Chapter 11

The Constructive Approach to the Dynamic View of Language

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Introduction

Human languages have a variety of characteristics. To study the evolution and dynamics of language using simulation models, it is important to consider which characteristics should be adopted and abstracted when constructing the model. The features that are adopted and the way in which they are modelled represent what researchers of language evolution recognize as the essence of language[1].

In many cases, the role of language as a tool for communication is abstracted as its essence. That is, the evolution and dynamics of language are formalized in terms of how people come to use the same lexicon and grammar for communication. Although communication is one of the most important aspects of the evolution of proto-language from animal communication systems, human language is not only a tool for conveying one's mind to others. The activities of communication induce various effects on the speakers and listeners in addition to the exact "transmission of messages". For example, the act of communicating extends and reshapes the cognitive structures of language users. This function may separate human language from animal communication systems.

[1] This refers not only to the study of the evolution and dynamics of language but to the whole of linguistic studies. Tokieda (1941) has insisted upon the relationship between the essence of language and the study of language as follows, "The mission of the study of language should be not to arrange particular linguistic data and organize them into linguistic laws but to clarify the profile of language as the subject of study of language (p.iv)."

Let us consider the system of symbols in the light of this point. The establishment of shared connections between symbols and their referents in human language does not in itself demonstrate a qualitative difference between human language and animal communication systems, but it does show a quantitative difference in the amount of information transmitted. A crucial dissimilarity between human and animal communication systems is that new symbols and referents can be created in human language, and these can bring about changes in the system of symbols. Language users do not learn the system of symbols as an existing structure of the world, but create the system through the subjective activity of perpetual interaction with the external world and through communication with other individuals. The system of symbols changes when the relationship of individuals to the world changes through this creative process. This kind of change can induce modifications in the structure language. To study the evolution of language from a dynamic viewpoint is to consider such dynamics brought about by individuals' creative processes to be a fundamental feature of language use.

Language as a complex system

Models of language that take account of these kinds of dynamics consider language to be a complex system characterized by emergence, subjectivity and dynamics.

It is said that "emergence" is the phenomenon through which the functions or global orders of a system arise spontaneously from the local interactions of elements of the system. Socially shared linguistic components such as grammar and lexicon do not exist *a priori* but emerge from interactions among language users without peculiar central controls and powers. Thus it is natural to look on the evolution of language as a typical phenomenon of emergence.

In a linguistic system the agents who participate in the local interactions are the language users. Language comes into existence when subjective users of the language exist. The subjective user embodies a cognitive system that makes its internal structure by embedding the behaviour of others and of the external world within him/herself. He/she engages in cognitive activities by acting toward others and the external world, and changes its structure and relationships with others and the external world (Kaneko & Tsuda, 1997; Kaneko & Ikegami, 1998).

Evolutionary linguistics focuses not on the linguistic structure at a temporal point, but on change in language. Language is regarded as essentially dynamic. The dynamics of language, hereafter DOL, can be divided into the following four levels in terms of time:

I. Origin,

II. Evolution,

III. Development,

IV. Sense-making and Conceptualization.

In the study of the origin and evolution of language, we turn our attention to the long-term change of linguistic structure. The origin of language involves the

problem of how a change from a situation without a linguistic system to one with such a system can occur. The studies on the evolution of language try to understand how the structural changes of language systems are established.

Development in language treats dynamics on a shorter time scale, and involves language acquisition, in which we study how infants can learn the existing language structure, and second language acquisition, in which we study how users of one language learn a new language.

'Sense-making' is the process of giving words meaning (Fukaya & Tanaka, 1996), and also involves dynamics on a much shorter time scale. Words that are exchanged between subjects do not have *a priori* meanings but are given subjective meanings in the context of communication. In the next subsection, we discuss the sense-making activity of individual language users as the basis of language dynamics.

Dynamic view of language

The complex systems' viewpoint on language puts a premium on the emergence, subjectivity, and dynamics of language as discussed above. Its fundamental tenet can be summarized as follows: language is carried on the shoulders of subjective language users who embed the whole of a system within which they behave and act according to the structure embedded. This means that they both form a linguistic system and are reflexively subject to the imposed restrictions of the system.

The dynamic view of language envisages language as it is altered with use. If a linguistic system did nothing more than conform to the subjects or users of the system, then the system would be static. In actuality, however, language systems continually change. The subjects not only confirm the linguistic system, but can also break linguistic 'rules' in their linguistic activities. The conceptualizing and sense-making acts of the language users as well as external forces such as environmental changes cause the linguistic system to change over time.

For instance, let us consider creative metaphors. Although metaphorical expressions that are already common are often a part of a linguistic system, we can also manufacture novel expressions. Such expressions are only 'invalid' if they are viewed from within the existing linguistic rules. When we listen to or read such expressions, we can subjectively understand them to some extent. How should we make sense of this phenomenon? If we consider subjectivity to be indispensable to language, the subjects make sense by themselves.

The production of creative metaphors may seem too unusual an occurrence to provide a basis for the proposal that language users create meaning. The subjective activity of making sense, however, is involved in all linguistic processes such as speaking and recognizing. Cognitive linguistics, in which metaphors are not mere rhetoric, but rather are important instruments for structuring our cognition, indicate that many expressions which are not used as metaphors can be considered originally metaphorical (Lakoff & Johnson, 1980; Taylor, 1995). Since such expressions have deeply permeated our minds, we are not conscious of their metaphorical nature. This means that there is no strict distinction between metaphorical and non-metaphorical expressions, and the assertions about

metaphors are more or less applicable to daily expressions. Let us broaden our interpretation of the function of metaphor as the (re)conceptualization (Nogales, 1999) of daily linguistic expressions. Even a declarative sentence is not a mere description of an objective phenomenon but a manifestation of how a subject recognizes the phenomenon. The subject who accepts a declarative sentence (re)structures his/her own conceptualization through being constrained by situations, contexts, experiences and the linguistic system.

Constructive approach

When the object of study, like the origin and evolution of language, is a difficult one on which to carry out experiments or to observe, we can rely on the constructive modelling that is often used in the field of complex systems (Kaneko & Tsuda, 1994; 2001; Kaneko & Ikegami, 1998), and especially in the study of artificial life. Models constructed with computers are regarded as laboratories in which we can show various emergent phenomena and clarify their information structure (Casti, 1999). Here we consider three major advantages of this approach.

The main merit of the constructive approach is to make subjects and their dynamics, both of which are likely to be stripped from the study of human-related phenomena like language, economics and social systems, into an object of mathematical scientific study. Although subjective activities are indispensable to language, “linguistic rules” are often regarded as objective entities detached from language users when language is treated descriptively. Namely, the subjective individuals who use language are eliminated. In our constructive approach, we base the model on the activities of speaking, listening and understanding language and describe “linguistic rules” as the result of the development and interactions between individuals.

A second merit of this approach is in its usefulness for understanding dynamic systems. To describe language, we can assume static structures and describe them. To study the temporal changes in language, one may use the diachronic approach (Saussure, 1959). However, this approach is more or less a way of comparing static models and is not well-suited for capturing language as an essentially dynamic phenomenon, since it shows differences in language by comparing structures that are statically described at different points of time. Adopting the constructive approach makes it possible to thoroughly investigate the state changes of such essentially dynamic systems.

A third merit of the constructive approach comes to light when we try to understand a system that is complex in its nature, such as life, society or language. Reproducing a complex system is often such an intractable difficulty that we, in this approach, do not try to duplicate the complex state of the system as it is. We construct a simpler system which is considered to be its ancestor, together with a mechanism to evolve it. By observing the increasingly complex processes and results, we will be able to understand the dynamics and features of the complex systems under scrutiny.

Development of Categorical Structure

In this section, we show an example of constructive research on language dynamics[2]. Focusing on sense-making activity in using language (level IV in the DOL), we construct a model in which a web of relations among words, which represents the internal structure of a language user, develops in the course of conversation. We call the model 'The Developing Word-Web Model'. We analyze how categorical structures develop as internal structure through conversation (level III in the DOL), and how the spreading of structures in a population and in individuals are related (level II in the DOL).

Modelling the sense-making process

In this model, the internal structure of a subject is expressed by a web of relations between words. We employ usage-based modelling (Wittgenstein, 1953; Langacker, 1999; Barlow & Kemmer, 1999; Hashimoto, 1997), in which language structures are organized according to the use of language in conversation. Therefore, the relations among words are not a copy of the relations among the objects indicated or referred to by the words.

The sense-making activities in using language are modelled as processes in which the words used are situated in a web of relations. Concretely, when a subject accepts a sentence, the relations between the words used in the sentence and all words which the subject knows are computed and renewed. Through this computation, the subjects change their internal structure dynamically in the course of a conversation. This renewal process is schematically indicated in Figure 1.

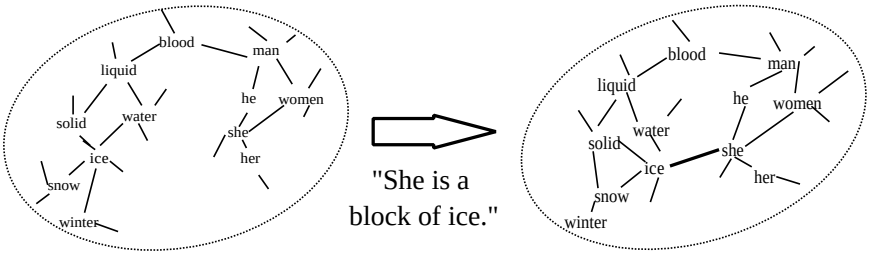


Figure 1. A sketch of the change that occurs in a word-web by the subject's accepting of a sentence. When a web representing the internal structure of a language user is in the state depicted on the left, in which there is no connection between the words 'she' and 'ice', he/she accepts the sentence "She is a block of ice" and changes his/her internal structure to the state depicted on the right, in which there comes to be a connection between the words 'she' and 'ice', and the whole shape is modified.

[2] Refer to Hashimoto (1998; 1999) for details.

The algorithm used to update the relations between words is based on the method of calculating similarity among words in a corpus proposed by Karov and Edelman (1998), with two modifications. First, we changed the method so as to calculate iteratively with conversation, since we are interested in the dynamics of categorization, not the final state of the structure. Second, we introduced 'texts' as an higher level category of elements of language than words and took the correlation of word appearance frequency in texts into consideration. In the present case, a text is a sequence of sentences spoken and listened to by subjects in conversation.

A relation between words *i* and *j* at the acceptance of the *n*-th sentence in the *t*-th text is a linear combination of 'word-similarity' and 'word-correlation'.

$$R_{t,n}(w_i,w_j) = \alpha^w \text{ (word-similarity)} + (1-\alpha^w)\text{(word-correlation)} \quad (1)$$

where α^w is a parameter that signifies the weight of word-similarity in the relation. The first term, word-similarity, is used to calculate the similarity between words in terms of how they are used in sentences. Two words that are used in one sentence come to have a strong word-similarity. The second term, word-correlation, concerns the pattern of appearance of words in texts. If the patterns of appearance of two words are similar, this term in the formula has a positive value, and vice versa. This quantity is determined by calculating the correlation of appearance probabilities of words in texts. The value of this quantity is calculated on the basis of the proximate sentence, $R_{t,n-1}$; if n=1, it is calculated on the basis of the last sentence at the proximate text t-1. Thus, if a subject continuously utters and accepts sentences, the relations between words change in succession.

Conversations among agents are modelled as exchanges of sentences. Conversation topics are introduced to two agents who are chosen from a given population. A conversation starts when one agent (the speaker) utters a sentence about one of the topics. If the other (the listener) accepts the sentence, he/she replies to the sentence. To qualify as reply, the sentence need not address the first topic precisely, but should contain any one word from the accepted sentence. The sentences have a chance to be modified before utterance so that new sentences and new words are introduced.

The word-web is represented by a matrix. When an agent utters or accepts a sentence including a word *w*, he/she calculates *R*(*w*,*w*') of all known words *w*' and renews the value in the matrix. If there is only one unknown word in the sentence to which he/she listened, the listener accepts the sentence, enlarges the matrix to incorporate the new word, and calculates its relation with other words (Figure 2).

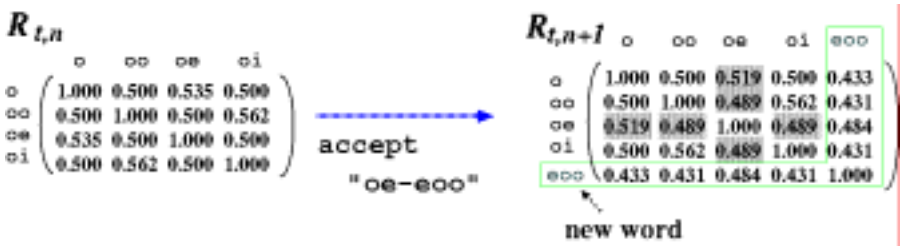


Figure 2. An example of how the matrix representing a word-web is renewed upon the acceptance of sentence. When an agent's internal state is represented by the matrix on the left and he/she accepts the sentence "oe-eoo", the elements in the row and column of the word 'oe', i.e., shaded elements in the matrix on the right, are updated. The matrix is then enlarged to incorporate the unknown word 'eoo'.

Stability and adaptability of categorical structure

We summarize the results of simulations in which the agents, who initially have no knowledge of words, communicate with each other and develop their internal structures.

The agents create clusters in the word-web based on the strength of the relations among words. There are two major shapes of clusters, flat clusters, in which words have a strong relation to each other, and gradual clusters, in which the relations between words gradually change. In actual simulations, these two types of clusters are interlaced.

This cluster formation can be interpreted as a means of categorization. Since the boundary of a flat cluster is sharp, it is quite clear whether an entity is a member of the cluster. This type of cluster is like a category in which the members are rigidly determined by necessary and sufficient conditions. In contrast to flat clusters, gradual clusters show a graded change in the relations among words from strong to weak. These two types of clusters can be combined, with some flat clusters being connected through gradual clusters. This structure is like a prototype category (Lakoff, 1987; Taylor, 1995). The extent to which words are included in a category is a matter of gradient. Part of the flat cluster corresponds to the central member of a category. Words having weak relations to the central member are peripheral members of the category.

When a new word is used or a word is used in an unusual way, word relations can change dramatically. The dynamics of the internal structure of an agent is exemplified in Figure 3. The change in the relations between a given word and other words in the course of conversations is superimposed on this graph. In the 21-st text (t=21), a word is used in a new way, and the relative strength of relations among words is turned over.

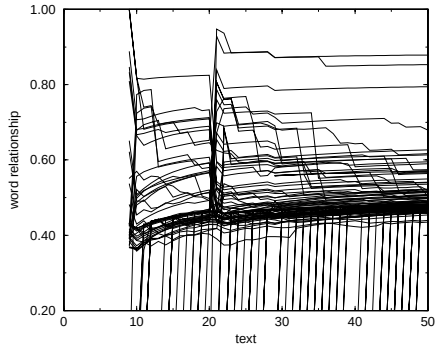


Figure 3. The dynamics of word relations in conversation. The x-axis represents the texts and the y-axis represents the relations of a given word with other words. In the 21-st text, we observe a large, rapid change in the relations among words.

The change in the word-web that occurs with the new usage of a word is depicted in Figure 4. The corresponding words before and after the change are connected by arrows. While words move coherently with other words in the same cluster, the word that has been used in a new way, which is connected with the corresponding word by a broken arrow, moves in a different direction from the others in its cluster and becomes a member of a different cluster.

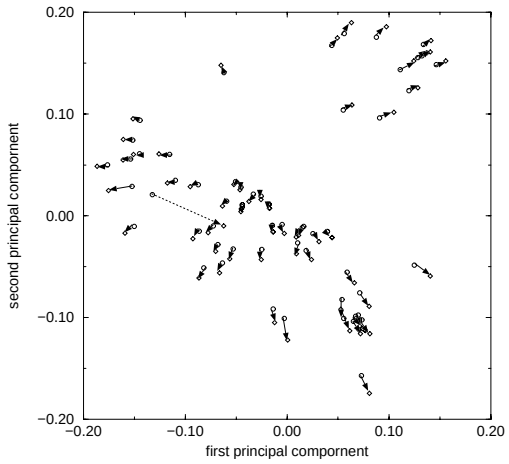


Figure 4. Change in the word-web resulting from the turnover of word relations. This diagram is the result of a principal component analysis of the matrices expressing the internal structure. The words that correspond to each other before and after the listener accepted the sentence containing the new usage are connected by arrows.

The dynamics with which the word-web preserves the whole structure and accommodates itself to new experience indicates the coexistence of global stability and local adaptability. This dynamic quality is the fundamental feature with which languages should be equipped. If a language is too rigid, its users will not be able to formulate new expressions to describe diverse experiences, and if it is too unstable, no structuralization will be possible either at the individual and/or global levels; hence, no communication will take place (Geeraerts, 1985).

Using a word in a new way induces remarkable change in a subject and connects two previously unconnected clusters. If, again, we think of clustering as categorization, the function of the dynamics resembles that of metaphorical expressions. Such expressions reconceptualize our experiences (Nogales, 1999) by connecting two different domains of categories.

Development of commonality and individuality

The population of agents develops both the shared and individual parts of the cluster structure through conversation. Establishing the shared structure is the basis of society, and is necessary for language to serve mutual understanding. The degree of sharing does not necessarily grow with conversation, and sometimes it diminishes. This is because the agents each experience a separate conversation history, and therefore can supply different senses for the same sentence and thus develop individuality. All of the agents within the system do not come to identical conclusions, but instead retain their individuality. Thus the relationships between agents change constantly, and the structure at the global level, namely the language structure, is dynamic. This reconciliation between commonality and individuality is also a fundamental feature of language systems.

Evolution of Grammar

This section describes a study of the evolution of grammar[3] involving longer time scale dynamics (level II in the DOL) than in the previous section. The agents engaging in conversations are assumed to have some internal rules that they use to produce and recognize sentences. The rules are expressed by generative grammar. We observe in a conversation network of agents the process of complexification and structuralization of grammars and the emergence of social rules that evolve from the shared usage of words in the population.

Conversation game between grammar systems

An agent is defined as having a generative grammar,

[3] Only the summary of the model and the results are explained here. The detailed description is in Hashimoto & Ikegami (1995; 1996)

$$G_i = (\{S,A,B\}, \{0,1\}, F_i, S) \tag{2}$$

where $\{S,A,B\}$ and $\{0,1\}$ are the sets of non-terminal and terminal symbols, respectively, F_i is a set of rewriting rules and S is the initial symbol. This grammar is used both for the production and acceptance of sequences. At the level of production, the agent begins rewriting from the initial symbol, S, applies the rewriting rules to the non-terminal symbols, and stops rewriting when rewritten sequence consists of the terminal symbols. For example, an agent with a rewriting rule list,

$$S \to A0B,\ A \to 10,\ B \to 11 \tag{3}$$

produces a sentence "10011" as

$$S \overset{S\to A0B}{\Rightarrow} A0B \overset{B\to 11}{\Rightarrow} A011 \overset{A\to 10}{\Rightarrow} 10011 \tag{4}$$

He/she then utters the sequence to all of the agents, who try to recognize it in terms of their own grammars. The acceptance process is the reverse of production. If a sequence that is heard can be rewritten to the initial symbol, it is recognized.

The agents in a conversation network of P agents engage in a game: they score according to the utterance and recognition of sequences. Each agent is able to utter R times in one time unit. The score an agent receives in a time unit is a weighted average of the scores based on the uttering and recognition of sequences as well as having his/her own utterances recognized by others[4],

$$p^{tot} = \frac{1}{R}\{r_{sp}(s^{sp} - f^{sp}) + r_{rec}(s^{rec}\sum_{recog}\frac{1}{step} - f^{rec}) + r_{br}\frac{s^{br} - f^{br}}{P}\} \tag{5}$$

where s^{sp}, s^{rec}, and s^{br} are the times of uttering, recognizing and being recognized, respectively; f^{sp}, f^{rec}, and f^{br} are the times of not uttering, not recognizing and not being recognized, respectively; and r^{sp}, r^{rec}, and r^{br} are the parameters for the weight of each term. The variable *step* is the number of rewriting steps taken before recognition occurs. The sum Σ_{recog} is taken only when an agent can recognize the sentence.

Here we introduce the evolutionary dynamics: some of the original agents are replaced with new agents according to their scores. The new agents are variations of the agents with higher scores. Since an agent is considered here to be a family or a population sharing the same grammar, the grammar of the higher-scoring agents has a higher chance to be inherited and spread with differentiation.

Emergence of common language and evolution of grammar

The simulation starts with the agents having the simplest, non-syntactic rules, namely $S \to 0$ or $S \to 1$, as the initial state. These agents can utter only a word.

[4] The definition of the score (5) is simplified with respect to that of Hashimoto & Ikegami (1995; 1996).

The product of the length of the sequences uttered and recognized measures the information handled by an agent. The information flow in the network is the average of the amount of information handled by all of the agents.

At the beginning of the evolution, the variety of sequences uttered develops with the growth of the information flow. At some point the growth stops. After that point, the information flow in the network shows a punctuated equilibrium evolution, as depicted in Figure 5, in which the flow rapidly grows and stops in turn.

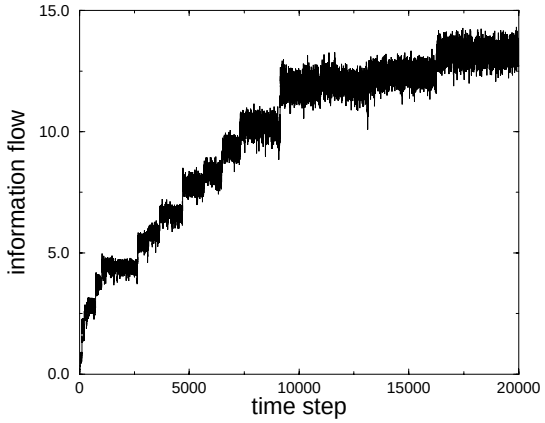


Figure 5. Transition of information flow in the conversation network. $r_{sp\_}$= 3, $r_{rec\_}$= 1, $r_{br\_}$= 1.

At equilibrium, a group is formed in which agents utter and recognize the common sequences. The agents who can understand such sequences get higher score. The formation of such a group suggests the emergence of a social rule in which it is preferable to use some particular sequences in communication. Agents who cannot recognize such sequences do not earn higher scores, even if they have a better ability to understand sequences on average. Such agents are often not able to survive in the network. This means that the formation of groups sharing common sequences suppresses the evolution toward a language with a large variety of sequences.

During the growth of a group with a common language, agents who can recognize a large variety of sequences emerge from the group. They can understand both common and new sequences. The development of a grammar with a high variety of sequences is effected by module-type evolution and the emergence of a loop structure in the grammar. Module-type evolution is to get a rewriting rule that can be attached to other rules to produce many sequences. Such rules resemble the type of word formation known as suffixation. The emergence of a loop structure enables an agent to use a loop in the production process. This allows the agent to produce an infinite number of sequences, in principle, through recursive production processes. Such looping corresponds to the embedding structure of phrases in natural language. These two types of evolution of grammar

are often realized by obtaining only one new rewriting rule, which spread rapidly through the network so that the information flow shows steep growth.

Double articulation

The grammars that agents arrive at are structured by reflecting the characteristics of the language used in a society. The agents, in general, have three types of rewriting rules:

$$N \rightarrow \text{sequence of } T, \tag{6}$$

$$N \rightarrow \text{sequence of } N, \tag{7}$$

$$N \rightarrow \text{sequence of } N \text{ and } T, \tag{8}$$

where N and T are a non-terminal and a terminal symbol, respectively. Rules of type (6) often code sequences that are shared in a group. Since being able to understand frequently used sequences quickly carries an advantage, the agents develop grammars in which the common sequences can be recognized in short rewriting steps. That is, they understand common and frequent sequences with rules of the following type:

$$S \rightarrow \text{frequent sequence of } T \tag{9}$$

which is a special version of the type (6) rules. Infrequent sequences are recognized by the joining of the sequences of terminal symbols coded by rule (6) to each other using rules (7) and (8). The type (6) rules can be seen to code ‘words’ and the type (7) and (8) rules ‘sentences’.

This structuring of grammar can be seen as a correspondence of ‘double articulation’ in natural language. This mechanism enables languages with a finite number of symbols to produce infinitely diverse sentences. By combining symbols to make words, and combining words to make sentences, we can produce an infinite number of structured sentences.

As we can understand from observing the evolution of agents in the model, double articulation brings stability and adaptability to language. Utilizing double articulation, the agents who emerge concurrently with the rapid increase in the information flow get new sequences without large changes in rewriting rules and already known sequences. In the simulation, such characteristics appear as the punctuated equilibrium in the development of the information flow.

Developing Word-Webs with Grammar

In the second section, we treated the dynamics of levels IV, III and part of II in the DOL, and in the third section we also discussed level II. In aiming to form a coherent understanding of the dynamics of language, here we integrate the approaches taken in sections two and three above into one model. The present

section discusses an attempt at such integration by presenting a model of the conversation network of agents having word-webs and grammars[5].

Articulation by grammar

Agents have an algorithm for inferring the relations among words. This algorithm was introduced in the second section, and a generative grammar was defined in the subsequent section. The grammar is used to parse sentences as sequences of words. For example, an agent with a grammar,

$$S \to A0B,\ A \to 10,\ B \to 11 \tag{10}$$

parses a sentence "10011" as

$$10011 \overset{A \leftarrow 10}{\Rightarrow} A011 \overset{B \leftarrow 11}{\Rightarrow} A0B \overset{S \leftarrow A0B}{\Rightarrow} S \tag{11}$$

and recognizes it as a sequence of words, "10·0·11". The parsing tree is shown in Figure 6(a). According to the results of the parsing, the agent updates his/her matrix of word relations.

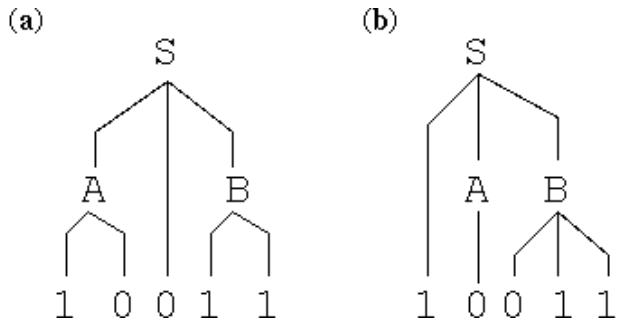


Figure 6. Examples of the parsing tree and articulation.

Incorporating the grammar into the analysis introduces another level of subjectivity. The parsing of a sentence differs in different grammars. For example, an agent with the grammar

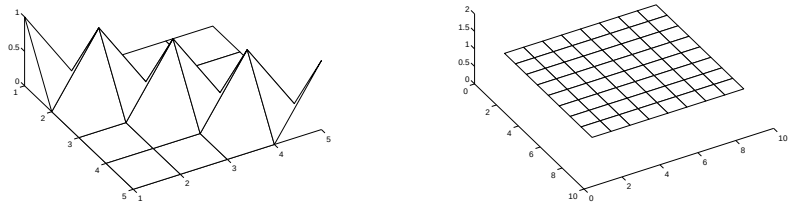
$$S \to 1AB,\ A \to 0,\ B \to 011 \tag{10}$$

parses the sentence "10011" as shown in Figure 6(b) and accepts it as a sequence of words: "1·0·011".

[5] This work was first reported in Hashimoto (1997).

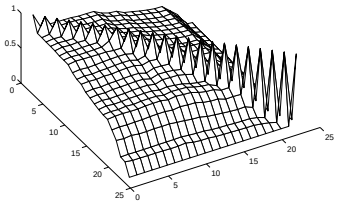
Structure and dynamics of categories

Words are clustered in a word-web as shown in the results in the second section above. The amount of variation in the shape, which depends on the initial grammar, is greater than the amount of variation in the Word-Web without grammar described in the second section above. We classify the cluster structures into six types according to their shapes. Examples of simple structures of each type are shown in Figure 7.

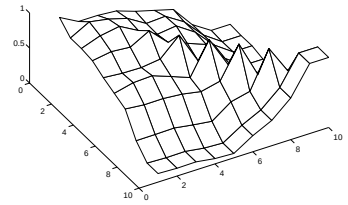


(a) solitary word

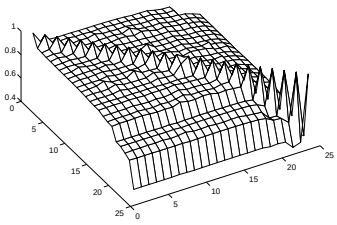
(b) flat cluster



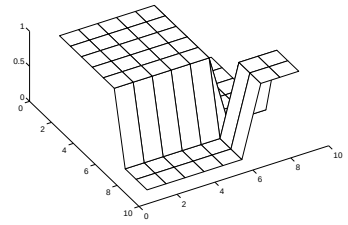
(c) gradual cluster



(d) two-peak cluster



(e) sub-clustering



(f) two clusters

Figure 7. Examples of typical structures of word relations. Each number on the X- and Y-axes indicates one word. The Z-axis shows the relation between the words. A word is selected as a standard word and put at the origin of the X-Y plane. The other words are arranged in descending order of the closeness of their relations to the standard word. The standard word is selected as that for which the decline is as smooth as possible.

The features of these shapes can be summarized as follows: (a) solitary word: a word that has no connection to other words; (b) flat cluster: the words in the cluster have almost identical relations with each other; (c) gradual cluster: the relations

between words in the cluster vary with the words and gradually change; (d) two-peak cluster: the words are in a cluster with two peaks of close relations within it; (e) sub-clustering: the cluster has a stepwise structure, and words are thought to be divided into sub-clusters; (f) plural clusters: the words form plural clusters without relations.

A solitary word is a word without any relation to other words (Figure 7(a)). Strictly speaking, we cannot say it is a cluster and also a category, since we do not have any categories with only one member in our knowledge system. There might be, however, such a simple structure at the very beginning of our developmental process.

The flat and gradual clusters (Figures 7(b) and 7(c), respectively) have the same structure and meaning as those in the second section. The two-peak cluster (Figure 7(d)) is an analogue of a category with two central members. It can be regarded as a polysemous category. All of the words in a single-peak structure are characterized by how strong relations they have with a central member in the category. Whereas in a plural peak structure, as in a case where there are two peaks, there are words which have strong relation with one central member but not with the other central member, and words which have some degree of relations with both central members of the category.

We can see the sub-clustering structure in two groups of words in a cluster (Figure 7(e)). One group consists of words with strong relations to each other and the other of words with rather weaker relations. The two groups can be regarded as two sub-categories within the category. This is the simplest case of a hierarchy of categories.

A general scenario for the development of a cluster structure is the following. At first an agent can recognize only a single one-word sentence. The agent then develops the ability to recognize several sentences, but these are all one-word sentences, and therefore, altogether, consist of several solitary words. The agent becomes able to articulate plural words in a sentence, which constitutes the forming of relations between words. Eventually words form gradual clusters. Following such initial development, the clusters change their structure through such processes as expanding their boundaries, making connections with each other, and incorporating solitary words.

When clusters expand their boundaries, the structure of the original cluster does not undergo a great change, thus satisfying the requirements for adaptability and stability in language. In terms of its flexibility, then, the original cluster resembles, in the context of dynamics, the prototype category.

Parallel to this development in word-space, the syntactic structure also develops from a sequential structure to a branch structure, and finally, to a loop structure.

Discussion

We formulated the evolution and dynamics of language on the basis of sense-making and conceptualization in language use. To base language on subjects' conceptualization is consistent with Tokieda's conception of language as process (Tokieda, 1941). He put forth "a theory in which the essence of language is

considered to be a set of mental processes (p.i)". Bakhtin has also stated that language is understood as an "activity, an unceasing process of creation realized in individual speech acts" in the individualistic subjectivist view of language (Volosinov, 1986).

We have argued that the merit of the constructive approach is to take account of individual subjects in an objective system of scientific study. Thus, we now have an actual apparatus with which to deepen and broaden the discussions begun by Tokieda and Bakhtin.

There are various strands of constructive approaches in the study of the evolution of language (Hashimoto & Ikegami, 1995; 1998; Steels, 1997; 2000; Arita & Koyama, 1998; Kirby, 1998; Batali, 1998). They investigate the process of the emergence and evolution of, for example, a shared lexicon or grammar. The emergence of global order as language-like behaviour is observed by modelling individuals in terms of their linguistic interactions. Note that carrying out computer simulations alone is not the same as taking the constructive approach. For example, the evolutionary game theoretical studies of the evolution of language by Nowak *et al.* (Nowak & Krakauer, 1999; Nowak, Plotkin & Jansen, 2000; Nowak, Komarova & Niyogi, 2001) are rather top-down and descriptive analyses.

In this paper, we have attempted to construct and understand the linguistic structures and the ceaseless dynamics within them that are induced by using language, with a special focus on sense-making by subjective individuals. Since the models and mode of analysis introduced in this paper assume that language users are equipped with categorical structures and grammars, they cannot, strictly speaking, treat the problem of the origin of language (level I in the DOL). However, we began with simulations involving agents with minimal abilities, namely, having no knowledge of words and no syntactic structure, and investigated the process of the development of categories and syntax as internal and social structures. We can conclude that the constructive approach is an effective tool for studying the origin as well as the evolution of language.

Conclusion

Language is not a static and objective entity, but an ever-changing system encompassing the subjective activities of language users. In this paper, we propose that the dynamic view of language is a foundation from which we can understand the dynamic aspects of language, especially the evolution of language. The dynamic view sees language as involving subjective processes of sense-making, and sees its dynamics as induced by its use. The constructive approach is advantageous as a methodology for analyzing language according to this dynamic view. In this approach, both subjective individuals as language users and conversations among them are modelled, and the development of the system is observed using computer simulations.

According to the viewpoint that we have articulated, then, we introduced three models that facilitated our inquiry into the evolutionary processes of language categories and grammar. In this study, it was shown that the coexistence of stability and adaptability as well as of commonality and individuality are

prerequisites for the existence of ever-changing languages, and these characteristics are actualized, in part, by the proto-typical categorical structure and by double articulation.

The study of evolutionary linguistics should go beyond regarding the establishment of a shared lexicon or complex syntactic structure as the emergence of language. We must aim to construct and comprehend dynamic communication systems in which the linguistic structure can always change in response to the development, through acts of communication, of the internal structures of subjective language users.

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