The Effects of Causal Connections on Memory of Discourse

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Suh & Trabasso(1993) has shown that readers integrate sentences through causal inferences at the points predicted by the Causal Network Model(Trabasso, van den Broek, & Suh, 1989). The purpose of the present study is to find out whether the causal connections confirmed by Suh & Trabasso remain in a stable representation of a discourse and affect its recall. For this, subjects read and recalled two versions of stories which were similar in their surface content but very different in their causal network structures. It was found that the subjects' recall was better for the sentences that had more causal connections according to the Causal Network Model. In conclusion, causal integrations that occur during on-line reading remain in a stable representation of a discourse and affect the recall of the discourse later.

Introduction

Studies about understanding and remembering of a discourse have reported that causal relations are very important in creating a coherent representation of a discourse. According to the studies, readers interpret the statements of a discourse based on the causal relations between the events and states described in the statements (Schank, 1975; Trabasso, Secco, & van den Broek, 1984, Fletcher & Bloom, 1989; van den Broek & Lorch, 1993).

Specifically, Trabasso and his colleagues proposed a model in which the representation of a discourse is expressed in terms of a network of causal relations.(Trabasso, Secco, & van den Broek, 1984; Trabasso & Sperry, 1985; Trabasso, van den Broek, & Suh, 1989). According to their Causal Network Model, people identify causal relations between the events and states described in the sentences and integrate the sentences.
based on the causal relations. Thus, the representation that is created after reading a discourse forms a network where the nodes refer to the sentences and the links between the nodes refer to the causal relations between the sentences (c.f. Trabasso, van den Broek & Suh, 1989).

Fig 1. Unit Causal Network

Causal Network Model proposed that all the narratives can be represented as a combination of unit networks shown in Figure 1. In the figure, 'S' stands for 'Setting', 'E' for 'Initiating event', 'G' for 'Goal', 'A' for 'Attempt', 'O' for 'Outcome', and 'R' for 'Response'. The subscripts i and j respectively refer to the ith episode and jth statement within an episode. For example, the story in Table 1 can be represented with one unit network as in Figure 2.

Table 1  Single episode story: Cheolsoo story

<table>
<thead>
<tr>
<th></th>
<th>Single episode story: Cheolsoo story</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>Once there was a boy named Cheolsoo.</td>
</tr>
<tr>
<td>E1</td>
<td>One day, Cheolsoo saw his friend Junghee riding a new bike.</td>
</tr>
<tr>
<td>G1</td>
<td>Cheolsoo wanted to have a bike.</td>
</tr>
<tr>
<td>A1</td>
<td>He asked his mom to buy a bike.</td>
</tr>
<tr>
<td>O1</td>
<td>His mother bought a bike for Cheolsoo.</td>
</tr>
<tr>
<td>R1</td>
<td>Cheolsoo was very happy.</td>
</tr>
</tbody>
</table>
S1 --> { E1 --> G1 --> A1 --> O1 --> R1 }

Fig 2. Causal Network of Cheolsoo Story

More complex stories can be generated and represented through repetitions and recursions of goals, attempts, and outcomes. The category that is most important in determining structures of stories is goal statement. Once a goal is set up in a narrative, following attempts are interpreted as the attempts to achieve the goal and following outcome is regarded as a statement describing whether the goal has been successfully achieved or not. Depending upon the success or failure of the goal achievement, the following episode is either about a new goal or the original goal.

The two versions of stories that Suh & Trabasso(1993) used in their study nicely demonstrate the variation of network structures depending on success vs. failure of goal achievement. They constructed two versions of stories as shown in Table 2. The numbers after the category notation refer to the episode number. When there are more than one statement of the same category in an episode, lower case alphabets are used to refer to the statements.

The two version are the same except for the three sentences marked with * sign next to them. Therefore, the two versions of the story are very similar in their surface contents. On the other hand, the network representations generated according to the Causal Network Model are very different for the two versions as shown in Figure 3. The difference of the network representations arises mainly from whether Jimmy's goal of getting a bike succeeds or fails. In the first version, Jimmy talked to his mother but his mother refused to buy a bike for him. Therefore, Jimmy decided to earn money, earned money by delivering groceries, and eventually went to a department store to buy a bike. These goals and actions are regarded as subgoals and attempts to achieve the higher goal of getting a bike. This structure is called hierarchical structure in the sense
that the goals have hierarchical relationship to each other. On the other hand, in the second version, Jimmy's goal of getting a bike is achieved by his mother's buying him a bike. The same goal of earning money and actions of going to the department store are not perceived as for getting a bike anymore. The goal of getting a bike and earning money has only sequential relations, and this structure is called sequential version. These perceived causal relations are expressed in the networks of Figure 3.

Table 2. Jimmy story

a) Hierarchical version

<table>
<thead>
<tr>
<th>Event</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI</td>
<td>Once there was a boy named Jimmy.</td>
</tr>
<tr>
<td>EI</td>
<td>One day, Jimmy saw his friend Tom riding a new bike.</td>
</tr>
<tr>
<td>GI</td>
<td>Jimmy wanted to buy a bike.</td>
</tr>
<tr>
<td>A1</td>
<td>He spoke to his mother.</td>
</tr>
<tr>
<td>O1</td>
<td>His mother refused to get a bike for him. (*)</td>
</tr>
<tr>
<td>R1</td>
<td>Jimmy was very sad. (*)</td>
</tr>
<tr>
<td>E2</td>
<td>Next day, his mother told him that he should have his own savings.</td>
</tr>
<tr>
<td>G2</td>
<td>Jimmy wanted to earn some money.</td>
</tr>
<tr>
<td>A2a</td>
<td>He asked for a job at a nearby grocery store.</td>
</tr>
<tr>
<td>A2b</td>
<td>He made deliveries for the grocery store.</td>
</tr>
<tr>
<td>O2</td>
<td>Jimmy earned a lot of money.</td>
</tr>
<tr>
<td>A3a</td>
<td>Jimmy went to the department store.</td>
</tr>
<tr>
<td>A3b</td>
<td>Jimmy walked to the second floor.</td>
</tr>
<tr>
<td>O3</td>
<td>Jimmy bought a new bike. (*)</td>
</tr>
</tbody>
</table>

b) Sequential version

<table>
<thead>
<tr>
<th>Event</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI</td>
<td>Once there was a boy named Jimmy.</td>
</tr>
<tr>
<td>EI</td>
<td>One day, Jimmy saw his friend Tom riding a new bike.</td>
</tr>
<tr>
<td>GI</td>
<td>Jimmy wanted to buy a bike.</td>
</tr>
<tr>
<td>A1</td>
<td>He spoke to his mother.</td>
</tr>
<tr>
<td>O1</td>
<td>His mother got a bike for him. (*)</td>
</tr>
<tr>
<td>R1</td>
<td>Jimmy was very happy. (*)</td>
</tr>
<tr>
<td>E2</td>
<td>Next day, his mother told him that he should have his own savings.</td>
</tr>
<tr>
<td>G2</td>
<td>Jimmy wanted to earn some money.</td>
</tr>
</tbody>
</table>
A2a He asked for a job at a nearby grocery store.
A2b He made deliveries for the grocery store.
O2 Jimmy earned a lot of money.
A3a He went to the department store.
A3b He walked to the second floor.
O3 Jimmy bought a new basketball. (*)

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**Fig 3.** Causal networks of Jimmy story
Suh and Trabasso (1993) tried to confirm whether the two versions with similar surface contents are indeed understood and represented as drastically different causal networks as predicted by Causal Network Model. The main differences between the two structures lie in whether the goal sentence G1 is connected to G2, A3a, or A3b. Thus, they tried to confirm the connections between those sentences by testing whether the content of G1 is activated right after G2, A3a, or A3b. In order to do this, while subjects read each sentence at their own pace, a probe containing a key word from G1 ('bike' in the case of Jimmy story) was presented right after G2, A3a, or A3b. Subjects had to decide whether the probe word was from the sentences that they had been reading or not. It was found that goal probe recognition was faster in the hierarchical version than in the sequential version after G2, A3a, and A3b as predicted. These results were interpreted as suggesting that the goal concept was activated after these sentences in the hierarchical version but not in the sequential version. Furthermore, probe recognition was not faster in the hierarchical version after A2a and A2b which are regarded as attempts for the subgoal G2. These results also supported the prediction of the Causal Network Model that assumed causal connection of attempts are made for the immediate goal but not for the superordinate goal.

While Suh and Trabasso (1993) showed that the causal connections are made during on-line reading as proposed by Causal Network Model, the purpose of the present study is to investigate whether those causal connections affect recall of the discourse. If the causal connections are to affect recall, they should remain in a stable memory representation after reading of the discourse is completed.

Previous studies on reading comprehension have indicated that the inferences and connections that occur during on-line reading do not necessarily remain in the memory representation of the discourse to affect later recall and recognition. For example, Potts, Keenan and Golding (1988) have shown that predictive inferences occur during on-line
reading when there are enough contextual information. However, when the content of the predictive inference was tested after some delay the activation disappeared. Based on their findings, Potts et. al. claimed that predictive inferences are not included in the stable memory representation of a discourse. Cook, Limber, and O'Brien(2001) also showed that the concepts activated by predictive inferences were no longer activated several sentences later, leading to the same conclusion as that of Potts et.al.(1988).

The kind of inference that were suggested to occur during reading but not to be included in the representation by Potts et. al. and Cook et. al. was predictive inference. Predictive inference is regarded as elaborative inference in the sense that it is not required to achieve a coherent representation of a discourse. Besides, the contents of predictive inference may or may not turn out to be true in the story. On the other hand, causal inferences help make a coherent representation. Therefore, causal inferences are more likely to remain in the memory representation.

Even if causal connections remain in the memory representation of a discourse, it is not clear how they affect recall. Two hypotheses are considered about this issue in the present study. The first hypothesis, claimed by Trabasso and his colleagues, proposes that the statements with more number of connections are recalled better. In exploring about how the characteristics of causal network affect recall, Trabasso and his colleagues could confirm in several studies that the sentences with more causal connections were recalled better (Trabasso, Secco, & van den Broek, 1984; Trabasso & van den Broek, 1985). The reason for better recall could be that more number of connections provide more paths to access the statement, leading to better recall.

The fact that the number of connections matters implies that the direction of causal inference does not matter. That is, both the antecedent and the consequence in the causal pair were supposed to be remembered better as long as they are connected. However, the processes of causal
connections implicated by Suh and Trabasso (1993) are certainly involved with directionality of causal inferences. Therefore, based on Suh and Trabasso, a different hypothesis can be made.

In Suh and Trabasso (1993), it was assumed that the goal, which is the antecedent, is reinstated and activated when the connected subgoal or attempt, which is the consequence, is read. Thus, the first goal, G1, of the hierarchical version gets to be reinstated and activated several times throughout the reading of the story. These repeated reinstatements of the goal imply that the goal stays in working memory longer in the hierarchical version. Kintsch (1978) found that the propositions that were assumed to stay longer in working memory according to his Leading-edge Model were recalled better later. In that sense, G1 is likely to be recalled better in the hierarchical version.

However, this explanation does not apply to the subgoal or attempt statements that are connected to G1 as consequences, because they are not assumed to be reinstated more in the hierarchical version. Therefore, the processing assumptions in Suh and Trabasso predict that while G1 will be recalled better in the hierarchical version the subgoal G2 and attempts A3a and A3b will not be.

The present study is going to test these two hypotheses. The first hypothesis assumes that both the antecedent and consequence of a causal connection are recalled better, predicting that G1, G2, and other connected statements would be recalled better. The second hypothesis assumes that only the antecedent that is reinstated is recalled better, predicting that only G1 will be recalled better in the hierarchical version.

Although Trabasso and his colleagues found that the statements with more number of connections are recalled better, their studies were mostly based on regression analysis rather than experimental controls. The present study uses the stories that are controlled in their surface content and will be able to provide more clear answer to this issue.
Experiment

In order to investigate whether the causal connections that were shown to occur during on-line reading by Suh and Trabasso (1993) remain in the memory representation of a discourse and how they affect recall, subjects were asked to read and recall the stories that were used by Suh and Trabasso.

Discussions of recall will be made in several categories. First, recall of the whole story will be considered. Recall of the whole story may have different result than recall of individual sentences in respect to the number of connections. Second, recall of the two goals will be examined. Third, recall of the rest of the sentences will be examined in two parts. The first part refers to the statements of the first episode excluding G1. In Jimmy story of Table 2, the first part includes A1, O1, and R1. The second part refers the rest of the statements excluding G2. The first part and the second part differ in terms of the connections with G1 in two version. In the first part, two versions are the same in terms of the connections between G1 and the sentences in that part. In the second part, however, G1 has more connections to the sentences of the hierarchical version than those of the sequential version.

If the activations of goals shown in Suh and Trabasso (1993) were made only at the time of reading but would not remain in the memory representation, the recall patterns of two versions would not be different for any category.

If the sentences can be remembered better with more number of connections as claimed by Trabasso and his colleagues, the hierarchical version would be recalled better than the sequential version as a whole because the hierarchical version has more number of connections. As for goal sentences, G1 and G2 have more number of connections in the hierarchical version than in the sequential version and are more likely to be recalled better. As for the two parts, the two versions are not different in the number of connections in the first part, whereas they are different in
the second part. Thus, better recall will be found only for the second part.

If better recall is made only when the sentence is reactivated, then G1 is likely to be recalled better in the hierarchical version than in the sequential version. However, G2 and other sentences are not likely to be recalled better in the hierarchical version because they are not assumed be reactivated more in the hierarchical version.

Method

Subjects. 28 college students from Seoul National University and Sungshin Womens University participated in the experiment. They were all native speakers of Korean.

Materials. For experimental stories, eight stories that were used by Suh and Trabasso (1993) were translated from English into Korean. Each story has hierarchical and sequential version. The hierarchical version has a structure where the attempts for the first goal failed and a subgoal is set up to achieve the first goal. After the subgoal is achieved through the attempts for it, the first goal is finally achieved. In the sequential version, the first goal is achieved early in the first episode. After the first episode, the rest of the sentences are the same as those in the hierarchical version except for the last outcome sentence. (cf. Suh & Trabasso, 1993). The number of sentences in experimental stories is between 13 and 18. Other than experimental stories, 4 filler stories were used. The filler stories were used so that the subjects would not notice the regularities of the story structures of hierarchical and sequential versions. The structures of the filler stories were varied without any particular rules but were similar to the experimental stories in their length and level of difficulty.

Procedure. Subjects were given a booklet containing 8 experimental stories and 4 filler stories. Each subject read 4 hierarchical versions and 4
sequential versions of experimental stories. Stories that each subject read were systematically varied for versions using Latin Square. The 12 stories were presented in random order.

In the booklet, one story was written in one page. Subjects were asked to read the stories in the order presented at their own pace and not to go back to the part already read. After subjects completed reading the stories, they performed an arithmetic task for 5 minutes in order to remove the information of the stories from the working memory. After that, subjects recalled and wrote down the experimental stories in the booklet. In each page of the booklet, the setting statement and initiating event statement were given as a recall cue. For example, in the case of Jimmy story in Table 2, the recall cue was 'Once there was a boy named Jimmy. One day, jimmy saw his friend Tom riding a new bike.' Subjects were asked to recall the sentences that follow the cue sentences and write down as closely as they can.

Results

Subjects recall was scored by individual sentences. Whether a certain sentence was recalled or not was decided by whether the main proposition was recalled. For example, when the sentence to be recalled was 'Jimmy made deliveries at a grocery store', responses that include 'Jimmy made deliveries' or 'Jimmy delivered' were judged to be correct recalls of the sentence.

Table 3 shows recall rates for the whole story, G1, G2, the first part, and the second part.
Table 3. Recall in two versions

<table>
<thead>
<tr>
<th></th>
<th>Hierarchical version</th>
<th>Sequential version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole story</td>
<td>7.39</td>
<td>6.25</td>
</tr>
<tr>
<td>G1</td>
<td>.64</td>
<td>.52</td>
</tr>
<tr>
<td>G2</td>
<td>.49</td>
<td>.37</td>
</tr>
<tr>
<td>First part(A1, O1, R1)</td>
<td>1.70</td>
<td>1.80</td>
</tr>
<tr>
<td>Second part(A2a-O3)</td>
<td>4.55</td>
<td>3.56</td>
</tr>
</tbody>
</table>

For the whole story, an average of 7.39 sentences were recalled in the hierarchical condition whereas 6.25 sentences were recalled in the sequential version. This difference was statistically significant (F(1,222)=8.5, p <.01).

Recall of G1 was .64 and .52 in the hierarchical and sequential version, respectively. The difference was marginally significant (F(1,122)=3.12, .05< p <.1). A significant difference was expected based on both the number of connections hypothesis and activation hypothesis. The difference was found in the right direction but it was only marginally significant.

Recall of G2 was .49 in the hierarchical version and .37 in the sequential version. The difference was expected by the number of connections hypothesis but not by the activation hypothesis. It turned out that the difference was marginally significant again.

Recall of other sentences than goals was examined. Recall of the first part was found to be 1.70 for the hierarchical version and 1.80 for the sequential version. This difference was not significant (F(1,222)=.30, p >.10). This result was expected by both hypotheses since the number of connections of this part was not different between versions.

Recall of the second part was 4.55 in the hierarchical version and 3.56 in the sequential version, whose difference was significant (F(1,222)=16.43, p<.001). The difference was expected by the number of
connections hypothesis but not by the activation hypothesis.

Discussion

In the present study, different recall patterns were found between two versions. They suggest that the causal inferences between goal sentences and other sentences that were shown to occur by Suh and Trabasso (1993) remain in a stable memory representation of a story. Those causal connections do not disappear after a momentary activation but are retained in the representation of stories to affect recall.

The results support the predictions based on the number of causal connections with remarkable precision. The number of connections hypothesis predicted better recall in the hierarchical version for all the categories except for the first part of the story where the two version are not different. Although the predicted differences of the goal sentences were found to be only marginally significant, this marginality can be understood considering the fact that the dependent variable of recall was either 1 or 0, which led to large variances. Except for the recall rate of the first part, recall was found to be higher for the hierarchical version than in the sequential version.

The hypothesis that better recall is made when the statement is reinstated and reactivated predicted that only G1 will be recalled better in the hierarchical version than in the sequential version. This prediction was not supported because other statements than G1 were recalled better in the hierarchical version.

Then, why does causal connection bring about improvement of recall? As mentioned earlier, more number of connections may provide more paths to access the statement, leading to better recall. Another possibility is that the raised activation of G1 in the hierarchical version is transferred into those sentences directly connected to G1 at some point. These possibilities need to be explored with further researches.

The experiments of Suh and Trabasso (1993) were conducted to native
speakers of English with stories in English language. On the other hand, 
the present study used Korean subjects and stories in Korean translated 
from Suh and Trabasso(1993). Unlike word recognition or syntactic 
processing, there has not been many cross-cultural studies on the effects of 
language differences in discourse processing. One may suspect that there 
are not much effects of language differences in text level of processing. 
However, considering individual differences in inferences reported by 
several studies(Lee, Kim, Kim & Yoo, 1999; Long, Oppy, & Seely, 1997; 
Long, Oppy, & Seely, 1994), there could be processing differences 
depending on different languages. Although converging evidence between 
the present study and the studies by Trabasso & his colleagues(Trabasso, 
Secco, & van den Broek, 1984; Trabasso & van den Broek, 1985) supports 
the assumption that the speakers of two languages go through the same 
processing, future studies with the same language would be desirable.

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