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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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 (Grasser, 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 shown 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.

The Classification of Clauses

In the second step of the analysis of texts as event chains, each clause 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 obligatorily 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 chain 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 determining the readability 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 (Greenser, 1981; Sanford & Gardner, 1981; Schank & Abelson, 1977). Comprehension, then, in this approach involves an active process of constructing 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 inference 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
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’ passes. 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.

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 data 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 chain. Each event chain 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.

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
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Is 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

Of the storyteller is also negatively correlated with the number of words in the narrative. Thus older children tell fewer inferences than those told by the younger children. The four year olds, but contained, proportionally, more long stories involved more stated actions, inferred physical states, and inferred mental states per 100 words shorter narratives.

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 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
For such that there is a back-up or regression to a causally-connected chain of events. These junctures, reflecting the linear projection of a causally-connected chain of events, are determined by the content and organization of the text. These junctures are also significant in the production of the text. Consequently, pauses between clauses during the re-telling may occur. To investigate this possibility, pauses at between-clause junctures were examined.

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

For each re-telling of the film was parsed into a causal event chain. Vagaries in the oral versions were resolved by reference to the original film. A single judge parsed the 12 re-tellings. A second judge independently parsed four. The judges agreed 93% of the stated actions, physical states, and 80% of the inferred causal links. Each pause, as in the original transcripts, was classified as either occurring within a cause or between two clauses. The between-clause pauses were identified as occurring 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 90% of the time. Examples of the four types of pauses are given in Table 5.

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**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.

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Pauses were more likely to occur between clauses than within clauses, \( \chi^2(1) = 7.84, p < .01 \). Of the between-clause pauses, those at continuations of the event chain were less likely than those at the two types of discontinuities, \( \chi^2(1) = 15.25, p < .01 \). However, pauses at gaps in the event chains were as likely as pauses at back-ups to prior causal links, \( \chi^2(1) = 1.71, p > .10 \).
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 reordered as the story is told. One consequence is that speakers pause while telling the story between links in the event chain. The between-clause 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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<th>Author</th>
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<td>Lorge, I.</td>
<td>Predicting the reading difficulty of selections for children.</td>
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Acknowledgements

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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 AB/ by holding onto a handrail. A9/ Many are unable MS10/ to step over a low A13/ and into a cabin. A11/ They enter A12/ by sitting on the doormat 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 ridiculous 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 six feet tall standing on the other slab, although the two slabs are really on the same level. It is the guess of Einstein and many other scientists that gravity is pulling harder at that spot.
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Table 2
The Best Regression Equation for Measuring the Inference Load of a Text

C_0 = 0.92
p
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

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<td>-.86</td>
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<td>Inferred Mental States</td>
<td>.23</td>
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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
A5 He was attacked by a monster
PS3 He got in his ship
A6 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 the 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 sting rays
A9 A ray was going after Josh
A10 A shark chased the sting ray
A11 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

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 MERGED 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
A11→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.

\[ C = 0.07 \]
\[ P \]
\[ R^2 = .75 \]

multiple \( R = .87 \)

adjusted \( R = .70 \)

residual mean square = 2.11

standard error of the estimate = 1.45

\[ F(5.48) = 12.85, p < .001 \]

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<td>Inverse Word Length</td>
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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, -5- looks at the bushes...

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)...

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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

Inferred Links

Types of Causal Links