PRIMED RECOGNITION OF CAUSALLY RELATED SENTENCES AND RETRIEVAL DIRECTIONALITY

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ABSTRACT

To investigate the characteristics of comprehension processes, representational structure, and retrieval directionality of causally related sentences, three experiments were conducted. In Experiment 1, it was found that causally related sentences were primed faster than sentences causally unrelated. Experiment 2 showed the following results; (a) reading times for the second sentences in causally related sentence pairs were longer than the first sentences, (b) this was more apparent in Backward causal order input than in Forward causal order input, (c) there was a clear retrieval asymmetry in Forward input but not in Backward input, and (d) when the input and primed-recognition-test causal orders matched, sentences were primed faster than if they were mismatched. In Experiment 3, the reading and recognition time gains with causal context were obtained. Experiment 3 supported the findings in Experiment 2. The results of the three experiments were interpreted as supporting the view that causally related sentences are processed more deeply, stored in closely integrated units, retrieved faster in forward order retrieval, and that priming is a better method of investigating these features than are recall measures.

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Understanding a text is primarily the process of understanding the relations among the text elements, and the problem of understanding the relationship among text elements can be seen largely as the problem of establishing causal chains across series of sentences. The importance of establishing causal chains for understanding text and constructing coherent representations has been pointed out by many researchers (e.g., Schank, 1975, 1976; Schank & Abelson, 1977; Warren, Nicholas, & Trabasso, 1979; van Dijk & Kintsch, 1983; Trabasso, Secco, & van den Broek, 1984; Black, 1985). Trabasso (1981) argued that understanding and representing a story is essentially a chronology of alternating events and states with causal links and that this representation in terms of a causal chain is then used to perform a variety of operations such as recalling, summarizing, recognizing, question answering, and so forth. He assumes that without this causal representation, all these operations would not be possible.

If this is the case, then how do we infer or process causal relation information, and in what way does the processing of causal information affect our understanding, recalling, and recognizing the text and question-answering of the text?

Several studies have been done on how we could incorporate the CAUSAL concept in memory structure models and on how it could affect our comprehension and memory performance. Schank (1975), Lehnert (1978), Mandler and Johnson (1977), Stein and Glenn (1979), Black and Bower (1980), Omanson (1982), Graesser (1981) and Graesser and Goodman (1985) have all proposed possible ways of representing the causal concept as a key feature in memory structure. Trabasso et al. (1984) further presented a model of a non-linear causal network with a non-intuitive but logical definition of causal relations.

On the question of how CAUSAL relation concept in text affects our comprehension and memory of the text, several studies have been done on the effect of causal concept processing on reading time (Haberlandt & Bingham, 1978; Keenan, Baillet, & Brown, 1984), question answering (Stein & Glenn, 1979; Lehnert, 1980; Trabasso, Stein, & Johnson, 1981), summarization (Omanson, 1982; van den Broek & Trabasso, in press), inferencing (Trabasso, 1981; Warren et al., 1979; Singer, 1983), and importance rating (Trabasso & Sperry, in press; van den Broek & Trabasso, in press).

Many more studies have focussed on the effect of causal concept processing on recall of the text and on its relationship to comprehension.

Black and Bern (1981) reported that story sentences with closer causal chains were free- and cued-recalled better. Black and Bower (1980) reported that causally related sentences, which were represented with critical paths, were recalled better. Bradshaw and Anderson (1982) showed that central items from the causally related sentence sets were learned faster and recalled better. Haberlandt and Bingham (1978) reported that causally related sentences were read faster than the causally unrelated sentences. Lee (1979) reported that theme words of causal paragraphs were recalled better than those of additive (non-causal) paragraphs. He also showed that with causal paragraphs, the increasing number of input sentences had a greater positive effect on the recall of theme words, while with causally unrelated sentence paragraphs or with defining sentence paragraphs, the effect was much smaller. Lee (1981) also indicated that causally related paragraph sentences tended to be recalled in an all-or-none fashion while noncausal paragraphs in a piece-meal fashion. Keenan, Baillet, and Brown (1984) reported that sentences with greater causal relatedness were read faster. Mandler and Johnson (1977) reported that episodes with CAUSE connections were recalled better than episodes with non-causal TEMPORAL and AND THEN connections. Trabasso et al. (1984) reported that events with more causal connections or events on causal chains were recalled better than those with less causal connections or those not on causal chains.

Yet the data obtained by using recall measures leave some questions unanswered. Studies with recall measures have not shown clearly whether causally related information is stored together in close connection, or whether causal information is retrieved faster than non-causal information, or whether retrieval directionality of causal information is symmetrical or asymmetrical, or how we process, represent and retrieve the causal information that unfolds in unnatural backward order.

These features could be better captured and understood by employing recognition time measures. Not many studies have been done, however, on recognition of causal information. The work by Keenan et al. (1984) was an exception. Furthermore, no experimental studies have been done to investigate the characteristics of causal information representation and its retrieval by using a primed recognition method, which as McKoon and Ratcliff (1980) pointed out, is a better way of investigating the characteristics of memory representation and its effects on retrieval.

This problem of the insufficiency of recall measures to answer some questions is more apparent in the issue of retrieval directionality of causally related information. As Werner and Kaplan (1963) argued, proceeding from cause to consequence should be the normal direction of retrieval rather than proceeding in a backwards fashion. If we take this view, we could argue that retrieving in a forward direction (from CAUSE to RESULT) of causally related information should be better than retrieving in a backwards direction (from RESULT to CAUSE). However, the results of Black and Bern (1981) and Bradshaw and Anderson (1982) have not borne out this intuitive expectation. Black and Bern reported that the number of recalled sentences was equal for the forward cued-recall condition and for the backward cued-recall condition. Bradshaw and Anderson reported that the target sentences presented as CAUSE ('Resulted-in' condition in their study) sentences were recalled slightly but not significantly better than the target sentences presented as RESULT (°Caused-by' condition) sentences. These results of symmetry or bi-directionality seem counter-intuitive and contrary to Werner and Kaplan's argument.

The reason the above two studies did not obtain the results of possible asymmetry could be found in the insensitivity of the recall measures to detailed memory processes. As discussed above, McKoon and Ratcliff (1980a, 1980b) pointed out the insensitivity of recall measures and showed that the primed recognition is a better method of investigating some memory processes. If we would follow this argument and employ a primed recognition measure, we might obtain some evidence of asymmetry in the retrieval of causally related information.

The present study was an attempt to investigate, by employing the primed recognition time measure, whether causally related sentences are stored in closer connection and retrieved faster than causally unrelated paragraph sentences, and whether retrieval of causally related information is symmetrical or asymmetrical in directionality. In addition to this, the study also investigated how we process causal information when the direction of causation mismatches with the normal forward CAUSE-->RESULT order; that is, how we process causally related sentences if the cause and result sentences are presented in backward order of RESULT-->CAUSE, and how this affects the retrieval of the causal information.

In Experiment I we investigated whether a difference in the representation structure of causally related and unrelated information gets reflected in primed recognition latencies. In Experiment II it was investigated whether the directionality in retrieving causally related sentences is symmetrical or not, and whether Backwards causal order input has any effect on comprehending and retrieving the causally related sentences. In Experiment III we examined how much reaction time is gained by presenting sentences in a causal relation context rather than in a random unrelated context.

EXPERIMENT 1

In this experiment it was investigated whether causally related sentences are represented in close connection and retrieved faster than causally non-related sentences. McKoon and Ratcliff (1980a, 1985) argued that priming is a particularly effective procedure for investigating the structure of paragraphs in memory. It was argued (McKoon & Ratcliff, 1980b) that priming effects could show whether successively tested items were closely connected in memory. If the connection between two items A and B was stored in the memory representation of the text, then item A should prime item B. McKoon and Ratcliff reported that when subjects were asked to verify, i.e., recognize whether the proposition of a test sentence was true according to paragraphs they had studied, they responded faster if the test sentence or item was primed by a closely connected sentence.

If we assume that causally related sentences are stored in memory in a more closely connected unit than causally unrelated sentences and that the priming method effectively reflects the representation structure, then we can predict that primed recognition or verification of a test sentence will be faster if the sentence is preceded by a causally related sentence in the same paragraph than if it is preceded by a causally unrelated sentence. This prediction was investigated by presenting CAUSAL paragraph sentences and NON-CAUSAL (ADDITIVE) paragraph sentences, and then testing the recognition of target sentences using a priming method.

METHOD

SUBJECTS. Forty Introductory Psychology students at Korea University participated in the experiment in partial fulfillment of the course requirements. They were run individually or in pairs.

DESIGN. The experiment was a one-way within subjects design. Type of paragraph was the only variable with two levels; namely CAUSAL paragraphs and ADDITIVE (NON-CAUSAL)paragraphs.

MATERIALS. Based on Lee (1979), forty theme words were selected and two different types of story paragraphs were constructed for each theme word. One paragraph was of CAUSAL type and the other was of ADDITIVE type. Each paragraph consisted of four sentences with five to seven words per sentence. The CAUSAL paragraph and the ADDITIVE paragraph for each theme word were exactly the same, except that the third sentence (in some cases two sentences: the second and the third sentences) in the CAUSAL paragraph was constructed such that subjects could easily infer a causal relation between the third and fourth sentence. On the other hand, the third sentence in the ADDITIVE paragraph was constructed such that subjects could not infer such a causal relation. The classification into CAUSAL paragraphs and ADDITIVE paragraphs was made based on agreement among three independent raters. If all three raters agreed that the third and the fourth sentences could be connected by employing one of Halliday & Hassan's (1976) CAUSATIVE conjunctions (e.g., 'because', 'so', 'as a result of', 'in consequence of') then the paragraph was termed a CAUSAL paragraph. If the two sentences can be connected by employing Halliday & Hassan's ADDITIVE conjunctions (e.g., 'and', 'or', 'and then', 'further'), then the paragraph was defined as an ADDITIVE (NONCAUSAL) paragraph. The conjunctions were not given explicitly in both paragraphs, thereby forcing the subjects in the experiment to generate these conjunctions implicitly in their effort to connect the sentences. All of the paragraph sentences were given in Korean.

In addition to these 40 sets of CAUSAL and ADDITIVE paragraphs, forty filler paragraphs and twenty practice paragraphs were constructed. Each of these paragraphs told about something other than the 40 theme words used in CAUSAL and ADDITIVE (NON-CAUSAL) paragraphs. The sentences in these paragraphs were unrelated to the sentences in the CAUSAL and ADDITIVE paragraphs. Some of the filler and practice paragraphs had causal connections between sentences, while some did not. Each subject was shown twenty CAUSAL paragraphs (20 theme words), 20 ADDITIVE paragraphs (the other 20 theme words), 40 filler paragraphs, and 20 practice paragraphs. Two study lists were constructed. Each list consisted of twenty CAUSAL paragraphs for the first twenty theme words, twenty ADDITIVE paragraphs for the remaining theme words, and forty filler paragraphs. The two lists differed only in that the paragraph for the same theme word was CAUSAL in one list while ADDITIVE in the other. Each subject was presented with one of the lists. For each paragraph in the lists, six test sentences were further constructed: Two were sentences totally unrelated to the paragraph sentences, two were sentences that had the same meaning as the two (the third and fourth) sentences of the paragraph (these were made by deleting an unimportant adjective or adverb from the paragraph sentences), and the other two were sentences that were related to the paragraph sentences but with different meanings (these were constructed by replacing a key-noun, verb, or adjective).

PROCEDURE. Subjects were presented with forty-eight study-test trials, including eight practice trials. In each trial subjects first studied two paragraphs (any combination of CAUSAL, ADDITIVE, and FILLER paragraphs). The eight sentences of the two paragraphs were shown simultaneously for 14 seconds. Then in the test phase, twelve test sentences (six test sentences for each paragraph studied) were presented one by one. The order of presentation of the test sentences was random except that the SAME MEANING test sentences for one paragraph were presented in such a way that the priming test sentence (the third sentence of a studied paragraph) came before the primed test sentences (the fourth target sentence of the same studied paragraph).

No primed sentence appeared in the first, second, or third position of the twelve test sentences. No test sentence of one target paragraph was immediately followed by a test sentence from another paragraph. All the sentences in the study phase and in the test phase were presented by an APPLE II computer with Korean Alphabet ROM card. Subjects were instructed to read a pair of paragraphs presented during the study phase, then to read each of the test sentences presented one by one, and to respond, by pressing the key '/' or 'z', 'yes' or 'no', to indicate whether the test sentence had the same meaning as one of the studied paragraph sentences. They were told to respond as fast as possible. After the experimenter had read aloud the above instruction which appeared on the CRT screen, the computer sounded a bell three times in close succession, and then -- 2.50 seconds after the last bell sounded -- two paragraphs (eight sentences) were displayed at the same time for 14 seconds. Then the display disappeared, a bell sounded, and 220 msec later a test sentence appeared at the center of the screen. The presentation of the twelve test sentences was self-paced by the subjects. Once a subject had made either a 'yes' or 'no' key response to a test sentence, the test sentence disappeared immediately, and 240 msec later the next test sentence appeared at the center of the screen until the subject pressed a key. After the last test sentence was responded to, the bell was sounded three times in close succession. Then the next two paragraphs were displayed and the new study-test trial began. There were fifty study-test trials including ten practice trials. Each subject saw 1000 sentences in total: 160 target sentences (4 sentences per paragraph X (20 CAUSAL plus 20 ADDITIVE paragraphs)), 160 filler sentences (40 paragraphs), 480 test sentences (6 sentences X (40 target paragraphs and 40 filler paragraphs)), and 200 practice sentences (8 practice study sentences and 12 practice test sentences for each of

10 exercise trials). Each response time was recorded automatically by the computer.

Results

Only the latencies of correct responses to the test sentences were analyzed. In addition to this, the following were excluded from the analysis: 1) reaction times greater than 5 secs., 2) those shorter than 200 msecs, and 3) those longer than 2.5 standard deviations from the mean reaction time of the subject. The proportion of the excluded reaction times was 1.3% of total responses. The mean reaction time for CAUSAL paragraphs was 981.8 msecs., and that for ADDITIVE paragraphs was 1017.9 msec.. This difference was significant ($F(1,1334)=5.90$, $MSe=74602.49$, $p<.05$). The error term included subject variance and material variance. The error rate was 6.6% for both of the paragraph types.

DISCUSSION

As predicted, the results showed that the sentences from the CAUSAL paragraphs were responded to faster than those from the non-causal ADDITIVE paragraphs. That is, the test sentence that had the same meaning as the fourth sentence of a studied paragraph was correctly recognized (i.e., verified) faster if the paragraph had been a CAUSAL paragraph than if it had been a non-causal ADDITIVE paragraph.

These results suggest that causally related sentences are stored in more closely integrated units than causally unrelated sentences (Haberlandt & Bingham, 1978).

One might argue that this priming effect was due to the difference in preexperimental associations between the primed and priming sentences. But an ad hoc experiment with test phase condition showed that this was not the case.

Without studying the pair of sentences, subjects did not show any significant priming effects.

EXPERIMENT 2

In this experiment, the reading time of sentences in causally related sentence pairs, and the primed recognition time for these sentences were investigated.

As discussed by Singer (1983), the integration of two causally related sentences will occur at the time the second sentence is read and thus, the reading time for the second sentence will be longer than for the first sentence. This asymmetry in reading time was investigated first.

In addition to this, the effect of the input causal order mode on reading time was also investigated. It was assumed that reading time will be a function of the input causal order mode.

If the causal events in a text evolve in the normal forward order of CAUSE-->RESULT, which fits well with normal schema of causation, then we could comprehend the text easier and faster than if the events evolve in the backward order of RESULT-->CAUSE, which is contrary to our assumed conception of causation. Thus, we could expect reading a Normal Forward (CAUSE--RESULT) sentence pair will take less time than reading an Unusual Backward (RESULT--CAUSE) sentence pair. However, if it was manipulated such that subjects would not know, until the second sentence appears, whether the sentence presented first will function as a CAUSE or as a RESULT sentence, then the reading time for the first sentence will be the same, regardless of the input causal order mode. On the other hand, the reading time for the second sentence will be longer in the Unusual Backward (RESULT--CAUSE) order pairs, since the processing of these pairs would involve some additional processing to resolve the mismatch between the causal order in the text and that in our usual conception of causation. This prediction was tested in this experiment.

With the same logic, we could expect a similar asymmetry and effect of input causal order mode in primed recognition time.

The above discussion argues that the forward causal order is easier to comprehend since it fits our normal conception of causation. Werner and Kaplan (1963) had also argued, as mentioned before, that the forward retrieving is the normal way of retrieving. If we follow this line of logic, then we could intuitively argue that forward retrieval will be easier than backward retrieval since the latter will involve some additional processing to resolve the mismatch between the required direction of retrieval and the usual mode of retrieval. This argument is in contradiction with the results of retrieval symmetry in Haberlandt and Bingham's (1978) and Bradshaw and Anderson's (1982) studies. But as discussed before, this lack of asymmetry in their studies could be attributed to the insensitivity of the recall measures they employed. As pointed out by McKoon and Ratcliff (1980a, 1984), the primed recognition time measure will be more sensitive in investigating memory processes. We could possibly obtain, by using a primed recognition time measure, evidence that shows retrieval asymmetry contrary to Haberblandt and Bingham's and Bradshaw and Anderson's results.

This possibility was investigated in this experiment. We could predict that recognition of a RESULT sentence primed by a CAUSE sentence (i.e., forward priming) will be faster than recognition of a CAUSE sentence primed by a RESULT sentence (inverse priming), since the latter involves additional processing to resolve the mismatch between the usual forward retrieving and the inversed retrieving required by the test.

The retrieval directionality will also interact with the input causal order mode. The recognition time of a primed sentence will be different depending on whether the causally related sentence pairs were presented at input in the

Normal Forward (CAUSE--RESULT) order or in the Unusual Backward (RESULT--CAUSE) order, and whether the priming causal order matches (forward) or mismatches (inverse) the input causal order.

We could propose that in reading a Normal Forward (CAUSE -- RESULT) sentence pair at input, subjects would encode a forward 'Cause--> schema-->Result' code only, while in processing a Backward (RESULT -- CAUSE) pair subjects would activate and encode the backward 'Result--> causal schema-->Cause' code as well as the forward 'Cause--> causal schema-->Result' code. This would interact with the priming causal order and lead to different priming effects for the Forward and the Backward order input. For the Normal Forward causal-order input, there will be a clear asymmetry in retrieval: the FORWARD PRIMING of RESULT (CAUSE --> RESULT) will be faster than the INVERSE PRIMING of CAUSE (RESULT --> CAUSE), since the direction of the priming in the former matches the encoded directions while that of the latter mismatches. For the Unusual Backward input order there will not be any clear asymmetry; since the backward direction code as well as forward direction code was encoded at input, the target sentence will be recognized at the same speed in the forward priming and in the inverse priming condition. If we would stretch the above logic further, we could also expect that the primed recognition of the sentences in the Backward-order-input mode will be faster than or as good as that in the Normal Forward-order-input mode.

The above arguments can be summarized in the following predictions:

1) Reading time will be longer for the second sentences in causal sentence pairs,

2) reading time for the second sentences will be longer in the Backward-order-input mode than in the Forward order input mode,

3) in the Forward-order-input mode, there will be a retrieval asymmetry, with faster primed recognition under the forward direction priming

(CAUSE-->RESULT) than under the inverse direction priming (RESULT-->CAUSE), and

4) in the Backward-order-input mode, there will be no retrieval asymmetry, and the primed recognition time will be faster than the Forward-order-input mode.

METHOD

SUBJECTS. Thirty-seven Korea University undergraduate students served as subjects for a credit in an introductory psychology course. The data of nine subjects were excluded from the analysis: Four of them showed mean correct response rates less than 20%, and the other five reported that they had responded fast without properly reading the primed sentences.

DESIGN. A 2X2 within-subjects design was used. One factor was the STUDY (input) causal order mode with two levels: Forward mode (CAUSE--RESULT) and Backward mode (RESULT--CAUSE). The other factor was the target sentences, of which the reading times and recognition times were measured, with two levels (sentence presented first and sentence presented second). As shown in Tables 2 and 3, the second factor can be rearranged and interpreted in terms of CAUSE sentence vs. RESULT sentence, or match vs. mismatch between STUDY and TEST modes.

MATERIALS. For each of 120 target sentences, two pairs of sentences were constructed: cause--RESULT pair and CAUSE--result pair (the lower case indicates the context sentences and the UPPER case indicates the target sentences). The same target sentence appeared as a RESULT sentence in one pair, and as a CAUSE sentence in the other pair. In each pair a context sentence was paired with the target sentence: the context sentence served as cause sentence for RESULT target sentences and as result sentences for CAUSE target sentence. Fifty-two students rated the causal relatedness of each pair and were asked to indicate the causal direction. Out of 120 target sentences, and 240 context sentences, 40 target sentences and their 80 context sentences were selected. They were the ones of which the rated causal relatedness of cause-->RESULT pair and of CAUSE-->result pair were high and about the same (Mean Rated Relatedness was 3.33 for the former and 3.38 for the latter on 4-point scale), and those for which the causal direction indicated by subjects matched that indicated by the experimenter.

By varying the presentation order of sentences in each pair, the following four STUDY pair modes were constructed. An example is given in Table 1.

Forward-Causal-Order mode <CAUSE--RESULT>: CAUSE--result (C--r)
cause--RESULT (c--R)

Backward-Causal-Order mode <RESULT--CAUSE>: RESULT--cause (R--c)
result--CAUSE (r--C)

Insert Table 1 about here

PROCEDURES. Presentation of sentences and response time recording was done by APPLE II microcomputer with Korean Alphabets ROM card. Ten pairs of sentences were presented in each condition. All 40 target sentence pairs were randomly mixed and presented in 5 pairs for each STUDY-RECOGNITION trial. Subjects first studied 10 sentences of 5 pairs and then did a recognition test on 20 test sentences. The 10 studied sentences were presented in such a way that a target sentence always preceded or followed its context sentence (see Table 1). The presentation was self-paced by the subjects. Subjects were asked to read and comprehend each sentence as fast as possible then push the space bar for the next sentence. They were told that after they had seen 10 sentences, a bell would be sounded briefly three times, and then they would be presented with test sentences. They were asked to respond 'yes' or 'no', by pressing the 'z' or '/' key, to indicate whether they had seen the test sentence during the STUDY phase. They were asked to respond as fast as possible. After all ten sentences were read, 20 test sentences were presented one by one. A subject's °yes' or °no' key response to a test sentence caused the presentation of the next test sentence. Among 20 test sentences, 10 were the studied sentences and 10 were new sentences, constructed by changing one or two words from the studied sentences. The 10 studied test sentences were presented such that the TARGET sentence always followed (was primed by) its context sentence. Ten new test sentences were presented randomly. In half of the priming tests, the causal order in recognition TEST mode matched that of the input STUDY mode, while in the other half of the test it mismatched that of the input mode (see Table 3).

Results

In analyzing the data, reading times less than 200 msecs and more than 2.5 standard deviations above a subject's mean were eliminated. Recognition response times less than 200 msecs and more than 2.5 standard deviations were also eliminated.

Reading Time. The mean reading times for the first and second sentences as a function of the STUDY causal-order mode are presented in Table 2.

Insert Table 2 about here

As Table 2 shows, the sentences presented second were read more slowly than the sentences presented first (F91,747)=7.10, $p<.01$). An additional analysis of the interaction between the input order mode and the target sentences read showed that in the Backward order input mode the reading time for the second sentences (CAUSE) was longer than that for the first sentences (RESULT) ($F(1,747)=4.88$, $p<.05$), while in the Forward order condition the reading time for the second sentences (RESULT) was slightly but not significantly longer than that for the first sentence (CAUSE) ($F(1,747)= 2.42$, $p>.05$). The reading time for a pair of sentences as a whole was about the same for Forward order pairs (1165.42 msec) and for Backward order pairs (1176.98 msec).

Primed Recognition Latencies. The mean primed recognition latencies for different conditions are given in Table 3.

Insert Table 3 about here

The results showed that the main effect of priming mode was significant ($F(1,745)=12.80$, $p<.01$). The forward direction priming (causal order modes at input and at test matched) was faster (697.40 msec.) than the inverse priming (causal order modes at input and at test mismatched) (773.30 msec.). The reading time for the second sentences was about 40 milliseconds longer in the Backward order input mode than in the Forward order input mode, but this difference was not significant.

When the mean recognition latencies for different conditions were individually compared, it was found that in the Normal Forward-order input mode the forward direction priming (study-test matched) (707.04 msec.) was faster than the inverse direction priming (study-test mismatched; mean = 773.30 msec.) ($F(1,745)=5.81$, $p<.05$). On the other hand, in the Backward-order input mode,the primed recognition time was slightly but not significantly faster with matched priming than with mismatched priming. That is, the retrieval asymmetry is apparent only in the Forward-causal order input condition, but not in the Backward-causal-order input condition.

A further analysis showed that if the input and test modes matched, the second sentences from the Backward-causal-order pairs and those from the Forward-causal-order pairs were recognized at the same speed. On the other hand if the study and test modes mismatched (i.e., inverse priming), then the priming of the first-presented sentences from the Backward-causal-orders pair was significantly (about 43 msec) faster than from the Normal Forward-causal-order pairs ($F(1,747)=4.07$, $p<.05$).

In other words, when STUDY (input) mode and RECOGNITION TEST mode matched, the target sentences studied second were recognized at the same speed for Forward order mode and for Backward order mode (i.e., input STUDY mode does not matter). On the other hand when STUDY presentation mode and RECOGNITION TEST mode mismatched, then the primed recognition of the first-studied sentences was significantly (about 43 msec.) faster for Backward order mode than for the Forward order pairs (i.e., input STUDY mode does matter, and Normal Forward order mode is slower than the Unusual Backward mode).

Discussion

The results of Experiment 2 can be summarized as follows: (a) the second sentence in a causally related sentence pair was read more slowly than the first sentence, (b) the reading time for the second sentence was slightly but not significantly longer in Forward input mode than in Backward input mode, (c) with Backward-causal order sentence pairs, the reading time for the second sentence was significantly slower than that for the first sentence, while the reading time was the same for both of the sentences in the Normal Forward order pairs, (d) there was a clear retrieval asymmetry in the forward-causal order input mode but not in the backward-causal order input mode, and (e) if the input causal order mode and the test causal order mode mismatched (inverse priming), the target sentence was primed faster for the Forward order input pairs than for the Backward-order input pairs.

The result (a) of longer reading time for the second sentence supports our assumption that integration of causally related sentences occurs at the time of processing the second sentence. It also supports Singer's (1983) argument that forward inference is not reliably drawn at the time of reading the first sentence, which would have predicted a shorter reading time for the second sentence.

The result (c) of longer reading times for the Backward-causal-order input pairs suggests that Backward order sentence pairs lead to additional processing. It seems that some additional processing steps are needed to resolve the conflict between the normal forward causal order in our causal schema and the backward causal order present in the Backward -order input sentences. Some possible processing steps that might have been involved in processing the Backward-order input sentences will be discussed in the General Discussion.

The result (d) of the clear presence of retrieval asymmetry in Forward-order pairs supported our intuitive argument that forward direction retrieval will need fewer processing steps and will be faster than the inverse direction retrieval. It also shows Haberblandt and Bingham's (1978) and Bradshaw and Anderson's (1982) retrieval asymmetry were due to the insensitivity of the recall measures, and it supports McKoon and Ratcliff's (1980a, 1980b) argument that primed recognition time is a better measure of some memory processes than recall measures. The clear presence of asymmetry in the Forward-order input mode and its absence in the Backward-order input mode also supports our argument that the memory representation of a Forward order input pair has a uni-directional code, while the representation of a Backward order input pair has two codes, forward and backward. This possibility will be discussed further.

The result (e) of superiority of Backward-order input mode in inverse priming (study-test mismatched) also supports the above interpretation. The most probable reason why the Backward order input sentences were faster in inverse priming than in the Forward order input sentences could be that the former was encoded with two codes, one for each direction, and one of them matched with the retrieval direction required at the recognition test, while the latter was encoded with one uni-directional code, which mismatched the retrieval direction required at test.

The result (b) of no significant difference in second-sentence reading time for the Forward order input mode and for the Backward order input mode contradicts our prediction. It seems that this experiment was not sensitive enough to capture the significant difference in reading time for the second sentence in the Forward and in the Backward pairs. This problem will be discussed in the General Discussion.

Experiment 3

This experiment investigated how much of the primed recognition latencies of Experiment 2 was due to the pure effect of priming.

In Experiment 2, we obtained the mean reading time and mean primed recognition time for target sentences when they were presented one by one, but in the context of causally related sentences. Each target sentence was followed or immediately preceded by another causally related sentence. The reading times or the recognition latencies for individual sentences in isolation were not measured independently. Without these measures, we do not know how much of the reading time or the primed recognition time in Experiment 2 was due to the pure effect of presenting or priming the target sentences in the context of causally related sentences. In order to find this pure effect, we should first measure the reading times or recognition latencies of individual sentences without any causal sentence context, and then find the differences between these measures and the measures obtained in Experiment 2 for individual sentences. These differences will indicate how much of the gain in reading times and primed recognition latencies were entailed by the causal context sentences.

From the analysis of these gains in response times, we could also find out whether the effects obtained in Experiment 2 were reliable. If the effects we found in Experiment 2 were reliable, the gains in reading time and primed recognition time obtained in Experiment 3 will show the same tendencies as those in Experiment 2. The analysis of gains in reading time and recognition time will also remove the effects, if there were any, of possible heterogeneity of target sentences in Experiment 2.

METHOD

SUBJECTS. Eleven Korea University undergraduate students served as the subjects. None of them had participated in, or heard about the previous experiments.

MATERIALS AND PROCEDURES. The materials and the procedures were the same as in Experiment 2, except for the following modifications. The presentation of sentences at the STUDY phase as well as at the RECOGNITION TEST phase was in random order. All the sentences were randomly mixed with only one constraint; no causally related target sentences were presented less than 60 sentences apart. Subjects were instructed that they should try to comprehend each sentence individually.

Result

The reading times for individual sentences in random presentation were measured first. Then the reading times obtained for individual sentences in Experiment 2 were subtracted from the reading times obtained in this experiment. The resultant gains in reading time were analyzed. As shown in Table 4(a), the gains in reading time showed the same tendencies as in Experiment 2. The sentences presented second gained significantly less than those presented first ($F(1,743)=8.93$, $p<.01$). And the difference in gains for the first-read sentences and for the second-read sentences was significant only in the Backward order input pairs (F(1,7430)=6.16, p,<.05).

Insert Table 4 about here

The gains in recognition time were obtained in the same way. As shown in Table 4(b), the gained recognition time showed the same tendencies as those of primed recognition latencies in Experiment 2. Gains were greater in Backward-order input mode than in Forward-order input mode (F(1,744)=4.88, p<.05). The inverse priming of CAUSE sentences in Forward-order pairs showed the least gains. The results also showed that the difference in recognition time gains for Forward-order input pairs and for Backward-order input pairs was significant only in the inverse (MISMATCHED) priming condition. In this condition the recognition time gains in Backward-order input pairs were almost 100 msec greater than in the Forward-order input pairs.

DISCUSSION

The results of this experiment showed that reading and recognizing sentences in causal context takes less time than reading and recognizing sentences without context. The results also supported the findings obtained in Experiment 2. The gains in reading and recognition times were less for the second sentences. And the Forward- order input pairs gained less than the Backward-order input pairs under the inverse priming condition.

An ad hoc analysis of the reading time gains for the non-target sentences showed similar tendencies. The analysis also showed that the reading time gains for the second sentences was significantly smaller (about 150 msec) in the Backward input condition than in the Forward input condition. This indirectly supports our prediction of longer reading time for the second sentences in

Backward input condition. It suggests that significantly longer reading time for the second sentences of Backward order input could be obtained by employing other list materials.

GENERAL DISCUSSION

We can summarize the main findings of this study as follows; (a) the causally related sentences are retrieved faster than the sentences causally unrelated; this indicates that causally related sentences are stored in closely integrated units, (b) integration of sentences in causally related sentence pairs occurs at the time of processing the second sentence, and this causes the reading time for the second sentence to be longer than that for the first sentence, (c) this tendency is more apparent in the Backward causal pairs, (d) sentences presented second are recognized faster than the sentences presented first, and this difference is stronger in the Normal Forward causal pairs, (e) priming was greater when the input causal order mode and the test order mode matched than when they mismatched, (f) in inverse (input-test modes mismatched) priming, the recognition of the first sentence in the forward pairs took more time than that in the Backward pair.

The above results give support to our initial assumptions about the nature of processing, and of retrieval characteristics of causally related information. However, there are certain problems in generalizing the results of this study.

The first problem concerns the generalizability of findings of this study, especially the findings in Experiment 2. It might be argued that the processing involved in Experiment 2 was a processing of causal cohesion between two lower level sentences rather than a processing of causal coherence at a global level. Thus it can be argued that the generalizability of our findings and explanations are limited. We understand this possibility. Yet, there are not many theoretical studies that can clearly explicate the differences and relations between the processing of causal relations at a local level and at higher global levels. Without a clear explication of this issue, it is difficult to specify what real limitations our findings have.

The second problem is that of the prediction of longer reading time for the second sentences in Backward input mode than in the normal Forward input mode. This prediction was not supported in Experiment 2: though the second sentences in the Backward input mode were read 40 msec. faster than those in the Forward mode, the difference did not reach a significance level. Nevertheless, Experiment 3 showed that our prediction was not entirely incorrect. An ad hoc analysis of the non-target sentences showed significantly shorter reading time gains in Backward mode than in Forward mode, which means that the second sentences in Backward mode were actually processed longer. This suggests that we could get significantly longer reading time for the second sentences in Backward mode than in Forward mode if we would employ other list materials. This possibility should be investigated in future research.

In spite of the above problems, this study has shown a reliable evidence for faster reading and faster recognition of causally related sentences.

With respect to why and how sentences with causal relations are understood faster and retrieved better, different explanations were put forward by several researchers. Depending on their emphasis, we can divide these explanations into four groups.

The first group of explanations proposed was that a causal relation connects two or more individual events in a more integrated coherent unit, thereby reducing the number of units to remember and making the representation more distinctive and durable over time. It was pointed out that causally related information is connected in a tighter and more integrated structure (Mandler & Johnson, 1977), integrated in a more coherent unit (Black & Bower, 1980; Lee, 1979; Trabasso et al., 1984; Black, 1985), and a higher abstraction level unit (Lee, 1979, 1981). As discussed by these studies, this integrated unit is retained longer and retrieved better because of its coherence and higher level distinctiveness.

The second group of explanations emphasizes the availability of a greater number of retrieval paths. Black and Bern (1981) pointed out that the CAUSE (the first) sentence in causally related sentences serves as an effective memory cue. Bradshaw and Anderson (1982), Lee (1979), and Trabasso et al. (1984) argued that causally related sentences are stored with a greater number of associative connections and redundant inferential connections, which then serve as multiple alternative retrieval paths. These multiple connections make the representation easier to access.

The third group of explanations was proposed mainly by Trabasso and his colleagues (Trabasso et al., 1984; Trabasso & van den Broek, in press; van den Broek & Trabasso, in press). They basically accepted the first two explanations with some modification of the second, but their emphasis was on the importance of an event being on the event chain. They pointed out that the availability of a greater number of connections or conceptual dependencies accounts for some small variance in recall and summarization performance. The simple availability of a greater number of sentence or conceptual connections is not enough. Whether an event is on the causal chain or not is crucial and accounts for a greater amount of variance. This explanation is more general than the above two. However, it does not present a detailed explanation of what makes an event in a causal chain more easily recallable. They stopped short of implying that being in a causal chain somehow causes the target information to be encoded with a greater number of connections and in a more coherent and integrated unit. More detailed specific explanations beyond that were not given.

The fourth group of explanations tried to interpret the positive effects of causal relation processing in terms of a 'processing depth' concept. This view was proposed by Haberlandt and Bingham (1978), Black and Bern (1981), and Keenan et al. (1984). Haberlandt and Bingham (1978) argued that causally related sentences are processed less deeply -- contrary to our intuitive expectations -- than causally unrelated sentences. Their view was based on experimental results of the shorter reading time of causally related sentences. Black and Bern (1981) raised an opposite interpretation on the basis of some experimental findings of better recall for causally related sentences: that causally related sentences might be processed more deeply. But, faced with the results of Haberblandt and Bingham's experiment, they did not pursue this view further. Keenan et al. (1984) revived this view, but some with modification. They proposed that the amount of processing employed in connecting sentences is a quadratic function of sentence relatedness: With 'highly' and 'least' causally related sentences, relatively little processing occurs, while with intermediately related sentences more processing occurs and these sentences are better recalled. Lee (1979, 1981) also asserted that causal information processing involves deeper processing. And in this study we found that causally related sentences are primed better.

How then can a 'processing depth' interpretation explain this contradiction that causally related information is read in less time, i.e., processed less deeply, and still be recalled better and retrieved faster?

The issue in question here is the definition of DEEPER PROCESSING. If, by 'DEEPER PROCESSING', we mean to simply activating greater amounts of information from our knowledge or simply employing greater amounts of time to process the target information, then we could say, as Haberlandt and Bingham (1978) did, that causally related sentences are processed less deeply than the causally unrelated sentences. On the other hand, if we mean by 'DEEPER PROCESSING', activating higher levels of knowledge and representing in units at higher levels of abstraction, then we could say that causally related sentences are processed more deeply. This view of two different types of DEEPER PROCESSING has been proposed by Lee (1979). He termed the former type as a simple 'spreading elaboration' type of deeper processing, and the latter as an 'integrative elaboration' type of deeper processing. In this framework, it can be argued that deeper processing does not always presuppose more processing time, and that some 'integration into higher level units' or 'applying higher level knowledge' can occur in less time than that needed for some simple diffuse 'spreading activation' type of processing. If we take this view, we can argue that causally related sentences can be processed more deeply, even in shorter time, than the time needed for processing non-causal sentences, and still be recalled better and recognized faster. The fact that causally related sentences can be processed (read) in less time and can still be retrieved better is not paradoxical but consistent in this framework of deeper processing.

In addition to the above four explanations, Lee (1979, 1981) proposed the following additional explanations.

First Lee proposed that we can consider the processing of causal relation in text as a way of providing ABSTRACT COREFERENCE across two or more neighboring sentences.

In normal causal relations, an antecedent state or event A happens first and then a consequence or result event B follows. In reading causally related sentences, we usually make an inference of 'Something (A) happens and BECAUSE OF THAT something (B) happens.' In this inferencing, the relative pronoun 'THAT' refers back to the entire antecedent event(s). That is, in an effort to understand the RESULT sentence B and to relate it to the preceding information, we make abstract references to the antecedent sentence A, through the use of causal conjunctions. Thus, we could argue that causal information processing involves processing of abstract referential connections.

This abstract reference will then facilitate comprehension and memory just as the lexical coreference does (Haviland & Clark, 1974; Miller & Kintsch, 1978). Haviland and Clark pointed out that coreferential processing always involves the process of reactivating -- i.e., retrieving -- certain old, 'given', or coreferenced information. Likewise, we could argue that processing of causal information in text involves reactivating or implicitly retrieving the CAUSE information while processing RESULT information. This practice of retrieving CAUSE information would bring about a positive effect on retrieval. The CAUSE sentence will be easily retrieved at output and it will increase the probability of retrieving the RESULT sentence, as well.

We can find yet another reason why the abstract reference processing would facilitate comprehension and memory. As discussed by Kintsch, Kozminsky, Streby, McKoon and Keenan (1975), Manelis and Yekovich (1976), and Lee, Kim and Yoon (1984), we could argue that the presence of coreference with the previous sentence makes the current sentence easier to process and to comprehend. This would allow subjects to devote their processing time and efforts not so much on the processing of the literal meaning of the sentence but rather on deeper elaborative and inferential processing. This would lead to the activation of a greater amounts of higher level information, which in turn will give richer and more specific descriptions (Norman & Bobrow, 1979) and distinctiveness (Jacoby & Craik, 1979) to the representation. This will result in easier access, better discrimination, and easier reconstruction of the target causal information at later testing.

Lee (1979) further proposed another possible reason why causal information processing might have positive effects on memory performance. He argued that the causal relation concept is a higher ABSTRACTION level concept, which gets represented at a higher level in the propositional structure than individual sentence propositions. This higher level proposition is more distinctive than the lower level propositions of individual sentences since there are fewer similar or interfering propositions (or concepts) at the higher abstraction level than at a lower level. The availability of this higher level relation concept would give extra specificity and richness to the representation of the target information, which in turn will be easier to retrieve and reconstruct at output. This causal relation concept will also serve as an additional higher level retrieval cue much as category name functions serve as a retrieval cue in clustering phenomena. The availability of this additional higher level retrieval cue will increase the probability of retrieving the target sentences; read faster, recalled better, and primed faster.

The next issue is that of retrieval directionality. Contrary to previous research, the present study has shown that there is a retrieval asymmetry. This indicates that the previous findings of retrieval symmetry were due to the insensitivity of the recall measures used, and that primed recognition is a better method of investigating certain component processes of comprehension and memory, and that retrieval asymmetry is a fact to be dealt with by memory models. Existing models of memory retrieval, however, do not explicitly deal with this asymmetry in retrieving causally related information. A better account of how input mode and retrieval mode interact and result in retrieval asymmetry is necessary.

Next, we can discuss what different processing steps are involved in comprehending and retrieving sentences in the Forward input mode and in the Backward input mode. It was assumed that Backward input requires some additional processing steps over Forward input, and that the former is stored with forward (from CAUSE TO RESULT) and backward (from RESULT back to CAUSE) memory codes while the latter is stored with only forward code.

The findings of this study can be interpreted as supporting this assumption. The reading time results suggest that processing of the first sentence in the Forward input mode and in the Backward mode are not much different, except that the first sentence in the Forward mode has a slightly greater chance of activating the causal schema than that in the Backward mode. The results of reading time, primed recognition time and gains in each suggest that the second sentence in the Backward pairs took more steps to process and was encoded with two direction codes. It seems that the processing of the second sentences in the backward pairs involves the steps of recognizing 'the presence of something unusual in the causal order', reinstating the first sentence, rearranging the backward order into forward order, and storing two directional codes with a tag of 'something inverse was present'. To investigate whether these processing steps are really employed, we need additional studies with the analysis of protocols of subjects.

The final issue concerns the conceptualization of different types of causation. Different types of causation have been proposed in several studies (RESULT, ENABLE, REASON, and INITIATION in Schank (1976); CAUSE, and GOAL in Wilks (1977); CAUSE, ENABLE, REASON, and PURPOSE in deBeaugrande and Colby (1981); MOTIVATION, ACTUALIZATION, TERMINATION, and EQUIVALENCE in Lehnert (1981); LEADS-TO, ENABLE, and RESULTS in Graesser (1981) and in Graesser and Goodman (1985)). There is, however, a lack of consensus among these studies on what basis the classification of causation should be made and how many different types of causation there are. Some of the above classifications were made based on logical relations without directly relating or matching to some detailed specifiable processing steps. We could argue that different types of causality should reflect; (a) whether the antecedents and the consequences are processed differently, (that is whether forward inferences (prediction) or backward inferences (postdiction) are more reliably drawn), (b) whether this entails retrieval asymmetry or symmetry, (c) whether the usual forward order and the unusual backward order inputs are processed differently, and (d) whether these involve activation of different types and abstraction levels of knowledge. A new conceptualization of causation in this direction is needed.

Footnotes

The experiments were conducted by San-Sup Choi and Heug-Chul Lee of Korea University.

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Table 1. <Examples of Sentence Pairs>

(C: CAUSE target sentence c: cause nontarget sentence
R: RESULT " " r: result " ")

STUDY MODE	PAIRS	
C--R	C--r	C: The student got poor marks on exams.
		r: The student regretted not having worked harder.
	c--R	c: A student had not worked hard enough.
		R: The student got poor marks on exams.
R--C	R--c	R: The student got poor marks on exams.
		c: A student had not worked hard enough.
	r--C	r: The student regretted not having worked harder.
		C: The student got poor marks on exams.

Table 2. <Reading Time for Target sentences (in msec.)>

STUDY MODE	TARGET READ	
R--C	R	C
(backward)	1129.97	1224.00
C--R	C	R
(forward)	1145.35	1185.48

Table 3. <Primed Recognition Latencies (in msec.)>

STUDY MODE	PRIMING TEST MODE	
R--C	c--> R	r--> C
(backward)	729.91	687.30
C--R	r--> C	c--> R
(forward)	773.30	707.04
Study-Test Mode	: in Conflict	: Matched

Table 4. <Gains caused by presenting the target sentence immediately prior to or after a related non-target sentence>

(Gains=RT on random presentation of individual sentences - RT in Table 1 or Table 2)

(a) <GAINS IN READING TIME (in msec.)>

R--C	R=255.74	C=114.86
C--R	C=225.84	R=177.65

(in random individual presentation: C=1355.36 R=1372.96)

(b) <GAINS IN RECOGNITION TIME (in msec.)>

R--C	R=250.65	C=235.24
C--R	C=159.61	R=230.82

(in random individual test: C=731.88 R=718.82)