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RESEARCH BULLETIN

ABSTRACT IDEAS: THE RELATION OF LINGUISTIC TIME AND PSYCHOLOGICAL TIME

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Abstract Ideas: The Relation of Linguistic Time and Psychological Time

Abstract

In the first section a sketch of a tense logic is presented and a mechanism is suggested for including aspects of the tense logic into the Grammar (theory of language). Specifically, several grammatical structures are shown to incorporate temporal features. A semantic projection mechanism is utilized to amalgamate the temporal features in elements of the Auxiliary, Conjunctions, Adverbials and, in addition, the inherent temporal features of Nouns and Verbs to yield an overall reading of temporal specification.

The second section examines the psychological validity of a tense logic model. Two alternative hypotheses are considered to account for the encoding of structures of temporal specification. The first is a derivational theory of complexity of the sort proposed in recent psycholinguistics. The other is a theory based on the structure of the tense logic model. The results of the recall and recognition experiments appear to support the tense logic hypothesis that the subjects encode sentences (and perhaps discourses) into an Event Space in which the temporal information concerning both explicit and implicit predicates (events) is represented. The Event Space appears to be subject to Tense Shift laws. It would appear that subjects are sensitive to the temporal information in conjunctions as well as the information expressed by the elements of the verbal auxiliary. This supports the hypothesis that the overall temporal specification is derived by the amalgamation (projection) of temporal features or properties of various linguistic structures, and, furthermore, that the encoded representation can be conceived of as a complex Event Space in which the temporal relations among all the events in an utterance or discourse are specified.

Abstract Ideas: The Relation of Linguistic Time and Psychological Time[1]

Richard Hurtig

Educational Testing Service

Introduction

One of the critical functions of utterances in any natural language is to express propositions about objects and events. In each utterance the objects, and states and events involving those objects, are placed in some form of temporal relationship. Thus, the predicate (verb) and its arguments (nouns and complement structures) are all assigned locations on a temporal scale. It is the relationship of these locations on the time scale which constitutes the temporal specification of an utterance. The goal of the present study is to develop a tense logic which can account for temporal specification, and also to test the psychological validity of such a formal model of temporal specification.

A tense logic is a formal characterization of the temporal features of a predicate or a proposition and thus is a representation of temporal specification. It serves to place the event (action or state) in temporal perspective relative to the time of the utterance. Since natural language permits the description of events which need not be contemporaneous with the utterance, it must have a means of keeping distinct the moments of time. However, these moments in time are mapped in terms of the relative order of events, rather than in terms of absolute clock time. Various linguistic constituents serve to mark temporal relations: while Tense and Aspect (perfect/progressive) have traditionally been considered the major vehicles of temporal specification,

constituents like conjunctions and adverbials also specify temporal relations among events. A tense logic provides a single unified model to account for the temporal relations expressed by the various linguistic constituents.

The present study attempts to validate two parallel hypotheses which derive from a tense logic. The first is that the relations among the events in a sentence or discourse (event space) which the tense logic expresses constitute a sufficient semantic representation of temporal specification. The second is that the encoding of sentences and short discourses, as measured by recall and recognition tasks, is affected by the form of the event space posited by the tense logic.

Tense Logic and Linguistic Theory

As in so many other aspects of grammar Jespersen had some keen insights into the nature of temporal specification. Originally, in "Tid og Tempus" in Oversigt over det danske videnskabernes selskabs forhandlinger (1914, pp. 367-420) and more completely and readily available in his two chapters on time and tense (19 and 20) in The Philosophy of Grammar, Jespersen (1924) presents a comprehensive analysis of many of the problems of temporal specification. Reichenbach (1947), building Jespersen's (1924) discussion of tenses, proposed the description of tenses in terms of a tense logic. He defined temporal specification as the relationship of events or states in time. The temporal specification of an utterance should express the relative location of the time of the event (E), the time of speech (S), and points of temporal reference (R). The time of event (E) denotes the abstract location on a time scale of the event or state denoted in the predicate. The time of speech (S) is the point on the time scale which is co-occurrent with the absolute present,

that is, the time that the sentence (token) is uttered. As time passes so does the point of speech. The introduction of points of reference (R) enables the specification of implicit events or states denoted by the predicate or the syntactic construction that it is in. We can extend Reichenbach's definition of these reference points and consider them to bound or delimit the temporal range of the event explicitly denoted by the predicate. For example, in the case of the perfect tenses the presence of the verbal auxiliary (have -en) indicates that the predicate is terminated (E occurs prior to the time R) that termination is a token of a time of reference. Events introduced in subordinate or complement clauses also serve as reference points. Thus, the general temporal relations can be seen as the expression of the relations between the point of speech and the point of event, the point of reference and the point of event, and the point of speech and the point of reference. The nature of the event itself outside of its relation to the point of speech and the point(s) of reference can be described in terms of a set of binary features or properties (i.e., ± progressive, ± inchoative, etc.). These features designate the event as having certain characteristics of continuity, duration, habitualness, etc.

The paradigm of configurations of the points related in temporal relations which Reichenbach (1947, p. 297) outlined can be extended so that affixal tense constructions and periphrastic construction in English can be accounted for by the same form of description. Each Temporal Relation should be considered to be a specification of the time of event (E) relative to the time of speech (S) and the time(s) of reference (R). Thus, in some cases (R) and (E) are simultaneous, that is, (E) is not delineated by anything but itself. (R) is explicitly included in all temporal relations in order to be able to deal

with temporal change (see discussion of tense laws below). (R) is not an event(s) but rather a temporal reference point(s). However, events can occur at reference points. What is perhaps most important is that there appears to be no distinction between the tense-logic configurations which are expressed by morphological means and those which are expressed periphrastically: In English only the cases of multiple reference and antecedent[2] reference require periphrastic constructions. This lack of distinction of the types of configurations on the basis of some regular difference in the surface structure realizations actually corresponds to our intuitions of temporal specification. Namely, the interpretation of an utterance's temporal specification is no different for a morphological construction than for a periphrastic construction; the semantic readings can be identical. In English tense is expressed morphologically while aspect and mood (subjunctive use of modals) require periphrastic constructions. Greek and Slavic languages, on the other hand, express aspect and mood morphologically.

The elements of the tense logic also can mark the relationship between predicates. Sentences containing more than one verb (+V-Aux) express some form of temporal relation between the two or more verbs. These relations are expressed by conjunctions; languages have developed means of expressing these conjunctions in various ways. The tense logic can specify the temporal identity relations among two (or more) predicate temporal relations. That is, the logic will mark the temporal order among tensed predicates. For example, 1, 2, and 3 express some form of temporal relation between the first and the second clause.

(1) John left as Mary entered.

(2) John left before Mary entered.

(3) John left after Mary entered.

The conjunction relations are expressed in the tense logic in the following manner:[3]

(4) $E_1 \equiv E_2$ ("≡" simultaneous with)

(5) $E_1 < E_2$ ("<" before)

(6) $E_1 > E_2$ (">" after)

This logic of conjunction is far too strong a mechanism, however, since it will allow any two tensed predicates (temporal relations) to be related by any of the conjunction relations (i.e., *Harry will dance before he had come). Even a restricted formulation of the conjunction relations which specified only simultaneities of points in time (as in 7-9) would similarly generate many strings not found in some natural languages in that it does not take into consideration the temporal relations of the events (E), vis-à-vis the time of speech (S) which alter the tense of each (E).

(7) $E_1 \equiv E_2$

(8) $R_1 \equiv E_2$

(9) $R_1 \equiv R_2$

In English there are selectional restrictions which in a given conjunction relation allow only specific time point configurations in either clause. Hence for (10),

(10) x before y ($E_1 < E_2$)

the type of tense configuration in which E_1 and E_2 can occur in is restricted.

(11) John hit Mary before he left town.

(12) *? John had hit Mary before he will leave town.

(13) * John hits Mary before he had left town.

One could argue that a conjunction demands certain features to be present in the temporal structure of the two clauses before it can be selected (a process similar to verb selection in terms of subjects and objects). The conjunction relations can be specified not only in terms of event relations, but also in terms of the specific temporal relation in each of the two clauses.

Each temporal relation can be expressed in the following format, for convenience

(14) [SE, SR, RE]

which represents the relationships among the points in the configuration. Such point relationships can be marked to express the temporal order of the points.

(15) <SE or +SE S before E

(16) ≡SE or ±SE S simultaneous with E

(17) >SE or -SE S after E.

A given triad of these relational markings would then express a given configuration in the tense logic. For example,

(18) John had hit Mary = [-SE, -SR, -RE], [E-R-S]

Insert Figure 1 about here

Intuitions about conjoined clauses are not in terms of the tenses in each clause but rather in terms of some conjunct of the two. An interpretation of the tense of one clause or the other is in a sense only a component of the complex temporal relation of the entire sentence. Thus sentence (19) can be seen as having (20) as the complex underlying temporal relation.

(19) Sam had hit Mary before John kissed Sue.

(20) E_1 ——— $\begin{matrix} E_2 \\ R_2 \\ R_1 \end{matrix}$ ——— S

From this complex temporal relation it is easy to derive the constituent temporal relations as well as the temporal feature of the conjunction. The temporal relation of the first clause would be

(21) E_1 ——— R_1 ——— S = [-SE, -SR, -RE]

that of the second clause would be

(22) $\begin{matrix} E_2 \\ R_2 \end{matrix}$ ——— S = [-SE, -SR, ±RE]

and the conjunction would be represented as marking the temporal order represented as

(23) E_1 ——— E_2 = [E_1 < E_2]

(see Figure 2 for tense logic of complex sentences).

Insert Figure 2 about here

Adverbs, prepositional phrases of time or duration and even noun phrases can also be marked in terms of temporal features. Thus NPs like Shakespeare and Adverbials like yesterday would be assigned the feature

(24) E ——— S = [-SE]

and as such would violate the selectional restrictions associated with sentences containing a future temporal relation, where the selection of the verb demanded

contemporaneity of the predicate spent and one of its arguments (subject or object).

There is no doubt that any semantic theory will have to take into account some form of tense logic in order to fully specify the semantics of tense, aspect and other structures of temporal specification. The real question boils down to whether or not the logical propositions of this formalism (that is, the event relations) are in and of themselves a sufficient statement of the semantic structure of temporal specification or whether inherent features of the events themselves must also be considered.

Up to this point we have referred to specific temporal features of predicates within the general scope of traditional linguistics. More specific tense logics provide us with a range of temporal operators which enable us to characterize in an explicit form the semantic features of temporal specification which we associate with specific verbs. The traditional linguistic analysis of verbs incorporated binary features into the lexical representations; such features would mark temporal features inherent in verbs (e.g., $\pm$ continuous, $\pm$ inchoative). A logic with tense operators and propositional quantification makes explicit the content of the semantic features. For our purposes, it is of some value to present a general characterization of such a logic in order to suggest the manner in which the inherent temporal features in verbs can be incorporated into the amalgamated reading of temporal specification. The function of the simple tense operators (F,P,G,H) can be related to the time point relations of our simple expansion of the Reichenbachian tense logic: Fp "it will be that p" (S-E) and Pp "it has been that p" (E-S). The G and the H operators correspond to continuous states in the future and past respectively: Gp "henceforth always p" and Hp "heretofore always

p." Combinations of operators correspond to the tense-aspect configurations: FPp "it will have been that p" (S-E-R).

The quantification of tensed statements yields the general underlying form of inherent temporal features of verbs. For example, the feature ± habitual/repetitive can be captured by the following propositional quantification:

(25) $PF(\forall p)(p \supset Fp)$ "at some point in time it occurs that everything that is then the case will be realized at some future time."

A verb like "die," a predicate that denotes a state transition, will have that temporal feature represented by a proposition marking the end of time for a given proposition:

(26) $(\forall p)FGp$ "There is a future time (of p) after
$[\exists t][t > n.\sim(\exists t')(t' > t)]$ which there is no time (of p) at all."

Similarly, noun and noun phrases can be seen as having inherent temporal features. Thus, the phrase "dead man" would, like the verb "die," include the end of time feature expressed above.

In that the features of verbs and noun phrases can be characterized in terms of the propositional quantification in tensed statements, and that the tensed statements are characterizable in terms of our expanded Reichenbachian tense logic, the process of semantic projection which incorporates features of the Auxiliary as well as the inherent features of verbs and noun phrases can be represented as a single simple amalgamation process which relates points in time.

Prior (1957, 1967, 1968) has contributed much to our general understanding of tense-logic and modal-logic by presenting a clear discussion of much of

the intricate work recently done in logic. Linguists have for the most part not become deeply concerned with the details of the logic; they have attempted to synthesize some of the major claims and fit them to their current formalisms of linguistic description. The discussion in Prior which appears to be most appropriate to the current work in linguistics lies in what he terms the precursors of tense logic (1967, chap. 1). The notions of time, discussed in that chapter, underlie any tense logic and are the core of any understanding of tense and other related linguistic forms of temporal specification.

The major principle running through all work on tense logic or temporal specification in natural languages comes from McTaggart's paper on the "Unreality of Time" (1908). He proposes two types of classifications of positions of events in time: the A-Series (past, present and future) and the B-Series (earlier-later). All points in time, hence events in time, can be specified in terms of either the A or B series. Some arguments have been raised as to which series presupposes the other. If events change, then they must change in terms of the A series. The B series is not a specification of change as the relation of events remains constant. For example, the creation of Eve was, is, and will always be later than the creation of Adam. On the other hand, at some point the creation of Eve was future, then present, and finally past. The B series specifies a fixed relationship in time between events while the A series specifies changes in events in terms of a time of assertion (judgment).

A whole debate on the reality of the two time series and their interrelation ensued subsequent to McTaggart's work, with the postulation of tense-logical laws by Findlay (1941) as a part of the outcome. These laws were [illegible] to be included in modal logics. The central point of the Findlay tense

law (27) is that all events,[5] past, present, and future, will eventually become past. While not all "future" events will necessarily become past, all real events must become past.

(27) ((X present) or (X past) or (X future)) → (X past) Future

Reichenbach's proposal attempted to handle the problem of tense by examining the relationships of points in time. Reichenbach succeeded in providing the basis of an adequate description of syntactic tense, however, Reichenbach provided no mechanism to deal with temporal change. For Reichenbach, present was defined as coincidence with the time of the utterance (sentence). The introduction of the tense laws required the positing of future presentness and a past presentness in order to state the relation between McTaggart's two-time series (A + B). Curiously, one can find such deferred present tenses in periphrastic constructions in natural languages. Though Reichenbach never suggested it, there is no reason that the point of speech could not stand in another time point relation with a deferred present time.

(28) I will say (tomorrow) that John came.
(E_1) (E_2)

(29) S - E_2 - E_1

In (28 and 29), E_1 serves as the present (point of speech) with which E_2 is in a past relation.

(30) I said that John will come.
(E_1) (E_2)

(31) E_1 - E_2 - S

In the same manner in (30 and 31), E_1 serves as the present point with which E_2 is in a future relation.

These forms of "deferred presentness" appear to occur primarily with performative verbs like say, declare, etc. and appear to be less acceptable with other verbs like believe, think, etc.

The expanded form of tense logic presented above is a very rudimentary one. Several more detailed logics have been recently proposed and currently utilized by logicians working on the problems of temporal specification (see Rescher & Urquart, 1971, for a review). For the purposes of the general syntactic discussions which follow and the presentation of the psychological data this simplistic tense logic is sufficient.

Given that an adequate description of temporal specification can be achieved with the tense logic described above, it remains for us to suggest how such a description is integrated into the larger linguistic description.

Tense in logical formulations has been seen as an argument in a proposition.

f (x,y,t) = x loves y at time T

The t argument specifies the time space relation of the entire proposition. Such a formulation would have its drawbacks in a linguistic description. Note that the questions which are related to sentences like those below have different entailments.

(32) John hit Mary.

(33) John has hit Mary.

(34) Who hit Mary?

(35) Who has hit Mary?

(34) entails one person hit Mary, which can be questioned: who is he? On the other hand one reading of (35) entails that people hit Mary, which can be questioned: who are they? The correct answer to (34) could be sentence (32)

while (35) really calls for an enumeration of events. So (36) could be the correct answer to (35) but not to (34)

(36) John and Max hit Mary.

if (36) is read as two distinct events. (33) cannot be the answer to (35) unless it is read as a statement of repetitive action on John's part.

Such evidence strongly argues against the designation of temporal specification as a logical modality. Symbolic logic expresses modalities with the following formalism:

(37) T [f(x,y)] = at time T, x loves y

In this manner the fact that the entailment of the predicate and its subject and object are independent of time is properly represented. Such an analysis argues for a mechanism of semantic projection which amalgamates the temporal features from all constituents to the full reading of temporal specification assigned to #S# (sentence).

In English, the structure of syntactic tense and the mechanism of projecting its feature specification to higher nodes in the underlying syntactic phrase market (VP, S) are crucial to any theory which attempts to account for the apparent temporal constraints on nodes (ADV, Prep Phrase) which function to modify higher nodes. In Standard Transformational-Generative Theory (Chomsky, 1965), syntactic tense is introduced by the rule which expands the AUX (Auxiliary) node.

(38) AUX → Tense (Modal) (Perf. Aspect) (Progressive Aspect)

This rule accounts for the distribution of auxiliary verb elements simply and adequately. For our purposes this rule is sufficient to state adverbial restrictions given the use of subcategorization and projection principles.

In many ways the Aux rule really belongs to the morphological component as its primary function is the realization and ordering of auxiliary verb particles. In the Standard Transformational Theory each of the elements, excluding modals, is binary: Tense can be either past or non-past (± Past); Perfect aspect is either (± Perfect); Progressive aspect is (± Progressive). Applying the notion of subcategorization to the minor class constituent AUX, the features may be represented as follows:

(39) AUX → ±AUX ± Past

(40) +Past → ± Perfect

(41) -Past → ± Perfect

(42) ±Perfect → ± Progressive

(43) -Perfect → ± Progressive

Each realization of the Auxiliary verb has a set of features assigned to it. Just like the subcategorization rules for verbs and nouns, the above rules are nonhierarchical; they are cross-classifying. The reading (feature set) of the auxiliary verb is projected up to the VP node yielding a temporal reading for the VP. The basic effect of the projection is characterized by the following rule.[6]

(44) [+Aux αPast αPerfect αProgressive] [+VP] ⟶

[+Aux αPast αPerfect αProgressive] [+VP αPast αPerfect αProgressive]

A similar rule projects the temporal reading up to the S node.

(45) [+S] [+VP αPast αPerfect αProgressive] ⟶ [+S αPast αPerfect αProgressive] [+VP αPast αPerfect αProgressive]

The adverbial node also undergoes subcategorization. The rules would be of the following form:

(46) Adverb $\longrightarrow$ [+Adv $\pm$ Temporal]

(47) [+Temporal] $\longrightarrow$ [$\pm$ Past]

Selection of adverbials will in part be dependent on the tense marker of the verb phrase dominating the Adverb node. In the environment of an α tense VP only the α tense adverbs can be selected.

(48) [+adv] / $\_$ (VP αtense) $\_$ $\longrightarrow$ [+adv α tense]

The lexicon might contain entries of the following form

(49) Yesterday: [+Adv, +Temporal, [+Past]]

(50) Tomorrow: [+Adv, +Temporal, + [-Past]]

A sentence like

(51) *John will run yesterday.

could be marked unacceptable on the grounds that it violated the selectional restrictions on adverbs (48). On the other hand, the grammar does not need a selectional rule of the sort mentioned above since the deviance of sentence (51) can be accounted for by a projection rule (44). Since the temporal feature assigned to the VP is [-past], and since the adverb yesterday has a temporal feature assigned to it in the lexicon,

(52) Yesterday: [+Adv, + Temporal, + past]

the semantic rule which projects the temporal features[7] of the Verb and the Adverb to the S node would have to yield an interpretation which would be marked as contradictory (in terms of temporal specification). Figure 3 illustrates how such an interpretation would be derived. Similarly the temporal features assigned to an embedded clause would be projected by a semantic rule to the dominating predicate node and subsequently to the S node. Figure 4 illustrates this projection process with the resulting interpretation marked as contradictory, while Figure 5 illustrates how a complex temporal relation is derived by the projection mechanism.

Insert Figures 3-5 about here

Thus, with a notion of inherent temporal features expressible in a tense logic for the auxiliary, verbs, adverbs, conjunctions, and noun phrases and a mechanism of semantic projection, it is possible to account for the temporal specification of an utterance. The complex event relationship assigned to an utterance (or in fact to sequences of utterances) can be viewed as its event space.

Tense Logic and the Encoding of Linguistically Specified Events

If linguistic theory is to be an investigation into the structure of the mind (Chomsky, 1968), then the descriptive levels proposed in the linguistic theory must be shown to have psychological validity. Psycholinguistic research in the 1960's attempted to "prove" the psychological reality of the specific rules posited by the linguists (e.g., Coding Hypothesis, Derivational Theory of Complexity). Equivocal empirical findings have led psycholinguists to alter their goals from proving the reality of specific rules to the validation of the structural levels posited by such rules. In this context it is of interest to examine whether the formalism of tense logic posited as the semantic representation of temporal specification has psychological validity. That is, do subjects encode the temporal information of sentences in terms of a tense logic (a logical Event Space which specifies temporal relations among predicates and utterances), or can their behavior best be characterized in terms of the linguistic (morpho-syntactic) rules which generate the constituents which contain temporal features (a derivational theory of complexity: each linguistic rule is a psychological operation)?

The hypothesis which I am proposing assumes that the underlying psychological representation of temporal information corresponds to the tense logic model proposed above. That is, subjects' encoded representation of the temporal relations among predicates (events) specified in sentences corresponds to the tense logic configurations of the sort presented in Figure 2. Furthermore, that representation is built up by a mechanism, similar to the semantic projection rules described above, which incorporated the temporal features of the individual predicates (events) and their respective temporal modifiers (adverbials). In addition, the hypothesis claims that the encoded Event Space is subject to the effects of the Findlay Tense law. For example, an event which is encoded as a present (e.g., contemporaneous with the time of speech) will with the passage of time be recalled as a past event vis-à-vis a new time of speech. $(S_{to} \xrightarrow{E_{to}} E_{to} - S_{to+1})$. Thus the encoded representation (thought) can be seen as derived from the inherent temporal features of the linguistic structures and the recall of linguistic structure is affected by the logical operations on the abstract representation.

Such a hypothesis contrasts with a Derivational Theory of complexity account which assumes that subjects' encoded representations will be determined by the linguistic complexity of the utterance in terms of the number of features or rules involved in its derivation.

The following is a presentation of some empirical work designed to examine the "psychological reality" of temporal specification in terms of the two hypotheses stated above.

One function of the reading of the temporal specification of a verb phrase (event or state description) is to place the event or state description in some form of temporal perspective vis-à-vis other events or states. Various

linguistic constituents enable us to mark how contemporaneous two events are in time. Temporal adverbials can be used as explicit markers of duration and sequence of events. Conjunctions may also serve as explicit markers of sequence. Tense and aspect can, however, also mark duration and sequence. These markings are more implicit in the sequence restrictions of the language (e.g., implicit information in sequence of tense restrictions).

In order to determine the effect of such implicit markers on contemporaneity judgments, Hurtig (1974; EXP 1) asked subjects to make contemporaneity judgments for two event sentences (two and-conjoined clauses) in which perfect and progressive aspect as well as the durative nature of the verb were manipulated.

Traditionally, the presence of the progressive marker has been associated with a temporal extension of the event or state; the perfective marker, on the other hand, is associated with a temporal curtailment of the event or state. Therefore, one would expect that sentences with a progressive should be interpreted (temporal specification) as having their two events more contemporaneous than sentences unmarked for aspect. By the definition of the temporal zones (past, present and future) events in the past and the future need not be contemporaneous while those in the present must be. Durative verbs should be more contemporaneous than non-durative verbs since the former by definition occupy some temporal space. A simple combinatorial projection mechanism operating with the interpretations of the individual features listed above would yield readings of greatest contemporaneity for durative present progressives and of least contemporaneity for non-durative past or future perfectives.

The empirical results indicate that the semantic projection mechanism involved in the determination of contemporaneity is not a simple combinatorial projection rule, since only one feature (perfect aspect) appeared to affect

the subjects' contemporaneity judgments. This finding indicates that sequence information (and thereby contemporaneity judgments) is based on the presence of the perfective marker. The perfective serves not only as the marker of event termination but also as an implicit marker of an event (reference) which intervenes in time between the event specified by the verb and the time of the utterance (absolute present moment). This interpretation is in accord with the schema of temporal specification as set forth by Jespersen and Reichenbach in their discussion of tense logic. Events marked as perfective are therefore judged to be less contemporaneous with unmarked events because the perfective marker is interpreted as an intervening event, thereby establishing implicitly an interval between the explicit events in the sentence. The fact that our intuitions about contemporaneity can be seen as a reflex of a syntactic marker for temporal event sequence (in that the perfective implies a sequence of predicate event (E) and an unspecified referent time point (R)) would appear to support the view that a Tense Logic captures the relevant features involved in assigning a temporal specification to utterances; that is, the durative feature of the progressive aspect and of the durative verbs is not relevant to the specification of event order.

A pilot study (Hurtig, 1974) revealed that subjects make tense shift errors even in a fairly short term recall situation. The free recall data indicate that subjects actively shift tenses on the basis of a tense logic metric. The recognition recall data seem to support the notion that the subjects encode sentences, more specifically the events specified by the predicates, in terms of the logical order of events rather than the surface tense-aspect forms.

Assuming that subjects establish an Event Space when sentences are encoded and that points (temporal) in that Event Space are subject to Findlay's law, then it should be the case that recall errors (in sentence memory experiments) which involve the verbal auxiliary should be predictable in terms of logical tense shift.

Such a hypothesis predicts that errors in recall should gravitate in the direction of the linguistic forms which mark events as temporally distinct events receding into the more distant past. That is, present tenses should be recalled as past tenses and past tenses should be recalled as past perfect tenses.

An alternative hypothesis (Derivational Theory of Complexity: Linguistic operations = Psychological operations) based on a syntactic theory which claims that elements of the auxiliary are really main verbs (for discussion of Higher Verb Hypothesis see Bach, 1967; McCawley, 1971; Ross, 1967) would predict that those sentences with fewer higher verbs should be recalled more accurately since the presence of each higher verb requires the application of at least one additional transformation. More importantly, recall errors should gravitate towards simpler forms. That is, constructions using the past perfect and the past progressive should be recalled as simple past.

Several studies (Clark & Stafford, 1969; Harris & Brewer, 1973; Mehler, 1964) involved manipulations of elements of the auxiliary and therefore can be examined to determine whether the encoding of the auxiliary is best described by a Tense Logic model or a syntactic Derivational Theory of Complexity. Table 1 presents the percentage of tense shift errors which are predicted by the respective theories outlined above. These percentages of total errors were computed in the following manner: An error was scored as

being predicted by the tense logic model if the temporal relations expressed in the recalled form could be derived from the original temporal relation by the application of Findlay's law. Thus a simple past tense ($\frac{E}{R}$-S) which was recalled as a past perfect tense (E-R-S) would be scored as a predicted error, while one recalled as a present perfect tense (E-$\frac{S}{R}$) or as a simple present tense ($\begin{smallmatrix}S\\|\\(E)\\|\\R\end{smallmatrix}$) would be scored as an unpredicted error. On the other hand, an error was scored as being predicted by a Derivational Theory of Complexity (based on the Higher Verb Analysis) if the recalled form of the auxiliary involved the reduction of its form (e.g., fewer higher verb incorporation transformations). Thus a past perfect (have + past) which is recalled as a simple past (past) would be scored as an error predicted by the Derivational Theory of Complexity. Overall, the Tense Logic Model can account for approximately 60% of the errors and the Derivational Theory of Complexity can only account for 30% of the errors.

Insert Table 1 about here

It is of some interest to consider whether the tense shift effect is solely a Memory factor in adults or whether it is in part also involved in the active processing of sentences. Miller and McKean (1964) studied the latency to perform various linguistic transformations. Of interest to this study is their investigation of the effect of Perfect and Progressive aspect in the Past tense. In their (restricted) set of materials there is only one possible tense logic shift (simple past/past perfect). Miller and McKean found significant ($p = .05$) differences in the amount of presentation time required for subjects to transform one auxiliary verb sequence to another

in all conditions except for the one which involved the transformation from past perfect to simple past. This exception, on their view, results from the fact that this was the only case that involved a pair of sentences that differed only by the insertion or deletion of a single lexical item ("had"). However, a reanalysis of just their experimental conditions (that is, those conditions in which the subject had to transform the string) reveals that presentation time is always greater for cases where a syntactic reduction occurs (i.e., have-past → past, be-past → past, have-be-past → be-past). In terms of temporal features the presentation time was always shorter when the change was in the direction predicated by the tense logic laws (i.e., past → have-past, be-past → have-be-past).

These data would seem to support the view that sentential processing, as well as memory, is subject to the effects of the tense logic laws operating on the temporal specification of events.

Experiment I

In order to test directly the psychological validity of the Event Space that can be constructed by a tense logic, it is necessary to manipulate the order of events specified in a sequence of sentences (discourse) or clauses and determine whether order of events is a controlling factor in recognition.

Recently, Bransford and Franks (1973) reported patterns in the recognition of simple as well as compound predicates in a memory paradigm. Their general finding was that regardless of the nature of the learning sets, compound sentences were falsely recognized even if they themselves were not in the learning set but their constituent simple predicates were. Likewise, simple predicates were recognized even though they only occurred as constituents of compound sentences in the learning set. Bransford and Franks argue that such results

suggest that in the encoding of sentences, predicates rather than surface forms are stored. The nature of their materials was such that it was always possible either to combine predicates (from the learning set) into a complex sentence or to partition a complex sentence into its constituent predicates. Due to this it is not clear that the subjects' performance was due to the encoding of the learning set in terms of a deep predicate analysis or of a surface configuration. If materials could be designed so as to preclude certain combinations or partitionings, then a finding of the sort reported by Bransford and Franks would speak directly to the question of the nature of the encoding process. Specifically, the materials should vary the structure of the predicates in terms of logical relations without changing the general referents of the predicates or their respective subjects and objects. For example, in English as in many other natural languages, there are certain restrictions on the sequence of tenses in compound structures. These constraints on the tense structures should have some effect on subjects' ability to construct or to partition compound predicates. If subjects recognize compounds or derived simple predicates which do not fit the surface sequence constraints, then it might be argued that the level of storage of the predicates does not take into account that level of structure (linguistic) at which tense is explicitly marked. If, on the other hand, recognition of complex predicates is constrained, then it remains to be determined whether the constraint is due to the recall of surface tense structures or the encoded temporal specification (logical) assigned to the specific surface tense structures.

Materials. The materials consisted of sentences derived from four "idea sets" (short discourses). The sentences used were modified from those reported in Bransford and Franks (1971). Idea set A sentences correspond exactly to

those in Idea set A of Bransford and Franks. In Idea set B the tense of the acquisition and recognition list sentences were altered so that acceptable tense sequences would result if logical tense shifts occurred in memory. In set C the tenses were altered so that recognition could not be predicted by memory tense shifts. Set D was divided so that some of the sentences were derivable by logical tense shifts and some were not. Four sentences of totally new material were added to the recognition list (1-four, 1-three, 1-two and 1-one predicate sentence). One sentence from each idea set occurred on both the acquisition and recognition lists, otherwise all the remaining sentences on the recognition lists were derived. (See Appendix for lists.)

Procedure. All the acquisition sentences (20) were read to the subjects by the experimenter. Subjects were instructed to listen to the sentences carefully as there would be a recall task later in the experiment. Sentences from all four idea sets were randomly shuffled together. Following the presentation of the sentences the subjects were instructed to repeat 10 seven-digit numbers. The recognition sentences were presented immediately following the digits task. The sentences were presented visually in a packet in which the sentences were randomly shuffled. The subjects were instructed to indicate whether or not they had heard the sentences on the recognition list, in addition they were asked to rate their judgments on a five-point confidence scale.

Subjects. Ten Columbia University students served as subjects.

Results. The overall response distribution is presented in Table 2 and in Figure 6. The subjects replicated the Bransford and Franks result in the

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Insert Table 2 and Figure 6 about here

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condition in which there was no manipulation of tense (A). In the condition in which the tenses were manipulated in such a way that the correct temporal order of predicates was maintained (B), a similarly high false recognition rate was found. However, in the condition in which the tense manipulations yielded changes in the temporal order of predicates (C) the rate of false recognition was significantly lower. In the sentences of the fourth idea set, those sentences which maintained the temporal order of events (D') had a high false recognition rate, while those sentences which altered the temporal order (D") had a lower false recognition rate. The finding of a higher false recognition rate on those sentences which maintained the temporal order (A,B,D') in contrast to those sentences in which the temporal order was changed (C,D") is significant by subject ($p < .001$, by a Friedman two-way analysis of variance) as well as by sentence ($p < .008$, by a one-tailed sign test). Comparison of conditions A and B yielded no significant difference by subject or by sentence. However, comparison of condition A and condition C showed a significantly higher false recognition rate for the former ($p < .01$ by a Wilcoxon matched pairs signed ranks test by subject, and $p = .05$ by a Fisher exact test by sentence). Table 3 presents the mean confidence rating by condition. False recognitions (yes) were rated higher than correct rejections (no) only for condition A, however this difference is not significant. There was no significant difference in either the B or C condition. There is no difference in the ratings between conditions for false recognition responses. On correct rejection responses, conditions B and C have a higher confidence rating but this difference is also not significant.

This general lack of difference in the confidence ratings supports the view that while subjects made significantly fewer false recognition responses

on sentences in condition C (where there was a temporal change), they were no less certain of the false recognitions that they did make. The slightly lower confidence ratings for correct rejections of sentences in condition A could be the reflection of a slight bias against saying "no."

Insert Table 3 about here

Discussion. Stuart Katz (1973) has suggested that the false recognition rate can be altered by the instructions given to the subjects. In his study, setting the subject to pay close attention to the individual sentences in the acquisition list lowers their false recognition rate. The question then is: Do different instructions force the subjects to encode the sentences on the acquisition list differently, and if so, which of their behaviors is the "natural language encoding process"? Is encoding subject to nonsyntactic structure like the semantic structure of temporal specification? The results of the present experiment appear to at least point to an answer.

It is generally held that we perceive events (processes, actions, states), among other things, as occurring in time. Any operations we perform on the encoded representation of the event is in a sense "time tagged." Natural language provides a variety of means for the marking of the time of the event. Specifically, these linguistic markers position the event in time vis-a-vis the time of the utterance. Sentences themselves are similarly viewed as events. That is, a sentence describes an event and its position in time. Thus, if a sentence itself is encoded as an event occurring at t_1, then any process which deals with the sentence at t_{1+x} views the sentence as a "past" event and by logical inference (modus ponens) the event described by the sentence is viewed as past. Therefore, unless we have specific need of verbatim

(surface structure) form of the sentence, our hypothesis claims that we treat the temporal elements of the predicates in terms of their logical temporal specification.

In the general Bransford and Franks paradigm, a general event space, on which all the predicates of the idea set are placed, is established. In Katz's paradigm subjects encode the surface structure of sentences rather than an Event Space marking temporal relations among predicates. In conditions C and D" of my experiment it is the case that a single Event Space is established, and that sentences in the recognition list are recognized expressing different temporal orders for the events, This appears, intuitively, to suggest that subjects, in encoding, attempt to place the events predicated by the utterance into a temporal configuration. The increment in the number of correct rejections in condition C would be the result of the subjects' awareness that the temporal relations in the encoded Event Space is not identical to the ones in the sentences in the recognition list.

Thus, both of the encoding strategies can be seen as "natural language encoding processes." Linguistic material is encoded as a function of the subjects' perception of the demands of the task. That is, subjects are doing the same kind of thing in both paradigms: the differences result from the degree to which subjects encode the events from different sentences into a single multiple-event Event Space.

So far we have considered the relation of Tense-Aspect configurations to the encoded temporal specification (Event Space). In the discussion in the first section, I indicated that other linguistic structures also contribute to the overall temporal specification of an utterance. It should therefore be the case that the temporal information inherent in conjunctions should

affect the encoding of the sentences in which they occur. Specifically, sentences with conjunctions which establish a strong temporal ordering of the events in conjoined clauses should be resistant to errors involving the structures of temporal specification. In addition, the errors which do occur in recall should be of the form which does not involve a change in the temporal order of events.

Clark and Clark (1968) presented subjects with two clause sentences with conjunctions which established the temporal order of the events in the two clauses. They utilized a memory paradigm with prompted recall. A reanalysis of their error data in terms of the contrast of linguistic (left to right order of clauses) versus temporal order suggests that subjects make fewer errors that involve just changes in the temporal order (12%) than errors that involve only changes in the linguistic order (35%).

Bever (1970) studied children's comprehension of temporal versus linguistic order in two predicate sentences. Table 4 presents the percentage of correct responses (acting out of sentence with dolls) by age group for sentences in which the clause order corresponds to the temporal order of events and for sentences in which it does not. The percentage of correct responses for sentences in which the clause order corresponds to the temporal order increases

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Insert Table 4 about here

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considerably with age. Bever suggested that the emergence of the strategy which the four-year-old utilizes in sentence comprehension (namely, that the order of mention corresponds to the temporal order of events) is the one which appears to operate in adult memory processes. Thus the child appears to be establishing a correlation between a psychologically independent Event Space

and the linguistic mechanism for the expression of the content of that Event Space. The child can be seen as acquiring strategies for mapping linguistic sequences onto the internalized Event Space. Further investigation is necessary to determine whether specific aspects of the Event Space (temporal relations) are acquired over time or whether the full logical specification emerges as a whole. In that the acquisition of the perfect aspect is subsequent to the acquisition of the simple tense constructions it might be argued that the child does not initially mark events in relation to any other events. Such arguments presume the form of the language to shape the form of the child's thought processes. The question of whether thought precedes language or vice versa, with regard to temporal specification, remains to be empirically tested.

Experiment II

It would appear from the data cited above that the subjects are sensitive to the temporal features inherent in conjunctions. If the temporal information in conjunctions serves to organize sequence of events into Event Spaces, then it should be the case that sentences which contain conjunctions which explicitly order events (e.g., "before") should be more resistant to recall errors than sentences which contain conjunctions which do not explicitly order events (e.g., "except").

The following study was performed to test whether in the encoding of sentences subjects are sensitive to such a distinction in temporal order information of conjunctions.

The materials consisted of 22 clause sentences in which conjunction type was varied. The conjunctions were of two types: those which explicitly establish an order of the events of the two clauses (e.g., BEFORE) and those

which did not explicitly order the events (e.g., EXCEPT). (See Appendix for lists of sentences.)

Procedure. The sentences were administered in two blocks. The subjects were presented each sentence for five seconds. After the subjects had studied each of the sentences in a given block, the subjects were required to do a free recall for all the sentences in the block. This procedure was repeated with the sentences shuffled each time for a total of five learning and free recall pairs. Then the procedure was repeated for the second block of 10 sentences. The order of presentation of the sentence blocks was balanced across subjects. Subjects were recalled a week later for an additional free recall of all of the sentences.

Subjects. Twenty New York City College students who were paid for their participation served as subjects.

Results. Of interest to us here is the incidence of errors in the recall of the tense of the sentences as a function of the conjunction type (note the tenses in the learning sentences were simple past in both clauses of all but one sentence, the remaining sentence had a surface structure present tense which was used in a "habitual" sense).

The incidence of errors in sentences which contain conjunctions which did not explicitly mark a temporal order of events was significantly higher (12%) than for sentences in which the temporal order was explicit (.8%) in the conjunction. (By subject, $t = 6.39$, 19 df, $p < .0005$, one tailed; by sentence, $t = 2.54$, 18 df, $p < .025$, one tailed.) The incidence of tense shifts which result in changes of temporal order is extremely low (.08%) The overwhelming majority of errors (95%) involved the substitution of a conjunction which did not explicitly alter the order of events ($p < .001$, one-tailed sign test by subject + sentence).

In addition, the majority of conjunction errors (90%) were not accompanied by tense recall errors ($p < .001$, one-tailed sign test by subject + sentence). Furthermore, there were no cases in which a conjunction error which changed temporal order was accompanied by tense errors. There is a significantly higher incidence of concomitant tense errors, that is, errors occurring in both clauses as opposed to those in just one clause. (By subject, $t = 3.99$, 19 df, $p < .0005$, one tailed; by sentence, $t = 1.93$, 19 df, $p < .05$, one tailed.) Tense errors in both clauses involved shifts to the identical tense. That is, the tense error in one clause was identical to the one found in the other: for the sentences in the simple past the error form was the "present habitual tense," while for the one sentence with the present habitual tense the error form was the simple past. In only two errors, both in the second clause of the same sentence (on successive trials by the same subject), was the tense shift not identical in both clauses (.08% of total errors). Only in these cases did a tense error result in a shift of temporal order (the sentence contained a weak temporally ordering conjunction). The probability of an error in one clause given an error in the other clause is .77.

The results in terms of the other experimental variables in the stimulus sentences are to be discussed elsewhere (Bever & Hurtig, work in progress), and as they were counterbalanced across the conditions under examination here do not bear on the issues at hand.

Discussion. It would appear that features of temporal specification in conjunctions can have a facilitating effect on the encoding of sentences. Specifically, if the conjunction is one which marks the temporal order of events, then recall of the temporal features of the events in the sentence is better. Subjects are more likely to substitute conjunctions which do not

explicitly change the order of events (e.g., before → and then) than to substitute ones which do (e.g., before → after). Furthermore, the errors in conjunctions are independent of errors on tenses, that is, they do not result from errors in tense.

This last point, might appear at first, to be counter intuitive vis-a-vis the general tense logic model that has been proposed above. That is, if what the subject does is encode an Event Space, then a tense change (error) should be complemented by change in the conjunction which would maintain the correct order of events.

However, in those cases where the conjunction explicitly ordered the events, the conjunction errors did not change the temporal order of events and the incidence of these errors was extremely low (0.8%). And in the cases where the conjunctions did not establish a strong temporal order of events the incidence of tense errors is higher. Therefore, since errors in conjunctions did not change the temporal order of events, there was no necessity of a compensatory tense shift. Likewise, in those cases where tense errors occur, the conjunction was not explicitly marking order in the first place, and therefore no compensatory conjunction shift was necessary. Furthermore, the number of cases in which clause order was reversed was negligible (0.2%), thereby further reducing the likelihood of any concomitant tense or conjunction substitutions.

Epilog

In conclusion, it would appear that the temporal ordering established by certain conjunction types is critical to the accurate recall of the other elements of temporal specification in an utterance, and, as such, supports the general hypothesis that the overall temporal specification of an utterance

is the result of the amalgamation of the temporal features on a variety of linguistic structures (in the case of the present study: tense/aspect and conjunctions).

The fact that the linguistic form of the conjunction affects the encoded representation might be seen as evidence supporting the Whorfian hypothesis. However, there is nothing in the surface linguistic structure of the conjunctions which constrains the encoded representation of the sentences. Rather, it is the inherent semantic representation (temporal relation) of the conjunction which appears to affect the encoding of the sentence, specifically the encoding of the auxiliary verb structures. Thus, it can still be argued that encoding of linguistic material is constrained by nonlinguistic structure (e.g., thought: Tense Logic).

Current work in linguistics and psycholinguistics (see for discussion, Bever, 1970; Bever, Carroll, & Hurtig, in preparation) has suggested that there is an interaction of underlying cognitive structures. In that light, one can consider the interaction of the abstract tense logic and the linguistic structures of temporal specification as case in point. Temporal specification is then the result of the interaction of two systems of knowledge: the Tense Logic and the grammar.

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Footnotes

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[2]Referent point occurs earlier in time than the event point.

[3]Subscripts refer to events in order of mention.

[4]That is, the "as yet nonexistent" event (E) will (perhaps only hypothetically) occur after the speech event (S).

[5]Events can be actions, states or merely points in time.

[6]The use of the α notation is the same as that used for marking number and gender in nouns.

[7]Features can be stated in terms of tense logic relations, see (15)-(17) above.

Table 1

Percentage of Errors Predicted

	Mehler (1964)	Clark & Stafford (1969)	Harris & Brewer (1973)
Derivational Theory of Complexity	30	34	26
Tense Logic	73 (80)[a]	60	53

[a] If Modal Auxiliary (could) is considered to function like Perfect Aspect (have -en).

Table 2

Percentage of Distribution of Recognition Responses

	(A)	(B)	(C)	(D')	(D")
False Recognition (Yes)	80%	82%	43%	85%	43%
Correct Rejection (No)	20%	18%	57%	15%	57%
	Identical Tense	Tense-Logic Shift	Non-tense-Logic Shift		

Table 3

Mean Confidence Ratings[a]

Response	Condition A Identical Tense	B Tense-Logical Shift	C Non-tense-Logical Shift
Yes	3.88 n = 56	3.96 n = 49	3.88 n = 33
No	3.00 n = 14	3.82 n = 11	3.62 n = 37
Difference	0.88	0.14	0.26

[a]Rating scale: 1 = least confident; 5 = most confident.

Table 4

Percentage of Correct Responses (from Bever, 1970)

	Age		
	2	3	4
Clauses in Temporal Order of Events	60%	68%	95%
Clauses Not in Temporal Order of Events	57%	43%	51%
Difference	3%	25%	44%

Figure 1

Tense Logic for Simple Predicates

TEMPORAL RELATION	LINGUISTIC REALIZATION	
	MORPHOLOGICAL	PERIPHRASTIC
S-R-E		after he rests he will dance
S-E R	he will dance	
S-E-R	he will have danced	he will dance until 3 PM
S-E R		as of now he will dance
S-R E		he is dancing until tomorrow
S E R	he dances (is dancing)	
E-S R	he has danced	
R-S E		he is dancing since yesterday
E-S R	he danced (was dancing)	
E-R-S	he had danced	
R-E-S		after he ate he danced
S E (historical, habitual) R	(the moon orbits the earth)	
R-S-E		he has and will dance since 3
E-S-R		he has and will dance until 3
(DOUBLE REFERENTS)		
S-R1-E-R2		(a) he will dance from 3 until 4 (b) after he dances he will rest until 3
S-E-R2 R1		he will dance from now until 3
R1-E-R2-S		(a) he had been dancing since 3 (b) he danced from 3 until 4
R1-S-E-R2		he will have been dancing since yesterday

Note.--For each linguistic realization the logic assigns a configuration of point of event (E), point(s) of reference (R), and point of speech (S). That configuration corresponds to the temporal specification of the linguistic realization. In the examples the event (E) is "dancing."

Figure 2

Tense Logic of Complex Sentences

(Subscripts refer to the clause order. For each example the temporal relation of each clause and the conjunction is given in addition to the complex temporal relation for the entire complex sentence.)

1. John had called Mary before Max called Sue.

$E_1\text{-}R_1\text{-}S$ $\quad E_1 < E_2$ $\quad E_2\text{-}S$ $\quad R_2$

$R_1 \equiv R_2$ $\quad E_1\text{-}E_2\text{-}S$ $\quad R_1$

2. John called Mary before Max had called Sue.

$E_1\text{-}S$ $\quad E_1 < E_2$ $\quad E_2\text{-}R_2\text{-}S$

R_1 $\quad R_1 < R_2$ $\quad E_1\text{-}E_2\text{-}R_2\text{-}S$ $\quad R_1$

3. John had called Mary after Max called Sue.

$E_1\text{-}R_1\text{-}S$ $\quad E_1 > E_2$ $\quad E_2\text{-}S$ $\quad R_2$

$R_2 < R_1$ $\quad E_2\text{-}E_1\text{-}R_1\text{-}S$ $\quad R_2$

4. John called Mary after Max had called Sue.

$E_1\text{-}S$ $\quad E_1 > E_2$ $\quad E_2\text{-}R_2\text{-}S$ $\quad R_1$

R_1 $\quad R_1 \equiv R_2$ $\quad E_2\text{-}E_1\text{-}S$ $\quad R_2$

5. John called Mary as Max called Sue.

$E_1\text{-}S$ $\quad E_1 \equiv E_2$ $\quad E_2\text{-}S$ $\quad R_1$

R_1 $\quad R_1 \equiv R_2$ $\quad E_1\text{-}S$ $\quad E_1$ $\quad E_2$ $\quad R_2$

Figure 2 (Continued)

6. John called Mary before Max called Sue.

E_1-S $\quad E_1 < E_2 \quad E_2$-S $\quad E_1$-E_2(R_2)-S (R_1)

$R_1 \equiv R_2$

7. John called Mary after Max called Sue.

E_1-S $\quad E_1 > E_2 \quad E_2$-S $\quad E_2$-E_1(R_1)-S (R_2)

$R_1 \equiv R_2$

8. John had called Mary as Max called Sue.

E_1-R_1-S $\quad E_1 \equiv E_2 \quad E_2$-S ($R_2$) $\quad E_1$-R_1-S (R_2)

$R_2 < R_1$

9. John had called Mary as Max had called Sue.

E_1-R_1-S $\quad E_1 \equiv E_2 \quad E_2$-$R_2$-S $\quad E_1$-R_1-S (E_2 R_2)

$R_1 \equiv R_2$

10. John called Mary as Max had called Sue.

E_1-R_1-S $\quad E_1 \equiv E_2 \quad E_2$-$R_2$-S $\quad E_1$-R_1-S (E_2 R_2)

$R_1 \equiv R_2$

11. John had called Mary before Max had called Sue.

E_1-R_1-S $\quad E_1 < E_2 \quad E_2$-$R_2$-S $\quad E_1$-E_2(R_1)-R_2-S

$R_1 < R_2$

Figure 2. (Continued)

12. John had called Mary after Max had called Sue.

E_1-R_1-S $\quad E_1 > E_2$ $\quad E_2-R_2-S$ $\quad E_2-E_1-R_1-S$ (with R_2)

$R_2 < R_1$

13. John had called Mary and then Max called Sue.

E_1-R_1-S $\quad E_1 < E_2$ $\quad E_2-S$ (with R_2) $\quad E_1-R_1-E_2-S$ (with R_2)

$R_1 < R_2$

14. John had called Mary and then Max had called Sue.

E_1-R_1-S $\quad E_1 < E_2$ $\quad E_2-R_2-S$ $\quad E_1-R_1-E_2-R_2-S$

$R_1 < E_2$

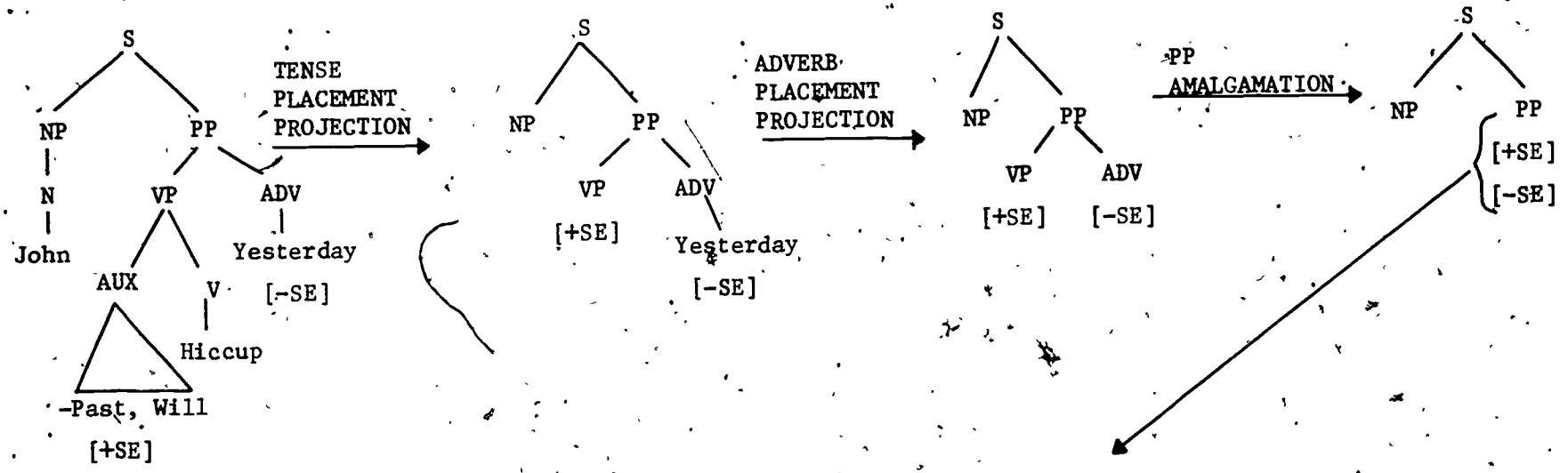
15. John called Mary and then Max called Sue.

E_1-S (with R_1) $\quad E_1 < E_2$ $\quad E_2-S$ (with R_2) $\quad E_1-E_2-S$ (with R_1 R_2)

$R_1 < R_2$

Figure 3

*John Will Hiccup Yesterday



READING:
CONTRADICTORY TEMPORAL SPECIFICATION.

Figure 4

*John Will Hiccup While He Ate Breakfast

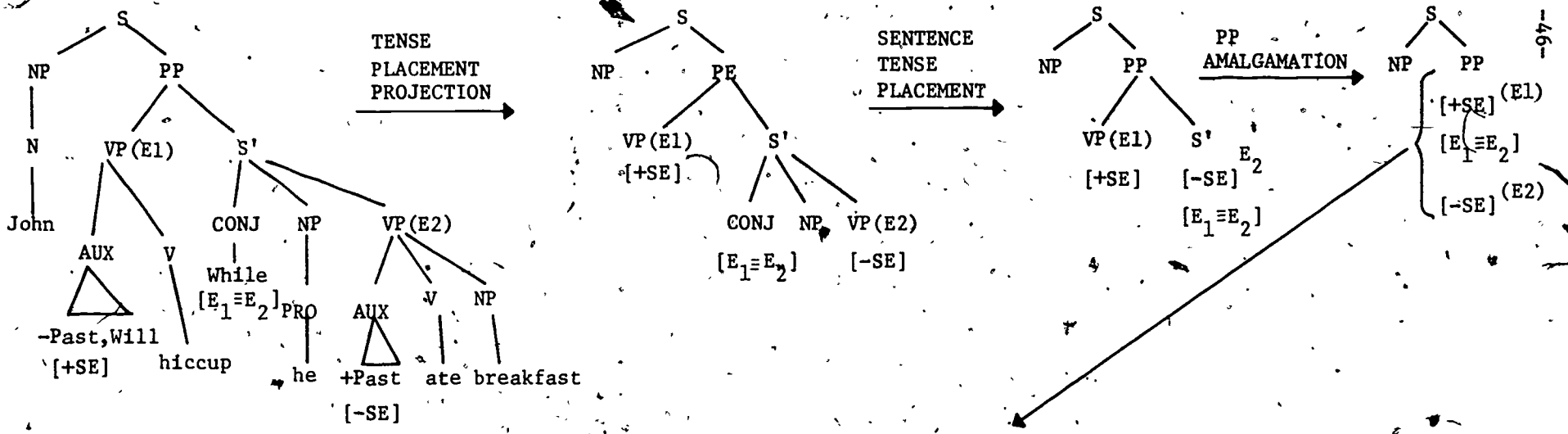


Figure 5

John Will Leave Before Joan Arrives

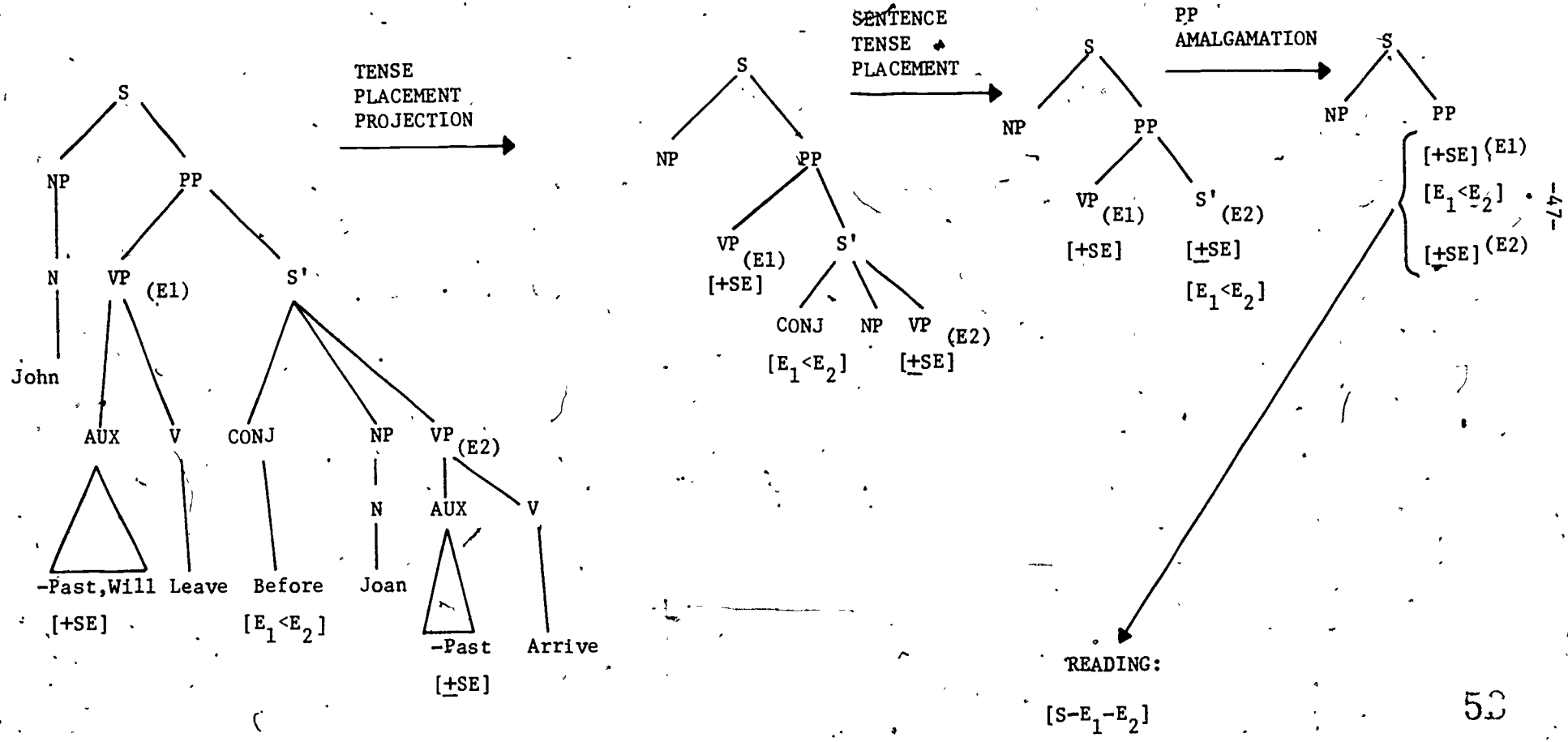
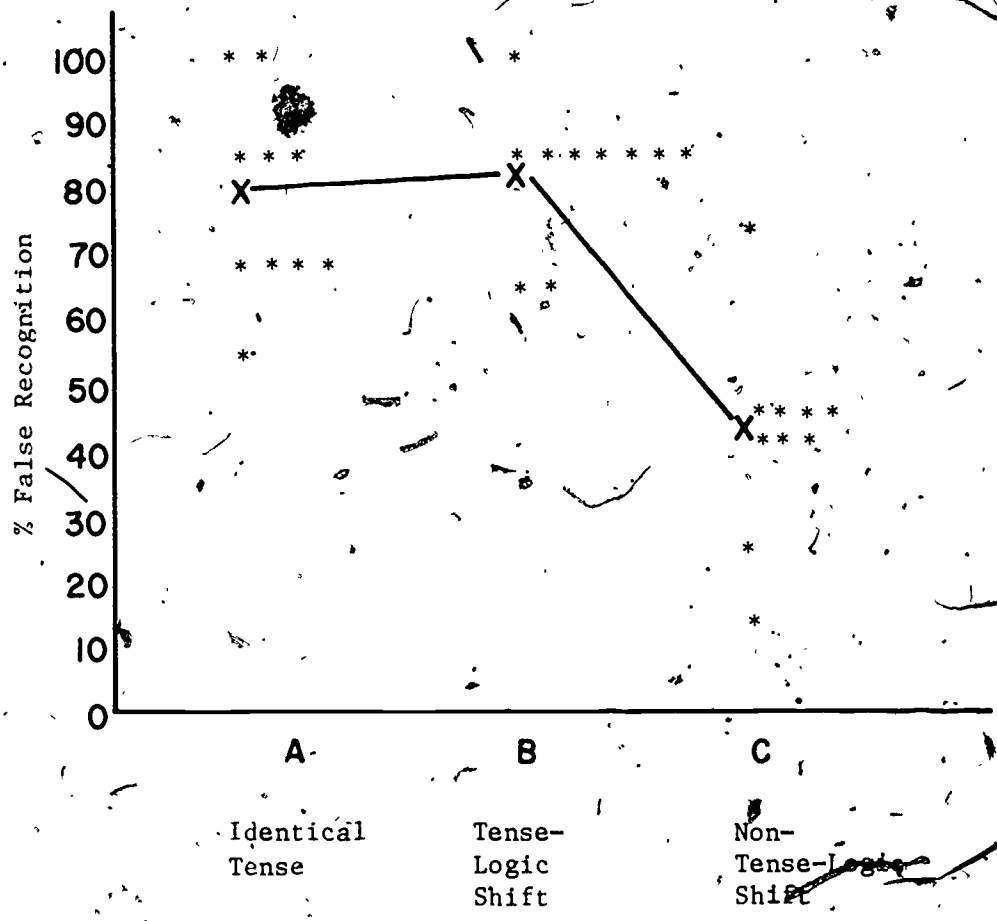


Figure 6

Experiment III

Distribution of Subjects by Condition and False Recognition Rate



APPENDIX

Experiment I. Acquisition and Recognition Sentences.

Set A:

Acquisition:
The ants were in the kitchen
The jelly was on the table
The ants in the kitchen ate the jelly
The ants ate the sweet jelly
The ants in the kitchen ate the jelly which was in the kitchen
The ants ate the sweet jelly which was on the table

Recognition:
The ants in the kitchen ate the sweet jelly which was on the table
The ants in the kitchen ate the sweet jelly
The ants ate the sweet jelly
The sweet jelly was on the table
The ants ate the jelly which was on the table
The jelly was sweet
The ants ate the jelly

Set B:

Acquisition:
The breeze is warm
The breeze has been blowing from the sea
The warm breeze has stirred the evening air
The breeze has stirred the evening air
The breeze blowing from the sea has stirred the evening air
The breeze blowing from the sea has stirred the heavy evening air
The warm breeze has stirred the heavy evening air

Recognition:
The evening air had been heavy
The breeze stirred the evening air
The warm breeze was blowing from the sea
The breeze has stirred the evening air
The warm breeze blowing from the sea stirred the evening air
The warm breeze blowing from the sea stirred the heavy evening air

Set C:

Acquisition:
The rock rolled down the mountain
The hut is at the edge of the woods
The rock which rolled down the mountain had crushed the hut
The rock had crushed the tiny hut
The rock had crushed the tiny hut at the edge of the woods
The rock which rolled down the mountain had crushed the hut at the edge of the woods

Recognition:
The hut is tiny
The rock has crushed the hut
The tiny hut will be at the edge of the woods
The rock has crushed the hut at the edge of the woods
The rock had crushed the tiny hut
The rock which has rolled down the mountain has crushed the tiny hut
The rock which has rolled down the mountain has crushed the tiny hut at the edge of the woods

Set D:

Acquisition:
The man had been bald
The man rested on the couch
The man resting on the couch read the story
The man read the story in the newspaper
The bald man read the story
The man resting on the couch read the story in the newspaper
The bald man read the story in the newspaper

Recognition:
The story is in the newspaper
The man reads the story
The bald man is resting on the couch
The man read the story in the newspaper
The bald man resting on the couch reads the story
The bald man resting on the couch read the story in the newspaper

Fillers for Recognition:
The cat ate the goldfish
The cabinet which is broken will be mended
The bright student drove to the mansion by the lake
The horse which won the race ate the fresh hay which was in the barn

Experiment II. Sentences

I.

the chef entered the kitchen then the rabbi blessed the food
the cowgirl bought the dog before the wolf ate it
the moron looked at the people then the lovers wrote them
the carpenter fixed the door before the handyman fell on him
the shrewd broker kept slaves then the senator called for him
the young mother screamed at the boy when he upset the baby
the librarian coached the actors and they amused the audience
the shoemaker loved the orphans when he helped business
the technicians disliked the programmer and they held up the experiment
the major liked the fair when the circus came to town
the retired boxer chased the kids and the boy scout helped the blind
the architect built the schools while the government subsidized them
the boss hired the pretty typist and the secretary looked at her
the investigator found the ballerina while the artist painted him
the nurse scolded the patient and the farmer fed her
the athlete swam across the river except it wandered toward the church
the power stations polluted the sea but it took care of the beach
the planter grows coffee trees although he ruins the land
the tugboat rescued the damaged ships but it saw the iceberg
the marine patrolled the beaches although the enemy scared the officers

II.

the chef entered the kitchen before the rabbi blessed the food
the cowgirl bought the dog then the wolf ate the chicken
the moron looked at the people before the lovers wrote them
the carpenter fixed the door then the handyman fell on it
the shrewd broker kept slaves before the senator called for him
the young mother screamed at the boy and the girl upset her
the librarian coached the actors when they amused the audience
the shoemaker loved the orphans and they helped business
the technicians disliked the programmer when they held up the experiment
the mayor liked the fair and he came to town
the retired boxer chased the kids while the boy scout helped the blind
the architect built the schools and the government subsidized the park
the boss hired the pretty typist while the secretary looked at her
the investigator found the ballerina and the artist painted her
the nurse scolded the patient while the farmer fed her
the athlete swam across the river but the tourists wandered toward him
the power stations polluted the sea except it took care of the beach
the planter grows coffee trees but they ruin the land
the tugboat rescued the damaged ships although it saw the iceberg
the marine patrolled the beaches but he scared the officers

III.

the chef entered the kitchen then he blessed the food
the cowgirl bought the dog before the wolf ate the chicken
the moron looked at the people then the lovers wrote poems
the carpenter fixed the door before the handyman fell on it
the shrewd broker kept slaves then the senator called for them
the young mother screamed at the boy when the girl upset her
the librarian coached the actors and the commercial amused her
the shoemaker loved the orphans when they helped business
the technicians disliked the programmer and he held up the experiment
the mayor liked the fair when he came to town
the retired boxer chased the kids and he helped the blind
the architect built the schools while the government subsidized the park
the boss hired the pretty typist and the secretary looked at the shipment
the investigator found the ballerina while the artist painted her
the nurse scolded the patient and the farmer fed him
the athlete swam across the river except the tourists wandered toward him
the power stations polluted the sea but the city took care of them
the planter grows coffee trees although they ruin the land
the tugboat rescued the damaged ships but they saw the iceberg
the marine patrolled the beaches although he scared the officers

IV.

the chef entered the kitchen before he blessed the food
the cowgirl bought the dog then she ate the chicken
the moron looked at the people before the lovers wrote poems
the carpenter fixed the door then the handyman fell on the curb
the shrewd broker kept slaves before the senator called for them
the young mother screamed at the boy and the girl upset him
the librarian coached the actors when the commercial amused her
the shoemaker loved the orphans and the manufacturers helped him
the technicians disliked the programmer when he held up the experiment
the mayor liked the fair and it came to town
the retired boxer chased the kids while he helped the blind
the architect built the schools and he subsidized the park
the boss hired the pretty typist while the secretary looked at the shipment
the investigator found the ballerina and the artist painted the portrait
the nurse scolded the patient while the farmer fed him
the athlete swam across the river but the tourists wandered toward it
the power stations polluted the sea except the city took care of them
the planter grows coffee trees but the climate ruins him
the tugboat rescued the damaged ships although they saw the iceberg
the marine patrolled the beaches but they scared the officers

V.

the chef entered the kitchen then the rabbi blessed it
the cowgirl bought the dog before she ate the chicken
the moron looked at the people then he wrote poems
the carpenter fixed the door before the handyman fell on the curb
the shrewd broker kept slaves then the senator called for legislation
the young mother screamed at the boy when the girl upset him
the librarian coached the actors and the commercial amused them
the shoemaker loved the orphans when the manufacturers helped him
the technicians disliked the programmer and the strike held them up
the mayor liked the fair when it came to town
the retired boxer chased the kids and they helped the blind
the architect built the schools while he subsidized the park
the boss hired the pretty typist and he looked at the shipment
the investigator found the ballerina while the artist painted the portrait
the nurse scolded the patient and the farmer fed the cow
the athlete swam across the river except the tourists wandered toward it
the power stations polluted the sea but the city took care of it
the planter grows coffee trees although the climate ruins him
the tugboat rescued the damaged ships but the airplane saw it
the marine patrolled the beaches although they scared the officers

VI.

the chef entered the kitchen before the rabbi blessed it
the cowgirl bought the dog then it ate the chicken
the moron looked at the people before he wrote poems
the carpenter fixed the door then he fell on the curb
the shrewd broker kept slaves before the senator called for legislation
the young mother screamed at the boy and the girl upset the baby
the librarian coached the actors when the commercial amused them
the shoemaker loved the orphans and the manufacturers helped them
the technicians disliked the programmer when the strike held them up
the mayor liked the fair and the circus came to him
the retired boxer chased the kids while they helped the blind
the architect built the schools and they subsidized the park
the boss hired the pretty typist while he looked at the shipment
the investigator found the ballerina and he painted the portrait
the nurse scolded the patient while the farmer fed the cow
the athlete swam across the river but the tourists wandered toward the church
the power stations polluted the sea except the city took care of it
the planter grows coffee trees but the climate ruins them
the tugboat rescued the damaged ships although the airplane saw it
the marine patrolled the beaches although the enemy scared him

VII.

the chef entered the kitchen then it caught fire
the cowgirl bought the dog before it ate the chicken
the moron looked at the people then they wrote poems
the carpenter fixed the door before he fell on the curb
the shrewd broker kept slaves then he called for legislation
the young mother screamed at the boy when the girl upset the baby
the librarian coached the actors and the commercial amused the audience
the shoemaker loved the orphans when the manufacturers helped them
the technicians disliked the programmer and the strike held him up
the mayor liked the fair when the circus came to him
the retired boxer chased the kids and the boy scout helped him
the architect built the schools while they subsidized the park
the investigator found the ballerina while he painted the portrait
the boss hired the pretty typist and she looked at the shipment
the nurse scolded the patient and she fed the cow
the athlete swam across the river except the tourists wandered toward the church
the power stations polluted the sea but the city took care of the beach
the planter grows coffee trees although the climate ruins them
the tugboat rescued the damaged ships but the airplane saw them
the marine patrolled the beaches but the enemy scared him

VIII.

the chef entered the kitchen before it caught fire
the cowgirl bought the dog then the wolf ate her
the moron looked at the people before they wrote poems
the carpenter fixed the door then it fell on the curb
the shrewd broker kept slaves before he called for legislation
the young mother screamed at the boy and she upset the baby
the librarian coached the actors when the commercial amused the audience
the shoemaker loved the orphans and the manufacturers helped business
the technicians disliked the programmer when the strike held him up
the mayor liked the fair and the circus came to it
the retired boxer chased the kids while the boy scout helped him
the architect built the schools and the government subsidized him
the boss hired the pretty typist while she looked at the shipment
the investigator found the ballerina and she painted the portrait
the nurse scolded the patient while she fed the cow
the athlete swam across the river but he wandered toward the church
the power stations polluted the sea except the city took care of the beach
the planter grows coffee trees but the climate ruins the land
the tugboat rescued the damaged ships although the airplane saw them
the marine patrolled the beaches but the enemy shelled them

IX.

the chef entered the kitchen then the rabbi blessed him
the cowgirl bought the dog before the wolf ate her
the moron looked at the people then the lovers wrote him
the carpenter fixed the door before it fell on the curb
the shrewd broker kept slaves then they called for legislation
the young mother screamed at the boy when she upset the baby
the shoemaker loved the orphans when the manufacturers helped business
the librarian coached the actors and she amused the audience
the technicians disliked the programmer and the strike held up the experiment
the mayor liked the fair when the circus came to it
the retired boxer chased the kids and the boy scout helped them
the architect built schools while the government subsidized him
the boss hired the pretty typist and the secretary looked at him
the investigator found the ballerina while she painted the portrait
the nurse scolded the patient and he fed the cow
the athlete swam across the river except he wandered toward the church
the power stations polluted the sea but they took care of the beach
the planter grows coffee trees although the climate ruins the land
the tugboat rescued the damaged ships but the airplane saw the iceberg
the marine patrolled the beaches although the enemy shelled them

X.

the chef entered the kitchen before the rabbi blessed him
the cowgirl bought the dog then the wolf ate it
the moron looked at the people before the lovers wrote him
the carpenter fixed the door then the handyman fell on him
the shrewd broker kept slaves before they called for legislation
the young mother screamed at the boy and he upset the baby
the librarian coached the actors when she amused the audience
the shoemaker loved the orphans and he helped business
the technicians disliked the programmer when the strike held up the experiment
the mayor liked the fair and the circus came to town
the retired boxer chased the kids while the boy scout helped them
the architect built the schools and the government subsidized them
the boss hired the pretty typist while the secretary looked at him
the investigator found the ballerina and the artist painted him
the nurse scolded the patient while he fed the cow
the athlete swam across the river but it wandered toward the church
the power stations polluted the sea except they took care of the beach
the planter grows coffee trees but he ruins the land
the tugboat rescued the damaged ships although the airplane saw the iceberg
the marine patrolled the beaches but the enemy scared the officers