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ABSTRACT

This paper is a short tutorial in formal grammar with speculative examples of how it could be used as a research tool for task analysis, the description of lesson structure, the modeling of interactive dialogue, and perhaps the instructional design process. Gagne's notion of "events of instruction" is used in an example of the application of linguistic techniques to instructional system design, and it is suggested that use of analogy is one way to think about the problems involved, e.g., the events of instruction may be compared to parts of speech, and sentences are made up of parts just as lessons are. It is argued that sentences are infinite in variety but constrained structurally; some instructional designs may be thought of as well-formed strings while others may violate our intuitions of well-formedness; and a grammar of instructional design would assign descriptions to lesson materials. A brief explanation of the term "formal grammar" as used in linguistics is followed by descriptions of other grammars proposed by researchers, including a story grammar, a cinema grammar, a computer-interface grammar, a lesson grammar, and a grammar of instructional design. A summary suggests that while the ideas presented in this paper are far from complete, formal grammar as an instructional design device will at least facilitate the identification of testable hypotheses about optimal sequences, and might also be modified to help designers generate lessons more fluently or to allow the computer generation of large numbers of different, acceptable lesson structures that can be fleshed out by subject experts. The various grammars described are presented in nine figures. (11 references) (BBM)

Title:

Applying Linquistic Analysis to Instructional Design

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Applying Linguistic Analysis to Instructional Design

The terminology of linguistic discourse is often applied to instructional design situations. We speak of tutorials and dialogues, interface languages and interactions. It is rare to see these terms taken literally, however. The discipline of linguistics has formal description techniques which may allow us to describe the structure of computer-based interaction with greater objectivity. Such devices have been applied to stories (Mandler and Johnson, 1977), the cinema (Carroll, 1980), computer interfaces (Reisner, 1981; Moran, 1981; Payne and Green, 1986) and classroom discourse (Mehan, 1979). The application of such formal devices to instructional systems design is a logical extension of such a trend.

This paper is a short tutorial in formal grammar with speculative examples of how it could be used as a research tool for task-analysis, the description of lesson structure, the modeling of interactive dialogue, and perhaps the instructional design process.

As an example of the application of linguistic techniques to ISD, consider Gagné's well-known "events of instruction." It is hard to evaluate the theoretical status of the events. How could they be empirically tested? Are all events necessary always? How are they to be related to course-level events, units, lessons, and sub-lessons? Must they be applied in a fixed order? If not, to what extent can the order be transformed?

One way of thinking about these problems is to analogize. The events of instruction may be compared to the parts of speech. Sentences are made up of parts just as lessons are. Sentences are infinite in variety but they are constrained structurally. In other words, certain strings of words are considered to be well-formed while others are not. The description of these constraints is a goal of linguistics. Instructional designs may be thought of as sentences made up from events. Some combinations of events may be thought of as well-formed strings while others may violate our intuitions of well-formedness. A grammar of instructional design would assign descriptions to lesson materials. A basis for assigning descriptions to the structure of instruction may be thought of as a theoretical goal of instructional design research.

Formal Grammar

At the mention of the word "grammar," some people remember tedious sentence diagramming exercises performed under the scrutiny of a schoolmarm. Others recall laboring to memorize Latin verb conjugations and noun declensions. Those who write professionally think of the handbooks they consult to ensure the propriety of their usage. To the linguist however, grammar is not an artifact of language study nor an arbitrator of style. Rather, the linguist views grammars as tools to describe the complex cognitive system which language is.

The use of the plural "grammars" is deliberate: to the linguist grammar is not the monolith that it is to man in the street. Linguists ardently debate the relative merits of a number of grammars, such as Case grammar, Tagmemic grammar, Transformational-Generative grammar and Traditional (Latinate) grammar, to name a few. Power and parsimony are the chief criteria considered in attempts to empirically determine which system is superior.

The concern with parsimony leads to the formal, that is, symbolic, property of modern grammars. The ideal of power requires that a finite set of rules account for

the infinite number of possible sentences which any language has. One such grammar is Phrase Structure (PS) grammar, which is an algebraic system using symbols to represent variables. It has rules which specify whether a given string of words belongs to the set of valid English sentences. Moreover, it has rules which break down ("rewrite" in the linguistic terminology) sentences into their constituents. Figure 1 is a simple PS grammar of English.

Story Grammar

One of the first and best-known applications of formal grammar outside of pure sentential syntax was Mandler and Johnson's (1977) paper on story grammar. Essentially, Mandler and Johnson asserted that traditional stories (fairy tales, legends, etc.) have a structure which can be represented formally. The importance of this claim rests on the assumption, borrowed from linguistics, that such structures are "psychologically real." That is, such grammars are representations of knowledge that experienced story-readers hold in their heads. Mandler and Johnson's grammar (Figure 2) consists of a finite set of primitives and a finite set of recursive rewrite rules which are capable of describing an indefinitely large number of stories.

S → NP + VP
NP → DET. + N + (S)
DET. → {the, a, this, that, etc.}
N → dog, window, neighborhood, hope, etc.

VP → { Vi + (PP) / Vt + (NP) / be + Adj }

Vi → walk, coughed, spoke, etc.
Vt → hit, cover, inform, etc.
be → am, are, is, was were, been, being
PP → Prep + NP
Prep → to, for, at, etc.
Adj → blue, tall, old, etc.

Figure 1. A simple phrase structure grammar of English

There is a need for a short explanation of notational conventions. Parentheses indicate optional items. Parentheses marked with a superscripted index n indicate that the item may occur one or more times. Brackets indicate mutually exclusive items. EVENT* indicates that one terminal event is conjoined with one or more other terminal events within a single higher-level node. STATE* has a similar meaning. Three types of connection are allowed: AND, THEN, and CAUSE. AND and THEN define temporal relations and CAUSE defines an explanatory relationship. These connections are rendered in lower case in the figure to improve readability.

FABLE → STORY and MORAL

STORY → SETTING and EVENT-STRUCTURE

SETTING → { STATE* (and EVENT*) | EVENT* }

STATE* → STATE ((and STATE)^n)

EVENT* → EVENT (({ and | then | cause } EVENT)^n) ((and STATE)^n)

EVENT-STRUCTURE → EPISODE ((then EPISODE)^n)

EPISODE → BEGINNING cause DEVELOPMENT cause ENDING

BEGINNING → { EVENT* | EPISODE }

DEVELOPMENT → { SIMPLE-REACTION cause ACTION | COMPLEX-REACTION cause GOAL-PATH }

SIMPLE-REACTION → INTERNAL-EVENT ((cause INTERNAL-EVENT)^n)

ACTION → EVENT

COMPLEX-REACTION → SIMPLE-REACTION cause GOAL

GOAL → INTERNAL-STATE

GOAL-PATH → { ATTEMPT cause OUTCOME | GOAL-PATH (cause GOAL-PATH)^n }

ATTEMPT → EVENT*

OUTCOME → { EVENT* | EPISODE }

ENDING → { EVENT* (and EMPHASIS) | EMPHASIS | EPISODE }

EMPHASIS → STATE

Figure 2. Story Grammar

This story grammar can be used to define the structure of a traditional story (taken from Mandler and Johnson), such as that listed in figure 3.

1. It happened that a dog had got a piece of meat
2. and was carrying it home in his mouth.
3. Now on his way home he had to cross a plank lying across a stream.
4. As he crossed he looked down
5. and saw his own shadow reflected in the water beneath.
6. Thinking it was another dog with another piece of meat,
7. he made up his mind to have that also.
8. So he made a snap at the shadow,
9. but as he opened his mouth the piece of meat fell out,
10. dropped into the water,
11. and was never seen again.

Figure 3. Traditional Story

Figure 4 is a tree-structure (based upon Mandler and Johnson) which represents the traditional story with each phrase assigned a structural description. Each numbered node in the tree structure represents the corresponding phrase in the story. The circles with C's, A's, or T's in them represent CAUSE, AND, or THEN connections. As can be seen, this grammar is capable of defining the structure and therefore is empirically justified. If the grammar had not been capable of defining the story, it would have had to have been modified as a result of this empirical test.

Cinema Grammar

Carroll (1980) reports an attempt to write a grammar of the cinema. He builds his attempt upon the assumption, not that cinema is a language in the same sense as English, but rather on the methodological assumption that cinema has structure and that that structure may be elucidated using the formal techniques of linguistics. Figure 5 represents a portion of that grammar. The grammar as represented is not complete and is only presented to give a flavor of the type of analysis Carroll attempted. As can be seen, the grammar consists of a set of recursive rewrite rules which define the structure of scenes and events. The notation is similar to the previous grammars. The adequacy of this grammar is not crucial to our argument. It suffices to point out that grammars can be applied to objects which have temporal structure and relatively abstract primitives.

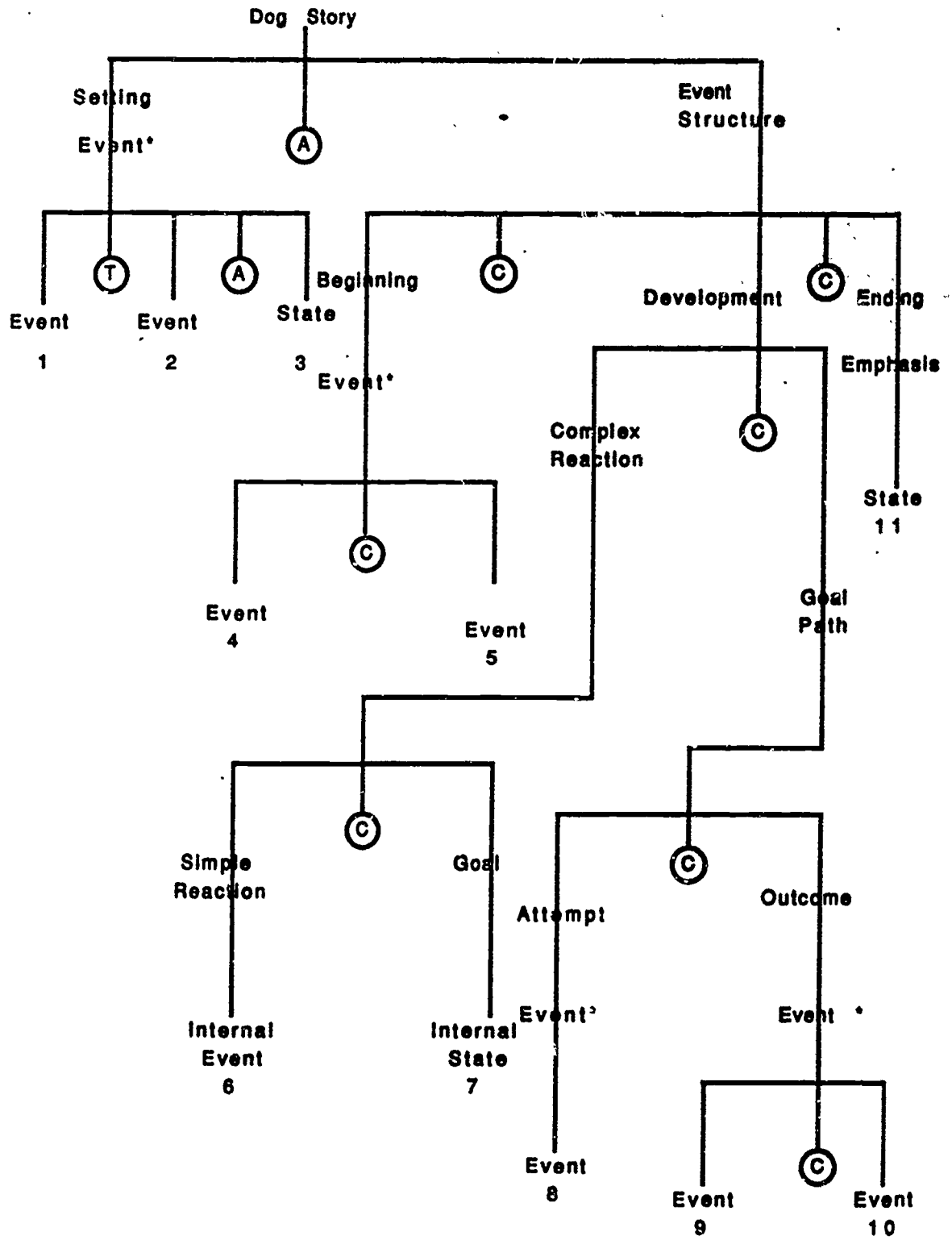

Figure 4. Tree-structure of the story in Figure 3

SCENE → LONGSHOT + DETAIL*
DETAIL → DETAIL + SCENE + DETAIL
EVENT → NOMINAL + SEQUENCE
SEQUENCE → ACTION*
ACTION → PREPARATORY-ACTION + FOCAL-ACTION
P → A*
F → A*

Figure 5. A cinema grammar

Computer Interface Grammar

Reisner (1981) first reported an attempt to apply formal grammar to a human factors design problem—the design of a command language for an interactive graphics program. Reisner pointed out that human factors design had tended to use behaviorist models for its methodology. Reisner argued that cognitive factors such as simplicity and consistency would be relevant to the design of "action languages" such as those used to control computer functions. Basically, Reisner argued that cognitive factors would influence the learnability of action languages and that these factors could be best modeled by a grammar. She wrote a grammar consisting of rewrite rules similar in notation to the examples from story and cinema grammar. Her grammar could also be expressed in tree diagrams after the fashion of the Backus-Naur Form used in computer science. Taking Reisner's ideas further, Moran (1981) gives an elaborate description of a command language grammar and elucidates how computer-based activities can be modeled grammatically at four levels of analysis from keyboard actions to intentions. Payne and Green (1986) take this approach one step further by developing a task-action grammar (TAG) which allows tasks to be mapped onto actions. The power of Payne and Green methodology is that cognitive structures (tasks) may be directly related to behaviors (keystrokes) while capturing such notions as simplicity and consistency. Payne and Green's hypothesis is that users can recognize action language consistencies across tasks and therefore can cognitively structure those tasks at a more abstract (i.e., simpler) level rendering the learning process easier. Thus a TAG makes predictions about the relative learnability of functionally comparable interfaces. These predictions are amenable to empirical testing. Such information is useful to the software designer, but it also could serve as a task analysis methodology for instructional designers who need to predict learning difficulties with computer interfaces.

Lesson Grammar

Mehan (1979) reported a description of the structure of actual lessons presented by a classroom teacher. Mehan asserted that the activities of the classroom seemed not to be under immediate stimulus control. It is well-known that actions under immediate stimulus control can be described by a finite state automaton (a Markov device), but behavior of a certain degree of complexity requires at least a context-free grammar. Mehan's work is important to the present paper in that it demonstrates the use of a formal grammar in an area closely allied to computer-based instruction. If lessons as complex as those delivered by an actual teacher can be effectively modeled with a grammar it would seem that lessons delivered under the controlled conditions of CBI could also be so described. Figure 6 presents a part of

Mehan's grammar. As can be seen, lessons consist basically of three parts. The main part, the Middle, consists of topically related sets. These sets are interaction sequences which consist of an initiation, a response, and an evaluation. An evaluation can be an interaction sequence itself, so the internal structure of these interactions can be arbitrarily complex. The implications of this grammar for the description of CBI are obvious.. Can it fully describe existing CBI? This question is empirical and can only be satisfied by the actual description of existing materials.

Lesson → Opening-phase + Instructional-phase + Closing -phase
Opening, closing-phase → Directive + Informative/ Informative + Directive
Instructional-phase → Topically-related-set (=TRS) + (Topically-related-set)^n
TRS → Basic + Conditional-sequence (or Interactional-sequence)
Interactional-sequence → Initiation + Reply + Evaluation
Evaluation → Interactional-sequence

Figure 6. A lesson grammar

Events of Instruction

As an example of the application of linguistic techniques to ISD consider Gagné's well-known "events of instruction" as illustrated in figure 7. It is hard to evaluate the theoretical status of the events. How could they be empirically tested? Are all events always necessary? How are they to be related to course-level events, units, lessons, and sub-lessons? Must they be applied in a fixed order? If not, to what extent can the order be transformed?

1.	Gaining attention
2.	Informing learner of lesson objective
3.	Stimulating recall of prior learning
4.	Presenting stimuli with distinctive features
5.	Guiding learning
6.	Eliciting performance
7.	Providing informative feedback
8.	Assessing performance
9.	Enhancing retention and learning transfer

Figure 7. The events of instruction

One way of thinking about these problems is to analogize. The events of instruction may be compared to the parts of speech. Sentences are made up of parts just as lessons are. Sentences are infinite in variety but they are constrained structurally. The description of these constraints is a goal of linguistics. Lessons may be thought of as sentences made up from primitive events. Primitive events may be grouped structurally under larger, more abstract events. Gagné's events are of the more abstract type since they do not specify actual lesson activities. An example of the transformation of the events of instruction into an instructional grammar applicable to CBI is given in figure 8.

Instructional-Unit → Beginning + Middle* + End
Beginning → GA(gaining attention) + IL(informing...) + SR(stimulating recall)
Middle* → Middle + (Middle)^n
Middle → PS(presenting...) + GL(guiding...) + EP(eliciting...) + PF(...feedback)
End → AP(assessing...) + EL(enhancing...)
GA→ bright color, loud sound, motion, etc.

Figure 8. A grammar of instruction

Note that this grammar makes empirical claims about the order of the events and their optionality or lack thereof. Since lessons often consist of more than one objective they may be arbitrarily complex. This grammars suggest how some of that complexity may be handled formally. No claim is made that this grammar is descriptively adequate. In fact, it surely is not. Lessons may consist of multiple instructional units. Several things may be presented before guiding and eliciting take place. This grammar does not capture these facts. However it does indicate the kinds of formal descriptions which can be accomplished. The advantage of such formalisms is that actual instructional designs may be checked against this grammar and validated for their "instructional grammaticality." Just as native speakers can recognize sentences that are not well-formed, experienced learners presumably can recognize lessons that are ill-formed. Empirical hypotheses about such lessons could be tested. Do learners learn less from "ungrammatical" lessons? Do learners slow down when presented with lesson events which violate their expectations of normality? These are a few of the questions which could be investigated with structural descriptions of the type provided by grammars.

A Grammar of Instruction Design

A common statement heard in ISD circles is that instructional design is "iterative." What this means is that designers iterate through a process of analysis, synthesis, and evaluation when producing instructional materials. That this model is not perfectly satisfactory is not news. Gagné and Briggs (1979) state that "This cyclical or iterative nature of the process is real, but its details cannot be shown accurately in advance, either by feed-forward or feedback loops in diagrams or by arrows connecting numbered stages in a list." (p. 20-21) One would expect that if the process truly is iterative, empirical evidence for that "reality" could be collected. On the other hand if design is not iterative, perhaps the cyclical metaphor is just the most powerful model that can be applied given the available descriptive language.

Alternative metaphors are available, though. There are those who have noted that design seems to be like a "conversation" with a problem situation (Schön, 1983). A conversation model of instructional design is not iterative. Just as conversations seem to develop opportunistically based upon speech acts and responses, designers in action seem to act alternatively on higher-level and lower-level problems, working on what seem to afford most chance of success at any given moment (Stauffer and Ullman, 1988). Linguists have attempted to characterize the structure of conversations through discourse analysis (e.g., Stubbs, 1981). The means

by which discourse structures are represented is by grammars, much like in Mandler and Johnson and Mehan above. If the design process is indeed like a conversation then, contrary to Gagné and Briggs, its detail can be shown in advance, although its actual trajectory cannot be predicted. As an example of this possibility, the following design grammar is given. The minimal interactive unit of design is hypothesized to be the transaction which consists minimally of two events, an initiation and a response. Other types of events are feedback and interfaces. Interfaces are events which themselves initiate another transaction. Events consist of acts which are actual behaviors performed by instructional designers. Examples of acts are collecting needs data, doing task analysis, evaluating results, etc. A sample of such a grammar is given in Figure 9.

Design Session → $(\text{Transaction})^n$

Transaction → I + R + (I/F) + (F)

I/F → Transaction

I → do needs analysis, do task analysis, ...

R → needs data, task representation, ...

I/F → evaluate results, ...

F → student behaviors, ...

Figure 9. A grammar of instructional design

The first thing to say about this grammar is that it is obviously inadequate. Design projects consist of more types of sessions and transactions than are represented. Some of those activities involve interactions with team members, reading research reports, attending conferences, removing constraints, etc. However, it does illustrate the kind of structural description which goes beyond simply saying that ISD is "cyclical." A cycle is a model of design. It may be the best that can be done if one restricts oneself to representing design with informal language. As is well-known though, science has generally been advanced by using formal devices. There is no reason why the science of the study of instructional design processes should handicap itself by restricting itself to informal language. In fact, a precedent for our argument can be found in Knowlton's classic 1966 article "On the definition of 'picture.'" Knowlton justified his attempt to develop a metalanguage for talking about pictures with a quote from Antoine Lavoisier.

> ...we cannot improve the language of any science without at the same time improving the science itself; neither can we, on the other hand, improve a science without improving the language or nomenclature which belongs to it. (p. 157)

Summary

The ideas presented in this paper are far from complete. The possibilities of formal grammar as an instructional design device are unknown. At least it will facilitate the identification of testable hypotheses about optimal instructional sequences. Perhaps it will shed light on ISD from a theoretical standpoint but will have no practical application. Perhaps it can be modified to help designers generate lessons more fluently. Perhaps such grammar will allow the computer-generation of indeterminately large numbers of different, acceptable lesson structures which can be fleshed out by subject matter experts. The automation of instructional design will require at the very least some formal theory of instruction. The most powerful formal theories known are grammars.

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