Computation vs. Memory in Japanese Causative Formation: Evidence from Agrammatic Aphasics*)

Yoko Sugioka, Takane Ito and Hiroko Hagiwara

There has been much controversy concerning the mental mechanisms involved in the processing of complex words, especially between the dual mechanism theory and the single mechanism theory over inflectional morphology. In this article we present a new set of data from Japanese causatives drawn from the experiments on aphasic patients, which show that two different types of causatives may involve two different mechanisms of rule and associative memory, thus demonstrating the validity of the dual mechanism theory over the processes of derivational morphology.

Keywords: dual mechanism theory, computation, associative memory, derivational morphology, Japanese causatives, agrammatic aphasia

1. Introduction

In this article we will discuss the question of what mental mechanisms are involved in the processing of polymorphemic words, and present a new set of data drawn from the experiments on aphasic patients. This issue has drawn a large number of researchers, and there has been contrasting views and debates, especially over the mechanisms involved in inflectional morphology. In our study we take up derivational morphology, and claim that derivational affixation processes in Japanese involve two different mechanisms of rule and associative memory.

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The paper is organized as follows. We will first review the controversy over the processing of complex words in the literature, including our recent work (Section 2), then the background concerning the morphological process we take up in this study, Japanese causatives (Section 3). Section 4 contains our hypothesis and predictions, followed by the details of the experiments as well as their results and discussion (Section 5). Section 6 gives general discussion and concluding remarks.

2. Dual Mechanism Theory of Morphological Processes

2.1 Dual Mechanism Theories and Single Mechanism Theories

In the psycholinguistic discussion on how polymorphemic words are processed, there has been heated debate between the proponents of “Dual Mechanism” (henceforth DM) theories and those arguing for “Single Mechanism” (SM) theories. DM theories, as will be reviewed below, claim that regular, fully productive morphological processes are dealt with by computational rule while irregular, only partially productive ones are by
Table 1 Pinker & Prince’s (1992) DM Model

<table>
<thead>
<tr>
<th>Inflection</th>
<th>mechanism for dealing with existing words</th>
<th>mechanism for overapplication</th>
<th>characteristic properties</th>
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<tr>
<td>Regular Inflection</td>
<td>computational rule</td>
<td>computational rule</td>
<td>default rule does not depend on frequency</td>
</tr>
<tr>
<td>(walk/walked, boy/boys)</td>
<td>(output not listed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irregular Inflection</td>
<td>associative memory</td>
<td>analogical extension</td>
<td>family resemblance depends on similarity and frequency</td>
</tr>
<tr>
<td>(swung/swung, tooth/teeth)</td>
<td>(listed in networks)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suppletion</td>
<td>rote memory</td>
<td>none</td>
<td>depends on frequency</td>
</tr>
<tr>
<td>(go/went)</td>
<td>(pairs listed in isolation)</td>
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associative memory. In contrast, SM theories, most notably argued for by the connectionist camp (see Elman et al. 1996 for review), argue that associative memory is responsible for both types of morphological processes. In the debate, English past tense formation has been the focus of investigations.

Traditionally, English inflectional morphology was seen as involving a dichotomy between rule-governed regular forms and memory-based irregular forms. The rule status of regular inflection was confirmed, it was claimed, by the fact that children “overapply” the regular suffixation, producing forms like goed and holded. This shows that children learn -ed suffixation as a rule: if each past tense form were memorized one by one, these overregularized forms could never occur. It has turned out, however, that irregular inflectional patterns are also “overapplied”: children produce forms like brung as the past tense form of bring in spontaneous speech, and splung as the past tense form of spling in experiments (Bybee & Slobin, 1982; Bybee & Moder, 1983; Frasada & Pinker, 1993; Xu & Pinker, 1995, among others). Given that irregularly inflected forms constitute phonologically similar patterns, their overapplication (“overirregularization” in a sense) can reasonably be assumed to be due to the process of analogical extension by some kind of pattern associator. Thus, overregularization alone would not provide enough evidence for the status of -ed suffixation as computational rule.

SM theories and DM theories agree on the validity of associative memory approach to irregular patterns, but disagree on how to deal with regular morphology. SM theorists argue that regular -ed suffixation should also be dealt with by associative memory, claiming that regular/irregular difference is merely a matter of degree of “regularity”. Proponents of DM theories argue against this, positing that regular morphology shows qualitatively different properties from irregular patterns. As we mentioned in section 1, the present paper argues for a DM theoretic view on derivational morphology, and a review of arguments for DM approaches to inflectional and derivational morphology is in order.

2.2 DM Approach to Inflectional Morphology

2.2.1 Default Rule Application vs. Associative Memory

Let us summarize in Table 1 how the DM theory as proposed by Pinker and his colleagues (Pinker, 1991, 1997; Pinker & Prince, 1992, among others) deals with inflectional morphology. The rote memory treatment of suppletion is uncontroversial: suppletive pairs are memorized one by one, and this does not provide any possibility of overapplying the pattern. Therefore, we will focus on the differences between regular and irregular inflection in what follows.

First, irregular inflection, but not regular in-
flection, depends on frequency. It is well-known that irregular inflection is limited to basic words with high token frequency. Pinker & Prince (1992) point out that less frequent verbs like *slay* tend to historically change into the regular verb class. There are also some verbs in English like *afford, gate-crash, forgo, sight-see*, which are mostly used in non-finite (i.e. tenseless) forms (either after auxiliary verbs or in infinitival/gerundive forms), and seldom occur in the past tense context. When we construct past forms of these verbs, regular forms (e.g., *afforded, gate-crashed*) are perfectly acceptable while irregular forms (*?forwent, ??sight-saw*) are very awkward (Adams, 1973; Pinker & Prince, 1992). These examples show that irregular inflection, unlike regular inflection, is not readily accepted when the inflected form is low in token frequency. This difference is also tested in various psycholinguistic experiments. Clahsen et al. (1997) examined frequency effects on German regular/irregular inflection, and found that the lexical decision times for high frequency inflected forms were significantly shorter than those of low frequency forms in irregular inflection, while no such frequency effect was observed in regular inflection. Ullman (1999) elicited acceptability ratings on English past tense forms from adult native speakers, and found that the ratings of irregular past tense forms, but not those of regular past tense forms, correlated positively with their past-tense frequencies\(^1\). The difference in frequency effects simply follows from the DM model: irregular past forms are listed in the lexicon as such, and they must have high frequency in order to be stably stored in memory, while regular past forms are not listed but are computed on-line using a symbolic rule, to which frequency is irrelevant. Such a difference, on the other hand, is not expected in SM models.

A second difference between regular and irregular inflection concerns "similarity" or "neighborhood" effects. Since the DM model assumes that overapplication of irregular patterns is due to analogical extension based on associative memory, it is predicted to be sensitive to the similarity of a given item to ones in a prototypical pattern. Regular forms, formed by productive rule, is predicted to be blind to such similarity. This prediction is supported by various psycholinguistic researches. Prasada & Pinker (1993) conducted elicitation and acceptability rating experiments, and found that *splung*, for instance, was readily produced and accepted as an inflected form of a novel experimental verb *spling*, whereas *nust* is not produced nor accepted as an inflected form of *nist*. This is because the pattern *spling/splung* is supported by many neighbors i.e. similar patterns (*swing/swung, cling/clung*, etc.), but *nist/nust* is phonologically too far from existing *i/u* alternation patterns. Regular -ed forms, in contrast, were readily produced and accepted as the past tense forms of novel verbs that deviate from English phonotactic patterns and hence resemble no existing regular pair (e.g. *ploamph/ploamhed*). It is also reported that children's spontaneous overapplication of irregulars, but not that of regulars, tends to be phonologically similar to existing patterns (cf. Bybee & Moder, 1983; Marcus et al., 1992, Xu & Pinker, 1995). Ullman's (1999) study on acceptability ratings by adults also revealed regular/irregular discrepancy: ratings of irregular past tense forms (*blew*) correlated with measures of the number of their neighbors (*threw, grew*), but ratings of regulars (*walked*) did not correlate with measures of the number of their neighbors (*stalked, balked*\(^2\)). The observed difference in sensitivity to similarity is exactly what the DM model predicts.

As a third difference, we may note the default nature of regular inflection. Since irregular inflection is not totally predictable, it must be as-

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\(^1\) See Marchman (1997) for a report that regulars are also sensitive to frequency, and Ullman (1999) for a criticism.

\(^2\) See Stemberger (1993) and Marchman (1997) for reports that overapplication of regular inflection is also sensitive to phonological similarity, and Ullman (1999) for some criticism.
summed that each irregular verb/noun has a feature that specifies its past/plural form. Regular inflection, in contrast, can be assumed to apply as default to all verbs/nouns which lack such a feature. Denominal verbs, even if they contain irregular verbs, tend to take regular inflection (Williams, 1981b; Kiparsky, 1982). The items marked with an asterisk (*) are unacceptable:

1. a. He fled/*flew out to center field.
   b. He grandstanded/*grandstood to the crowd.

Pinker & Prince (1992) explain this as follows. In these examples, the base verb (e.g. fly “to move through the air”) is converted into a noun (fly “a fly ball”), which in turn is converted into a verb (fly “to hit a fly ball”). The base verb has the feature [+irregular past], but this feature cannot be inherited by the deverbal noun, for nouns cannot have features concerning tense. Hence the derived verb no longer has this feature, resulting in the default application of regular inflection. It is not tenable to assume that these denominal verbs are memorized as regulars, for Kim et al. (1991, 1994) revealed that acceptability ratings by adults and children were sensitive to the morphological structure even for novel experimental verbs. When a verb was assigned denominal structure (e.g. to line-drive meaning “to hit a line drive”) the subjects tended to give higher acceptability ratings to the regular form (line-drove) than to the irregular form (line-drove), whereas when the verb is understood to be derived from verbs (to line-drive “to drive along a straight line”) the preference was reversed3). These findings support the idea that regular inflectional processes, but not irregular inflectional patterns, have the property of default rule.

Another difference is that the irregular forms are listed in the lexicon as such, while regularly inflected forms are not. This means that irregulars, but not regulars, can be input to morphological processes like compound formation, which generally involve items listed in the lexicon. Regular plural nouns cannot appear inside compounds (*claws-mark, *rats-infested) while irregular forms can (teeth-mark, mice-infested)(Kiparsky, 1982), and children, who cannot be assumed to learn this difference from data, also obey the constraint (Gordon, 1985). The DM theory provides a straightforward explanation: irregular plural forms, but not regular forms, are listed in the lexicon so that they can be input to compound formation.

Concerning the “listedness” property, we may also mention priming studies on inflected words. Stanners et al. (1979) reported that regular past tense forms had the same amount of priming effects on their stems as the stems themselves, while irregular forms exhibited smaller amount of priming effects on their stems. This suggests that a regularly inflected form is “decomposed” into the stem and -ed in lexical processing with only the stem listed in the lexicon, while an irregular form and its stem are listed separately. Subsequent experiments on lexical decision times, however, yielded inconsistent results on the priming effects of irregular forms (see Clahsen et al. (1997) and Münte et al. (1999) for review), some reporting full priming effects, while others finding no priming effect at all. This confusion led Münte et al. (1999) to conduct a priming experiment using ERP (Event-related potentials) instead of lexical decision times as their measures. They found that a modulation of N400 component, typically observed in repetition priming, was present when regular past tense forms were used as the primes for their stems, but not when the primes were irregular forms. Even though conflicting results on lexical decision times reported in priming literature are hard to interpret, Münte et al.’s (1999) new findings provide additional evidence to the validity of Stanners et al.’s claim that regulars, but not irregulars, are decomposed in lexical processing.

3) See Harris (1993), Daugherty et al. (1993) and Shirai (1997), among others, for attempts to give semantically-based accounts to these data.
2.2.2 Neurological Dissociation between Regular and Irregular Inflection

Thus there is ample linguistic and psycholinguistic evidence of different properties of regular and irregular inflection that suggests these two processes are supported by different mental mechanisms. It could still be argued, however, that the observed differences between the two processes are simply differences in the degree of productivity. If we assume that the applicability of a pattern is determined by its type frequency, the observed differences between regular and irregular inflection (at least in English, which is most extensively studied so far) can be attributed to the difference in type frequency: -ed, which has extremely high type frequency is applicable to verbs with extremely low token frequency (no frequency effect) and to verbs with extremely low similarity to existing patterns (no similarity effect) (cf. Bybee, 1995). We can convincingly argue against such a claim if we can show that the two inflectional processes are supported by different neurological mechanisms: if the differences were merely a matter of degree, it would be very difficult to relate them with neurological dissociations. Interestingly enough, recent years have seen accumulating evidence to this effect from neurolinguistic researches.

Jaeger et al. (1996) reported the results of a PET (Positron Emission Tomography) study on the regular, irregular and novel past tense production by normal adults. They found that some frontal lobe areas (the left dorsolateral prefrontal cortex and the left anterior cingulate cortex) were activated only in regular and novel past formation, while some posterior area (the left middle temporal gyrus) was activated only in irregular past formation. Weyerts et al. (1997) and Penke et al. (1997) conducted ERP studies on German inflection, reporting that an early component of LAN (Left Anterior Negativity) was observed when the subjects encountered violations of regular inflectional rules, but not when they dealt with violations of irregular inflectional patterns.

Evidence has also been drawn from clinical population. Marslen-Wilson & Tyler (1997) observed a double dissociation for regular and irregular English past formation in priming tasks by three aphasic patients. With past forms as primes, the subjects were asked to do the lexical decision task for the verb stem, in which normal controls showed priming effects for both regular and irregular forms. Two aphasic subjects showed positive priming effects for the irregular past tense, but significant negative interference effects for the regular past tense. The other subject exhibited the opposite pattern, with significant priming effects for the regular past tense, but with no priming for the irregular past tense. Penke et al. (1999) report similar dissociation between regular and irregular inflection: in elicitation tasks on German participle forms, they found that irregular inflection is selectively impaired while regular inflection is spared in agrammatic patients. Ullman et al. (1997) also found a similar dissociation between regular and irregular English past tense formation: patients of Alzheimer’s disease and a posterior aphasic patient with word-finding difficulties produced many errors with irregular past forms while they

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4) Another possible argument against the claim that the difference is in degree is that the same types of differences are observed in languages whose regular forms do not have very high type frequency. Clahsen and his colleagues (Clahsen et al., 1992; Clahsen & Rothweiler, 1993; Marcus et al., 1995, among many others) have conducted extensive research along this line, dealing with German participle and plural noun formation.

5) The stimuli were designed so that all novel verbs were inflected with the regular -ed suffixation.

6) The patients whose irregular inflection is selectively impaired are reported to be “agrammatic” in both Marslen-Wilson & Tyler (1997) and Penke et al. (1999). This is in apparent conflict with our report below that agrammatic Broca’s patients exhibit selective impairment in regular morphological processes. While it is not clear what precisely is meant by “agrammatic” in these studies, let us mention here that, as we will discuss in some detail in 5 and 6, our findings are consistent with the general understanding of the Broca’s area as the center for syntactic computation.
did better with regular past tense formation (including novel verbs); patients of Parkinson’s disease and a Broca’s aphasic patient exhibited the opposite pattern.

All these neurolinguistic findings, together with the whole range of linguistic/psycholinguistic evidence discussed in the previous subsection, constitute convincing support for the DM approach to inflectional morphology.

2.3 DM Approach to Derivational Morphology

With exceptions of an earlier work by Anshen & Aronoff (1988) and a recent study by Alegre & Gordon (1999), the controversy surrounding the validity of DM models has centered around inflectional morphology, and little attention has been paid to derivational morphology. For an adequate theory of morphological processes in general, however, it is essential to see if the proposed model can account for derivational processes. We have elsewhere argued that the DM theory as reviewed above does prove tenable in derivational morphology (Hagiwara et al., 1999). We conducted two experiments on normals and on aphasic patients, and argued that two nominal suffixation processes in Japanese are supported by different mental and neurological mechanisms: -sa suffixation involves computational rule while -mi is best treated in terms of associative memory. This previous study of ours and the present study are complementary in the sense that the two deal with different types of derivational processes, and hence they together make up a coherent argument for a DM theoretic view of derivational morphology. Therefore, let us make a little detailed review of the arguments in Hagiwara et al. (1999).

It should first be noted that -sa and -mi, both of which attach to an adjectival stem to derive a noun (taka-i ‘high’, taka-sa/taka-mi ‘height’), exhibit a remarkable difference in their productivity (Sugioka, 1984; Kageyama, 1993). Only a small number of commonly used adjectives accept -mi suffixation, and hence a gap exists even among adjectives in the same semantic field (atataka-mi ‘warmth’, but *tumeta-mi ‘coldness’). In contrast, -sa can attach to virtually all adjectives, including newly coined words (2a), polymorphemic derived adjectives (2b), and compound adjectives (2c). Note that -mi forms corresponding to (2) are all unacceptable.

(2) a. keba-i ‘flashy’: keba-sa /*keba-mi
b. kodomo-rasi-i ‘child-like’:
   kodomo-rasi-sa /*kodomo-rasi-mi
c. oku-huka-i ‘end-deep, profound’:
   oku-huka-sa /*oku-huka-mi
   (cf. huka-mi ‘depth’)

There is also semantic difference between the two (Sugioka, 1984). Deadjectival nominals with -sa is perfectly transparent in their meaning, denoting abstract state or property “the degree/fact of (adjective)-ness”. Nominals with -mi, on the other hand, denote concrete properties tangible or palpable by five senses (e.g. taka-mi ‘high place’, maru-mi ‘round shape’) or some particular characteristics (e.g. yowa-mi ‘weak point (in character etc.)’), and it is not perfectly predictable which of the possible meanings a given item takes. This non-transparency and idiosyncrasy of meaning mi-suffixed forms exhibit is typical of lexical items listed in the lexicon, whereas the transparent and predictable meaning of sa-suffixed forms suggests that they are not listed.

These linguistic observations led us to hypothesize that -sa is dealt with by computational rule, while mi-suffixed forms are listed with their stems in the associative memory. To test this hypothesis, we conducted an acceptability rating experiment on normal adults using novel experimental words. The prediction was that -sa forms would be accepted as nominal forms of novel verbs much more readily than -mi forms7, and that overapplication of -mi to novel words, if it does occur, would exhibit similarity effects (cf. 2.2). Both of these predictions were borne out.
The subjects gave significantly higher acceptability ratings to -sa forms than to -mi forms, even in contexts where -mi forms should be preferred for semantic reasons, which shows that -mi resists overapplication. More importantly, the ratings for -mi, but not those for -sa, exhibited sensitivity to the “adjective-like-ness” of the novel adjectives. We carefully devised two types of novel adjectives, one group consisting of forms with some phonological feature(s) absent in Japanese adjectives and the other consisting of forms without any such feature. The ratings for -mi forms showed significant difference between these two groups of words, with the former group rated less acceptable, whereas the ratings for -sa forms did not exhibit such difference.

Our second experiment was conducted on aphasic patients to see whether the two nominal suffixation processes are subserved by different areas in the brain. Exploiting the semantic difference mentioned above, two sets of sentential contexts were devised: in one type of contexts -sa forms sound much more natural than -mi forms, and in the other -mi forms are preferred. We presented novel adjectives and the corresponding -sa/-mi forms in these contexts, and asked the subjects to choose either -sa or -mi form that better fits the given context. Among other things we found that agrammatic Broca’s patients selected -sa forms only 50% of the time, compared to 92-100% exhibited by normal controls and patients of other aphasic types (Wernicke’s, transcortical-motor, and Word meaning (Gogi) aphasia), even in the contexts where -sa forms are semantically required. In the contexts where -mi forms are preferred, Broca’s patients chose -mi nominals more often than the other subject groups. These results strongly suggest that Broca’s aphasics retain the mental mechanism for -mi suffixation, while the mechanism responsible for -sa suffixation is impaired: the two types of suffixation processes are neurologically dissociated.

Thus the two experiments have confirmed that our hypothesis is on the right track. Like regular/irregular inflection, -sa suffixation and -mi suffixation constitute a rule/associative memory dichotomy. This means that the DM theory is applicable to derivational morphology, and opens up a way to a more comprehensive theory of morphology. The two suffixation processes studied in Hagiwara et al. (1999), however, do not represent all the types of derivational processes. In particular, the processes do not involve any change in argument structure observed in many other derivational processes. The suffix -sa is a pure category changer, in the sense that it changes the syntactic category of the stem from A to N, and does nothing else: no change in meaning, no change in argument structure. Therefore, the mental computation performed by applying the rule of -sa suffixation is somewhat simple, like in the case of -ed suffixation. But there are other derivational processes that involve more complicated computation of the change in argument structure, which nevertheless exhibit full productivity and syntactic nature. Does the rule status under discussion also hold true of such processes, so that the DM model is applicable to argument structure changing derivational processes? We will discuss the possibility in what follows.

3. Causatives in Japanese

3.1 Argument Structure-changing

Morphology and Lexicon-Syntax Interface

There are a number of morphological operations that alter the base word’s valency (the
number of arguments selected by a predicate; i.e. Subject, Object, and so on), which determines the argument structure, and hence the basic sentence structure (Williams, 1981a). The following examples are from category-changing derivational affixation.

(3) -able (two-place verb → one-place adjective)
    Bill believed the story.
    / This story is believable.

(4) -ify (one-place adjective → two-place verb)
    This plan is simple.
    / Jane simplified the plan.

There also are processes of affixation to verbs which change the verb's argument structure. Typically, passivization reduces the number of arguments:

(5) Passive (two-place verb → one-place verb)
    Cathy kicked the soccer ball.
    / The soccer ball was kicked.

And causative formation (aruk-‘walk’/arukase-ru ‘make walk’), as we will see below, adds the causer argument to the base verb's argument structure.

These and other such processes have sparked controversy over the role of the lexicon vis-à-vis syntax since the early days of generative grammar. In the very early stage of generative grammar, almost all productive processes were relegated to the syntactic component, while the lexicon was a mere depository of lexical items with their idiosyncrasies. By that criterion most phrasal or sentence-level phenomena, as well as some word-level processes, e.g. tense and number inflection (walk-ed, boy-s) and nominalization (destroy the city/destruction of the city) were viewed as belonging to syntax (Chomsky, 1957; Lees, 1960). In early 1970s, after the lexicon and word formation were studied more extensively (e.g. Aronoff, 1976), it was pointed out that while some word formation processes, such as inflection and gerund formation (Mary danced/Mary's dancing), are productive and compositional enough to be treated as syntactic, there are a large number of non-productive or non-productive word formation processes with accordingly various degrees of idiosyncrasies, which are best included in the lexicon and handled by redundancy rules (Chomsky, 1970; Jackendoff, 1975). Because of this variety in productivity and idiosyncrasies found with word formation processes, some researchers resorted to the idea called “lexicalism”, which maintains that all morphological (i.e. word-level) operations belong to the lexicon (e.g. Di Sciullo & Williams, 1987). In the lexicalist view of the grammar, morphology, especially derivational morphology, is autonomous from syntax.

In view of the lexicon-syntax interface, argument structure-changing affixation arguably has a mixed character. It certainly has syntactic effects to the extent that it alters what is projected as the subject or the object of the sentence, and more importantly, can in some cases create a structure with complex properties, as we will see for causatives below. Furthermore, many of these affixation processes are quite regular and compositional. On the other hand, the processes themselves are morphological (word-level) and sometimes exhibit lexical properties; that is, some of them are not totally productive or predictable in the form and the meaning. Consequently, there have been various theories on how to treat them, which has been one driving force for the models of generative grammar to diverge in different directions over its development.

Simply speaking, some theories include some argument structure-changing affixation such as passives in syntax (e.g. Baker, 1988) by analyzing them as a syntactic rule of movement, and try to account for their behaviors using principles that govern sentence structure or interpretation, which have been postulated for other syntactic phenomena. On the other hand, others adhere to the aforementioned lexicalist view and claim
that the argument structure-changing affixation belongs to the lexicon. In lexicalist theories the change in argument structure is seen as the effect of lexical rules that govern the lexical representations, separate from syntactic rules which apply to sentence-level units.

What makes this controversy more complex is the fact that argument structure-changing affixation processes vary in their productivity and compositionality, or their “syntactic” character. Consequently, some researchers (e.g. Fabb, 1984) relegate most of them, including the category-changing ones (e.g. -able (3), -ify (4)) to syntax, while others (e.g. Wasow, 1977) view only a subset of them, such as passivization (5), to be syntactic. Although there are such discrepancies among different researchers, and specific models and analyses change with the development of new frameworks, the issue of the lexicon-syntax interface regarding productive morphological processes remains a fundamental and vital one in generative grammar.

3.2 Japanese Causative suffix -sase

Causatives in Japanese, formed by the suffix -(s)sase as exemplified below, have also been discussed extensively in the context of the lexicon-syntax interface issue9).

(6) a. Kodomo ga ne-ta.
   child NOM sleep-PAST

b. Hanako ga kodomo o ne-sase-ta.
   Hanako NOM child ACC sleep-CAUSE-PAST

(7) a. Taro ga purin o tabe-ta.
   Taro NOM pudding ACC eat-PAST

b. Hanako ga Taro ni purin o tabe-sase-ta.
   Hanako NOM Taro DAT pudding ACC eat-
   -CAUSE-PAST

As we can see from (6-7), when -sase attaches to a verb, the argument structure of the verb is augmented by the addition of the causer, so an intransitive verb is turned into a transitive verb (6)10), and a transitive verb into a ditransitive verb (7).

The affixation of causative -sase not only increases the number of the arguments but also creates biclausal structure. Let us briefly review two pieces of evidence to that effect11). First, it has been noted that -sase causative sentences differ from simple transitive or ditransitive sentences in that not only the subject NP (the causer) but also the object NP (the causee) can be the antecedent for the reflexive pronoun, a property attested to be restricted to subjects in Japanese. See the following contrast; the -sase causative sentence (8a) is ambiguous with both Hanako and kodomo as a possible antecedent for the reflexive pronoun, while only Hanako can be the antecedent in the simple transitive sentence (8b).

(8) a. Hanako ga kodomo o zibun no
    Hanako NOM child ACC self GEN
    heya de ne-sase-ta.
    room LOC sleep-CAUSE-PAST

   ‘Hanako made the child sleep in
   Hanako’s / the child’s room.’

b. Hanako ga kodomo o zibun no
    Hanako NOM child ACC self GEN
    heya de sika-tta.
    room LOC scold-PAST

   ‘Hanako scolded the child in
   Hanako’s / *the child’s room.’

This fact indicates that both the causer (Hanako) and the causee (kodomo) behave as “subjects” at some level of representation.

Secondly, -sase causative sentences induce an

9) The following abbreviations are used for glosses: NOM: nominative; ACC: accusative, LOC: locative; DAT: dative; GEN: genitive

10) The causee argument in (6b) can also be marked with Dative (ni) case, and in that case the sentence has the meaning of permission (‘let’) rather than coercion (‘make’), where the causee is interpreted as acting upon his or her will. The semantic and syntactic differences between so-called ‘o-causative’ and ‘ni-causative’ have been studied in detail; see Matsumoto (1996, Chap. 6) and the references cited there. In this study we deal only with coercive (‘make’) causatives.

11) For more details and other evidence, see Matsumoto (1996: Chap. 6), and the references therein.
ambiguity in the adverb interpretation; it can modify either the base verb or the V-\text{sase} complex. In the following example (9a), the manner adverb \text{sassato} can be interpreted as modifying either the act of Taro’s eating (i.e. modifying \text{tate}) or Hanako’s act of causation (i.e. \text{-sase}). Naturally there is no such ambiguity found in (9b) with the simple verb \text{ate}.

(9) a. Hanako ga Taro ni purin o
Hanako NOM Taro DAT pudding ACC
\text{sassato} tabe-sase-ta.
quickly \text{eat-CAUSE-PAST}
‘Hanako quickly fed pudding to Taro. / Hanako made Taro eat pudding quickly.’

b. Hanako ga Taro ni purin o
Hanako NOM Taro DAT pudding ACC
\text{sassato atae-ta.}
quickly give PAST
‘Hanako quickly gave pudding to Taro.’

These properties exhibited by the sentences containing \text{-sase} causatives naturally led to a biclausal analysis, whereby \text{-sase} is represented as a verb that takes a causer subject NP and an event clause as arguments (Kuroda, 1965; Shibatani, 1973, 1976; Kuno, 1973). As shown below, the underlying biclausal structure (10a) yields the simplex structure (10b) by predicate raising, which combines the verb of the embedded clause with \text{-sase}.

(10) a. Hanako ga [kodomo ga ne] -sase
Hanako NOM [child NOM sleep] -CAUSE

b. → Hanako ga kodomo o ne-sase
Hanako NOM child ACC sleep-CAUSE

This syntactic approach to \text{-sase} affixation captures the complex property of \text{-sase} causative sentences shown above in (8a) and (9a), in that the ambiguity can be attributed to the underlying biclausal structure, where there are two subjects and two verbs.

However, if we look at the morphological side, it is clear that \text{-sase} is not an independent verb but a bound morpheme, and so with the emergence of Lexicalist approaches to word formation as discussed in 3.1, \text{-sase} affixation was also claimed to be lexical, not syntactic (Miyagawa, 1980; Farmer, 1984). The advocates of the lexical analysis of causatives emphasized the fact that, although \text{-sase} affixation supplies an additional argument, the case marking patterns of the causativized verbs are parallel to that of simple verbs, either transitive (\text{ga-o}) or ditransitive (\text{ga-ni-o}), and not complex, e.g. with two subject marking (\text{ga-ga}). This property would follow, the lexicalist approach claims, if V-\text{sase} forms are placed in the lexicon, since the array of possible case marking patterns are designated in the lexicon. In this approach the biclausal property of \text{-sase} sentences are accounted for by the lexical rule of \text{-sase} affixation which alters the argument structure of the base verb; V-\text{-sase} is created in the lexicon as a verb with a transitive or ditransitive case marking patterns.

So the controversy over the lexicon-syntax interface in word formation processes resulted in two different approaches to \text{-sase} causative affixation in Japanese, which is syntactic in its effects but morphological in its form. This controversy over the status of \text{-sase} affixation is more revealing, when we contrast it with another morphological process with similar function, namely, lexical causatives, to which we turn now.

3.3 Lexical vs. \text{-sase} Causatives in Japanese

In addition to \text{-sase} causatives we have just seen, Japanese has another type of causatives, called “lexical causatives”, which corresponds to the transitive form in transitivity alternation\textsuperscript{12}. The following examples show the two types of causatives in question.

\textsuperscript{12} The transitivity alternation is not one-way; in some cases an intransitive form is morphologically more basic, while for some verbs transitive form is more basic, and there also are verb stems that take both transitive and intransitive markings. In this study we deal only with non-causative/lexical causative alternation.
Lexical causatives as exemplified by (11b) basically denote direct causation, while \(-\text{sase}\) causatives mostly denote indirect causation. (See 3.4 below for more details.)

From a cross-linguistic point of view, languages employ different means to express causatives; in English most cases of non-causative/causative alternation involves no overt morphological marking on the verb (\textit{the window broke/Mary broke the window}; \textit{cut/cut, shorten/shorten}) except for some verb pairs (\textit{rise/raise, lie/lay, fall/fell}). Indirect causation, on the other hand, is often expressed periphrastically (e.g. \textit{make someone run}) though not always (e.g. \textit{march the soldiers}). So in a language like English the two types of causatives are morphologically as well as syntactically distinct. In Japanese, as shown above (11-12), both \(-\text{sase}\) causatives and lexical causatives are morphologically marked.

Unlike \(-\text{sase}\) causatives, the question over the lexicon-syntax interface has not been raised for lexical causatives; hence its name. This is because, for one thing, they do not exhibit the biclausal character. See the following contrasts: the lexical causative sentence (13a) does not involve the ambiguity in the interpretation of the reflexive pronoun, unlike the \(-\text{sase}\) causative (cf. (8a) above); and similarly, in (13b) the adjunct can only modify the action of the agent (Hanako), unlike the \(-\text{sase}\) causative sentence where adjunct can be ambiguously interpreted (cf. (9a) above):

\[
\begin{align*}
(11) & \quad \text{Lexical causative: } narab-u/narab-e-ru \\
& \quad \begin{array}{l}
\text{a. Tukue ga naran-de iru.} \\
\text{desks NOM line up BE}
\end{array} \\
& \quad \text{‘Desks are lined up.’} \\
& \quad \begin{array}{l}
\text{b. Hanako ga tukue o narab-e-ta.} \\
\text{Hanako NOM desks ACC line up -PAST}
\end{array} \\
& \quad \text{‘Hanako lined up the desks.’}
\end{align*}
\]

\[
\begin{align*}
(12) & \quad \text{-sase causative: } narab-u/narab-ase-ru \\
& \quad \begin{array}{l}
\text{a. Seito ga itiretu ni naran-de iru.} \\
\text{students NOM line in line up BE}
\end{array} \\
& \quad \text{‘Students are lined up (in one line).’} \\
& \quad \begin{array}{l}
\text{b. Sensei ga seito o itiretu ni teacher NOM student ACC line in narab-ase-ta.} \\
\text{line up -CAUSE-PAST}
\end{array} \\
& \quad \text{‘The teacher directed the students to stand in one line.’}
\end{align*}
\]

\[
\begin{align*}
(13) & \quad \begin{array}{l}
\text{a. Hanako ga Taro o zibun no} \\
\text{Hanako NOM Taro ACC self GEN}
\end{array} \\
& \quad \begin{array}{l}
\text{kuruma ni no-se-ta} \\
\text{car LOC ride-CAUSE-PAST}
\end{array} \\
& \quad \text{‘Hanako made Taro ride} \\
& \quad \text{Hanako’s / *Taro’s car (=gave a ride)’}
\end{align*}
\]

\[
\begin{align*}
(13) & \quad \begin{array}{l}
\text{b. Hanako ga Taro o kuruma ni} \\
\text{Hanako NOM Taro ACC car LOC}
\end{array} \\
& \quad \begin{array}{l}
\text{isoiide no-se-ta.} \\
\text{hurriedly ride-CAUSE-PAST}
\end{array} \\
& \quad \text{‘Hanako hurriedly made Taro ride the} \\
& \quad \text{car.’}
\end{align*}
\]

These facts amply show that the lexical causatives, unlike \(-\text{sase}\) causatives, are not biclausal and do not call for an analysis involving an embedded clause. Consequently, it has been assumed that they are not derived by affixation but are represented as such in the lexicon. In other words, the lexicon-syntax controversy we saw in 3.1. is relevant only for \(-\text{sase}\) causatives.

### 3.4 Two types of causatives and the DM model

In the light of the DM model on the mental lexicon as discussed in 2, the difference between the two types of causatives as revealed by the linguistic analyses suggest that they may involve two different mechanisms of rule vs. associative memory. In other words, it is possible to conceive that while \(-\text{sase}\) causatives are formed “on-line” by a rule (V + \textit{sase}) on a par with other syntactic processes of sentence building, lexical causatives are listed as such in the lexicon, linked with the intransitive verbs with the same stem by associative memory (\textit{narabe-}/\textit{narab-}). At the same time, the rule of \(-\text{sase}\) affixation concomitantly requires computation...
of change in argument structure of the derived
-sase form, whereas both intransitives and cor-
responding lexical causatives come with argu-
ment structure and thus no such computation
is required. If this turns out to be the case, it
would indicate that argument structure-changing
affixation can also exhibit a dichotomy paral-
lel to the ones found in inflectional morphology
of tense/number marking and derivational mor-
phology of nominalization. That, in turn, would
have some significant bearing on the issue of the
lexicon-syntax interface as discussed in Section 3.

There are two differences between the two
types of causatives which corroborate our con-
tention. The first point is the regularity of the
affixation process. The non-causative/lexical
causative distinction is not uniformly marked;
there are a number of affixes involved in mark-
ing lexical causatives including -(a/o)s, -ase,
-e, among others. So we can say that lexical
causative marking is “irregular” in a way similar
to the irregular marking of tense in English as
discussed in Section 2. This is in contrast with
the -sase causative, which involves a single suffix
-(s)ase (the alternation between -sase and -ase is
phonologically conditioned), and so is completely
regular. See the following set of examples.

(14) a. non-causative: narab-u

  line up (vi)-PRESENT

  lexical causative: narab-e-ru

  line up (vi)-PRESENT

  -sase causative: narab-ase-ru

  line up-CAUSE-PRESENT

b. non-causative: toor-u

  go through-PRESENT

  lexical causative: too-s-u

  put through-PRESENT

  -sase causative: toor-ase-ru

  go through-CAUSE-PRESENT

c. non-causative: hanare-ru

  go away-PRESENT

  lexical causative: hana-s-u

  detach-PRESENT

  -sase causative: hanare-sase-ru

  go away-CAUSE-PRESENT

The second point is related to, though not
the same as, the first point. Namely, there is a
great difference in productivity between the two
causatives. As just mentioned, there are various
lexical causative affixes, and it is not predictable
which affix attaches to which verb. For instance,
-e attaches to many consonantal verbs (“5-dan
katsuyoo” verbs) but not to others:

(15) a. tat ‘stand’ / tat-eru

  muk ‘turn toward’ / muk-eru

b. kik ‘take effect’ / *kikeru (cf. kik-asu)

  wak ‘boil (vi)’ / *wakeru (cf. wak-asu)

Furthermore, lexical gaps are observed such that
an intransitive non-causative verb lacks the cor-
responding causative counterpart for no obvious
reason.

(16) tukareru ‘get tired’ / *tukarasu

  sabiru ‘get rusty’ / *sabirasu, *sabisu

On the contrary, -sase causative formation is per-
fectly productive. It attaches not only to simple
verbs as in (14) but also to suffixed verbs as in
(17a) or to compounds as in (17b, c).

(17) a. omosio-gar-as-tea

  fun-feel-CAUSE-PAST

  ‘caused (someone) to enjoy, amused’

b. yomi-hazime-sase-ta

  read-begin-CAUSE-PAST

  ‘made (someone) begin to read’

c. Tate-sugi-sase-ta.

  eat-overdo-CAUSE-PAST

  ‘made (someone) eat too much’

  cf. *tate-sug-osi-ta (Note: the lexical
               causative of sugi-ru: sug-os-u)

-(s)ase can also attach to verbs of non-Japanese
origin, including so-called light verbs of Chinese
origin (18a) and borrowings from English (18b),
as well as to neologisms (18c).
(18) a. chuuche-s-ase-ta
    hesitation-do-CAUSE-PAST
    'made (someone) hesitate'

b. negur-ase-ta
    neglect-CAUSE-PAST
    'made (someone) neglect'

c. bakkure-ase-ta
    skip (a class)-CAUSE-PAST
    'made (someone) skip a class'

In fact, there are no lexical gaps in -sase causative. Also, it is noteworthy that causative formation like (17-18) is simply impossible with lexical causative. These observations lead us to hypothesize that lexical causative is dealt with by associative memory, while -sase causative is by regular rule.

Now let us move on to the semantic difference between the two types of causatives, which have been extensively studied in the literature (e.g. Shibatani, 1976). Roughly speaking, the lexical causative has the interpretation of direct or manipulative causation, while the -sase causative is interpreted as indirect or directive causation. Thus, the lexical causative (19a) means that Hiroshi physically manipulated the entity denoted by the object, while it is not the case with the -sase causative (19b), and this semantic difference explains the fact that the -sase causative usually rejects inanimate causee as shown in (19c)

(19) a. Hiroshi ga hon o tana ni tat-e-ta
    Hiroshi NOM book ACC shelf LOC stand-
    -CAUSE-PAST
    'Hiroshi stood the book on the shelf.'

b. Hiroshi ga kodomo o tat-ase-ta
    Hiroshi NOM child ACC stand-CAUSE-PAST
    'Hiroshi made the child stand.'

c. *Hiroshi ga hon o tana ni tat-ase-ta.
    Hiroshi NOM book ACC shelf LOC stand-
    -CAUSE-PAST
    'Hiroshi made the book stand on the shelf.'

In the experiment discussed below, we exploit this semantic difference between the two causatives in constructing our stimulus sentences.

4. Hypothesis and Predictions

In order to test our hypothesis that these two types of causatives involve two different mental/neurological mechanisms, i.e. -sase causatives involve computation whereas lexical causatives are dealt with by associative memory, we conducted a series of experiments with brain-damaged aphasic patients. In this section, we report preliminary results from the study of agrammatic Broca's aphasic patients.

First let us briefly review the characteristics of language disorders in Broca's aphasia and the recent findings relevant to the present study. Broca's aphasia is a type of syndrome resulting from acquired focal brain damage to Broca's area as well as its adjacent and deeper areas. The patients have difficulties in speaking, whereas their ability of auditory comprehension is relatively well retained. A subtype of this aphasia, so-called "agrammatic aphasia," is characterized by a selective loss of function words in speech, which is commonly known as a telegraphic style. In comprehension, the patients sometimes have difficulties in processing certain syntactic structures. When no semantic clue is available, they have problems in assigning thematic roles to noun phrases in syntactic structures such as reversible passives which contain a gap or a trace, while no such problem arises in comprehending those without a gap/trace (Grodzinsky, 1986, 1995; Hagiwara, 1993, among others). Thus, it has been claimed that it is due to the disrupted chains between a trace and its antecedent that the patients are unable to retrieve the thematic role that the antecedent NP inherits from its trace in the original position (Großdinsky, 1995, 2000, but see Mauner et al., 1993; Hickok & Avrutin, 1996, and Caplan, 2000). On the other hand, normal sensitivity to the sentences involving affix (=head) movement operations, as
opposed to the disrupted ability in judging sentences with phrasal movement operation, was also observed in grammaticality judgement task (Grodzinsky & Finkel, 1998). These facts led some researchers to claim that the Broca’s area is strongly, and solely, related to a core part of syntax, i.e. traces of the displaced phrasal units in syntactic representation (Grodzinsky, 2000).

Another group of researchers relates syntactic deficit in sentence comprehension to the decrease in the verbal working memory system. (Caplan & Hildebrandt, 1988; Caplan & Waters, 1999, this volume). This position is supported by the findings from various sources; studies of brain-damaged patients and normal subjects, and those with neurophysiological as well as neuroimaging techniques. To illustrate, the PET and functional Magnetic Resonance Imaging (fMRI) studies find that the processing of center-embedded sentences as opposed to right-branching sentences evoked a localized increase in regional cerebral blood flow in a part of Broca’s area (Stromswold et al., 1996; Caplan et al., 1998). It is also reported that the processing of sentences with long unbounded dependencies elicited an early negative wave, the so-called LAN, in the left anterior region in an ERP study (Kluender & Kutas, 1993). The advocates of such processing account claim that Broca’s area supports large amount of processing resources in assigning syntactic structure and using that structure to determine the meaning of a sentence (Caplan & Waters, 1999). It is important to note that, although the processing explanation is certainly plausible, it remains to be seen what kinds of computations are operating and how they are implemented in this area when the processing cost increases.

Despite the apparent differences in viewpoints, it remains consistent in these proposals that Broca’s area is related to processing of phrasal units in sentence comprehension and production. In contrast to these accounts, we have recently suggested that Broca’s aphasics have trouble with not only processing at a phrasal level but also processing of a certain type of word-level unit (Hagihara et al., 1999). As explained briefly in 2.3, we have shown that a productive default-like process of derivational affixation was abnormal in Broca’s aphasics where the lesion includes Broca’s area, but not in other types of patients whose lesion spared this area. Assuming that -sase causatives involve the application of a default rule whereas lexical causatives are dealt with by associative memory, as is explained in section 3.4, we predict that Broca’s aphasics patients would experience difficulties in dealing with the rule-based -sase causatives, while they are able to deal with lexical causatives. In what follows, we will report that this type of dissociation is in fact observed in a series of experiments.

5. Experiments

5.1 Experiment 1

In experiment 1, we tested both production and comprehension abilities of each patient.

5.1.1 The Production Task

Subjects For the present study, two aphasic patients of the Broca’s type and one patient diagnosed as atypical type, among the pool of aphasics, were recruited under the condition that they exhibited an agrammatic comprehension pattern. The case histories of the individual patients are presented in Appendix 1. Two Broca’s patients had lesions in the left frontal lobe but they were not extended to the posterior language areas. The patient of atypical type had a very small-circumscribed lesion in the Putamen and exhibited a typical agrammatic comprehension pattern. Their results and those with three age, sex and education-matched normal controls were subject to the same analyses.

13) They exhibit near-normal abilities in comprehending active sentences with canonical word order, whereas passive sentences and the sentences with non-canonical word order are difficult for them to interpret.
Materials and Procedure  In testing production, a sentence completion task was used. The target predicates consisted of three kinds of verbs: non-causatives, lexical causatives, and -sase causatives. Exploiting the semantic differences discussed in 3.4, we devised our stimulus sentences based on two types of contexts: one in which the lexical causative, but not the -sase causative, sounds natural, and the other in which the -sase causative sounded more natural than the lexical causative.

(20) Non-causative context:
Seito ga koutei ni itiretu ni student NOM school yard LOC line in naran-da line up-PAST
'The students lined up in a line in the school yard.'

(21) Lexical causative context:
Seito ga toranpu no kaado o student NOM playing cards ACC narab-e-ta/*narab-ase-ta line up-CAUSE-PAST
'A student arranged playing cards.'

(22) -sase causative context:
Sensei ga seito o oogoe-de teacher NOM student ACC loud voice with itiretu-ni narab-ase-ta/*?narab-e-ta line in line up-CAUSE-PAST
'The teacher made students line up in a line with a loud voice.'

Each stimulus consisted of a picture and an incomplete corresponding sentence which described the event represented by the picture. In the corresponding sentences, the verb roots (minus the final consonant) of the target predicates were given, and the subjects were asked to fill in appropriate tense morphemes (23a) or causative endings (23b, c).

(23) a. target: non-causative (cf. 20)
Seito ga koutei ni itiretu ni nara ________.

b. target: lexical causative (cf. 21)
Seito ga toranpu no kaado o nara _________.

c. target: -sase causative (cf. 22)
Sensei ga seito o oogoe de itiretu ni nara _________.

We selected fifteen verbs for each type of target predicates, which are listed in the Appendix 2. A total of 90 test sentences were both constructed and divided into two forms, each of which consisted of 45 sentences. We devised the material so that each verb would appear only once in a given context in one session. The two forms were tested in separate sessions after a one- or two-week interval. The stimuli sentences were randomly ordered in each set. The length of the sentences was controlled to four or five items. The main session was preceded by a practice session with examples of each type of predicate to ensure that each subject understood the task. Along with the corresponding pictures, the stimuli sentences were presented to the subject both visually and orally. The subjects were then asked to complete the sentence by adding the appropriate ending to the verbal stem orally or in a written form. The subjects were tested individually in a quiet room by a speech therapist.

Results and Discussion  The results of the production task are presented in Table 2 with the percentages of the correct responses for the two groups of subjects on each of the three types of predicates. Before the analyses, the data were processed by arcsine transformation. A mixed analysis of variance (a mixed ANOVA) was applied to the three sentence types under the conditions that the verb type was the within-subject factor and the group type was the between-subject factor. Results revealed significant main effects of the group type ($F(1, 4) = 24.80, p < .01$) and the verb type ($F(2, 8) = 62.56, p < .01$). A significant interaction effect of the verb type by group type was also revealed ($F(2, 8) = 13.24, p < .05$), as shown in Figure 1. HSD multi-
Table 2  Patients' Performance in a Production Task Given in Percentage Correct

<table>
<thead>
<tr>
<th></th>
<th>non-causative</th>
<th>lexical causative</th>
<th>Sase causative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>98.9</td>
<td>96.7</td>
<td>80.0</td>
</tr>
<tr>
<td>Aphasics</td>
<td>95.6</td>
<td>76.7</td>
<td>13.3</td>
</tr>
</tbody>
</table>

Figure 1  Patients' Performance in a Production Task

ple comparison tests showed that in aphasics the differences among the three verb types were all significant ($p < .05$), and in normals, the significant difference was observed only between -sase causatives and the other two types ($p < .05$).14)

Although the results from aphasics showed three-way distinction among non-causatives, lexical causatives, and -sase causatives, what is striking is the large gap between lexical causatives (76.6% correct) and -sase causatives (13.3% correct). This demonstrates that production of -sase causative forms is extremely difficult for aphasics, which corroborates our contention that affixation of -sase involves computation. Furthermore, the results of the error analysis revealed that all the errors the patients made in the lexical causative context were to produce non-causative forms, while in -sase causative context half of the errors included lexical causative forms (50%, 46%, 46%) and most of the remaining errors were non-causative forms with only 5% error rate of the no response pattern in total. This tendency in the direction of errors also shows that the lexical causative forms were easier for the subjects to produce than -sase causative forms.

As for the unpredicted difference between the non-causative forms and lexical causative forms, we should mention that the patients' difficulty in inserting affixes in both causative context is not so surprising because, task-wise, it is obvious that production task is not easy for the aphasic patients of the non-fluent type. One of their main characteristics of disturbances lies in speaking in

14) One might wonder whether the aberrant performance in production task by aphasic patients in -sase causative context is related to the somewhat low score of -sase suffixation by normal controls (80% correct) compared to the near perfect scores in other two contexts. A possible cause of this may be that some of the verb forms used are relatively unfamiliar; namely, the -sase causative form of inchoatives (e.g. *taore-sase* 'make fall') is not so frequently used because of the lexical causative form with the same base (*tao-su* 'fell'). See footnote 15 for further discussion of this question as revealed by the results of Experiment 2.
Table 3  Patients' Performance in a Forced-choice Comprehension Task
Given in Percentage Correct

<table>
<thead>
<tr>
<th></th>
<th>non-causative</th>
<th>lexical causative</th>
<th>Sase causative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls</td>
<td>100</td>
<td>96</td>
<td>92</td>
</tr>
<tr>
<td>Aphasics</td>
<td>87</td>
<td>86</td>
<td>44</td>
</tr>
</tbody>
</table>

Figure 2  Patients' Performance in a Forced-choice Comprehension Task

contrast to their relatively well-preserved ability in comprehension, as explained in section 4.

5.1.2 The Comprehension Task
The aim of the comprehension test is to examine the patients' ability of processing causative sentences more directly, admitting that the production task itself has a limitation in eliciting overall ability of affixation process.

Subjects  The same subjects as in the production task (5.1.1) participated.

Materials and Procedure  In this test, a forced-choice task was used. The subjects were shown a picture and asked to choose the appropriate item from a set consisting of a non-causative, a lexical causative, and a -sase causative, in an accompanying sentence. The comprehension experiment was conducted one to two months after the production experiment had been done for each patient by using the same stimuli sentences in the production task.

Results and Discussion  The results of the forced-choice task are presented in Table 3. Before the analyses, the data were processed by arcsine transformation. A mixed ANOVA was applied to the three sentence types under the same conditions, namely, that the verb type was the within-subject factor and the group type was the between-subject factor. As Figure 2 illustrates, significant main effects of both the group type ($F(1,4) = 26.05, p < .01$) and the verb type ($F(2,8) = 24.68, p < .01$) were revealed. The interaction effect of the group type by verb type was marginally significant ($F(2,8) = 3.53, p < .10$). HSD multiple comparison tests revealed that in normal controls there were no significant differences among the verb types. In
aphasic patients, on the other hand, the significant difference was obtained only between -sase causatives and the other two types, i.e. non-causative and lexical causative.

These results indicate that the -sase causative sentences are more difficult for aphasic patients to match up with the appropriate contexts than the lexical causative sentences. This is consistent with the results from the production task, and shows that the patients have difficulty not only with the production of the -sase affix but also the comprehension of the causative predicate containing -sase.

Given these interpretations, we can safely say that the overall results of the Experiment 1 reveal that the suffication process of -sase, like the productive nominal suffication of -sa discussed in section 2, is disrupted more severely than that of the lexical causatives in agrammatic aphasic patients tested and that our hypothesis is partially supported. In other words, the -sase suffication process can be regarded as a type of rule-based computational operations.

It should be noted, however, that this alone does not tell us if the patients retain the ability to compute the argument structure change due to -sase suffication. As discussed in Section 3, -sase assigns the causer role to its subject, augmenting the argument structure of the base verb, with the corresponding change in case-marking patterns. For example, taore- is a one-place predicate, but taore-sase has two arguments: in (24b) the causer role Jiro bears is assigned by the suffix -sase, and Taro, the agent of the base verb taore, is marked with the accusative case-marker -o.

(24) a. Taro ga hitori de taore-ta.
   Taro NOM himself by fall down PAST
   ‘Taro fell down by himself.’

b. Jiro ga Taro o taore-sase-ta.
   Jiro NOM Taro ACC
   fall down-CAUSE-PAST
   ‘Jiro made Taro fall down.’

The next question to ask is whether the aphasic patients are unable to acknowledge this change in argument structure caused by -sase suffixation. Based on our contention that the -sase suffication process is a type of rule-based computational operations, it is quite possible that the change in argument structure is also disturbed in aphasic patients because it too can be regarded as involving a rule-based syntactic process.

5.2 Experiment 2

In Experiment 2, the possibility of patients’ inability to recognize argument structure change is tested. We devised the stimulus sentences so that the two noun phrases in the two types of causative sentences are both animate nouns, making the causer NP and the causee NP can be reversible for the sake of the methodology adopted (See Procedure below). If the patients have difficulties in comprehending the thematic roles of the NPs in the -sase causative sentences but not in the lexical causative sentences, we may conclude that the computation of argument structure change, as well as the morphological process of attaching -sase suffix, is disrupted in Broca’s patients, which in turn suggests that the computation of argument structure change is syntactic in nature.

Subjects The same subjects as in Experiment 1 (cf. 5.1.1) participated in Experiment 2.

Materials and Procedure We selected 20 verbs for each type of causative sentences. Each verb was used twice, so there were 40 sentences for each type of causative. Examples of each type are shown below. Among the 40 lexical causative sentences, there were 20 sentences in which the verb shares its base with -sase causatives as in (25a), and 20 sentences in which the verb does not share its base as in (25b). Similarly, the 40 -sase causative sentences included 20 sentences with shared verb base as in (26a) and 20 sentences with unshared verb base as in (26b). In addition, 20 filler stimuli, which were simple
active sentences (e.g. Taro-ga Hanako-o oshi-ta ‘Taro pushed Hanako’) were also included. A total of 100 stimulus sentences were divided into two forms. We arranged the materials so that one verb would appear only once in each predicate type in one session. The stimuli sentences were randomly ordered in each set and two forms were tested in separate sessions after a one- or two-week interval.

(25)

a. Lexical causatives with the shared base:
   Taro ga Hanako o kouma ni no(r)-se-ta.
   Taro NOM Hanako ACC pony LOC ride-
   -CAUSE-PAST
   ‘Taro helped Hanako get on a pony.’

b. Lexical causatives with the unshared base:
   Taro ga Hanako o suityu ni sizum-e-ta.
   Taro NOM Hanako ACC water LOC sink-
   -CAUSE-PAST
   ‘Taro sank Hanako under the water.’

(26)

a. Syntactic causatives with shared base:
   Taro ga Hanako o kouma ni nor-a-se-ta.
   Taro NOM Hanako ACC pony LOC ride-
   -CAUSE-PAST
   ‘Taro made Hanako ride on a pony.’

b. Syntactic causatives with unshared base:
   Taro ga Hanako o rooka ni tat-a-se-ta.
   Taro NOM Hanako ACC hallway LOC stand-
   -CAUSE-PAST
   ‘Taro made Hanako stand in the hallway.’

A sentence-picture matching task was used. Two pictures were presented to the patients that included the correct one and the one in which the thematic role of the NPs was reversed. Subjects were tested individually and were asked to point to the picture which corresponded to verbally presented sentences.

Results and Discussion The percentages of correct responses on each of the four types are presented in Table 4 and in Figure 3. Since the focus of this experiment was to examine the subjects’ performance on lexical causative sentences and -sase causative sentences, we conducted a planned contrast comparing the means of correct responses of lexical causatives with the means of -sase causatives\(^{15}\). It revealed that the patients responded more correctly for lexical causatives than for syntactic causatives \((t(6) = 3.29, p < .05)\). The correct response of the filler sentences (simple active sentences) in each individual was 90%. The normal controls showed a ceiling effect on all types of sentences.

These results indicate that while normal controls have no problem in interpreting both types of causative sentences, the aphasic patients have more difficulties in comprehending -sase causative sentences than the lexical causative ones. More specifically, based on our assumption as mentioned in 3.4 that -sase causatives are formed “on-line” by the rule of -sase suffixation while lexical causatives are listed as such in the lexicon, and that -sase suffixation requires computation of change in argument structure of the derived -sase forms whereas no such computation is required for lexical causatives whose “causative” argument structures are listed in the lexicon, our results suggest that both of these two types of “on-line” computation are disrupted in agrammatic Broca’s aphasics.

\(^{15}\) We had originally divided the stimulus sentences of both causatives into two groups as explained above; those that share the verb base with the other type (25a, 26a) and those that do not (25b, 26b). The purpose of this experimental design was to check whether the relative unfamiliarity of the -sase form of the former (i.e. 26a) had any effect on the result (See footnote 14). The comparison of the two groups, which is omitted here for the sake of space, revealed no such effect; if anything, the patients’ performance on the -sase forms in the group with shared verb base was slightly better than those in the other group. This fact indicates that the less-than-perfect score on -sase causatives obtained by the normal controls in the production task in Experiment 1 (see Results on p.52 and footnote 14) is not due to the unfamiliarity of the verb forms used, and thus we can disregard this effect in interpreting the corresponding results obtained from the aphasic patients. The reason for the less-than-perfect score of normals for -sase causatives is not yet clear and needs further study.
6. General Discussion and Concluding Remarks

We have argued in this paper that the DM theory of morphology as proposed by Pinker and his collaborators is adequate to deal with some processes of derivational morphology. We have revealed, in particular, that there are two types of causative constructions in Japanese that could be argued to employ two different mental and neurological mechanisms, thus validating the rule/associative memory dichotomy view. Let us summarize our findings together with the findings of previous studies in Table 5.

Our findings bear a significant implication on the issue of syntax-lexicon interface as discussed in 3.1. It has turned out that the -sase causative, unlike the lexical causative, involves computational rule application. Since both the morphological operation of suffixation and the computation of argument structure change have proved to be impaired in Broca's agrammatic patients, and given the general understanding that the Broca's area is the center for core syntactic computations (cf. Section 4), we may reasonably conclude that these two operations (morphological and argument-structural) are "syntactic" rather than lexical in nature. Thus our results are consistent with the theories of morphology that place morphological processes both in the syntactic component and in the lexicon (e.g. Kageyama, 1993; Borger, 1991), and not with the strict lexicalist position (e.g. Di Sciullo & Williams, 1987).

Our findings can also be viewed as evidence against treating all morphological processes by the same type of syntactic operation. Recently, Hale & Keyser (1993) have developed a theory where "lexical" syntax takes care of word derivation under the same principles and constraints as phrasal/sentential syntax. Hale & Marantz (1993) have proposed a theory called "distributed morphology", in which "lexical insertion" takes place after syntactic operations combine terminal nodes, which consist of morphosyntactic feature bundles, to create words. In these theories, both lexical and -sase causatives...
Table 5  DM Model for Inflectional and Derivational Morphology

|-------------------------------|--------------------------|--------------------------------------------------|------------------------------------------|
| Default Rule Application     | -ed (past), -s (plural)  | -sa  
walk/walked, dog/dogs |narab-u/narab-ase-ru |
| Associative Memory           | swing/swung              | taka-i/taka-mi |narab-u/narab-etu |
|                              | tooth/teeth              |                     |toor-u/toor-su |

would be analyzed as involving the same type of “head-movement” operations. It is not straightforward how these theories can explain the difference between the -sase causative and the lexical causative as revealed in the present study.

Concerning the nature of impairment in agrammatic Broca’s aphasia, our findings may pose a challenge for the hypotheses previously proposed for English data. For example, the Trace-Deletion Hypothesis (TDH) put forward by Grodzinsky (1990, 1995) fails to account for our data in that the -sase causative sentence does not involve a so-called NP-trace, or a trace of a phrasal constituent. If this impairment may safely be assumed to be caused by the same reason as the well-documented impairment in passives, object relatives etc. (cf. Section 4), it would be required to seek for an explanation without recourse to the existence of an NP trace. Moreover, the TDH wrongly predicts that the agrammatic patients would perform well on the -sase causative sentence because it involves the head movement, or the X0-movement, which TDH claims to be retained in agrammatism (Grodzinsky, 1995; Grodzinsky & Finkel, 1998). Our findings seem to suggest that the types of performance explained by TDH constitute only a subtype of disorder in agrammatic aphasics. The working memory hypothesis in its present form (Caplan & Waters, 1999) is not explicit enough to account for the difference in performance between lexical causatives and -sase causatives by aphasic patients.

Before concluding our discussion, let us mention some remaining problems. First, although the results of our study suggest that -sase causatives involve rule or syntactic computation as opposed to lexical causatives, it is not yet clear what exact “syntactic” rule involved in the production and comprehension of -sase causatives is disturbed in Broca’s patients. Roughly speaking, there are at least two processes which are crucial in correctly handling -sase causatives; the affixation of -sase on one hand, and computing the change in argument structure on the other. The results of Experiment 1, especially the production task, showed that the patients have difficulty with the affixation process. As mentioned in 5.2, the results of Experiment 2 are consistent with the view that the patients do have some difficulty with change in argument structure. The exact nature of the problem posed by -sase causatives, however, must further be studied. For instance, is the affixation process the main obstacle, while change in argument structure is derivative, or is it vice versa? Furthermore, how crucial is the fact that causative formation augments argument structure, unlike passive? Does a larger number of arguments in itself contribute to the difficulty? Thus, in order to get a better understanding of the exact difficulty posed by computation of argument structure, it may be instructive to compare causatives with other constructions which involve the same number of arguments without change in argument structure.

Secondly, although our experiments revealed a significant difference in the patients’ performance on lexical causatives as opposed to -sase causatives, it was also observed that there was some difference between lexical causatives and
noncausatives. Specifically, the patients' performance was better for noncausatives than for lexical causatives in the Production Task in Experiment 1 as well as in Experiment 2. (See Figures 1 and 3 for the exact percentages.) Since our hypothesis based on the DM theory holds that lexical causatives are handled by memory on a par with noncausatives, this difference does not follow from the DM theory alone. As it was mentioned in 5.1, for the results of Experiment 1, it is conceivable that the task of filling in the right affixes itself presented some difficulty to the patients, even in the case of the lexical causatives which are hypothesized to be listed as such in the lexicon, but this point needs more study. As for Experiment 2, which showed even greater discrepancy between lexical causatives and noncausatives, it is unlikely that the difference is due to the difficulty of the task of picture-matching, which does not require production, and so we must further study possible factors involved, the mode of giving the stimuli sentences (oral in this case) being one of the candidates.

Although there are these and more questions yet to be answered, we hope our study has shown the possibility that the DM theory can be applied to various processes of derivational morphology, in addition to inflectional morphology which the large number of past and ongoing studies concentrate on. It is also hoped that our study point to the possibility that we can gain a greater insight into the fundamental nature of representation and processing of language in the human brain by collaborative endeavors in the fields of theoretical linguistics, psycholinguistics and neurolinguistics.

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Appendix 1  Case histories of the patients involved in the study

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Sex</th>
<th>Years of Education</th>
<th>Occupation</th>
<th>Handedness</th>
<th>Etiology</th>
<th>P.O.M.</th>
<th>Type of Aphasia</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>HS</td>
<td>61</td>
<td>M</td>
<td>16</td>
<td>teacher</td>
<td>R</td>
<td>CVA</td>
<td>6M.</td>
<td>Broca's</td>
<td>moderate</td>
</tr>
<tr>
<td>YS</td>
<td>62</td>
<td>F</td>
<td>12</td>
<td>none</td>
<td>R</td>
<td>CVA</td>
<td>14Y.</td>
<td>Broca's</td>
<td>moderate</td>
</tr>
<tr>
<td>TM</td>
<td>66</td>
<td>M</td>
<td>16</td>
<td>businessman</td>
<td>R</td>
<td>CVA</td>
<td>1Y.8M.</td>
<td>atypical</td>
<td>moderate</td>
</tr>
</tbody>
</table>

Abbreviations:  
Sex, M: male; F: female;  
Handedness, R: right-handed;  
Etiology, CVA: cerebrovascular accident (hemorrhage, thrombosis, or embolism);  
P.O.M. (post-onset months), M: months, Y: years.

Appendix 2  The list of verbs used in the experiment

modor-u ‘return’ (vi), modos-u ‘return’ (vt), modor-ase-ru ‘make-return’ (vc)  
hanare-ru ‘leave’ (vi), hanas-u ‘leave’ (vt), hanare-sase-ru ‘make-leave’ (vc)  
taore-ru ‘fall down’ (vi), taos-u ‘knock down’ (vt), taore-sase-ru ‘make-fall down’ (vc)  
okure-ru ‘be late for’ (vi), okurse-ru ‘put off/delay’ (vt), okure-sase-ru ‘make-be late for’ (vc)  
ori-ru ‘go down’ (vi), oros-u ‘drop’ (vt), ori-sase-ru ‘make-go down’ (vc)  
ki-ru ‘put on’ (vi), ki-seru ‘dress’ (vt), ki-sase-ru ‘make-put on’ (vc)  
nuke-ru ‘come out’ (vi), nukas-u ‘leave out’ (vt), nuke-sase-ru ‘make-leave’ (vc)  
narab-u ‘line up’ (vi), narabe-ru ‘line up’ (vt), narab-ase-ru ‘make-line up’ (vc)  
tat-u ‘stand (up)’ (vi), tatere-ru ‘set up’ (vt), tat-ase-ru ‘make-stand up’ (vc)  
muk-u ‘turn towards’ (vi), muke-ru ‘turn toward’ (vt), muk-ase-ru ‘make-turn towards’ (vc)  
todok-u ‘reach’ (vi), todoke-ru ‘deliver’ (vt), todok-ase-ru ‘make-reach’ (vc)  
agar-u ‘go up’ (vi), age-ru ‘raise/lift’ (vt), agar-ase-ru ‘make-go up’ (vc)  
tukar-u ‘soak’ (vi), tukeru ‘soak’ (vt), tukar-ase-ru ‘make-soak’ (vc)  
mawar-u ‘go around’ (vi), mawa-s-u ‘turn around/spin’ (vt), mawar-ase-ru ‘make-go around’ (vc)  
toor-u ‘go through’ (vi), toos-u ‘pass through’ (vt), toor-ase-ru ‘make-go through/pass’ (vc)

Abbreviations: (vi)-intransitive verb, (vt)-transitive verb, (vc)-causative verb