A Computational Treatment of V-V Compounds in Japanese

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Abstract

We examine how a large-scale computational grammar can account for the complex nature of Japanese verbal compounds. Previous computational Japanese grammars have tried to avoid the problem by simple solutions such as enumerating as many verbal compounds in the lexicon as possible. In contrast, we develop the analysis that is linguistically adequate and computationally tractable and thus meets the requirement of a syntactically and semantically precise natural language processing of Japanese like Bond et al. (2005). Our analysis distinguishes between two kinds of verbal compounds: syntactic compounds, which are fully productive; and lexical compounds, which are of varying productivity.

1 Introduction

In this study, we examine how a large-scale computational grammar can account for the complex nature of Japanese verbal compounds (V_1-V_2 compounds, hereafter), such as *yomi-owaru* (read-finish) 'finish to read'. It is necessary to develop a linguistically accurate and computationally tractable analysis for V_1-V_2 compounds, since they are common in written documents and spontaneous speech, and, despite their surface simplicity, they show various complexities. To date, several computational Japanese grammars have been developed, but little attention has been paid to V_1-V_2 compounds. In fact, their approaches are either enumerating all V_1-V_2s in the lexicon as if they were single words without internal structures (the exhaustive listing approach) or simply concatenating the V_1 and V_2 of any kind of V_1-V_2 without taking into account the differences in their syntactic and semantic composition (the simple concatenation approach). The former suffers from undergeneration since some patterns are very productive and moreover a V_1-V_2 can embed another one.

(1) Ken-ga musuko-o [[[nade-mawasi]-tuzuke]-sobire]-kake-ta
Ken-NOM son-ACC [[[stroke-slue]-continue]-fail]-be.about.to-PAST
'Ken was about to fail to continue to caress his son.'

The latter approach leads to overgeneration since not all combinations of two verbs are allowed:

(2) a.*yu-ga waki-age-ta
hot.water-NOM boil-raise-PAST
'Water reached a full boil.'

b. yu-ga waki-aga-tta
hot.water-NOM boil-go.up-PAST
'Water reached a full boil.'

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We develop the analysis of V_1-V_2s that is compatible with the linguistic analyses and observations made by Kageyama (1993) and Matsumoto (1996) while being computationally tractable. The analysis is implemented in JACY (Siegel and Bender, 2002) using the LKB system (Copestake, 2002) and evaluated with the Hinoki corpus (Bond et al., 2004) and the [incr tsdb()] system (Oepen and Carroll, 2000). A slightly different version of the grammar, along with the analysis tools, is available at the Deep Linguistic Processing with HPSG (DELPH-IN) website: `http://www.delph-in.net`.

2 Data

V_1-V_2s show differences in terms of how productive they are, how their transitivity and case-marking are determined, whether or not they are compositional, and what semantic composition they undergo if they are compositional. First, as for their productivity, some V_1-V_2s are very productive and allow even a phrase in the V_1 position. In (4), for example, the V_1-V_2 headed by *sobireru* (fail) allows the phrasal V_1, *nade-te age* (stroke-TE give), while the V_1-V_2 headed by *mawasu* (fondle) does not.

(3) a. Ken-ga musuko-o nade-sobire-ta
Ken-NOM son-ACC stroke-fail-PAST
'Ken failed to stroke his son.'

b. Ken-ga musuko-o nade-mawasi-ta
Ken-NOM son-ACC stroke-fondle-PAST
'Ken caressed his son.'

(4) a. Ken-ga musuko-o nade-te age-sobire-ta
Ken-NOM son-ACC stroke-TE give-fail-PAST
'Ken failed to stroke his son.'

b.*Ken-ga musuko-o nade-te age-mawasi-ta
Ken-NOM son-ACC stroke-TE give-fondle-PAST
'Ken caressed his son.'

Second, some V_1-V_2s inherit V_2's transitivity and case-marking (5), while others are given those of V_1 (6).

(5) a. Ken-ga huku-o kiru
Ken-NOM clothes-ACC wear
'Ken wears clothes.'

b. huku-ga kuzureru
clothes-NOM get.out.of.shape
'Clothes get out of the shape.'

c. huku-ga ki-kuzureru
clothes-NOM wear-get.out.of.shape
'Clothes get out of the shape by someone's wearing.'

(6) a. Ken-ga siai-ni katu
Ken-NOM game-DAT win
'Ken wins games.'

b. Ken-ga siai-o tuzukeru
Ken-NOM game-ACC continue
'Ken continues games.'

c. Ken-ga siai-ni kati-tuzukeru
Ken-NOM game-DAT win-continue
'Ken continues to win games.'

Third, some V_1-V_2s show semantic compositionality (7), but others are highly lexicalized (8).

(7) a. Ken-ga nikki-o kaki-hazime-ta
Ken-NOM diary-ACC write-begin-PAST
'Ken began to write a diary.'

b. Ken-ga naki-saken-da
Ken-NOM cry-shout-PAST
'Ken cried and shouted.'

(8) a. Ken-ga sono-ninmu-o uti-ki-tta
Ken-NOM that-mission-ACC hit-cut-PAST
'Ken aborted the mission.'

b. keisatu-ga hanzai-o tori-simaru
police-NOM crime-ACC take-fasten
'Police control crimes.'

Finally, compositional V_1-V_2s are composed in diverse ways. (9a)–(9b) correspond to (7a)–(7b), respectively.

(9) a. $\exists x$ $\exists y$ begin(x, write(x, y))

b. $\exists x$ and(cry(x), shout(x))

Table 1: Syntactic V_1-V_2s vs. Lexical V_1-V_2s

	Syntactic	**Lexical**
Productivity	Very productive; the V_2s allow almost any V_1.	Not so productive; the combination of V_1 and V_2 is more restricted.
Transitivity	The V_1's transitivity and case-marking are passed to the V_1-V_2.	Either V_1 or V_2 or both participate in the determination of transitivity and case-marking.
Compositionality	Compositional.	Some of them show varying degrees of compositionality, but others are highly lexicalized.
Semantics	The semantics of V_2 consistently embeds V_1's semantics.	There are various kinds of semantic composition.

3 Analysis

3.1 Linguistic Analyses

Kageyama (1993)'s insightful analysis claims that different behaviors of different V_1-V_2s are mostly predictable from how they are composed. He distinguishes two major types: syntactic V_1-V_2 compounds and lexical V_1-V_2 compounds. The two component verbs of syntactic V_1-V_2 compounds are combined in the syntax, while lexical V_1-V_2 compounds are formed in the lexicon. Accordingly, syntactic V_1-V_2s are generally as productive and compositional as ordinary phrases, but lexical V_1-V_2s are often irregular and idiomatic. Table 1 summarizes the characteristics of the two types in more detail.

Kageyama further divides syntactic V_1-V_2s into three types: Raising (e.g. V_1-*kakeru* (V_1-be.about.to) 'be about to V_1'), Control (e.g. V_1-*sobireru* (V_1-fail) 'fail to V_1'), and $\overline{\mathrm{V}}$ complementation types (e.g. V_1-*tukusu* (V_1-exhaust) 'work out to V_1'). This is supported by, among other things, a contrast in passivizability; Raising and Control types do not allow passivization of V_1-V_2, while the $\overline{\mathrm{V}}$ type does.

(10) hon-ga Ken-ni yomi-{*kake/*sobire/tukus}-rare-ta
book-NOM Ken-DAT read-{*be.about.to/*fail/exhaust}-PASS-PAST

Also, the three kinds show differences in whether V_2s thematically restrict their subjects and objects.

(11) a. ame-ga huku-o nurasi-{kake/*sobire/*tukusi}-ta
rain-NOM clothes-acc humidify-{be.about.to/*fail/*exhaust}-PAST
'The rain {was about/failed/worked out} to wet the clothes.'

b. Ken-ga atama-o hiyasi-{kake/sobire/*tukusi}-ta
Ken-NOM head-ACC cool-{be.about.to/fail/*exhaust}-PAST
'Ken {was about/failed/worked out} to cool off.'

Since V_2s of Control (-*sobireru*) and $\overline{\mathrm{V}}$ (-*tukusu*) types put a thematic restriction on a subject, which the subject, *ame* (rain) in (11a), cannot satisfy, only the Raising type (-*kakeru*) is grammatical in the example. In (11b), only the $\overline{\mathrm{V}}$ type is ruled out since it restricts an object to something that can be exhausted, but the object, *atama*, which is a part of the idiom, *atama-o hiyasu* 'cool off,' cannot meet the restriction.

Matsumoto (1996) classifies lexical V_1-V_2s into seven subtypes according to the semantic relations between V_1 and V_2. Each subtype, its example and a tentative semantics of the example are depicted in (12).

(12) a. Pair V_1-V_2s

ex) *naki-sakebu* (cry-shout) $\cdots$ and(shout(x), cry(x))

Ken-ga naki-saken-da
Ken-NOM cry-shout-PAST
'Ken cried and shouted.'

b. Cause V_1-V_2s

ex) *yake-sinu* (burn-die) $\cdots$ cause(burn(x), die(x))

Ken-ga yake-sin-da
Ken-NOM burn-die-PAST
'Ken was burned to death.'

c. Manner V_1-V_2s

ex) *kake-yoru* (run-come) $\cdots$ in.manner.of(come(x), run(x))

Ken-ga musuko-ni kake-yo-tta
Ken-NOM son-DAT run-come-PAST
'Ken ran up to his son.'

d. Means V_1-V_2s

ex) *tataki-kowasu* (hit-break) $\cdots$ by.means.of(break(x, y), hit(x, y))

Ken-ga sara-o tataki-kowasi-ta
Ken-NOM dish-ACC hit-break-PAST
'Ken battered down the dish.'

e. V_1-V_2s with Deverbalized V_1

ex) *sasi-semaru* (thrust-close) $\cdots$ emphasized.by(close(x), thrust)

Kiken-ga sasi-semaru
danger-NOM thrust-close
'Dangerous situation becomes imminent.'

f. V_1-V_2s with Deverbalized V_2

ex) *hare-wataru* (clear.up-cross) $\cdots$ modified.by(clear.up(x), cross)

sora-ga hare-wataru
sky-NOM clear.up-cross
'Skies are sunny.'

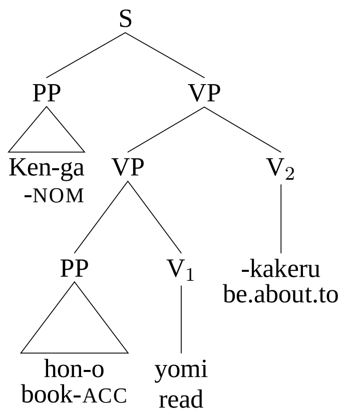
Matsumoto notes how the semantic relation determines the transitivity and the semantic composition of V_1-V_2 and posits a semantic analysis to deal with the phenomena. Although Matsumoto presents a precise and comprehensive analysis, it assumes fine-grained semantic notions and a complicating mapping theory. To implement this, the grammar would have to recognize which semantic relation holds between the two component verbs. But this depends heavily on world knowledge and pragmatic inference, and hence is not currently computationally tractable.

In sum, Kageyama (1993) and Matsumoto (1996) present useful analyses, but these must be revised to make them computationally tractable.

3.2 Computational Analysis — Proposal

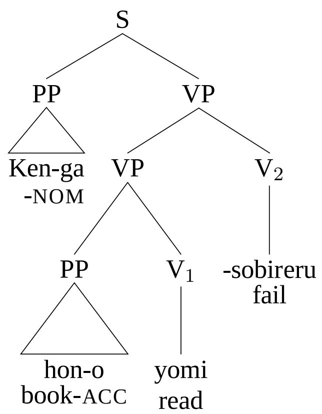
Our analysis of syntactic V_1-V_2s is mostly compatible with Kageyama (1993) but, as an HPSG analysis, assumes neither PRO nor government. (13) illustrates the analysis. (the V-embedding type corresponds to Kageyama's $\overline{\mathrm{V}}$ complementation type.)

(13) a. **Raising**
'Ken is about to read a book.'



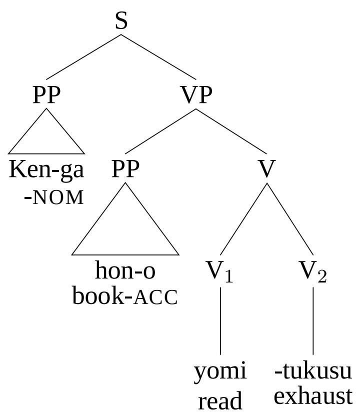
be.about.to(read(Ken, book))

b. **Control**
‘Ken fails to read a book.’



fail(Ken, read(Ken, book))

c. **V-embedding**
‘Ken reads a book thoroughly.’



exhaust(Ken, book, read(Ken, book))

The Raising and Control structures are almost the same as those of Sag et al. (2003); the subject of Raising type V_2 is "raised" from the V_1, and the subject of Control type V_2 controls that of the V_1. The V-embedding type has a structure where the subject and object of the V_2 control the subject and object of the V_1, respectively. These characteristics of the three are reflected in their semantic representations in (13). That is, the Raising type V_2, *kakeru* (be.about.to) in (13a), does not thematically restrict its subject, *Ken*, and object, *hon* (book), while the Control type V_2, *sobireru* (fail), puts a thematic restriction on its subject, *Ken*. The V-embedding type V_2 assigns thematic roles to both the subject and object. Clearly, these differences account for (11). Note, in addition, that the Raising and Control types have a VP embedding structure, while the V-embedding type does not. The contrast in (10) is accounted for by this difference; only the object of the V-embedding type is selected by both the V_1 and V_2, thus only this structure allows the passivization of V_1-V_2 as a whole. Other things to notice are that it is the V_1 that determines the V_1-V_2's transitivity and, in most cases, case-marking, and that their semantic structures are consistently embedding structures.

One of the divergences from Kageyama (1993) involves the V_1 passivization. Kageyama (1993) always accepts the V_1 passivization of Control type but necessarily rules out that of his $\overline{\text{V}}$ complementation type, based on the difference in their syntactic configurations: the VP complement vs. the $\overline{\text{V}}$ complement. But this is incorrect as shown in (14).

(14) a.*hon-ga yom-are-sobireru
book-NOM read-PASS-fail
'A book fails to be read.'

b. Ken-ga nagur-are-tukusu
Ken-NOM punch-PASS-exhaust
'Ken endures the successive punches.'

We basically allow all V_1 passivizations but semantically restrict them. In (14a), for example, the subject, *hon* (book), cannot be construed as FAILER. In (14b), on the other hand, *Ken* can be interpreted as the one who exhausts himself by being punched a lot.

As for lexical V_1-V_2s, we classify them into five subtypes roughly following Matsumoto (1996).

(15) a. **Right-headed V_1-V_2s**

b. **Argument mixing V_1-V_2s**

c. **V_1-V_2s with deverbalized V_1**

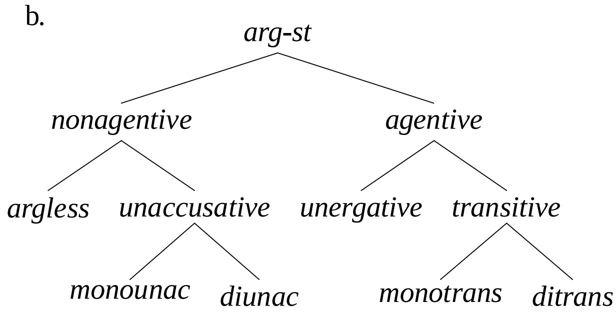
d. **V_1-V_2s with deverbalized V_2**

e. **Non-compositional V_1-V_2s**

The Right-headed and Argument mixing types jointly cover most of Matsumoto's Pair, Cause, Manner and Means compounds. The Non-compositional type is introduced to distinguish compositional and non-compositional V_1-V_2s. Unlike the finer grained semantic analysis of Matsumoto, our analysis leaves the exact semantic relationship under-specified. The constraints on composition come from an extended ARG-ST. As illustrated in (16), the ARG-ST consists of one EXTernal argument and two INTernal arguments and is classified into six types, following Imaizumi and Gunji (2000).

(16) a. $\begin{bmatrix} \textit{arg-st} & \\ \text{EXT} & \textit{index} \\ \text{INT1} & \textit{index} \\ \text{INT2} & \textit{index} \end{bmatrix}$

b.



c.

	EXT	INT1	INT2
argless	×	×	×
monounac	×	○	×
diunac	×	○	○
unergative	○	×	×
monotrans	○	○	×
ditrans	○	○	○

First, the Right-headed V_1-V_2 obeys the Shared Participant Condition proposed by Matsumoto (1996), which requires that the two component verbs share at least one argument that is co-indexed with an argument of the other component verb. Any two arguments can be co-indexed between V_1 and V_2 if the arguments agree in the EXT/INT distinction. The transitivity and case-marking of the V_1-V_2 are inherited from the V_2 (hence Right-headed). The semantics is totally compositional; the two semantic representations of the V_1 and V_2 are predicated by an underspecified semantic relation, which can be specified as Pair, Cause, Manner or Means by a component outside the grammar. For example, the semantic representations of the first two V_1-V_2s in (12) can be glossed as *unspec_rel(shout(x),cry(x))* and *unspec_rel(burn(x),die(x))*. The semantic relation cannot be fully specified in a purely syntactic account since it is affected by contexts, pragmatics, and world knowledge, as these become available, the relation can be constrained further. Research on specifying the semantic relation typically uses information about verb selectional restrictions and noun semantic classes that is not available in our grammar (Uchiyama et al., 2005).

Further, the underspecification greatly simplifies the implementation. The Right-headed V_1-V_2, formulated in this way, covers most of the lexical V_1-V_2s (Pair, Cause, Manner and Means of Matsumoto's) without making the grammar complicated.

Second, the Argument mixing V_1-V_2 has a peculiarity; it is ambiguous in that they can take arguments from either the V_1 or V_2. *nomi-aruku* (drink-walk), for example, can take as the object either something to drink (V_1's argument) or a place to walk (V_2's argument), according to Matsumoto (1996). To account for this, we underspecify the transitivity and case-marking of the V_1-V_2 such that they can be inherited from either the V_1 or V_2. Another peculiarity involves the fact that the V_2 is restricted to a *monotrans* verb that expresses a spatial motion,[1] while the V_1 is *transitive* and must not be a spatial motion verb. As for the semantics, it is the same as that of the Right-headed V_1-V_2 except that the semantic relation is alway construed as Manner.

Third, the V_1-V_2 with deverbalized V_1 includes a V_1 that is deverbalized and only emphasizes the content of V_2 in some way (Kageyama, 1993; Matsumoto, 1996). For instance, *sasi-semaru* (thrust-close), in our analysis, represents something like *emphasize(close(x))*. In the sense that the V_1 is deverbalized, the V_1-V_2 is considered not fully compositional. Naturally, as the V_1 is deverbalized, it is the V_2 that determines the transitivity and case-marking of the V_1-V_2. As Kageyama (1993) notes, there is no restriction on the possible combinations of the V_1 and V_2 in terms of ARG-ST.

Fourth, the V_1-V_2 with deverbalized V_2, as the name implies, includes a V_2 that loses its original verbal meaning and takes on an adverbial meaning that modifies the V_1 (Kageyama, 1993; Matsumoto, 1996). *hare-wataru* (clear.up-cross), for instance, can be glossed as *cross(clear.up(x))* in our analysis. Similarly to the V_1-V_2 mentioned in the last paragraph, this type of V_1-V_2 is also considered not fully compositional, since the V_2 has lost its original verbal meaning. Regarding the transitivity and case-marking of the V_1-V_2, the V_1 determines them since the V_2 is deverbalized. In addition, according to Kageyama (1993), the V_1 and V_2 of this type must agree in agentivity, unlike the V_1-V_2 with semantically deverbalized V_1.

The two types with a deverbalized component verb lexically encode an embedding semantic structure, similarly to the lexical treatment of the 'biclausal' nature of Japanese causatives proposed by Manning et al. (1996).

[1] In the JACY framework, a locative accusative argument is considered an object.

As for productivity, the first two types are more productive than the last two. Actually, we can freely coin a V_1-V_2 that belongs to the first one, the Right-headed V_1-V_2, as long as it is semantically and pragmatically plausible. On the other hand, the Non-compositional V_1-V_2 is absolutely not productive and literally non-compositional; the V_1-V_2 is totally lexicalized and should be analyzed as a single word.

All in all, even though our analysis might be coarser than Kageyama (1993) and Matsumoto (1996), it is sufficient to account for V_1-V_2's complex characteristics summarized in §2 and Table 1. Where there is insufficient information to decide the semantics we under-specify, which makes the analysis both correct and tractable.

4 Evaluation

To see if our implementation works well in practice, we conducted a corpus-based evaluation and examined its coverage, the amount of ambiguity, and efficiency. First, we extracted a small evaluation corpus from the Hinoki corpus (Bond et al., 2004). The evaluation corpus consists of 219 sentences, where each sentence contains at least one V_1-V_2. In addition, we prepared two versions of JACY: JACY-plain and JACY-vv. JACY-plain is given no V_1-V_2 implementation but contains 1,325 lexical entries in the lexicon, which were added by the developers over the course of its development. In contrast, JACY-vv is equipped with all the V_1-V_2 implementations but without any compositional V_1-V_2 entries in the lexicon. Table 2 shows the results of the experiment. We find that JACY-vv gains

Table 2: Experimental results

	JACY-plain	**JACY-vv**
Coverage (%)	52.1	63.5
Ambiguity (ϕ)	53.41	50.78
time (ϕ)	4.85	6.43
space (ϕ)	816779	995681

more coverage and less ambiguity than JACY-plain. The increased coverage is due to the remarkable productivity of the Right headed type. The reduction in ambiguity involves the more restricted nature of our approach to the free word order of Japanese. The table also shows the two versions' processing efficiency: **time** and **space**.[2] Adding the rules and lexical types for V_1-V_2s slightly degrades JACY-vv's efficiency. However, JACY-vv still works fast enough for practical NLP applications.

[2]**time** shows how long the grammar needs to parse one sentence, and **space** shows how much memory the grammar consumes to parse one sentence.

5 Conclusion

We have provided and implemented an analysis for Japanese verbal compounds that captures their syntactic and semantic properties. We follow Kageyama (1993) in dividing them into syntactic verbal compounds and lexical verbal compounds.

Syntactic compounds are fully compositional. There are three types: raising, control and $\overline{\mathrm{V}}$ complementation.

Lexical compound are of varying compositionality. We further divided them into five subtypes depending on how their argument structures combine: right-headed, argument mixing, deverbalized V_1, deverbalized V_2, and fully lexicalized non-compositional compounds. These types make use of an extended argument structure to constrain the classes of verbs that can appear in each type.

We implemented the analyses in the JACY grammar. We then tested them against corpus data to confirm their correctness.

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