Proceedings of the Annual Meeting of the Cognitive Science Society

Can Synchronization Deficits Explain Aphasic Comprehension Errors

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 9(0)

Authors

Gigley, Helen M.
Haarmann, Henk J.

Publication Date

1987

Can Synchronization Deficits Explain Aphasic Comprehension Errors?

Helen M. Gigley

Department of Computer Science
University of New Hampshire
Durham, NH 03824

Henk J. Haarmann[1]

ABSTRACT

The context dependent nature of language processing requires the synchronization of several subprocesses over time. One claim which follows is that de-synchronization is likely to disturb language processing.

Aphasia is a language disorder which arises following certain types of brain lesion. Many theories of aphasia are competence based theories and do not address aspects of performance which can be affected under conditions of processing degradation. The discussion in this paper will focus on de-synchronization as a possible explanation for aphasic language comprehension problems.

HOPE, a computer model for single sentence comprehension, provides a tool to systematically study the effects of various hypothesized de-synchronization problems on different language processing levels and on overall comprehension performance. HOPE includes a neural-like architecture that incorporates a grammar which functions in a predict/feedback manner. It illustrates one way in which serial-order input can map into synchronous, parallel subprocesses that can effectively produce normal sentence comprehension performance.

Using HOPE, the study of explicit de-synchronization effects on a cover set of stimuli sentences suggests error patterns to be sought in neurolinguistic evidence. Within a subset of a cover set of stimuli, simulation results from a slowed propagation lesion experiment will demonstrate how timing problems can result in observed aphasic comprehension performance.

1. INTRODUCTION

The context dependent nature of language processing requires synchronization of several subprocesses over time. One claim which follows is that de-synchronization as an example of a processing degradation is likely to cause problems with language processing.

Following brain lesion, usually on the left side, there is often a disturbance of language facility called aphasia. While it is known that brain process subserves language, until recently, theories of aphasia have been chiefly defined within competence theories of language instead of processing ones. (For some exceptions see, Von Monakow, 1914; Kolk, Van Grunsven, and Keyser 1985; Kolk and Van Grunsven, 1985.)

Neurolinguistic studies of aphasia, focusing on linguistic competence theories, analyze observed language difficulties in aphasia as the result of knowledge dissolution and/or rule degradation. In contrast, a processing based theory, the focus of this paper, attends to competence issues as studied in behavioral research, but also employs constraints developed within architectural considerations of the processing mechanism underlying the behavior.

There are several possible reasons for the general emphasis on competence theory motivated studies in neurolinguistics as opposed to processing degradation motivated ones.

(1) It is difficult to keep track of the on-line effect that a particular de-synchronization problem has on different levels of processing by just using paper and pencil. To give an example of a particular de-synchronization problem: How does an hypothesized slowing of propagation of activity after phonetic recognition affect the processing on different levels, such as the syntactic and the semantic level?

---

[1] Department of Psychology, University of Nijmegen, Montessorilaan 3, 6525 HE Nijmegen, The Netherlands.

The initial development of the reported research was supported though an Alfred P. Sloan Foundation Grant entitled "A Training Program in Cognitive Science" at the University of Massachusetts at Amherst. Continuing development is supported through a Biomedical Research Support Grant at the University of New Hampshire and through a grant from the Netherlands American Fulbright Committee and from IBM Netherlands NV.

(2) Human performance studies can only induce synchronization problems by manipulating the input to the language system. Internal manipulations, such as the slowing of activity propagation, as previously mentioned, are impossible. But such slowing might explain part of the differences in the results found in comprehension studies of aphasia which manipulate the rate of sentence input. (Brookshire, 1971; Blumstein, Katz, Goodglass, Shrier and Dworetski, 1985; Laskey, Weidner, and Johnson, 1976; Liles and Brookshire, 1975).

HOPE, a model of single sentence comprehension, was explicitly designed to provide a conceptual tool that enables on-line study of the effects of various hypothesized de-synchronization problems (Gigley, 1982; 1983; 1985b; 1986). Previous models of pathological language comprehension (Baron, 1975; Lavorel, 1982, Marcus, 1982) implemented to varying degrees, are rule based and do not include facility to manipulate the synchronization of information flow in the manner included in HOPE.

Using generally observed, independently affected competence knowledge as the basis of representations, HOPE was designed to be able to study how processing changes could affect overt behavior. It was not designed to specifically model, ''aphasia type x'' from the literature. In direct contrast to the role computational models assume in research in general,, the nature of the approach in HOPE is to study processing degradations, forming hypothesized patient performance profiles and to go to the literature or to design specific studies to determine the best fit to the behavioral data.

The best fit of simulation results that has been found to date appears in the data of studies of agrammatic patients. Kean (1985) describes, *Agrammatism is typically defined as a disorder of sentence production involving the selective omission of function words and some grammatical endings on words.* An extensive discussion of the clinical picture can be found in Kean (1985) and issues of knowledge loss theories related to it in Kolk and Van Grunsven (1985). Various difficulties which completely define any classification are discussed by Caplan (1985.)

HOPE's unique role as a model of language processing that includes issues related to neurolinguistic and neural-like processes will be discussed. To illustrate the specific features of HOPE's design which address the processing motivated lesions, we will describe how HOPE's lesionability is dependent on its neural-like architecture and on the time-coordinating function of its grammar. Then we will proceed by describing various possible ways to disturb the synchronization of HOPE's sub-processes. While HOPE also includes ways to lesion its competence factors, such as grammatical knowledge, or interpretation ability, these will not be discussed in this paper.

A brief description of a simulation run of HOPE will be used to demonstrate how de-synchronization can produce results which can be attributed to competence-based analyses. While other de-synchronization simulations can be shown to produce distinctly different results (Gigley, 1982; 1983; 1986) their scope cannot be described in detail here. Furthermore, within the simulations, we will discuss the need for a cover set of sentence stimuli and will discuss the implications of it on the design of suitable test stimuli during validation.

Finally, based on an hypothesized patient profile, the role of such modelling in providing a mechanism for exploring processing motivated theories of language performance will be shown. The final claim is that through the evolution of such modelling attempts a better understanding of the neural mechanisms subserving language will be gained.

2. THE LEVELS OF REPRESENTATION IN HOPE

The basic unit of computation is based on a lexical item. An example of an open class item is given in Figure (Closed class items have a less complex distributed form.) Each lexical item includes a phonetic representation, all meaning representations associated with it, an interpretation representation called pragmatic that reflects the correct meaning for the sentential context, and morphological information appropriate to the phonetic form.

Further competence knowledge includes a meaning for each syntactic category type that defines a down-line predicted category type and an associated semantic category type that occurs following correct interpretation and composition. Interpretation of a syntactic type is ''computed'' within an interpretation function that is defined for each syntactic type.

The lexical item is represented in a connected hypergraph formalism (Berge, 1970.) Spaces or hypergraphs are shown as enclosed areas in Figure 1. The neural-like computations over these units is described

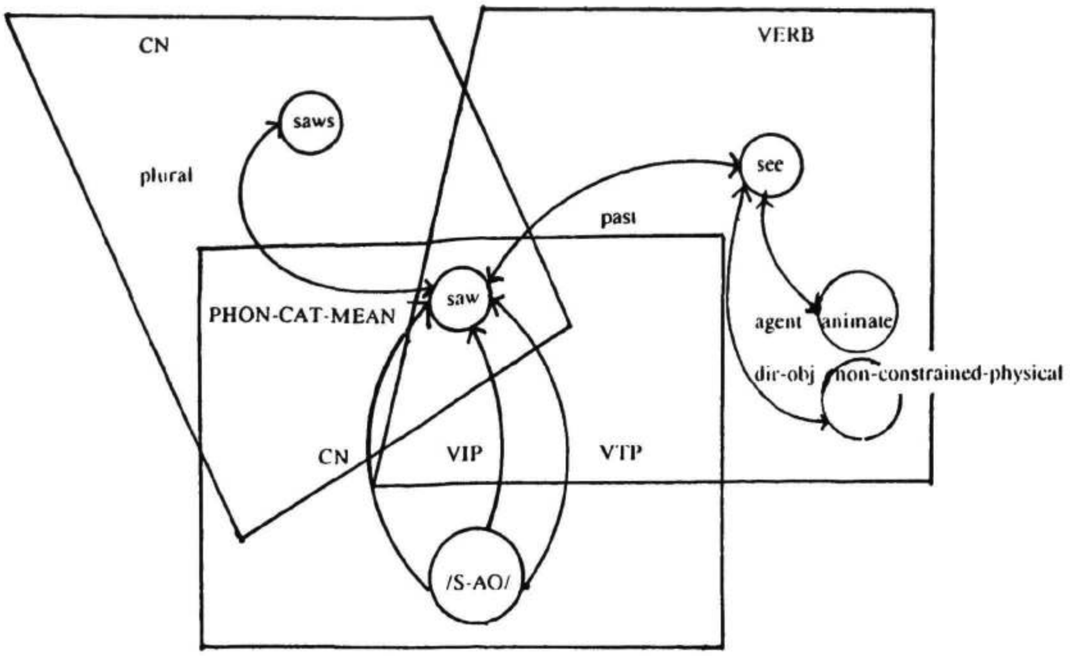

Figure 1: Example open-class word representation.

Open-class word representations are distributed across spaces, PHONETIC, PHON-CAT-MEAN, and morphologically related VERB and CN spaces. The order of activation of this information across time during processing is tuned to produce normal performance results.

below.

Briefly, sentences are input as phonetic word strings one word at a time. Then all meanings for each homophone are activated simultaneously (Seidenberg, Tanenhaus, Leiman and Bienkowski, 1982; Swinney, 1979) through spreading activation. These meanings interact with subsequent input producing the final state of simulated sentence comprehension. This is represented as the binding determinations for agent and object relationships on the interpreted verb form of the sentence and is activated as a subgraph in a pragmatic space.

At this point, one should note that each of units in the representations as illuustrated in Figure 1 receive activity in a neural-like manner. They are not all activated simultaneously, but over time as part of the process of syntactically motivated meaning disambiguation. Furthermore, each unit may lie in more than one space in the graph. Spaces currently denote, phonetic, meaning(PHON-CAT-MEAN), grammar, and pragmatic interpretations of the units. The hypergraph representation captures the redundancy supported in neurophysiology of multiple meaning/ multiple effect as each unit when active can affect different connected information in different ways depending on the spaces in which it lies. The details of this are relevant to processing but not critical to the focus of this paper. (For more detail see Gigley, 1982; to appear; and Gigley and Boulicaut, 1985.)

3. HOPE'S NEURAL-LIKE ARCHITECTURE

This section will describe HOPE's neural-like architecture as far as is necessary to acquaint the reader with the general notion of using a grammar as a coordinator of activation among levels of representation. For a complete understanding the interested reader is referred to Gigley (1982; 1983)

HOPE's architecture is neural-like. It is connectionist in the sense that all knowledge is represented as a distributed connected network of units that are activated over time. Each unit is intended to correlate with a pattern of activation over more abstract neural-like units (Hinton, 1981; Hinton, McClelland, and

Rumelhart, 1986; Smolensky, 1986.) A unit is **not** a grandmother cell. At an AI level, each lexical item is a collection of units that together are the "lexical item."(See Figure 1.)

HOPE's basic information unit is defined as a threshold unit with memory whose activity value is being manipulated by several automatically applied processes:

(1) Decay: All active units that do not receive additional input have their activity value exponentially reduced.

(2) Change of State computations: A unit can be in four different states and changes state automatically after it reaches threshold and fires.
  a) Short-term-memory state. The initial state of activation for a unit that has not reached threshold.
  b) Firing state. The state when the unit has reached or surpassed threshold and fires.
  c) Refractory state. When a unit has just fired, it is set to a state in which it cannot affect the computation.
  d) Post-refractory state. The state the unit is in after having been in the refractory state. Currently, the unit is subject to a different decay rate than before firing.

(3) Firing-information-propagation. Firing state propagates activity to other units. The propagated information is either excitatory or inhibitory. Excitatory information serves two different functions through feedback or feedforward (meaning spread) (Collins and Loftus, 1975; Hinton, 1981; Quillian, 1968/1980).

Activity input to units occurs over time across lexical item representations. Units are passive receivers of input; there is no self-modulation. The units that comprise each lexical item set are activated in a fixed-order over time using a spreading activation paradigm. The next section will illustrate this spreading activation. In Contrast, each time a unit fires, it dynamically computes where its information is sent. The effect of the activity on the units which receive inhibitory or excitatory input may differ from context to context.

An assumption shared with the connectionist approach is that units do not have the ability to look around to see if certain preconditions necessary for their action are fulfilled (Feldman and Ballard, 1982; Gigley and Lavorel, 1985; McClelland and Rumelhart, 1986.) Such preconditions viewed within an AI sense, can be thought of as patterns to be matched such as "DET followed by a CN."

HOPE does not compute rule interpretations of the occurrence of a rule pattern as suggested in competence theories. Any results in HOPE instead depend on activities arriving at the appropriate information within certain time-bounds. Propagation results are not all or non in effect but must have concurrency with other related activity propagation from other inputs down-line to attain a result similar to rule application. Evidence that a rule or pattern has occurred arises in the time-sequence trace of activity propagations during a simulation. A rule as stated above, becomes a prediction of the anticipated down-line information in a subsequent time interval.

Because of the predictions and feedback when they are confirmed, there is no formal syntactic structure built during the processing. As each unit fires it affects subsequent represented aspects of the lexical item in multiple ways. These generate a compositional interpretation for the input string (a predicate formalism) which captures the dynamic bindings of agent and object for the simple S-V-O sentences over which HOPE is currently being run.

This is in direct contrast to other connectionist-type models dealing with any of the normal processing issues in HOPE. These models include syntactic preprocessing or filtering (Cottrell, 1985; Waltz and Pollack, 1985; McClelland and Kawamoto, 1986.) HOPE claims this is not necessary and furthermore, that syntactic and semantic processing must occur in a fully integrated on-line fashion. Simultaneous on-line syntactic disambiguation and semantic interpretation is coordinated through the categorial grammar formalism, described later.

Computations are made over the entire graph representation of the current state of the solution (all active nodes of information) in a time-synchronized, lock-step fashion. A process interval is defined as one application of all processes to all information units. There is a separate interval driven process that determines the time-course of the introduction of the phonetically encoded words of a sentence. After each process time-interval, one can study the state of the entire graph (the process trace.)

The processes are governed by a set of modifiable parameters that determine rate of decay, amount of inhibition and excitation, height of the firing threshold, time lapse of activity propagation, and the initial activity levels of the short-term-memory, refractory and post-refractory states. Furthermore, a word-time-interval parameter determines when a new word is introduced. The processes are synchronized or externally tuned by the model user to define the **normal process model.** The modifiable parameters must be set in such a way that for a complete cover set of sentences, each will be correctly interpreted. A complete **cover set** of sentences is the minimal set of sentences which capture one example of each correct syntactic sentence the model is defined to process and include all combinations of syntactic form-class combinations for each position of the input. The parameter values are set relative to each other.

Once tuned, no computations such as waiting for signals, are necessary for synchronization. Furthermore, relative changes in the parameter values from their synchronized settings define processing lesion conditions. Note that usually only one modification of a parameter is made per simulation experiment although multiple "lesions" are possible in the model. Of critical import is the synchronization role of the grammar discussed next.

4. THE COORDINATING ROLE OF HOPE's GRAMMAR

The function of HOPE's grammar is to coordinate the on-line interactions of the compositional meaning representations of a sentence with the incoming words (Gigley, 1982, 1983, 1985a). This is achieved by using the activity states of the grammar to control feedforward and feedback relations which are encoded as part of the meaning of syntactic categories. Furthermore, the grammar currently serves as a filter of the amount of activity propagated in these relations. The goal of this section is to introduce this general notion of a predict-feedback cycle by means of a specific example. Later on we will see how de-synchronization can cause comprehension problems by disrupting this predict-feedback cycle and the events that happen as a consequence of it.

To give an example, the meaning of the lexical category, determiner, is encoded as: **DET := TERM/CN.** This is called a derived specification and is to be read as follows: A determiner (DET) PREDICTS a common noun (CN) and FORMS a TERM after successful compositional interpretation with the CN meaning. The interpretation computation is part of the category meaning as previously described.

The definition is drawn from categorial grammar (Ajdukiewicz, 1935, Lewis, 1972)). which makes the assumption that correct meaning composition can be assumed simultaneously with syntactic well-formedness. In categorial grammar, for example, a DET followed by a CN is semantically equivalent to a TERM, which can also be a syntactic type. Thus, the categories of both phrases THE SAW (DET CN) and PAUL (TERM) are syntactically and semantically TERMs which denote specific instances.

As an example, Figure 2 shows the time course of the semantic composition of the phrase /TH-UH S-AO/ (THE SAW) relative to the incoming phonetically encoded words using the determiner meaning DET := TERM/CN. The numbered E's in Figure 2 refer to events that will now be described. For clarity, decay and state computations (except firing) will not be discussed.

In the first time-interval: /TH-UH/ fires representing PHONETIC recognition (E-1). This has two effects:

SPACE	**time1**	**time2**	**time3**	**time4**	**time5**
PRAGMATIC				$E-7$	$E-12$
GRAMMAR		$E-3$		$E-10$	
PHON-CAT-MEAN	$E-2$		$E-5, E-6$	$E-8, E-9, E-11$	
PHONETIC	$E-1$		$E-4$		

Figure 2: Example of processing over time.

Numbered events (E-n) which occur during a simulation are described in the text. Time intervals are labelled, timeN

(1) Spreading activation to PHON-CAT-MEAN (lexical meaning) occurs in the same time-interval. This activates the category-meaning entries of the recognized phonetic word. /TH-UH/ has only one meaning entry: TH-UH <-- DET - THE. DET is its category and THE is a spelling representation for its meaning in PHON-CAT-MEAN (E-2).

(2) The predictive meaning of the category aspect of the recognized phonetic word's meaning, if it has one, will be activated in the GRAMMAR space the next time-interval. This is an example of fixed-time spreading activation. In this example the predictive meaning of DET in the grammar, CN, will be activated at time-interval 2 (E-3).

In the third time-interval, /S-AO/ fires at the PHONETIC level(E-4). Again, in the same time-interval spreading activation activates the category-meaning representations of /S-AO/: S-AO <-- VTP-SAW; <-- VIP SAW and <-- CN SAW, where VTP stands for a transitive verb phrase and VIP for an intransitive verb phrase (E-5). The category-meaning <-- CN SAW that is associated with /S-AO/, receives, like all other CN-meaning pairs, additional activity, because it is predicted in the grammar. This causes it to fire (E-6). Firing has three effects that will be visible in the fourth time-interval.

(1) The second aspect of each category meaning, the category specific interpretation function, is applied. The interpretation function for CN will interpret the lexico-graphically encoded meaning "SAW" which is associated with the firing CN as a generic NOUN on the PRAGMATIC level (E-7 in time4.)

(2) The activity of categories and meanings competing with <-- CN SAW will be inhibited (E-8).

(3) Because CN is a predicted category and active in the GRAMMAR, all lexical entries whose associated category predict a CN (here only DET) will receive additional activation by feedback (E-9) and the activity of the predicted category CN will be dampened in the grammar (E-10). Note that the CN itself does not predict another category in the simulation defined model.

Also, in the fourth time-interval, the category-meaning pair associated with /TH-UH/ <-- DET THE fires (E-11) after having received additional activation due to feedback. Because it does not have competing meanings or categories, no inhibition occurs. Its only effect will be the application of the interpretation function associated with the category DET, which checks to see if there is only one CN available for composition on the PRAGMATIC level and attaches it to a TERM indicating that it has been interpreted as a specific instance (E-12 in time5.)

HOPE allows a user to define his own specific model within the constraints of HOPE computations, his lexicon, category-meaning set, grammatical interactions, and associated interpretation computations for each category. In the 1982 model the following grammar was defined over a lexicon of items having different degrees of syntactic form-class ambiguity: 1) DET := TERM/CN; 2) VIP := SENTENCE/ENDCONTOUR; 3) VTP := VIP/TERM.

The derived specifications for DET and VTP (transitive verb) have been adopted from a categorial grammar of English, whereas the ENDCONTOUR, a symbol for the end of sentence intonation contour, in VIP's derived specification (intransitive verb), triggers the completion of a sentence and the stopping of processing. Among other things, firing of VTP results in the interpretation of the object case relation of the verb (dir-obj) and firing of VIP in the interpretation of the agent case relation of the verb. It is at this time, after firing, during interpretation, that the morphological and tense constraints between the verb and the lexical items are activated. The composition of a VTP with a TERM phrase is semantically equivalent to a VIP category as can be concluded from the derived specification.

Because of the time-sequence activation of parallel predictions and their affect on down-line input, the semantic composition of a phrase will only succeed if the individual units involved in its composition receive a sufficient amount of activity (inhibitory or excitatory) at the right moment in time. Here moment of time really is a time bounded window of one or more computed time-intervals.

Some of the modifiable set of parameters determine the relevant time-course employed for any given specific model defined. Other parameters affect the degree of interaction due to firing and decay.

5. DE-SYNCHRONIZATION OF THE PREDICT-FEEDBACK CYCLE

Any deviation from normal fine-tuning can be viewed as de-synchronization. Studying the effect of de-synchronization across the complete cover set of sentences provides the basis for defining hypothesized aphasic patient profiles. These can be used to better define and understand aspects of performance problems in aphasia.

Examples of de-synchronization effects are:

(1) Increasing the decay rate of all units may result in an activity level that is insufficient for threshold firing. The result of non-firing may be incomplete or erroneous interpretation.

(2) Increasing the rate of new word introduction. can cause incorrect down-line syntactic disambiguation. If a word or phrase associated with a predicted category comes in before the predict category is active in GRAMMAR it will not fire.

A more explicit encoding of the second lesion, achieved by slowing the effective propagation of spreading activation to grammatical meaning(s) (Haarmann, 1987), will be used here to illustrate how timing issues can be a factor of aphasic performance. Then the observed simulated performance will be compared to several studies of agrammatic aphasic performance to show where there is support for the hypotheses and to point out where additional studies must be done.

The effects of different de-synchronization lesions can be distinguished by running simulations using an entire cover set of sentences under particular "lesion" conditions. For example, for the correct (S-V-O) syntactic sentence form of: DET CN VTP DET CN, one must include sentences with lexical items having form-class combinations that match exactly, ie that are unambiguously of the correct form class, and also:

DET	CN VIP	CN VTP	DET	CN VIP
DET	CN VIP VTP	CN VTP	DET	CN VIP
DET	CN VIP VTP	CN VIP VTP	DET	CN VIP ...etc.

Table 1 shows the syntactic form of several of a cover set of sentences which are currently defined in HOPE. At least two examples for each form are given. The first one contains unambiguous lexical items. The second and subsequent sentences (4c and 4d) contain different degrees of lexical form-class ambiguities.

For each "lesion" simulation, one can define a patient profile that summarizes the performance pattern on the whole cover set of sentences. Even though only a very limited domain of linguistic constructions is covered (simple declaratives, S-V and S-V-O sentence types) the patient profiles appear to be suitably fine-grained to allow distinctions between various "lesion" conditions (Gigley, 1982; 1983; 1985b; 1986.) The patient profiles of the increased decay and the slowed propagation "lesions" are described in Gigley (1985c; 1986). Here we want to draw the attention to an interesting difference we found between the effect of slowed propagation on a cover set of sentences with and without syntactic ambiguities under the "lesion" condition of slowed propagation only.

6. AMBIGUITY AND SLOWED PROPAGATION

During simulation runs where the length of time to propagate activity from a syntactic category to its meaning is increased, with cover sets of sentences with and without syntactic lexical ambiguities, we have found differences that suggest how syntactic lexical ambiguity can affect language understanding. Instead of describing the differences for the whole cover set of sentences, this section will contrast the final processing states for the set of sentences of Table 1 in the "slowed propagation lesion" state. The final states of interpretation for each are summarized in Tables 2 and 3. Table 2 contains the results of the unambiguous sentences while Table 3 shows the results of the ambiguous ones. All syntactic form class sets are derived from definitions in Webster (1981).

Because of the levels of representation and the remaining activity of active units in them, HOPE provides an hypothesized patient profile across each level. Here, the discussion will focus on only the PRAGMATIC or interpretation level results. Be cautioned that an hypothesized patient profile requires a complete cover set of sentences for analysis and we are only dealing with a subset here. A full cover set is necessary to mathematically define all possible outcomes based on syntactic interactions and note specific patterns that

(1)	TERM	VTP	TERM		
	a. Paul	slapped	John.		
	b. Paul	saw	John.		
(2)	DET	CN	VTP	TERM	
	a. The	girl	slapped	John.	
	b. The	girl	saw	Paul.	
(3)	TERM	VTP	DET	CN	
	a. Paul	slapped	the	girl.	
	b. Paul	saw	the	girl.	
(4)	DET	CN	VTP	DET	CN
	a. The	girl	slapped	the	boy.
	b. The	girl	saw	the	boy.
	c. The	girl	saw	the	seal.
	d. The	girl	saw	the	building.

Table 1: Examples from a syntactic cover set of sentences.

Note: (a) sentences are unambiguous in each lexical item; (b) sentences contain lexical ambiguities. Sentences (4c) and (4d) contain more complex combinations of lexical ambiguities than their syntactic counterparts in sentences (4a) and (4b).

	CORRECTLY INTERPRETED CONSTITUENTS AND BINDINGS				
SENTENCE	AGENT	OBJECT	VERB	CONSTITUENT	
(1a)	PAUL	JOHN	SLAPPED		correct
(2a)	*absent	PAUL	SLAPPED		
(3a)	*absent	*absent	*absent	TERM-PAUL	
(4a)	*absent	THE BOY	SLAPPED		

Table 2: Summary final states of interpretation for unambiguous sentences.

In the table, *absent indicates there was no interpreted bound referent for the given role as intended from the input. Sentence 3a shows that while the proper name referent is understood, there is no verb understood and hence no bindings occur.

produce them.

The patient profile based on the information in Tables 2 and 3 will necessarily omit aspects of the profile definition due to its incompleteness. To give an idea of such a profile in this limited context, one can state that comprehension ability is inconsistent across an S-V-O analysis of sentence structure. Based on the simulation, one expects some sentences to be interpreted correctly, but not all. Evidence that this occurs in agrammatic aphasics has been reported in Schwartz, Saffran, and Marin, (1980) and related affects in agrammatic production have been reported for Dutch patients, in Kolk and Van Grunsven (1985).

A more fine-grained observation is that sentences which have agents and objects that are both proper names can be correctly understood and bound in some syntactic contexts, but not all (Gigley, 1985b; 1986). Compare sentences (1a) and (1b) where the verb syntactic-form-class ambiguity differs.

The simulation also suggests that certain error types will occur within certain syntactically ambiguous contexts. For one error type, where a noun meaning for an intended verb occurs as the final interpretation, recently presented evidence has been reported for French in the performance of a French aphasic (Hannequin, Deloche, Branchereau, and Nespoulous, 1986.) Such findings have not been clinically studied for

	CORRECTLY INTERPRETED CONSTITUENTS AND BINDINGS				
	AGENT	OBJECT	VERB	CONSTITUENT	
SENTENCE					
(1b)	JOHN	*absent	SAW-VIP	TERM-PAUL	reversal?
(2b)	*absent	PAUL			
		THE SAW	SAW-VTP		
(3b)	*absent	*absent	*absent	TERM-PAUL	
(4b)	*absent	*absent	*absent	TERM-THE SAW	
(4c)	*absent	*absent	*absent	TERM-THE SAW	
(4d)	non-morpho-logical agreement	*absent	BUILDING-VIP	TERM-THE SAW	

Table 3: Summary final states of interpretation for lexically ambiguous sentences.

Lexical ambiguity affects the ability of the hypothesized patient to understand. Often, only a noun will be understood. Often, it is not a noun which was intended by the "speaker." Sentence, (4d), shows two misinterpretations, one with respect to a noun referent and the other, a misinterpretation of an intended noun as a verb. Of additional interest is the fact that these meanings are semantically related.

English to date. It is through the enumeration of these contexts and corresponding error hypotheses and the ability to manipulate and study them that HOPE contributes a new dimension in the study of natural language processing.

In addition, within this simple lesion context, one sentence, (1b), demonstrates an incomplete interpretation which includes reversal of agent binding from the order presented in the sentence. These last two aspects of performance have been noted in clinical evaluations without any supported explanation. We suggest, based on the simulation results, that timing difficulties not directly observable nor manipulable, can provide an explanation of the agrammatic patient performance problems. For several misinterpreted sentences, on analysis of the over-time trace of the simulations (not provided due to space constraints) shows the cause of the misinterpretation to be that the predict category in GRAMMAR, CN, is activated too late for the CN. (See sentences 4b,c,d.) Slowed propagation can thus lead to the non-interpretation of certain sentence elements as well as misinterpretation of the intended syntactic sense of others. These "lesion" results suggest that neurolinguists, aphasiologists and clinicians should be careful in considering syntactic lexical ambiguities which might cause non-obvious difficulties in processing. It also demonstrates the import of the selectional constraints or the set of possible answers for the task and the recorded observations.

7. HOPE's UNIQUE PLACE IN ARTIFICIAL APHASIA

This section will discuss several characteristics that give HOPE a unique place in developing a processing motivated theory of normal natural language comprehension and comprehension in aphasia: dynamic lesionability and time-driven parallelism.

7.1. Dynamic Lesionability

Dynamic lesionability refers to the ability in HOPE to manipulate the dynamics of the process without rewriting or redesigning the system. It makes lesionability a factor which is separable from stored knowledge issues. The point is that one does not need to assume that a lesion causes a loss of some sort of knowledge or rule. It is not necessary that lesions affect competence defined in the linguistic sense.

The results of the de-synchronization lesions that were induced by changing the fine-tuning of HOPE's control process parameters seem to offer a conceptual justification of the importance that neuropsychologists attach to temporal constraints in brain processing (Von Monakow, 1914; Goldstein, 1948; Lenneberg, 1967; Luria, 1970; and Ojemann, 1983.) Jackson (1965/1884) was among one of the first neurologists to point out that brain lesions do not necessarily lead to a loss of knowledge. Almost a century later Wood (1978/82) and Gigley (1982,1983) provided computer simulations of this idea, although in different clinical contexts. Recently, within adaptation theory the importance of temporal constraints has been discussed by Kolk and van Grunsven (1985).

7.2. Time-driven Parallelism

A number of arguments have been put forward that emphasize the need and existence of parallel processing in intelligent systems (see for instance: Fahlman, 1982; Feldman and Ballard, 1982; Marslen-Wilson and Tyler, 1980; McClelland and Rumelhart, 1981; Scholes, 1978; Waltz and Pollack, 1985). But after choosing parallel processing one still needs to decide how to conceptualize it. The inclusion of lesionability directly affects the conceptualization of HOPE's parallelism.

HOPE's conceptualization of parallelism is depicted in Figure 3. The Figure shows a simplified abstraction from HOPE's real architecture, which was defined earlier. Spaces can be thought of as perspectives that provide a context for the interpretation of the knowledge they contain. They do not imply a rigid hierarchy of processing levels, but represent different viewpoints on representations activated over time.

We have previously discussed the lock-step parallel application of the basic computations of the HOPE architecture which "cut" through spaces. (See Figure 3). Simultaneously, HOPE's time-driven parallelism includes a third dimension.

One can study the events which occur within a space over time for all spaces simultaneously. The events which occur within a space over time take the appearance of separate independent processes within one type of knowledge.

Contrary to some other parallel approaches to natural language processing (Cottrell, 1983; 1985; McClelland and Kawamoto, 1986; Scholes, 1978; Waltz and Pollack, 1985), HOPE does not implement the processes within an individual space over time as separate independent processes. HOPE assumes no level specific processes. Instead, the processes are unit specific and homogeneous across all levels of representation. Level specific processes are not directly programmed but depend on the time-coordination of the results of all processes applied over the entire graph of information, and can be observed within one space representation over time.

This section has described dynamic lesionability and its role in processing models of natural language comprehension. It has also illustrated the HOPE conceptualization of parallelism. It shows that there may be many levels of parallelism in parallel processing models of cognition and that some apparent parallel effects may be the result of computations which are non-specific to those effects.

8. CONCLUSION

By virtue of its neural-like parallel architecture, which employs internal synchronization and time-driven parallelism, HOPE provides a tool to systematically study the effects of various de-synchronization problems on processing over time. De-synchronization problems occur as a consequence of a disturbance of the time-coordinating role of HOPE's grammar. By changing the values of the process parameters several lesions can be defined although only one is discussed in detail here. Lesions that imply the violation of temporal constraints in language processing appear to affect sentences differently depending on whether the sentences contain syntactic lexical ambiguities or not and to what degree the ambiguities exist.

The problem of comprehension may be characterized in terms of Karl Lashley's problem of serial order of behavior (1967): From a serially encoded input that is coming in on-line, a simultaneous meaning representation has to be constructed. Using HOPE, as a model of how this "construction" may be viewed, this paper demonstrates the vital role that synchronization plays in such a process. Furthermore, it demonstrates that synchronization problems, especially problems with temporal constraints, can affect this construction and thus be a cause of comprehension performance problems of aphasics.

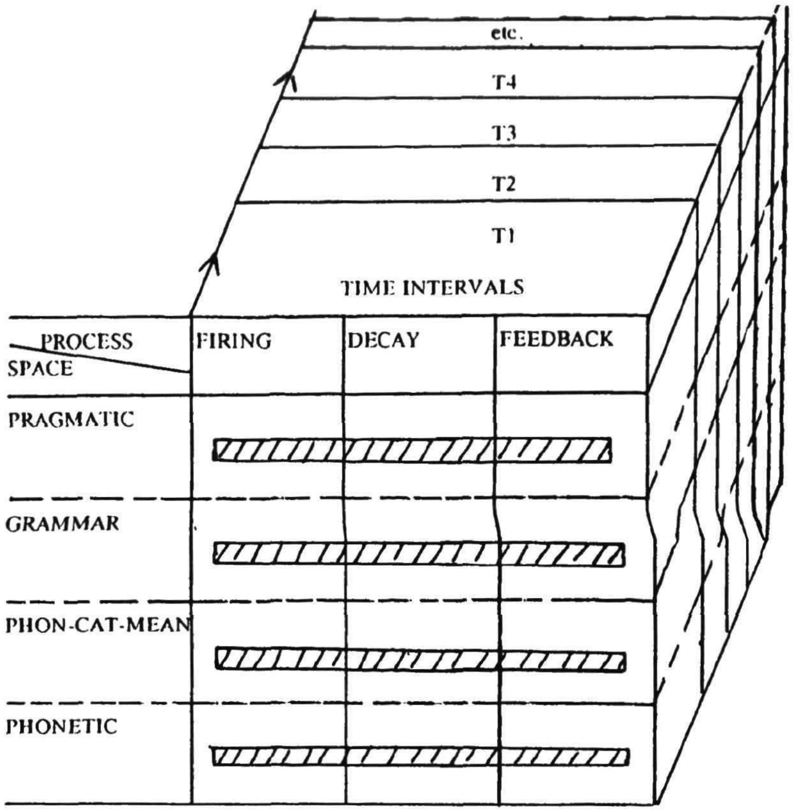

Figure 3: Overview of parallelism in HOPE.

To each unit in each space, each process is applied at the same time. Not all control processes of HOPE are shown: feedforward, inhibition, excitation, meaning spread, and change-of-state are not depicted.

Note: = process boundary.
----- = space boundary.
▨ = one unit.

9. REFERENCES

Ajdukiewicz, D. Die syntactische konnexitat, 1935. Translated as "Syntactic Connection" in **Polish Logic**, S. McCall, Oxford, 1967, 207-231.

Baron, R.J. Brain architecture and mechanisms that underlie language: an information processing analysis. In S. Harnad, H. Skelis, and J. Lancaster (Eds.), **Origin and evolution of language and speech**. The New York Academy of Sciences, 1975, 280, 240-256.

Berge, C. **Graphes et Hypergraphes**. Paris: DUNOD, 1970.

Blumstein, S.: Katz, B.: Goodglass, H.: Shrier, R. and Dworetsky, B. The Effects of Slowed Speech on Auditory Comprehension in Aphasia. **Brain and Language**, 24, 1985, pp.246-265.

Brookshire, R. Effects of trial time and inter-trial interval on naming by aphasic subjects. **Journal of Communication Disorders**, 1971, 3, 289-301.

Caplan, D. Syntactic and Semantic Structures in Agrammatism, in Kean, M.L. (Ed.) **Agrammatism**. Academic Press, 1985.

Collins, A.M., and Loftus, E.A. A spreading activation theory of semantic processing. **Psychological Review**, 1975, 82(6), 407-428.

Cottrell, G. W. **A Connectionist Approach to Word Sense Disambiguation.** Unpublished Ph.D. Dissertation, Department of Computer Science, University of Rochester, 1985.

Fahlman, S.E. Three flavors of parallelism. **Proceedings of the 4th National Conference of the Canadian Society of Computer Studies of Intelligence**, 1982.

Feldman, J.A., and Ballard, D.H. Connectionist models and their properties. **Cognitive Science**, 1982, 6, 205-254.

Gigley, H.M. **Neurolinguistically Constrained Simulation of Sentence Comprehension: Integrating Artificial Intelligence and Brain Theory.** Unpublished Ph.D. Dissertation, University of Massachusetts, Amherst, 1982.

Gigley, H.M. HOPE--AI and the dynamic process of language behavior. **Cognition and Brain Theory**, 1983, 6(1), 39-88

Gigley, H.M. Grammar viewed as a functioning part of a cognitive system. **Proceedings of the 23rd Annual Meeting of the ACL**, Chicago, July, 1985a.

Gigley, H.M. Computational Neurolinguistics -- What is it all about? **IJCAI-85 Proceedings**, Los Angeles, August, 1985b.

Gigley, H.M. Studies in Artificial Aphasia -- Experiments in Processing change. Baltimore, November, 1985c. **Proceedings, Ninth Annual Symposium on Computer Applications in Medical Care: Selected from conference to appear in IEEE Journal of Computer Methods and Programs in Biomedicine, 1986.**

Gigley, H. M. Lexical Ambiguity Resolution in Aphasia, Tech. Rep. 86-37, Department of Computer Science, University of New Hampshire, Durham, NH 03824; Draft of chapter for Cottrell, G.W., Small, S.L., and Tanenhaus, M.K. (Eds.) **Lexical Ambiguity Resolution in the Comprehension of Human Language**, to appear

Gigley, H.M. and Boulicaut, J.-F. Grasper: A Grpah Processing Tool for Knowledge Engineering in Cognitive Modelling, **Proceedings COGNITIVA 85**, Paris, 1985.

Gigley, H.M., and Lavorel, P.M. Computational Neurolinguistic Modelling Integrating "Natural Computation" Control with Performance Defined Presentations. CS-85(c)-26, Technical Report University of New Hampshire, Durham, NH

Goldstein, K. **Language and Language Disturbances.** New York, Grune and Stratton, 1948.

Haarmann, H. J. **A computer simulation of syntactic understanding in normals and aphasics: slowed activity propagation.** MS Thesis, Cognitive Science, Psychological Laboratory, University of Nijmegen, The Netherlands, 1987.

Hannequin, D.; Deloche, G.; Branchereau, L. and Nespoulous, J.-L. Noun-Verb Disambiguation in French and Sentence Comprehension in Broca's Aphasics, Paper presented at the Academy of Aphasia, Nashville,Tennessee, 1986.

Hinton, G.E. Implementing semantic nets in parallel hardware. In G.E. Hinton and J.A. Anderson (eds.), **Parallel models of Associative Memory.** Lawrence Erlbaum Associates Publishers, 1981

Hinton, G.E.; McClelland, J. L.; and Rumelhart, D. E. Distributed Representations, in J.L. McClelland and D. E. Rumelhart (eds.) **Parallel Distributed Processing**, MIT Press, 1986.

Jackson, J.H. The Croonian Lectures on the Evolution and Dissolution of the Nervous System. Reprinted in: R.J. Herrnstein and E.G. Boring (Eds.). **A Source Book in the History of Psychology**, Cambridge: Harvard University Press, 1965/1884.

Kean, M.L. (Ed.) **Agrammatism.** Academic Press, 1985.

Kolk, H.H.J., Van Grunsven, M.J.F. Agrammatism as a variable phenomenon. **Cognitive Neuropsychology**, 1985, 2(4), 347-384

Kolk, H.H.J., Van Grunsven, M.J.F., and Keyser, A. On parallelism between production and comprehension in agrammatism. In M.L. Kean (Ed.), **Agrammatism.** New York Academic Press, 1985.

Lashley, K.S. 1967. The problem of serial order of behavior. In L. Jeffress (Ed.), **Cerebral Mechanisms of Behavior.** Hafner Publishing Company, 1967, pp 112-146.

Laskey, E.Z., Weidner, W.E., and Johnson, J.P., Influence of linguistic complexity, rate of presentation, and interphrase pause time on auditory verbal comprehension of adult aphasic patients, **Brain and Language**, 3, 1976, pp. 386-396.

Lavorel, P.M. Production Strategies: A systems approach to Wernicke's aphasia. In M.A. Arbib, D. Caplan, and J. Marshall (Eds.), **Neural Models of Language Processes.** Academic Press, 1982.

Lenneberg, E.H. **Biological foundations of language.** New York: Wiley and Sons, 1967.

Lewis, D. General semantics. In Davidson and Harmon (eds.), **Semantics of Natural Language**, 1972, 169-218.

Liles, B.Z., and Brookshire, R.H., The effects of pause time on auditory comprehension of aphasic subjects, **Journal of Communication Disorders**, 8, 1975, pp. 221-235.

Luria, A.R. **Traumatic Aphasia.** The Hague: Mouton, 1970.

Marcus, M.P. Consequences of functional deficits in a parsing model: Implications for Broca's aphasia. In M.A. Arbib, D. Caplan, and J.C. Marshall (Eds.), **Neural Models of Language Processes.** Academic Press, 1982.

Marslen-Wilson, W., and Tyler, L. The temporal structure of spoken language understanding, **Cognition**, 8, 1980, pp. 1-71.

McClelland, J. L. and Kawamoto, A. H. Parallel Mechanisms of Sentence Processing: Assigning Roles to Constituents of Sentences; in J.L. McClelland and D. E. Rumelhart (eds.) **Parallel Distributed Processing**, MIT Press, 1986.

McClelland, J.L. and Rumelhart, D.E. An interactive activation model for context effects in letter perception: Part 1. An account of basic findings. **Psychological Review**, 1981, 88, 5, 375-407

McClelland, J.L. and Rumelhart, D. E. A General Framework for Parallel Distributed Processing, in J.L. McClelland and D. E. Rumelhart (eds.) **Parallel Distributed Processing.** MIT Press, 1986.

Ojemann, G.A. Brain organisation for language from the perspective of electrical stimulation mapping. **The Behavioral and Brain Sciences**, 1983, 4, 189-230.

Quillian, M.R. Semantic memory. In M. Minsky (Ed.), **Semantic Information Processing.** Cambridge, Ma: MIT Press, 1980.

Schwartz, M.F., Saffran, E., and Marin, O.S.M. The word order problem in agrammatism. I. Production. **Brain and Language**, 10, 1980

Seidenberg, M., Tanenhaus, M., Leiman, J., and Bienkowksi, M. Automatic access of the meanings of ambiguous words in context: Some limitations of knowledge based processing. **Cognitive Psychology**, 1982.

Scholes, R. Syntactic and lexical components of sentence comprehension, **The Aquisition and Breakdown of Language**, Johns Hopkins Press, Baltimore, 1978, pp. 163-194.

Smolensky, P. Neural and Conceptual Interpretation of PDP Models, in J.L. McClelland and D. E. Rumelhart (eds.) **Parallel Distributed Processing.** MIT Press, 1986.

Swinney, D.A. Lexical Access during Sentence Comprehension: (Re)Consideration of Context Effects. **Journal of Verbal Learning and Verbal Behavior**, 1979, 18, 645-660.

Von Monakow, C. **Die Lokalisation im Grosshirn.** Wiesbaden: Bergmann, 1914

Waltz, D. and Pollack, J. Massively parallel parsing: A strongly interactive model of natural language interpretation. **Cognitive Science**, 1985, 9, 1, 54-75.

Webster's New Collegiate Dictionary, G. & C. Merriam Co. 1981.

Wood, C.C., Implications of simulated lesion experiments for the interpretation of lesion in real nervous systems. In M.A. Arbib, D. Caplan and J. Marshall (Eds.) **Neural Models of Language Processes**, Academic Press, 1982.