move(e) \wedge manner2 \supset verb("aruku", e)
\]

\[
(\forall e) Accomplishment(e) \wedge manner3 \supset verb("nuru", e)
\]

\[
(\forall e) Accomplishment(e) \wedge manner4 \wedge location(e) \\
\supset verb("sosogu", e)
\]

Figure 3: Examples of the verbs' semantic structures
mapping open arguments — i.e., variables of semantic structures whose referents can be expressed syntactically by a phrase within the same clause as the predicate — onto grammatical functions or underlying syntactic configurations by virtue of thematic roles (thematic roles are positions in a structured semantic representation). In the case of Japanese, they are triggered by case particles. In STEP2, the verb’s semantic structures are invoked and unified with the outputs of STEP1. The examples of the linking rules and verbs’ semantic structures are shown in Figure 2 and 3 respectively.

However, since the real texts contain far more complexity and ambiguity than the examples given in this paper, we have to correct the outputs of the processes manually (the gapped arguments are filled by hand). We now focus on the processes that calculate the coherence relations.

4.2 The Properties Relevant to the Coherence Relations

What is essential for recognizing the coherence relation between clauses is that the constituents of one clause bear certain kind of structural relationship to those of the other. Although there are an infinite number of situations, there seems to be only a small number of properties relevant to the coherence relations that can hold between them. They are:

1) the identity and agentivity of the subjects in the two clauses
2) the thematic and aspectual properties of the event denoted by each clause
3) canonical events associated with the noun that is relevant to both clauses

Before going through the use of these properties, let’s consider the other information which affects our construal of the relations.

There are some adverbials or fixed expressions which coerce the interpretation into the specific relation. In addition, there are narrow-range verb classes which specialize the implicated relation by virtue of their inherent meaning. For example, verbs that take a temporal NP as the subject and means “the passage of time” such as sugiru(pass away), tatu(go by), keikasuru(elapse), etc., imply the Temporal Sequence relation when followed by te. Verbs that express “using” such as tukau(use), siyouhurstu(make use of), katuyousuru(apply), etc., imply the Means-End relation. They are summarized in Table 1. In Table 1, [TE] means temporal expressions such as days, months, years, centuries, etc. The verbs and fixed expressions appear in the first clause, while the adverbials in the second. These fixed expressions should be listed as a unit in the lexicon.

When these expressions appear in the test sentences, we can identify the relation regardless of the procedure described below. Otherwise, we have recourse to the aforementioned properties.

4.3 The Prototypes and the Extensions

In the previous study, We have classified verbs into 30 semantic categories, and for each category we have given a lexical conceptual structure (LCS) representation (Oishi and Matsumoto, 1997). Since the LCS representation involves lexical decomposition (Jackendoff, 1990), we can utilize the verb internal semantic structure so as to calculate coherence relations in a rarely principled way.

As mentioned in the introduction, we consider each relation as a category. Categories cannot be defined in terms of necessary and sufficient conditions, but rather each instance is categorized according to its similarity to the prototypes of the categories (Rosch, 1973; Lakoff, 1987; Taylor, 1989).

We define a prototypical structure for each relation by means of the predicates used in the LCSs as follows:

- **Circumstance**
  
  \[ x \text{ ACT}_2 \text{ WITH} \ x \text{ BE } z_1 \]

- **Additive**
  
  \[ x \text{ BE } z_1 AND x \text{ BE } z_2 \]

- **Temporal Sequence**
  
  \[ x \text{ GO TO } z_1 \text{ THEN } x \text{ GO (FROM } z_1 \text{ TO } z_2 \_2 ]

| relations         | categories          | examples                  |
|-------------------|---------------------|---------------------------|
| Temporal Sequence | passage verbs       | sugiru(pass away), keikasuru(elapse) ... |
|                   | ending verbs        | owaru(end), oeru(finish) ... |
|                   | continuing verbs    | tuzuku(continue), hikituzuku(follow) ... |
|                   | adverbials          | sonogo(after that), imadeha(nowadays) ... |
|                   | fixed expressions   | [TE]ni-natte(set in), [TE]hodo-site(after) ... |
| Means-End         | using verbs         | tukau(use), siyouhurstu(make use of) ... |
|                   | fixed expressions   | ni-yotte(by means of) ... |
| Cause-Effect      | fixed expressions   | dake-atte(on account of), wo-ukete(given) ... |
| Circumstance      | static relation verbs | sou(be parallel to), motozuku(be based) ... |
• Cause-Effect
  \[[x \text{ ACT ON } y]\_1 \text{ CAUSE } [y \text{ BECOME } z]\_2\]

• Means-End
  \[[x \text{ ACT}]_2 \text{ BY } [x \text{ ACT}]_1\]

• Contrast
  \[[x \text{ ACT}]_1 \text{ WHILE } [y \text{ ACT}]_2\]

• Concession
  \[[x \text{ ACT ON } y]\_1 \text{ BUT } [y \text{ NOT BECOME } z]\_2\]

Here, WITH, AND, THEN, etc., are mnemonic names for the relations and each can be considered as a function that takes two events or states as its arguments and returns a coherent event or state. We use the infix notation for each function rather than prefix. The square brackets identify the semantic structure of a clause and their subscripts denotes the surface ordering of the clauses linked by \(te\). ACT, BE, GO, and BECOME are also functions and they correspond to actions, states, movement, and inchoatives respectively. They express broad-range classes of the events which are constructed by the previous steps (see Figure 3). The whole structures incorporate the identity between the subjects of two clauses by the variables \(x\) and \(y\). Agentivity of each subject is implied by the types of the events: \(\text{ACT} > \text{GO} > \text{BECOME} > \text{BE}\).

Often, these prototypical structures are lexicalized and expressed by a single clause. For example, the Cause-Effect relation is lexicalized into accomplishment verbs (Talmy, 1985) and the Means-End relation can be expressed by an adjunct event noun followed by the case particle \(de\). They must be extended so that they can cover wider range of instances of \(te\)-linkage. The result of the extension is shown in Table 2 (for cases each of which shares a subject) and Table 3 (for cases each of which has distinct subjects), where each column corresponds to the type of the event in the first clause and each row to the second. The prototypes are boldfaced and they are extended to the other boxes with some directions and constraints.

For example, the Temporal Sequence relation has a prototype structure, which is roughly read as “someone goes to somewhere, and then he/she goes (from there) to elsewhere.” This expresses our common sense that one person cannot move along two different paths at the same time, which implies that the two movements by a person must be sequential. This prototype is extended so as to cover such situations as “someone goes to somewhere, and then he/she does something/becomes something/stays there” or “someone does something/becomes something/stays somewhere, and then he/she goes to elsewhere.” They are expressed by vertical and horizontal extensions of the prototype in Table 2. The

Table 2: The combinations of event types (identical subjects)

| 2nd clause | ACT | GO | BECOME | BE |
|------------|-----|----|--------|----|
| ACT        | Means | TempSeq | TempSeq | Circum |
| GO         | TempSeq | TempSeq | TempSeq | Cause |
| BECOME     | Cause | TempSeq | Cause | Circum |
| BE         | Cir(manner) | TempSeq | Additive | Cause |

Table 3: The combinations of event types (distinct subjects)

| 2nd clause | ACT | GO | BECOME | BE |
|------------|-----|----|--------|----|
| ACT        | Contrast |    | Circum |
| GO         | Contrast |    | Circum |
| BECOME     | Cause | Contrast | Cause | Circum |
| BE         | Concession |    | Contrast | Circum |

movements involved in these situations are location and the other events must be done volitionally by the same person. Another extension covers situations where “someone does something, and then he/she does something else.” This is based on the fact that one person cannot generally engage in two actions at the same time. Of course, any type of events may occur sequentially. However, there exists the constraint on the fitness with \(te\)-linkage as mentioned in the previous section.

The explanation for the other relations is detailed in (Oishi, 1998).

As a result of the extensions, many boxes have two or more relations. Notice that the nearer relations in the organization tend to be in the same boxes. To discriminate among them, we specify for each combination of event types such algorithm as follows (below, \(I(i,j)\) means that two clauses share a subject and \(D(i,j)\) means that two clauses have distinct subjects, where \(i\) is the event type of the first clause and \(j\) the second):

- \(I(\text{ACT,ACT}), I(\text{ACT,GO})\)
  If either clause contains the expressions which fix the temporal boundary, then \(\text{Temporal Sequence}\); else if the verb of the first clause involves a manner component, then \(\text{Circumstance}\); otherwise, \(\text{Means-End}\).
- \(I(\text{ACT,BECOME})\)
  If the second event is psychological, then \(\text{Cause-Effect}\);
else if the verb of the first clause involves a manner component, then *Circumstance*; otherwise, *Means-End*.

- **I(GO,BECOME)**
  If the second event is psychological, then *Cause-Effect*; otherwise, *Temporal Sequence*.

- **I(BECOME,GO)**
  If the first event is perceptual, then *Cause-Effect*; otherwise, *Temporal Sequence*.

- **I(BE,GO)**
  If either clause contains the expressions which fix the temporal boundary, then *Temporal Sequence*; otherwise, *Circumstance*.

- **I(BE,BE)**
  If the second state is psychological, then *Cause-Effect*; else if the both predicates are property-denoting adjectives or nouns, then *Additive*; otherwise, *Circumstance*.

- **D(BECOME,BECOME)**
  If the both subjects are marked with *wa*, then *Contrast*; otherwise, *Cause-Effect*.

- **I(BE,BE)**
  If the first state is relational, then *Circumstance*; otherwise, *Cause-Effect*.

- **D(BE,BE)**
  If the both subjects are marked with *wa*, then *Contrast*; otherwise, *Circumstance*.

On the other hand, there remain some boxes blank. They should be resolved by using the third property — the canonical events associated with the noun that is relevant to both clauses. The generative lexicon will serve the purpose (Pustejovsky, 1995). At present, however, we have not yet fully implemented the lexicon for nouns. Therefore, we give the Circumstance relation as a default.

### 5 Experiment and Discussion

An experiment of recognizing coherence relations of *te*-linkage were done for 280 sentences which were randomly extracted from EDR Corpus (EDR, 1995). The analysis results are shown in Table 4, where the coherence relations in the sentences were classified into 7 categories by authors and compared with the outputs of the program.

The relations are not balanced in number. This seems to be due to the genre of texts from which the test sentences were picked up (most of them were news articles). The numbers in parentheses show those of test sentences that matched with the fixed expressions in Table 1.

The precision on the whole is 82%. This shows that to a large extent we can cope with the problem to recognize the coherence relations between clauses (at least when linked by *te*), given the event types of the clauses and the fixed expressions in the lexicon.

Most of errors are caused by ambiguity of the relation. There were many examples which were difficult even for humans to make clear judgements. This reflects the fact that the coherence relations do not have definite borders.

However, there were some errors which show a crucial limitation of our method. This appears as the bad marks in both precision and recall for the Concession relation, even though the number is small. For example, there is a test sentence such as follows:

(19) ano hito-wa 82 sai-ni natte, annani koukisin ippai-da.  
that person-TOP 82 years-old-DAT become-te, so curiosity bc-fid-PRES  
“Although that person is 82 years old, (he/she) is full of curiosity.”

**Table 4: The results of the experiment**

| coherence relations      | judgement by human (a) | output of program (b) | number of agreements (c) | recall (%) | precision (%) |
|--------------------------|------------------------|-----------------------|--------------------------|------------|---------------|
| Temporal Sequence        | 89                     | 81(46)                | 79                       | 89         | 98            |
| Circumstance             | 75                     | 83(22)                | 63                       | 84         | 76            |
| Cause-Effect             | 64                     | 58(13)                | 48                       | 75         | 82            |
| Means-End                | 45                     | 48(12)                | 34                       | 76         | 71            |
| Additive                 | 3                      | 3                     | 3                        | 100        | 100           |
| Concession               | 3                      | 5                     | 1                        | 33         | 20            |
| Contrast                 | 1                      | 2                     | 1                        | 100        | 50            |
| Total                    | 280                    | 280(92)               | 229                      | 82         | 82            |
Since the combination of the event type here is I(BECOME,BE), our program gave it the Circum-
stance relation as a default. However, we know that in general the person who is 82 years old is not so curios, therefore the Concession relation arises. Thus, our common sense knowledge is crucial to our recognition of the coherence relations. In (Hovy and Maier, 1993), they classified the Concession relation as interpersonal (i.e., author-and/or addressee-related) rather than ideational (i.e., semantic), since they defined it as "one of the text segments raises expectations which are contradicted/violated by the other." The use of interpersonal relations is predicated mainly on the interests, beliefs, and attitudes of addressee and/or author. To deal with this problem, we must incorporate the notion of intentional structure and focus space structure (Grosz and Sidner, 1986).

Since we have focused on te-linkage in this paper, we need not to consider how clauses are combined. However, to detect the discourse structure, we need to extend the method so as to deal with the relations between sentences. We must estimate some kind of reliable scores among possible segments and choose the relation having the maximum score (Kurohashi and Nagao, 1994). These issues remain to be studied in the future.

6 Summary

Since the semantic relations exhibited by te-linkage vary so diversely, it has been claimed that the interpreter must infer the intended relationships on the basis of extralinguistic knowledge. The particulars of individual common sense knowledge are crucial to understanding any discourse (Hobbs et al., 1993; Asher and Lascarides, 1995). Nevertheless, one can, through the use of the relevant structures of events, eliminate a very large number of rules for calculating the plausible relations.

Although we have concentrated on te-linkage in this paper, we consider that the method can be applied to pure parataxis with necessary modifications. For the relations we have examined are not attributable to the meaning of te itself (though it restricts the range of them), but are implicated by the linked conjuncts. The same is true of English and and-and. In both and-and te-linkage, the perceived coherence relations are present even if the linked constitutes are in pure parataxis without and or te. Thus, this approach can be extended so as to detect the whole discourse structure, though further study must be done to examine all relations.

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