DOCUMENT RESUME

ED 234 341 CS 007 241

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TITLE Causal Inferences during Text Comprehension and Production.
PUB DATE May 83
NOTE 37p.; Paper presented at the Annual Meeting of the Midwestern Psychological Association (Chicago, IL, May 5-7, 1983).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150) -- Information Analyses (070)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Cognitive Development; Cognitive Processes; Elementary Secondary Education; Influences; *Logical Thinking; *Reading Comprehension; *Reading Processes; *Reading Research; Story Telling
IDENTIFIERS Causal Inferences; *Inference Comprehension; Linguistic Analysis; *Reader Text Relationship; Textual Analysis

ABSTRACT

As comprehension failure results whenever readers are unable to infer missing causal connections, recent comprehension research has focused both on assessing the inferential complexity of texts and on investigating students' developing ability to infer causal relationships. Studies have demonstrated that texts rely on four types of causal connections; one event may cause: a new physical or mental state, a new action, or a new motivation for action. The density of these stated or inferred connections largely determines text difficulty. Children's spontaneous oral stories can also be analyzed as causal event chains. Analysis reveals that these narratives increase in complexity as children grow, changing from the 2-year-old child's simple listing of events to the 10-year-old child's careful organization of motivations and consequences. The inferential complexity of texts is also reflected in the pauses during the oral retelling of films. Analysis demonstrates that pauses at event chain continuities are less frequent than pauses at discontinuities. (MM)

Causal Inferences During Text Comprehension and Production

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Paper presented to the Midwestern Psychological Association, Chicago, May, 1983.

A reader may fail to understand a text because it is unorganized or incoherent or because the reader is unable to recover the text's structural organization. This approach to reading assumes that reading difficulty and comprehension failure arise because readers are unable to process texts as coherent well-structured descriptions of causally connected chains of actions, physical states, and mental states (Graesser, 1981; Kemper, 1982; Omanson, Warren, & Trabasso, 1978; Schank, 1975; Schank & Abelson, 1977). These causal links of the event chain underlying the text may be directly stated. If so, the reader need only inter-connect these stated causal links by means of a taxonomy of possible causal events. The resulting causal event chain will thus explain "who did what to whom and why" and enable the reader to answer questions about the events described in the text. However, some of the actions, physical states, and mental states necessary to construct the underlying event chain may be missing from the text. The reader will need to infer these missing causal links in order to understand the causal event chain. These inferences may be derived from the taxonomy of possible causal events or based on background knowledge or special expertise. The comprehensibility of a text, thus, should reflect the its inferential complexity.

In order to assess the inferential complexity of texts, a procedure was developed to analyze the causal event chains underlying texts. This procedure was then applied to a variety of texts in order to obtain an inference load formula for predicting the grade level difficulty of texts. This approach to analyzing texts was then show to have broad generality by

its application to the analysis of the spontaneous, oral narratives of children and to the analysis of temporal pauses during storytelling.

A. The Event Chain Analysis of Texts

A three-step process for parsing texts was developed. Texts are decomposing into a linear sequence of actions, physical states, and mental states. Using a taxonomy of possible causal events, the event chain underlying the text is recovered and the inferred causal links are identified.

Clause segmentation

A text is initially divided into syntactically-determined clauses. Two general types of clauses are recognized: tensed clauses which contain verbs inflected for tense and untensed clauses which contain imperative or infinitive verbs that are not inflected. Four tense markers can be used to identify tensed verbs: -ed characteristic of past tense verbs, -s that marks third-person, singular present tense verbs, has that signals perfective tense verbs, and -ing of progressive tense verbs. Irregular verbs are those that are not inflected by these markers.

Tensed and untensed verbs may be found in simple, coordinate, or complex sentences. Complex sentences consist of a main or matrix clauses with one or more embedded clauses. Six types of complex sentences are recognized: sentences containing infinitive phrases, gerundive phrases, noun phrase complements, relative clauses, participal adjectives, and subordinate clauses. A text is parsed into clauses by first locating the verbs in each simple or coordinate sentence or in each matrix or embedded clause of a complex sentence.

The Classification of Clauses

In the second step of the analysis of texts as event chains, each clauses is classified as either an action, a physical state, or a mental state. As in the first step, syntactic criteria and procedures are used to classify the clauses. Actions are distinguished from states on the basis of three criteria: (1) Actions can be expressed with verbs in the "progressive" aspect. (2) Actions can answer questions such as "What happened?" or "What's happening?" (3) Actions can be used in imperative constructions. Actions include processes involving the change of state or condition of objects and the activities of agents.

States include both observable physical states and unobservable mental states. Physical states include states of possession, attribution, and specification. Mental states include emotions, cognitions, and intentions. Such states represent enduring, although not permanent, properties or characteristics of agents, objects, and locations.

Event Chain Construction

A taxonomy of possible causal connections is used to construct the event chain underlying a text. The taxonomy assumes that there are four types of causal connections: (1) One event may cause a new physical state--a resulting causal link. (2) One event may cause a new mental state--an initiation link. (3) One event may cause a new action by enabling the action to occur or (4) by providing a psychological motive or reason for the action. These four types of causation are constrained so that an action cannot cause a new action, a physical state cannot lead to a

new physical state, and a mental state cannot cause new mental or physical states.

Not all the causal links in the event chain underlying a text are explicitly stated. Some must be inferred. In general, action-action, physical state-physical state, mental state-mental state, and mental state-physical state sequences in a text require obligatorally inferred actions or states. These inferences are required in order to repair apparent violations of the causal taxonomy.

Thus the analysis of texts as causal event chains uses a causal taxonomy to establish connections between the actions and states described in the text. When necessary, actions and states are inferred to repair violations of this taxonomy.

B. Predicting Comprehensibility

Matching a text to the knowledge and skill of the reader is not a new idea; formulas for determing the rezdability of texts have been used for at least 40 years. To date, however, readability formulas have been based on the surface characteristics of texts. As a result, they are unable to distinguish a well-structured text from a sequence of randomly ordered sentences (Hirsch, 1977; Kintsch & Vipond, 1978; Klare, 1974/75).

The knowledge-based approach to text comprehension assumes that readers actively use background knowledge in order to interpret what they read (Graesser, 1981; Sanford & Garrod, 1981; Schank & Abelson, 1977). Comprehension, then, in this approach involves an active process of constucting a coherent chain of causally and temporally related events. Readers must understand the causes and consequences of physical and

historical events and of characters' actions and motives. The difficulty of a text should reflect how easily a reader can establish the causally connected event chain underlying a text. Hence, a primary source of comprehension difficulty is the inferential processing required to construct the causally connected underlying event chain. By measuring the inferential demands that a text places on readers, it is possible to adjust the difficulty of texts for readers who differ not only in reading skill but also in background knowledge and special expertise.

In order to match text and reader in terms of the inferential complexity of texts, an inference load formula for determining the inferential complexity of texts has been developed. This formula relies on the decomposition of texts into causally connected chains of events. Multiple regression techniques were used to obtain the best fitting regression equation for predicting the infernce load of texts that differ in grade level suitability (Kemper, in press).

Materials

The McCall and Crabbs (1979) Standard test lessons in reading consist of a series of short passages designed to evaluate reading and comprehension skills. Grade level norms, based on large scale field testing, are provided for students' performance on eight multiple-choice questions about each passage. The passages span third grade to high school reading levels. Sixty-two passages were selected from this corpus. Two coders independently parsed these passages into clauses identified as actions, physical states, or mental states. Then, using the causal taxonomy described above, the coders constructed the event chain underlying

each text. The event chain analysis of a sample text is presented in Table 1.

Insert Table 1 About Here

Results

A regression analysis was performed to obtain an inference load formula for assessing the difficulty of texts with different grade levels. The dependent variables was the grade level of each passage. Six independent or predictor variables were used; they were based on the density of stated and inferred causal links of each type. The mean number of actions, physical states, and mental states, both stated and inferred, was obtained from the two coders' parses. This number was divided by the number of words in the passage to give the density of each type of causal link.

The "best subset" approach to regression was used (Daniel & Wood, 1971). The six predictor variables were fitted to the grade level reading score for each of the 62 passages. Grade level is positively correlated with the density of stated actions and inferred physical states. Grade level decreases with the density of stated physical states and mental states. The incidence of stated actions is negatively correlated with the incidence of stated mental states but positively correlated with the inferred physical states and inferred mental states. Thus passages trade off stated actions with stated physical and mental states. The more difficult passages include more actions and fewer physical and mental states than do the easier passages.

The "best subset" of equations with two, three, and four predictors were obtained. Most include stated mental states; that with two predictors adds stated physical states. Most of the equations with three or four predictors include stated or inferred mental states and stated or inferred physical states. Overall, the "best" fitting equation, in terms of C_p and R^2 statistics, has three predictors: stated mental states, inferred mental states, and stated physical states. This equation is more fully described in Table 2.

Insert Table 2 About Here

Comparison of Inference Load and Dale-Chall Formulas

The "best" fitting regression equation can be used as an Inference Load formula for predicting the comprehension difficulty of texts. Its predictive power was compared to that of the Dale-Chall (1948) readability formula. Two coders computed both the Inference Load score and the Dale-Chall corrected grade levels of 18 new passages. The predicted grade levels obtained from the Dale-Chall formula correlate, $r(16) = +.63$, with the reported McCall-Crabbs grade levels. Nonetheless the inferential complexity of the passage correlated $r(16) = +.63$ with the reported grade levels.

Conclusions

Major readability formulas to date have been based on the surface aspects of texts. They do succeed in predicting performance on comprehension texts but there is no obvious explanation as to why measures

of sentence and word length should predict performance on comprehension tests. By decomposing texts into causal event chains, the inferential complexity of texts can be assessed and their comprehensibility determined. The inference load approach both predicts the relative difficulty of texts and explains the source of comprehension failure: Texts are difficult to understand when they require readers to make many inferences; comprehension failure results whenever the reader is unable to infer missing causal connections due to limitations in background knowledge of experience. Texts may be made easier to understand by adding missing causal links; the difficulty of texts may be increased by deleting some. By lowering the inference load of a text, it may be rendered comprehensible to readers who would otherwise be unable to infer missing causal links.

C. Development of Event Chains

The event chain analysis of texts was shown to have broad generality by applying it to the analysis of children's spontaneous, oral narratives. Storytellers must learn to construct causally ordered sequences of events. In order to tell a story, a child must be able to describe the events in such a way that the listener can follow the chain of causality. Not only must the storyteller describe the protagonist's actions, but the storyteller must also explain the character's motives, the circumstances that make some actions possible and others impossible, and the results of the character's actions. The present research examines chronological changes in the causal structure of children's narratives. Between the ages of two and ten years, children gradually master the ability to tell stories that describe causally connected sequences of events (Kemper, to appear).

Materials

Sutton-Smith (1981) has made available a collection of children's narratives. The children range in age from two to ten years. Initially 54 stories from the Sutton-Smith collection were analyzed.

Analysis

Each story was parsed by two judges into the underlying event chain using the procedure described above. Following the identification of the actions, physical states, and mental states mentioned in the narratives, the judges, using the causal taxonomy, recovered the underlying event chains. These event chains contained those inferred actions, physical states, and mental states necessary to repair violations of the causal rules. Two example stories and their analyses are presented in Table 3.

Insert Table 3 About Here

Results

The narratives were initially analyzed for chronological changes in causal structure. Figures 1 and 2 summarize the differences, across ages, in the densities of stated and inferred actions, physical states, and mental states. Stated actions are negatively correlated with stated physical states and positively correlated with inferred actions and inferred physical states. Stated physical states are negatively correlated with inferred mental states. Inferred actions increase with inferred physical states and inferred mental states. Inferred physical states and mental states are positively correlated. Thus storytellers trade off

ns and stated physical states with inferred mental states.
have a high density of stated actions also require many
particularly of actions and physical states.

Insert Figures 1 and 2 About Here

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of the storyteller is also negatively correlated with the
e number of words in the narrative. Thus older children tell
s. Significant negative correlations were obtained between
e storyteller and the density of inferred acitons, inferred
s, and inferred mental states. Age was positively correlated
ity of stated mental states. Thus older children told stories
fewer inferences than those told by the younger children. The
n year olds were longer, but contained, proportionally, more
than those of two year olds.

length of the stories increases with the age of the
the composition of the stories also changed chronologically.
s, inferred actions, inferred physical states, and inferred
are positively correlated with the inverse of the length of
. Thus, longer stories involved more stated actions, inferred
rred physical states, and inferred mental states per 100 words
shorter narratives.

of causal links children include in their narratives changes
ly as well. Initiations and motivations are largely absent in
f two and three year olds and gradually appear in those of

four to six year olds. Their reliance on enablement causation, correspondingly, declines as children learn to explain why characters act as they do.

The best fitting regression equation for predicting the age of the storyteller from the event chain analysis is presented in Table 4. It includes the densities of stated actions and mental states, of inferred physical states and inferred links, and of inverse word length as predictors. For this equation, $C_p = .07$ and $R^2 = .75$.

Insert Table 4 About Here

Conclusions

Between the ages of two and ten years, children gradually master the ability to tell stories that describe causally connected sequences of events. Stories told by two year olds are primarily lists of characters' actions; these actions are without cause or consequence. Gradually, children's stories change to include the motivating mental states and enabling physical states that cause the actions and the physical and mental states that are the consequences of the actions.

D. Pausing and Inferring

The event chain analysis of texts identifies three types of junctures between syntactically-defined clauses: (1) one clause may follow another as a smooth continuation of the event chain, (2) a gap in the event chain may occur between clauses such that one or more causal links may be missing between two temporally and causally successive links (3) a gap in the event

ur such that there is a back-up or regression to a causally-
the event chain. These junctures, reflecting the linear
of a causally-connected chain of event, are determined by
ecision made during the production of the text. These
ut the content and organization of a text may also affect the
uction of it. Consequently, pauses between clauses during the
story may occur. To investigate this possiblity, pauses at
hree types of between-clause junctures were examined.

82) has asked speakers to view a film and then to orally re-
y. The transcriptions of these oral re-tellings, from twenty
akers, include measured pauses. The pause data from 12
used. That from the remaining 8 speakers was not used as the
ere short and incomplete, as a result, coherent causal event
not be constructed from these re-tellings.

re-telling of the film was parsed into a causal event chain.
d vagaries in the oral versions were resolved by reference to
account of the original film. A single judge parsed the 12
second judge independently parsed four. The judges agreed
ifications of 93% of the stated actions, physical states, and
and 86% of the inferred causal links. Each pause, as
e orginal transcripts, was classified as either occuring
e or between two clause. The between-clause pauses were
fied as occuring at continuations of the event chain, gaps in

the event chain, or back-ups of the event chain. For the four re-tellings analyzed by the two judges, pauses were reliably classified 96% of the time. Examples of the four types of clauses are given in Table 5.

Insert Table 5 About Here

Results

Two analyses were performed to compare the incidence and duration of within-and between-clause pauses. The proportion of within-clause pauses and pauses at continuations, gaps, and back-ups of the event chain was determined for each speaker's re-telling. Then the average length, in seconds, of each type of pause was calculated for each speaker. Finally, the total time each speaker paused was determined and the proportion of this total pause time for each type of pause was calculated. The results, averaged across speakers, are presented in Figures 3 and 4.

Insert Figures 3 and 4 About Here

Pauses were more likely to occur between clauses than within clauses, $X^2(1) = 7.84$, $p < .01$. Of the between-clauses pauses, those at continuations of the event chain were less likely than those at the two types of discontinuities, $X^2(1) = 15.25$, $p < .01$. However, pauses at gaps in the event chains were as likely as pauses at back-ups to prior causal links $X^2(1) = 1.71$, $p > .10$.

There were no significant differences in the average length of the within- and between-clause pauses (all $p > .10$). However, when the total pause time is considered, more time was spent pausing between clauses than within clauses, t (11) = 3.71, $p < .05$. The speakers spent proportionally less time pausing at continuations of the event chains than at discontinuities, t (11) = 4.95, $p < .05$. However, the proportions of time spent pausing at gaps and back-ups of the event chain were similar, $p > .05$.

Conclusions

These results demonstrate that the oral production of texts reflects active decisions about causal organization. The event chain underlying a text may be abridged or temporally and causally re-ordered as the story is told. One consequence is that speakers pause while telling the story between links in the event chain. The between-clauses pauses appear to reflect at least three factors: causal continuities in the event chain, gaps between causally-successive links, and back-ups to causally prior links. The analysis demonstrates that between-clause pauses are more frequent than within-clause pauses and that pauses at event chain continuities are less frequent than pauses at discontinuities.

Summary

Research to date has demonstrated that texts can be reliably decomposed into chains of causally-connected actions, physical states, and mental states. The grade level suitability, in terms of reading level, of texts is a function of the density of stated mental states, stated physical states, and inferred mental states in the texts. From the third to twelfth

grades, the difficulty of texts increases with the complexity of the causal event analysis of the texts. Further, the spontaneous oral stories of children can be analyzed as causal event chains. This analysis reveals that the causal structure of children's narratives changes with their chronological ages. Children learn to include the motives and results of characters' actions in their narratives. Finally, pauses during the oral retelling of a film reflect the inferential complexity of texts. Gaps and retrogressions in the oral retelling's underlying event chain are associated with more and longer pauses than are smooth continuations. The analysis of texts as causally connected chains of events provides insight into factors that affect narrative comprehension and production.

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Acknowledgements

This research was supported by National Science Foundation Grant IST-811-0439. Thanks to Maggie Schadler, Mabel Rice, Nancy W. Denney, Meg Gerrard and the other F. B.'s for their support and encouragement.

Table 1

The event chain analysis of a sample passage. Slash marks segment the text into clauses. Each clause is labeled as an action (A), a physical state (PS), or a mental state (MS). The clauses are serially numbered. Following the passage, the underlying event chain is schematically presented. Inferred actions and states are indicated by the unlabeled nodes.

A mystery spot

/There is a "mystery spot" near Santa Cruz, California. PS1/ All trees in this mystery spot lean in one direction, A2/ but redwoods a short distance from it grow straight and tall. A3/ People have great difficulty PS4/ walking in the mystery area. A5/ Their feet feel like lead. PS6/ It is almost necessary PS7/ to drag themselves along the trail A8/ by holding onto a handrail. A9/ Many are unable MS10/ to step over a low doorsill and into a cabin. A11/ They enter A12/ by sitting on the doorsill A13/ and swinging their feet over it. A14/ When standing in the cabin, PS15/ they lean in the same direction as the trees. A16/ They feel MS17/ as though they are standing as usual, PS18/ but actually they are leaning at such an angle A19/ that they look ludicrous to people PS20/ watching them. A21/

/Two concrete slabs lie about six inches apart. PS22/ One is inside the mystery spot PS23/ and the other outside it. PS24/ When a person five feet tall PS25/ stands on the mystery-spot slab A26/ he looks taller

than a person PS27/ six feet tall PS28/ standing on the other slab, PS29/ although the two slabs are relly on the same level. PS30/

/It is the guess of Einstein and many other scientists PS 31/ that gravity is pulling harder at that spot. A32/

PS1--->A2 & A3

PS1--->A5--->PS4 & PS6

A5--->PS7--->A8

PS4--->MS10--->A11

MS10--->A13--->PS--->A14

A14--->PS--->A12

A12--->PS15--->A16 & MS17

PS18--->MS17

PS15--->A19--->PS20

A21--->PS20

PS1-->A--->PS22 & PS23 & PS24--->A26

PS25--->A26--->PS27

PS28 & PS29--->A--->PS27

PS30--->A--->PS27

PS32--->PS1--->A--->PS31

Table 2

The Best Regression Equation for Measuring the Inference Load of a Text

$C_p = 0.92$

$R^2 = .58$

adjusted $R^2 = .55$

multiple $R = .76$

residual mean square = 3.31

standard error of the estimate = 1.82

$F(3,56) = 5.44$, $p < .05$

Split-half cross validation: $F(28,27) = 1.08$, $p > .05$

Variable	Coefficient
Intercept	8.41
Stated Mental States	+.54
Stated Physical States	-.86
Inferred Mental States	+.23

Table 3

Event chain analyses of two example stories. Each is parsed into a sequence of actions, physical states, or mental states. They are numbered to facilitate interpretation of the event chains which follow. In these chains, inferred causal links are indicated in parentheses.

Story 1

A1 An astronaut went into space

AS He was attacked by a monster

PS3 He got in his ship

A4 He flew away

Event chain

A1-->(HE WAS IN SPACE)-->A2

A2-->(HE WAS AFRAID)-->(HE RE-ENTERED HIS SPACESHIP)-->PS3-->A4

Table 3 (continued)

Story 2

PS1 There was a little fish

PS2 It was named Josh

A3 He was going to a fair

PS4 There were fishers over the fair

A5 The fishermen caught everyone

PS6 The catch included Josh

A7 They put the fish in the hole

PS8 There were sharks and string rays

A9 A ray was going after Josh

A10 A shark chased the sting ray

MS11 The shark wanted something

A12 The shark ate the ray

A13 The sting ray stopped chasing Josh

A14 It ran away

A15 A fight occurred

A16 Another shark gobbled up Josh's family

A17 It left

PS18 The boat was sailing

PS19 And sailing

Table 3 (continued)

Story 2

PS20 And sailing

PS21 There was a big storm

A22 It hit rocks

PS23 It made a hole

A24 Josh escaped

A25 He went back

A26 He stayed there

PS27 He was big

Event chain

PS1-->(SOMEONE CHRISTENED IT)-->PS2

PS1-->A3-->(HE WAS AT THE FAIR)-->A5-->PS6

PS4-->A5-->(THE FISH WERE RESTRAINED)-->A7

A7-->(THEY WERE IN THE HOLE)-->A9, A10, A16, and A24

PS8-->A9, A10, and A16

A10-->(SHARK CAUGHT THE RAY)-->A12

MS11-->A10-->(THE RAY WAS AFRAID)-->A14

A12 and A14-->(THERE WAS A CONFRONTATION)

A16-->(IT WAS SATISFIED)-->A17

PS18, PS19, and PS20-->A22-->PS23-->A24

A24-->(JOSH WAS FREE)-->A25

A25-->(HE WAS HOME)-->A26-->PS27

Table 4

The best regression equation for predicting the age of the storyteller for the Sutton-Smith collection.

$C_p = 0.07$

$R^2 = .75$

multiple R = .87

adjusted R = .70

residual mean square = 2.11

standard error of the estimate = 1.45

F(5.48) 12.85, $p < .001$

	Coefficient	Contribution to R^2
Intercept	5.75	----
Stated Actions	+ .22	0.04
Inferred Physical States	- .61	0.07
Inferred Links	+ .27	0.05
Inverse Word Length	-1.96	0.08
Stated Mental States	+ .06	0.05

Table 5

Examples of within-clauses and between-clause pauses (in seconds) from oral retellings in The Pear Stories (Chafe, 1982). Between-clause pauses are classified as continuations, gaps, or back-ups.

1. Pauses within clauses

   ...a man goes by with a -.24- tak goat...

   ...there's a rock in the road and he -.25- hits it with his bike...

2. Pauses between clauses

   a. Continuations: those pauses between stated, causally-successive or collateral clauses

      ...the boys realize he's forgotten his hat -.55- So one of them whistles to him...

      ...he realizes that -.45- one basket is gone...

      ...(he) looks at the man, -1.5- looks at the bushels...

   b. Gaps: those pauses between two stated clauses that can be causally-connected by means of one or more inferred causal links; these pauses fill gaps in the event chain

      ...then he decides to take the whole basket. -.9- And he puts in on (his bicycle)

      ...and they're eating pears -1.2- and they walk off...

      ...this kid comes along with a bicycle -.55- And he rips off...

   c. Back-ups: those pauses between two stated clauses that cannot be connected by one or more inferred causal links, these pauses results from "backing-up" of the event chain to a previous link

...walking back...the way the first boy came -1.35- Meanwhile the man who's picking pears...

...then a boy comes by on a bicycle, the man is in the tree -.9- and the boy gets off the bicycle...

...as he's holding on to the handlebars he takes off with them. -6.35- then...a girl rides (toward him)...

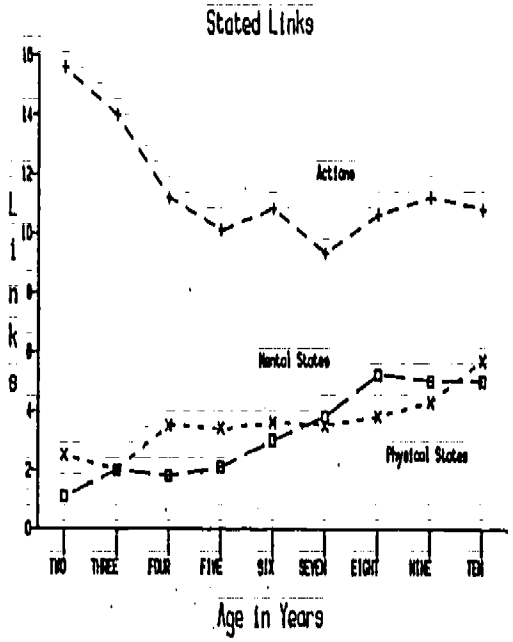
Figure Captions

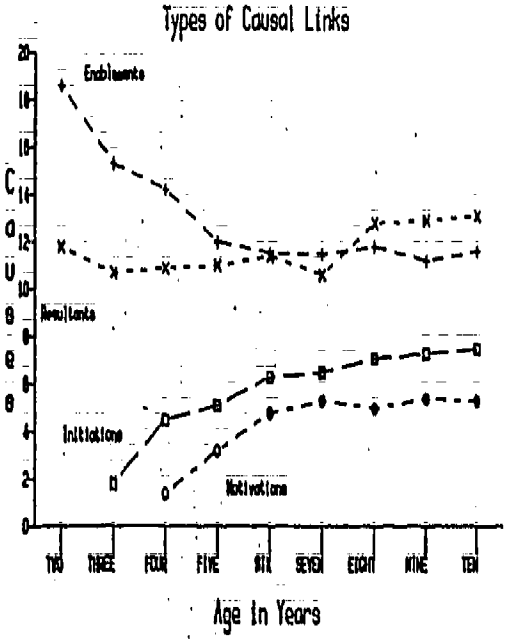
Figure 1: Chronological changes in the densities of stated and inferred actions physical states, and mental states in children's oral narratives.

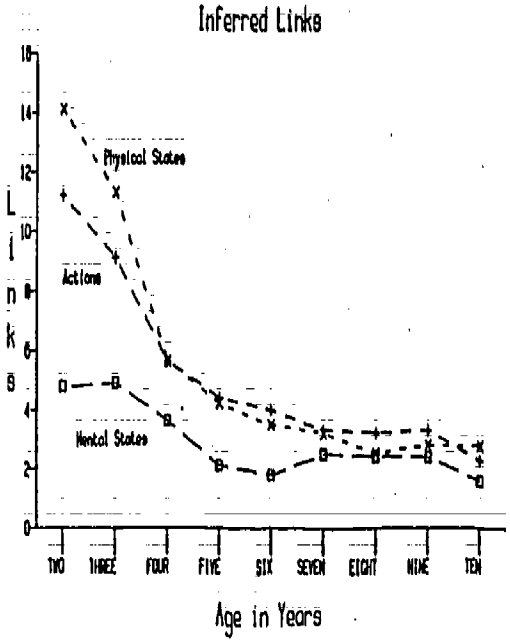
Figure 2: Chronological changes in the densities of initiation, motivation, resultant, and enablement causation in children's oral narratives.

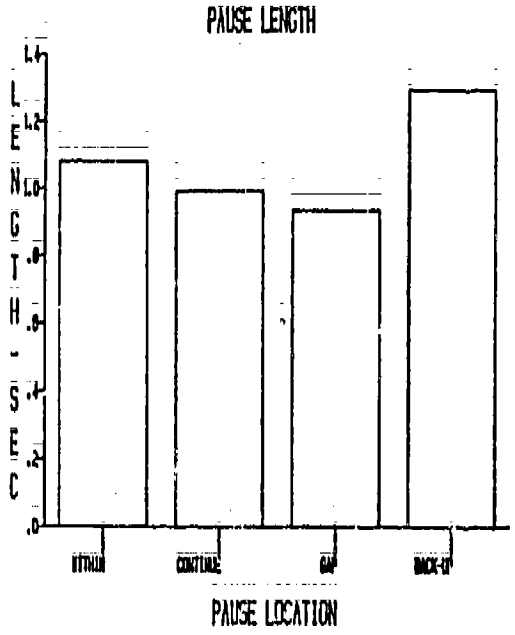
Figure 3: The mean number and a mean length (in seconds) of pauses within- and between-clauses during oral retellings in The Pear Stories (Chafe, 1982).

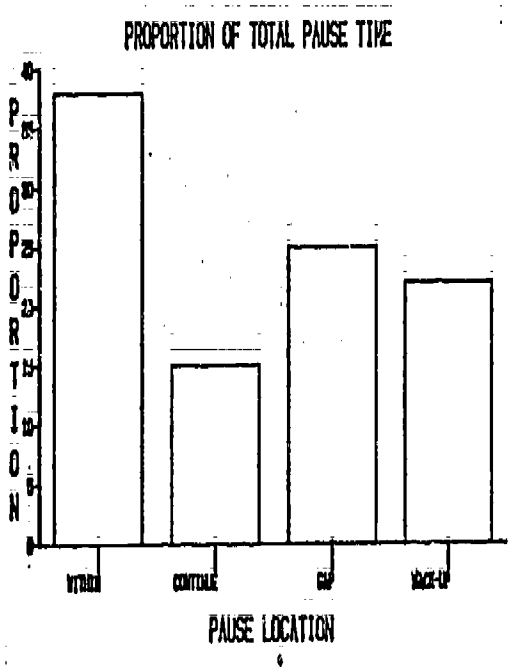
Figure 4: The percent of the total pause time for pauses within- and between-clauses during oral retellings in The Pear Stories (Chafe, 1982).

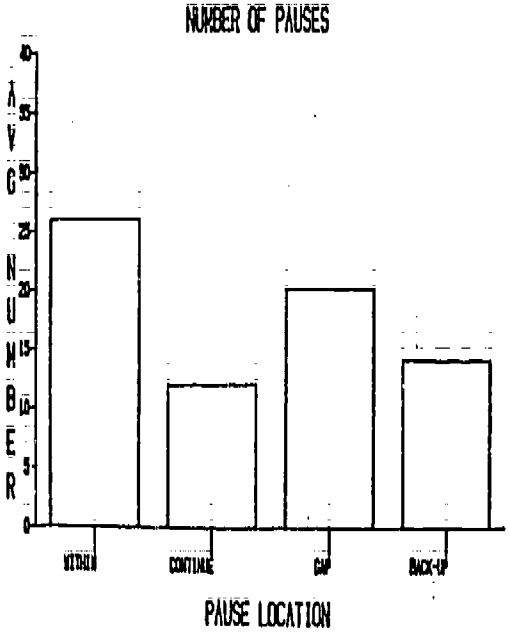

Stated Links
Links
Actions
Mental States
Physical States
TWO THREE FOUR FIVE SIX SEVEN EIGHT NINE TEN
Age in Years


Types of Causal Links
Causal Links
Enablements
Resultants
Initiations
Motivations
TWO THREE FOUR FIVE SIX SEVEN EIGHT NINE TEN
Age in Years


Inferred Links
Links
Physical States
Actions
Mental States
TWO THREE FOUR FIVE SIX SEVEN EIGHT NINE TEN
Age in Years


PAUSE LENGTH
LENGTH-SEC
WITHIN
CONTINUE
GAP
BACK-UP
PAUSE LOCATION


PROPORTION OF TOTAL PAUSE TIME
PROPORTION
WITHIN
CONTINUE
GAP
BACK-UP
PAUSE LOCATION


NUMBER OF PAUSES
AVG NUMBER
WITHIN
CONTINUE
GAP
BACK-UP
PAUSE LOCATION